Statewide Multifamily New Construction Energy Efficient Baseline Study

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Executive Summary

ES.1 Introduction

This executive summary summarizes the findings of the Statewide Multifamily New Construction Energy Efficient Baseline Study (MF) conducted by Regional Economic Research, Inc. (RER), a wholly owned subsidiary of Itron, Inc., Heschong Mahone Group (H-M-G), and ADM Associates (ADM) under Pacific Gas & Electric (PG&E) management.[1] The MF study was designed to investigate energy efficiency building standards and practices in newly constructed multifamily buildings throughout California. The study's primary purpose is to provide information to residential new construction (RNC) program managers across the state, thereby allowing them to assess and address the effect of recent and impending energy code changes on these programs.

The remainder of this Executive Summary includes a review of the project's objectives, the approach taken, problems encountered in attempting to reach the targets, and the key findings from the study including baseline characteristics and compliance analysis.

ES.2 Study Objectives and Approach

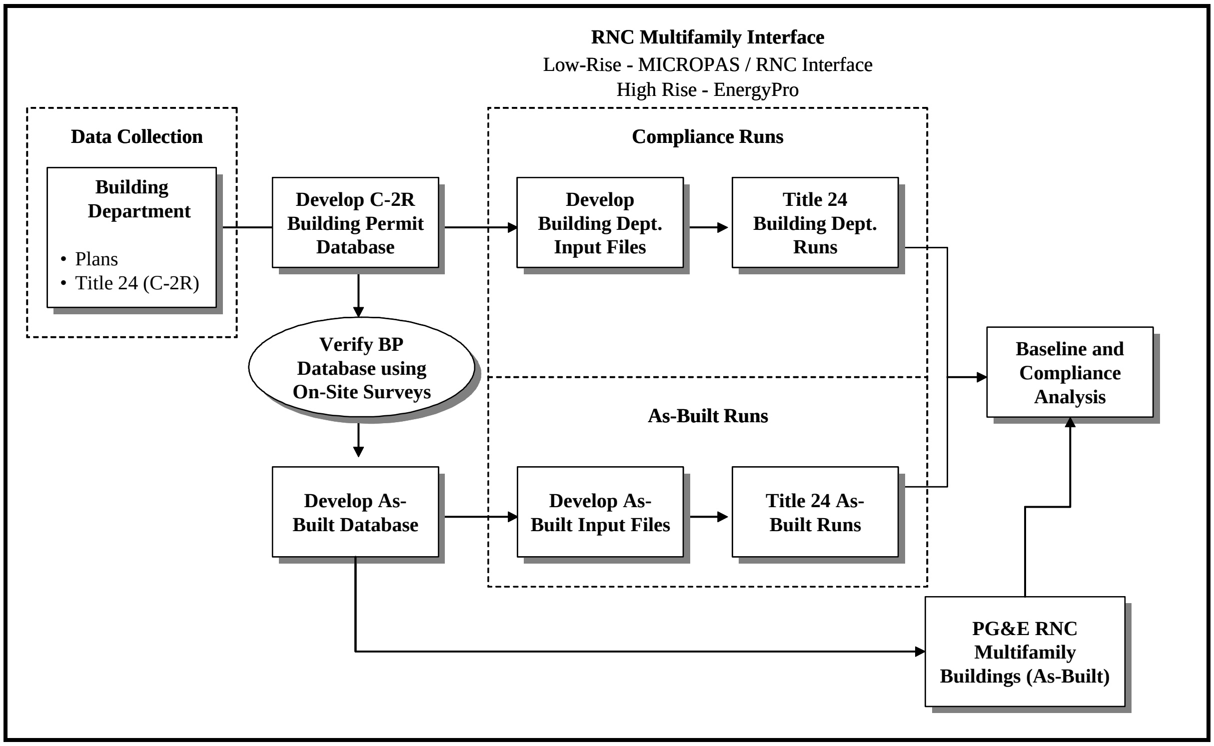
The objective of this study is to describe common building practices and analyze the Title 24 compliance of low-rise and high-rise multifamily buildings. The remainder of this section discusses the study approach to complete the baseline characterization and compliance analysis of the multifamily new construction sector. Figure ES-1 presents an overview of the approach, which can be broken out into seven major elements.

- ***Data Collection from Building Departments.*** Building plans and Title 24 compliance documentation for multifamily buildings built under either the 1995 or 1998 Standards were collected from a sample of California building departments.
- ***Verification of As-Built Building Characteristics.*** In this element, on-site surveys of the multifamily buildings, for which complete compliance documentation was collected, were conducted. The purpose of the on-sites surveys was to verify the as-built characteristics of each building. For this purpose, survey instruments[2] to collect data on discrepancies between the compliance documentation filed with the building department were developed.

[1] The detailed results of this study can be found in *Statewide Multifamily New Construction Energy Efficient Baseline Study.* RER, Inc. January 2003. Prepared for Pacific Gas & Electric.

[2] Appendix A contains the low-rise and high-rise on-site survey forms.

Figure ES-1: Overview of Study Framework



- ***Development of As-Permitted Input Files.*** Based on data collected from building departments, as-permitted input files were developed. In the case of low-rise buildings, MICROPAS[3] was used. In the case of high-rise buildings, EnergyPro[4] was used.
- ***Development of As-Built Input Files.*** The as-permitted input files were updated to reflect the as-built characteristics of each building. These files were used to simulate the as-built runs for the analysis and to develop baseline characteristics of each building type.
- ***Perform Permitted and As-Built Simulations.*** Permitted and as-built simulations were run for each building. These results are used to conduct the baseline and compliance analysis. Again, MICROPAS were used for the low-rise multifamily buildings and EnergyPro for the high-rise multifamily buildings.
- ***Baseline Assessment.*** A major result of the analysis is the development of baseline characteristics of the multifamily buildings. The focus of this effort was to develop baseline characteristics by climate zone and multifamily building type. Where possible, characteristics of the low-rise and high-rise multifamily buildings were assembled in a common format.

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3 MICROPAS is a CEC-sanctioned computer compliance tool used in determining Title 24 compliance for low-rise residential homes. MICROPAS was developed by ENERCOMP, Inc.

4 EnergyPro is a CEC-sanctioned computer compliance tool used in determining Title 24 compliance for high-rise residential buildings. EnergyPro was developed by EnergySoft.

- ***Compliance Analysis.*** Compliance analysis of each building was performed by developing % Compliance Margins for the as-permitted and as-built buildings under the Standard with which they originally complied and the 2001 Standards. Specifically,

$$\%\ Compliance\ Margin = \frac{(Standard\ Energy\ Budget - Proposed\ Energy\ Budget)}{(Standard\ Energy\ Budget)}$$

  This definition is consistent with the method that most residential new construction programs use to define program compliance. For instance, a home must be 20% better than 1998 Title 24 to qualify as an ENERGY STAR home.

ES.3 Data Collection

The original work plan called for the analysis of 50 low-rise and 50 high-rise newly constructed multifamily buildings. The first step in this process was the collection of Title 24 compliance documentation and building plans[5] from building departments.[6] However, several problems were encountered when attempting to collect the compliance documents and then in verifying the buildings. Below are some of the problems encountered and the approaches taken to try to overcome them.

- ***Some building departments did not have any compliance documentation.*** This prompted the project team to actively recruit Title 24 consultants.
- ***Addresses needed at some building departments.*** The project team collected addresses of multifamily buildings from several sources including the IOUs, Center City Development Corporation, and various Internet searches.
- ***Many high-rise buildings were not completed and occupied.*** Project management agreed to allow buildings that had a completed building shell and HVAC and DHW equipment installed.
- ***Thirteen building owners/managers refused to allow the on-site survey.*** Eight low-rise and five high-rise owners/managers refused to allow the verification team to survey their building. Reasons cited ranged from not being interested in a utility study to not wanting to disturb the residents living in the building.

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5 The data collection process and the other steps of this analysis are discussed in detail in Sections 2.3 – 2.5 of the full report.

6 The goal for data collection was higher than the targets for the analysis since it was assumed that some sites would drop out for one reason or another.

It is important to note that the process of collecting and verifying the compliance documentation for this project was iterative. The project team provided status reports to the project managers. The project team and project managers worked together to come up with as many solutions to the problems encountered as possible.

Reasons for Rejecting Buildings

The project team collected compliance documentation for 62 low-rise and 37 high-rise multifamily buildings. After reviewing the 99 sets of compliance documentation, 40 low-rise buildings and 18 high-rise buildings were found to have enough information to recreate the compliance results and construction of the building was verified. The next step was to verify the building shell characteristics and the equipment installed in the 58 buildings for which complete and verified compliance documentation was collected. Recruitment letters were sent to the property managers and/or owners of these buildings. These recruitment letters were sent on the letterhead of the IOU that serves the building.

Table ES-1 provides a summary of why the remaining 41 buildings were not acceptable for use in this study.

The next step was to verify the building shell characteristics and the equipment installed in the 58 buildings for which complete and verified compliance documentation was collected. Recruitment letters were sent to the property managers and/or owners of these buildings. These recruitment letters were sent on the letterhead of the IOU that serves the building.

Table ES-1: Summary of Reasons for Rejecting a Building

Reasons for Rejecting	# of Low-Rise Buildings	# of High-Rise Buildings
Total Collected	**62**	**37**
Incomplete Compliance Documentation[7]	17	7
Incomplete Plans	0	2
Alteration	0	1
Construction not Complete[8]	3	8
Building not Accessible[9]	0	1
Attached Single Family Building	2	0
Total Verified and Usable	**40**	**18**
Owner/Manager refused On-Site Survey	8	5
Total Surveyed	**32**	**13**
Attached Single Family/Incomplete Data	1	1
Total Included in Analysis	**31**	**12**

Next, the project team contacted the property manager/owner in order to set up an appointment to survey the building. Of the 40 low-rise buildings contacted, eight refused to participate. Of the 18 high-rise buildings contacted, five refused to participate.

ES.4 Summary of Findings

The following summarizes key findings from the multifamily new construction study. These include major findings from the baseline characteristics and the compliance analysis of newly constructed low-rise and high-rise buildings. Also included is a discussion on the lag time between the compliance date of a building and the date on which the building is first occupied.

Lag Time between Compliance Date and Occupied Date for Multifamily Buildings

Due to the large number of buildings that originally complied under the 1998 Standards and found to be still under construction, an analysis of the lag time between compliance date and occupied date was conducted for the 31 low-rise and 12 high-rise buildings. The original

7 Most of these buildings had plans and permit information but were missing some or all of the compliance documentation. In these cases, it was not evident that anything was missing until a detailed review was completed.

8 Please note that the requirement was not that the building was occupied, instead, the building need only to have the building shell completed and all HVAC and water heating equipment installed.

9 When verifying that this building was constructed, the project team was told that the building was used for mentally handicapped persons and that access to the property was impossible.

compliance dates[10] and occupancy dates were available for 26 of the 31 low-rise buildings and 11 of the 12 high-rise buildings. The lag times between the compliance date and the occupied date for the low-rise buildings ranged from 10 to 26 months with an average of 18 months. The lag times seen for the high-rise buildings were even longer – they ranged from 13 to 50 and averaged 24 months.

Baseline Characterization

The following is a summary of current building practices in the multifamily residential new construction sector. Findings are summarized below by building type.

Low-Rise Multifamily Buildings

The baseline characterization of low-rise multifamily buildings is based on 31 buildings. Due to this somewhat small sample, the results were not weighted, however the analysis provides a snapshot of the construction practices in low-rise multifamily buildings. Key building characteristics findings from the low-rise multifamily buildings surveyed are presented below.

- **Nearly all of the low-rise multifamily buildings surveyed had less glazing area than the prescriptive requirement.** The average glazing percentage of the buildings surveyed statewide was 12.7%.
- **Metal-framed, clear glass windows are the predominant window type found in the low-rise multifamily buildings surveyed (77%).** Dual-pane, metal-framed windows (42%) are more common than single-pane, metal-framed windows (35%).
- **Approximately 71% of the low-rise multifamily buildings surveyed have a hydronic heating system.** There is also a fair amount of central heat pumps in low-rise multifamily buildings (16%).
- **Central air conditioners are the most common space cooling equipment found in low-rise multifamily buildings (71%).** There is also a fair amount of central heat pumps in low-rise multifamily buildings (16%).
- **Nearly all of the low-rise multifamily buildings surveyed have storage gas water heaters installed.** Twenty-seven of the 31 buildings have individual storage gas water heaters for each dwelling unit. On average, these water heaters are 10% above standard.[11]

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10 The compliance date refers to the date in which the original compliance analysis was completed. In most cases, the date that the building department approved the project was not available.

11 Please see Section 3.3 for the explanation of how % above standard is calculated for storage gas water heaters.

- **Ceiling and wall insulation levels in low-rise multifamily buildings are usually below prescriptive values.**[12] For those buildings surveyed, the insulation levels were typically lower than prescriptive values, but always greater than or equal to the minimum R-values specified by the Standards.
- **Just over half of the bathrooms in the low-rise multifamily buildings surveyed have CFLs.** Furthermore, exterior lights with motion sensors were found only in one of the low-rise multifamily buildings surveyed, while exterior lights with daylight timers were found at just over half of the buildings.
- **Approximately 32% of the low-rise multifamily buildings surveyed have a common laundry facility and 58% have individual laundry equipment in the dwelling unit.** In those buildings with individual washer/dryers, all the equipment was supplied by the management.

High-Rise Multifamily Buildings

High-rise residential buildings are typically found in places where land is at a premium and real estate values encourage vertical growth. For this reason, high-rise buildings in California tend to be concentrated in the major coastal cities. In the sample of 12 buildings, eight are from RMST Climate Zone 2,[13] which includes CEC Climate Zones 6 and 7, a thin band along the coast from Santa Barbara through Los Angeles to San Diego. Few high-rise multifamily buildings were found outside the major coastal areas. Due to the small number of sites (12) in the sample, statewide trends in construction cannot be adequately predicted. However, these provide a snapshot of the construction practices in the portions of the state where high-rise buildings are most likely. Key building characteristics findings from the high-rise multifamily buildings surveyed are presented below.

- **The average WWR for the high-rise multifamily buildings surveyed is 22%.** The glazing percent[14] by building ranged from 14% to 42%.
- **Metal-framed windows are the predominant window type for high-rise multifamily buildings (66%).** It is interesting to note that dual-pane, low-E, metal-framed windows (33%) are just as common as dual-pane, clear glass, metal-framed windows (33%) in the high-rise multifamily buildings surveyed.
- **Of the high-rise multifamily buildings surveyed, hydronic heating is the most commonly found heating source, with equal percentages of central and individual water heaters used for the hydronic systems (33% each).** Central heat pumps are the next most common heating source in high-rise buildings (25%). There is one building with hydronic radiant floor heating.

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[12] The prescriptive values, the minimum values allowed by Prescriptive Package D in the 1998 standards, for both ceiling and wall insulation vary by CEC climate zone.

[13] For details on the climate zones used in this analysis, please see Section 3 of the full report.

[14] The percent glazing here refers to the window area to wall area ratio (WWR).

- **The heating systems installed in each of the high-rise multifamily buildings surveyed have higher than prescriptive efficiencies.**
- **Central air conditioners are the most common space cooling equipment found in high-rise multifamily buildings (67%).** There is also a fair amount of central heat pumps in high-rise multifamily buildings (25%). Of the 12 buildings surveyed, one does not have cooling equipment installed.
- **Just over half of the high-rise multifamily buildings surveyed have a central boiler.** Seven of the 12 buildings have a central boiler, while four have individual storage gas water heaters for each dwelling unit. On average, these water heaters are nearly 11% above standard.[15]
- **Ceiling and wall insulation levels in high-rise multifamily buildings are commonly equal to or just above prescriptive values.**[16]
- **Eight of the 12 high-rise multifamily buildings surveyed have CFLs in the bathrooms.** Furthermore, exterior lights with motion sensors were not found in any of the high-rise multifamily buildings surveyed, while exterior lights with daylight timers were found at 10 of the 12 buildings.
- **Approximately 8% of the high-rise multifamily buildings surveyed have a common laundry facility and 92% have individual laundry equipment in the dwelling unit.** In those buildings with individual washer/dryers, all the equipment was supplied by the management.

Analysis of Compliance

The following is an overview of the compliance groups and a summary of the results from the compliance analysis of low-rise and high-rise multifamily buildings.

Overview of Compliance Groups

The following four compliance groups were used as the basis for compliance analysis.

- **Non-Compliant.** This category includes sites that, based on the analysis, are not compliant with Title 24 code.
- **Compliant.** This category includes sites that, based on the analysis, are compliant with Title 24 code.
- **Overly Compliant.** This category includes sites that, based on the analysis, are overly compliant with Title 24 code. In particular, these sites have a % Compliance Margin greater than 20%.[17]

[15] Please see Section 3.3 in the full report for the explanation of how % above standard is calculated for storage gas water heaters.

[16] The prescriptive values, the minimum values allowed by Prescriptive Package D in the 1998 standards, for both ceiling and wall insulation vary by CEC climate zone.

Low-Rise Multifamily Buildings

Below is a summary of the results from the compliance analysis of the 30 low-rise multifamily buildings.

- **As-permitted[18] – one building was overly compliant.** Approximately 97% of the buildings (30) are identified as compliant (i.e., they are in the compliant or overly compliant compliance groups) and 3% of the buildings (1) are identified as non-compliant.[19]
- **As-built under the 1998 Standards – five buildings were overly compliant.** Four buildings were non-compliant and 22 buildings were compliant.
- **The low-rise multifamily buildings in RMST Climate Zone 2 (Southern Coast) have the highest average 1998 as-built % Compliance Margin (20%).** The buildings in RMST Climate Zone 4 (Central Valley) have the lowest average as-built % Compliance Margin (3%).
- **As-built under the 2001 Standards – 19 buildings would have been non-compliant.** As shown in Figure ES-2, only 12 as-built buildings would have complied under the 2001 Standards.
- **The low-rise multifamily buildings in RMST Climate Zone 2 (Southern Coast) have the highest average 2001 as-built % Compliance Margin (12%).** Meanwhile, the average % compliance margin of the low-rise multifamily buildings in RMST Climate Zones 3 (Southern Inland), 4 (Central Valley), and 5 (Mountains & Deserts) was negative (-2%, -9%, and -7%, respectively).

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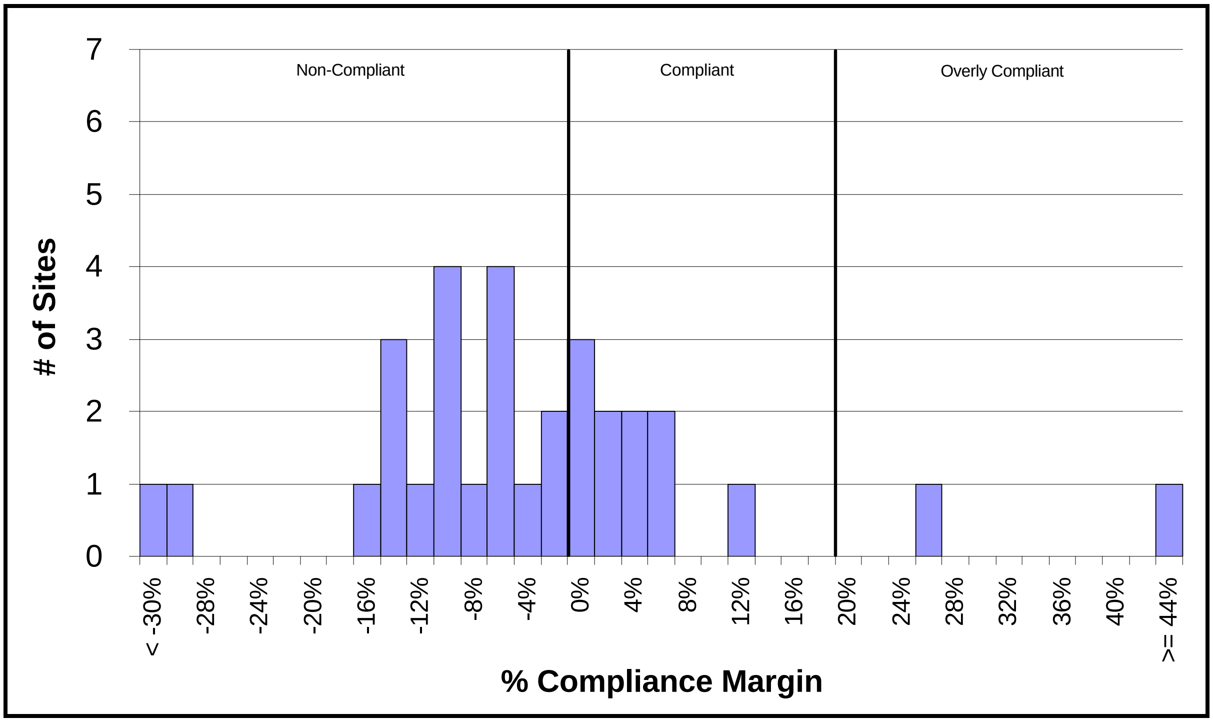
17 This category was defined to assess the share of homes that would meet the existing ENERGY STAR® New Home Construction requirements.

18 Under the Standards with which the building originally complied.

19 This site originally complied using a “per residence” method in EnergyPro 1.0. However, for consistency, all sites were run through the RNC Interface using a “per building” method, so it was impossible to reproduce the exact compliance margin for this building.

Figure ES-2: MICROPAS Results Summary – As-Built 2001 Standards – Low-Rise Multifamily Buildings



High-Rise Multifamily Buildings

Below is a summary of the results from the compliance analysis of the 12 high-rise multifamily buildings.

- **As-permitted[20] – one building was overly compliant.** Eleven of the 12 buildings are identified as compliant (i.e., they are in the compliant or overly compliant compliance groups) and one of the buildings was identified as non-compliant.[21]
- **As-built[22] – two buildings were overly compliant.** Eleven of the 12 buildings are identified as compliant (i.e., they are in the compliant or overly compliant compliance groups). Of the two buildings that were found to be overly compliant, one had less window area installed than was documented on the C-2R and the other had more efficient windows installed, a higher efficiency HVAC system installed, and a central water heating system (as opposed to individual water heaters) installed than was documented on the C-2R.

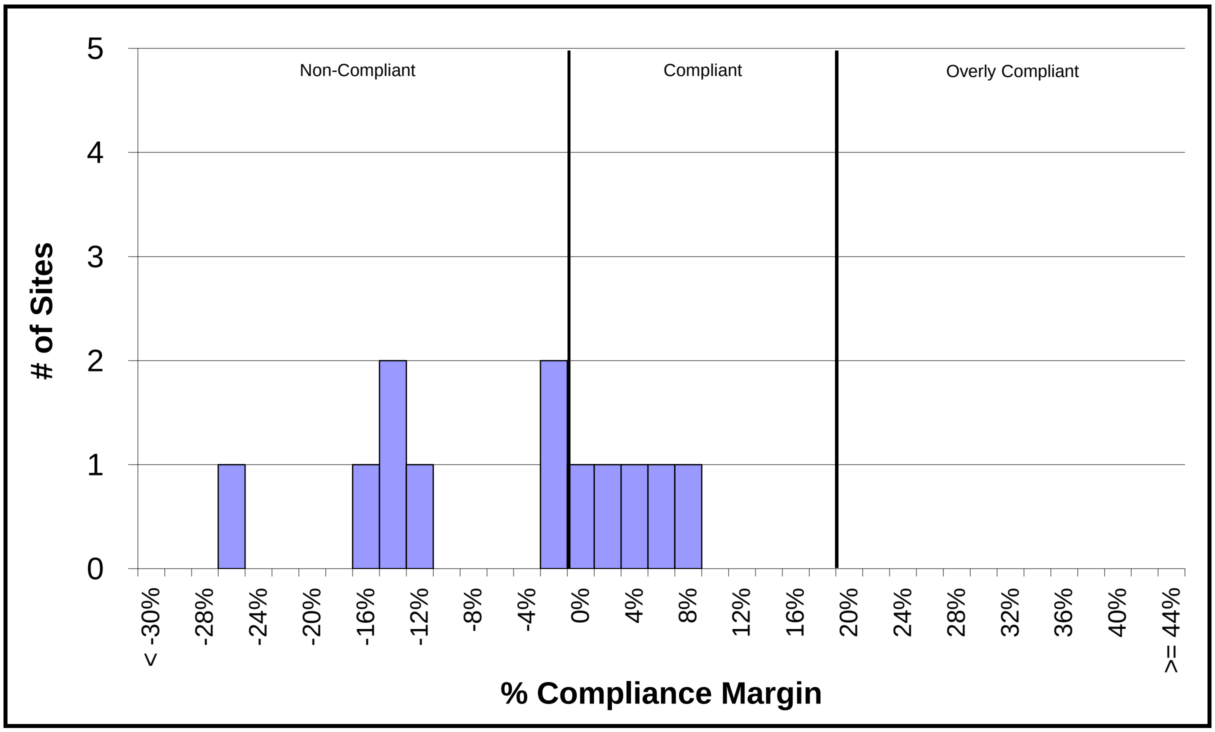
[20] Under the Standards with which the building originally complied.

[21] This site originally complied using a "prescriptive" method embedded in EnergyPro 1.0.[21] However, since, for consistency, all sites were run using the "performance" method, the exact compliance margin could not be reproduced.

[22] Under the Standards with which the building originally complied.

- **As-built – one building was non-compliant.** The main reason for non-compliance is the fan load, which remains constantly higher than assumed in the Title 24 standard budget runs due mostly to oversizing compared to ACM (Alternative Compliance Manual) standard assumptions.
- **As-built under the 2001 Standards – seven buildings would have been non-compliant.** As shown in Figure ES-3, only five as-built buildings would have complied under the 2001 Standards.

Figure ES-3: MICROPAS Results Summary – As-Built 2001 Standards – Low-Rise Multifamily Buildings



ES.5 Conclusions

The results of this study indicate that both low-rise and high-rise multifamily builders will need to modify the typical methods used for compliance and/or make changes to the standard construction practices used under the 1998 Standards, in order to just meet the 2001 Standards. For instance, a large number of buildings are able to comply with the 1998 standards without taking compliance credit for high efficiency measures (e.g., those buildings already employing measures like dual-paned windows and high efficiency water heaters). In some climate zones the homes, as they were constructed, will not comply with the 2001 standards. In other climate zones the homes, as they were constructed, will comply with the 2001 standards, but will not have the typically large compliance margins seen under the 1998 Standards. Both situations indicate that the energy consultants and builders, in most regions, will no longer be able to continue business as usual, which should present a good opportunity for managers of residential new construction energy efficiency programs to enlist energy consultants and builders in their programs. The key findings that support these conclusions are summarized below:

Low-Rise Multifamily Buildings

Implementation of the 2001 Standards has tempered the "excess" compliance margins—usually attributed to the use of lower-than-prescriptive glazing percentages and higher-than-standard efficiency water heaters—that are normally associated with multifamily buildings. Nearly two-thirds of low-rise buildings surveyed that complied under the 1998 Standards would not comply under the tighter energy budgets of the 2001 Standards. As such, changes to either the standard compliance practices or standard construction practices are likely to occur. However, the extent of the change required is likely to vary greatly by climate zone[23].

- In RMST Climate Zone 2, the 2001 average compliance margin is still very positive (12%) so existing practices can still be used to achieve compliance.
- In RMST Climate Zones 1 and 3, the 2001 average compliance margins are just slightly negative (-1% and -2% respectively), so a change to compliance practice might be all that is needed to achieve compliance. For example, using the performance parameters for the actual windows that will be installed rather than CEC default values might be enough to achieve compliance.
- In RMST Climate Zones 4 and 5, the 2001 average compliance margins are more severely negative (-9% and -7% respectively), due to the emphasis of the 2001 Standards on reducing cooling energy. As such, a change to both compliance practices and construction practices will likely be needed to achieve compliance.

In addition, low-rise residential multifamily buildings will generally not be impacted by the change proposed for the 2005 Standards to evaluate central water heating systems against a boiler-based system rather than against individual storage water heaters. This is because the most common hydronic heating system for low-rise multifamily units is a combination space/domestic water heating system that utilizes an individual storage water heater and fan coil for each dwelling unit. However, there are other proposed changes particularly the time dependent valuation of energy usage to the 2005 standards that will impact the low-rise residential buildings. The impact of all proposed changes on low-rise residential buildings is currently being evaluated.

The data from this study suggests that builders of low-rise multifamily units typically use individual unit water heaters as opposed to central systems. Further, builders typically install

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23 Note that for climate zones with relatively large cooling loads, such as the inland valley, compliance under the 2001 standards is substantially harder to achieve than compliance under the 1998 standards.

individual unit water heaters that are more efficient than the existing standards and construct buildings with lower than prescriptive glazing percentages. These factors offer builders the opportunity to trade-off this compliance margin benefit for lower than prescriptive requirements for insulation, windows, and space conditioning.

A review of the sample of homes in this study suggests that in some cases trade-offs could be taking place as evidenced by lower than prescriptive insulation, a high occurrence of single-pane metal windows, and some occurrences of electric resistance space heating systems. However, in other cases the compliance margin benefit from high efficiency water heating and relative low glazing percentages results in relatively high compliance margins. In either case, the common practice of installing high efficient individual unit water heaters and constructing buildings with lower than prescriptive glazing percentages enable builders of low-rise multifamily buildings to easily comply with the prevailing Title 24 (1995 or 1998) standards. However, the 2001 standards for the inland climate zones are more difficult to attain than the prevailing 1995 or 1998 standards.

High-Rise Multifamily Buildings

Conclusions are more difficult to draw from the high-rise analysis due to the small number of sites (12) and lack of sites in RMST CZ4. However, since fewer high-rise multifamily are built, and most of these tend to be located along the coast (RMST CZ1 and CZ2), the results may still provide a good characterization of high-rise multifamily residences. Key findings for high-rise multifamily buildings include:

- More than half of the high-rise buildings surveyed have central water heating systems, so high-rise buildings will be significantly impacted by the change proposed for the 2005 Standards to evaluate central water heating systems against a central boiler-based system, rather than against individual storage water heaters.
- There are other proposed changes particularly the time dependent valuation of energy usage to the 2005 standards that will also impact the high-rise residential buildings. The impact of all proposed changes on high-rise residential buildings is currently being evaluated.
- Regarding the issue of trading off the extra energy budget resulting from the use of central water heating systems, this does not seem to be an issue for high-rise buildings: insulation typically meets or exceeds prescriptive values, heating efficiencies are higher than minimum appliance standards, and dual-paned windows are most common and half of those are even low-e.
- Exterior lighting is generally controlled in accordance with the non-residential and high-rise lighting Standards via daylighting controls.

Common Issues

Key findings applicable to the entire multifamily segment include:

- For both low-rise and high-rise multifamily buildings, there is some evidence of specifying CEC minimum default window performance parameters on the compliance documentation, but installing windows that are better than these defaults. This supports anecdotes from other sources that Title 24 energy consultants do this to give the builder maximum flexibility during construction.
- Results from the building characteristics analysis show that low-rise and high-rise[24] multifamily residences are distinctly different in building envelope configuration, glazing percentages, and predominant space heating, space cooling, and water heating system types.
- CFLs are not present in the bathrooms of all multifamily buildings, as required by the Standards, but are implemented more often in high-rise buildings (two-thirds) than low-rise buildings (less than one-half).
- The management always supplies laundry equipment, whether located in a common area facility or within the individual dwelling units, in the low-rise and high-rise buildings surveyed.

[24] Note that some of the four-story high-rise buildings surveyed have similar building characteristics to the low-rise buildings surveyed.

1

Introduction

1.1 Overview

This report discusses results of a study of energy efficiency building standards and practices in newly constructed multifamily buildings throughout California. The study's primary purpose is to provide information to residential new construction (RNC) program managers across the state, thereby allowing them to assess and address the effect of recent and impending energy code changes on these programs. The study was conducted by Regional Economic Research, Inc. (RER), a wholly owned subsidiary of Itron, Inc., Heschong Mahone Group (H-M-G), and ADM and Associates, under Pacific Gas & Electric (PG&E) management.

1.2 Study Objectives and Approach

The objective of this study is to describe common building practices and analyze the Title 24 compliance of low-rise and high-rise multifamily buildings. To meet this objective, for the low-rise multifamily buildings, RER used the RNC Interface, which allows the data from compliance documentation or on-site surveys to be translated into MICROPAS input files. MICROPAS then processes these input files and the results are made available in a number of formats. H-M-G analyzed the high-rise multifamily buildings by developing tailored EnergyPro files for each building.

The project team then analyzed these results, together with the detailed on-site data, to ascertain common building practices and to complete the Title 24 compliance analysis. The major elements included in the approach are to review the compliance documentation collected from building departments throughout California, review the verification on-site surveys, identify baseline characteristics, analyze the compliance results, compare the as-permitted results to the as-built results, and analyze the multifamily buildings under the 2001 Standards.

1.3 Organization of the Report

The remainder of the report is organized as follows:

- Section 2 presents the approach used in conducting the analysis.
- Section 3 discusses and summarizes the current building practices in low-rise and high-rise multifamily buildings.
- Section 4 discusses the analysis of Title 24 compliance for low-rise and high-rise multifamily buildings.
- Section 5 presents the key findings of the project and comments on issues that are relevant to residential new construction program planners, and Title 24 compliance.
- The following appendices are included:
  - Appendix A: On-Site Verification Survey Forms
  - Appendix B: Detailed As-Built Differences

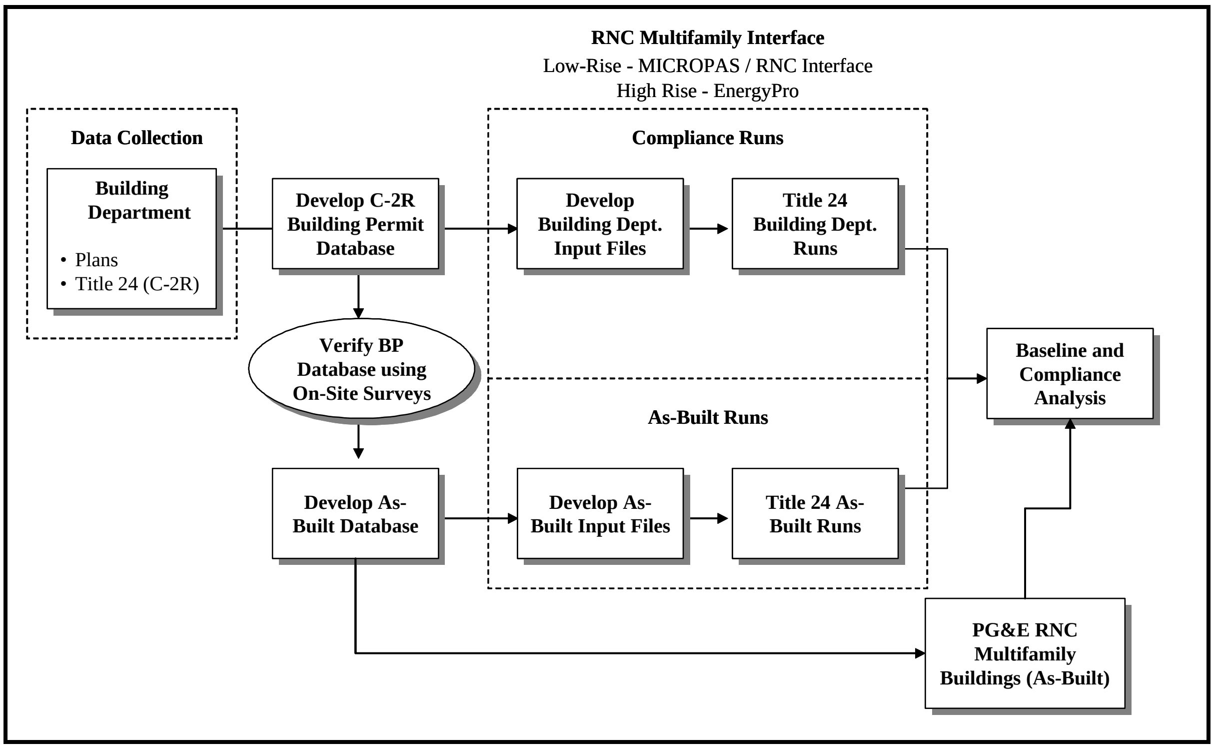
2

Methodology

2.1 Overview of Approach

This section discusses the study approach to complete the baseline characterization and compliance analysis of the multifamily new construction sector. Figure 2-1 presents an overview of the approach, which can be broken out into seven major elements.

Figure 2-1: Overview of Study Framework



- ***Data Collection from Building Departments.*** Building plans and Title 24 Compliance documentation for multifamily buildings built under either the 1995 or 1998 Standards were collected from a sample of California building departments.
- ***Verification of As-Built Building Characteristics.*** In this element, on-site surveys of the multifamily buildings for which complete compliance documentation was collected were conducted. The purpose of the on-sites surveys was to verify the as-built characteristics of each building. For this purpose, survey

instruments[1] to collect data on discrepancies between the as-built building characteristics and the compliance documentation filed with the building department were developed. Further, specific detailed information required by the RFP on piping, ductwork, and wiring for the HVAC and water heating systems were also collected.

- ***Development of As-Permitted Input Files.*** Based on data collected from building departments, as-permitted input files were developed. In the case of low-rise buildings, MICROPAS was used and in the case of high-rise buildings, EnergyPro was used. These as-permitted input files are consistent with the compliance documentation filed with the building departments during the building permit application process.
- ***Development of As-Built Input Files.*** The as-permitted input files were updated to reflect the as-built characteristics of each building. These files were used to simulate the as-built runs for the analysis and to develop baseline characteristics of each building type.
- ***Perform Permitted and As-Built Simulations.*** Permitted and as-built simulations were run for each building. These results are used to conduct the baseline and compliance analysis. Again, MICROPAS were used for the low-rise multifamily buildings and EnergyPro for the high-rise multifamily buildings.
- ***Baseline Assessment.*** A major result of the analysis is the development of baseline characteristics of the multifamily buildings. The focus of this effort was to develop baseline characteristics by climate zone and multifamily building type. Where possible, characteristics of the low-rise and high-rise multifamily buildings were assembled in a common format.
- ***Compliance Analysis.*** Compliance analysis of each building was performed by developing % Compliance Margins for the as-permitted and as-built buildings under the Standard with which they originally complied and the 2001 Standards.

Each of these major elements is discussed in further detail below.

2.2 Data Collection from Building Departments

This task involved collecting building plans and Title 24 compliance documentation for newly constructed multifamily buildings from California building departments. Below is an overview of the original targets, the documentation collected, and the documentation verified. The original sample design can be found in Appendix C.

[1] Appendix A contains the low-rise and high-rise on-site survey forms.

Original Targets

The original work plan called for the analysis of 50 low-rise and 50 high-rise newly constructed multifamily buildings. The first step in this process was the collection of Title 24 compliance documentation and building plans[2] from building departments for approximately 60 buildings of each type.[3] However, several problems were encountered when attempting to collect the compliance documents and when attempting to conduct the on-site building audits.

The primary difficulty in collecting enough sets of compliance documentation to reach the targets was simply finding newly constructed multifamily buildings. For low-rise buildings, the difficulty was in reaching the goals in RMST Climate Zones 1 and 5. However, for high-rise buildings, it was difficult to find buildings that were constructed over the last several years. Below is a summary of the problems encountered during this project and the approaches taken to try to overcome these obstacles.

- ***Some building departments did not have any compliance documentation.*** More building departments than expected did not have any compliance documentation on file for buildings that had already been constructed or they were unable to retrieve the documentation requested. This prompted the project team to actively recruit Title 24 Consultants. Project flyers were developed and sent to consultants throughout California. This method of obtaining electronic compliance files proved to be fairly successful.
- ***Addresses needed at some building departments.*** The project team collected addresses of multifamily buildings from several sources including the IOUs, Center City Development Corporation, and various Internet searches. While this did allow the project team to collect some additional sets of documentation, many addresses were for attached single family buildings, buildings that had not been built yet, or addresses that could not be found at the building department.
- ***Copying plans and compliance documentation.*** As expected, many building departments do not allow the building plans and/or compliance documentation to be photocopied. Therefore, the project team brought blank compliance documentation forms so that they could copy the necessary information. This was a long process especially for the high-rise buildings, where some sets of documentation took more than one day to copy.
- ***Many buildings that complied under 1998 Standards were not built.*** Project management agreed to increase the scope of the project to include buildings that originally complied under the 1995 Standards. This compromise

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[2] The data collection process and the other steps of this analysis are discussed in detail in Sections 2.3 – 2.5.

[3] The goal for data collection was higher than the targets for the analysis since it was assumed that some sites would drop out for one reason or another.

was reached because of the small number of changes between the 1995 and the 1998 Standards.

- ***Many high-rise buildings were not complete and occupied.*** Project management agreed to allow buildings that had a completed building shell and HVAC and DHW equipment installed.
- ***The documents collected for some buildings did not include all of the necessary information to recreate the compliance form.*** The project team attempted to contact the Title 24 consultant that performed the analysis to obtain the complete documentation information. This was successful for a few buildings, but not for a majority of them.
- ***Thirteen building owners/managers refused to allow the on-site survey.*** Eight low-rise and five high-rise owners/managers refused to allow our verification team survey their building. Reasons cited ranged from not being interested in a utility study to not wanting to disturb the residents living in the building.

It is important to note that the process of collecting and verifying the compliance documentation for this project was iterative. The project team provided regular status reports to the project managers and the difficulties encountered were discussed in detail. The project team and the project managers worked together to come up with as many solutions to the problems encountered as possible.

Compliance Documentation Collected

The project team collected compliance documentation for 62 low-rise and 37 high-rise multifamily buildings. The following describes the type of documentation that was collected for low-rise multifamily buildings and high-rise multifamily buildings.

Compliance Documentation Collected for Low-Rise Buildings

The following is a list of the type of documentation that was collected by the data collection team at the building departments for low-rise multifamily buildings:

- Information collected for most of the buildings contained a MICROPAS C-2R form. For other buildings, an EnergyPro or a Comply24 form was collected. The project team used these forms to develop the baseline energy usage needed for the analysis.
- Copies of the plans were also collected were possible. If plans could not be photocopied, the project team sketched the site and building, including detailed fenestration information.[4] Every effort was made to obtain copies of plans, however, in order to collect documentation on as many buildings as possible, this was not cause to drop a building.

4 Detailed fenestration information must contain placement and size of each window and glass door.

- Note that compliance documentation was only collected for one building per apartment complex.

Compliance Documentation Collected for High-Rise Buildings

High-rise residential projects present a special challenge because an EnergyPro model had to be developed for each (there is not an automated tool for generating EnergyPro runs from compliance documentation). There are two cases to consider.

- **Case 1. EnergyPro run exists.** In these cases, the project team contacted the energy consultant who prepared the run and requested an electronic copy of the input file.
- **Case 2. No EnergyPro run exists.** In these cases, the project team needed to extract the data from the available plans and documentation to construct an EnergyPro run. Because of budget limitations, this was not a detailed, site-specific building model. Rather, it was a prototype building having the same characteristics as the actual, per the Title 24 documentation (e.g., it has the same wall and window areas, floor areas, number of floors, insulation, glazing, HVAC system, etc.). While not as detailed as an original EnergyPro simulation, it was sufficiently useful for estimating compliance margins.

Each field staff member was provided with standardized forms on which to copy information from the Title 24 documentation (e.g., high-rise residential compliance forms), in case the compliance documentation cannot be photocopied. This approach was needed because some building departments do not allow the permit forms of high-rise buildings to be copied or scanned. However, hand-copying the data onto forms is allowed.

The information for which data was be extracted from the Title 24 documentation includes the following:

- Floor area,
- Wall area,
- HVAC system types, sizes and equipment efficiencies,
- Water heater system types, energy factors (EFs), recovery efficiencies (RE), and, if central DHW systems:
  - Storage tank details, if any,
  - Re-circulation pump sizes and efficiencies,
  - Location of piping, and
  - Type of re-circulation loop controls, if any.

  In addition, every effort was be made to obtain copies of plans for central water heating systems.

- Wall, ceiling, and floor insulation levels,
- Window thermal efficiencies (U-factor), solar heat gain coefficients, type of window frame, manufacturer, and model number (if available)
- Window area (the entire opening was be measured – not just the glass), and
- Duct insulation, location, and leakage, if available, and
- Type of lighting equipment for common areas.

In addition, similar to the documentation collected for low-rise buildings, the project team attempted to collect a copy of the plans for each site. Likewise, compliance documentation was only collected for one building per property.

Compliance Documentation Verified

After review of the 99 buildings for which compliance documentation was collected, 40 low-rise buildings and 18 high-rise buildings were found to have enough information to recreate the compliance results and construction of the building was verified. Table 2-1 summarizes why the remaining 41 buildings were not acceptable for use in this study.

As shown, most of the low-rise multifamily buildings rejected at this stage were due to incomplete compliance documentation. Several of these buildings were missing one or more pages of the C-2R form. One reason for this was that only every other page was found at the building department – these were perhaps copy errors of the building department. Another common problem was that since many building departments did not allow photocopies, hand copies of forms other than MICROPAS C-2R forms (i.e., EnergyPro and Comply24) were often missing information. This was typically because the data collection team had blank copies of a MICROPAS C-2R form to complete and the output of the various software programs does not have the same format. When verifying construction, an additional two buildings were found to be attached single family buildings. Upon further review, the compliance documentation was incorrect in reporting the residence type.

Similar problems were found with the high-rise buildings for which documentation was collected. Eight of the buildings were not far enough along in construction to be able to perform a meaningful on-site survey. An additional nine did not have complete compliance documentation. Of these, two did not have plans that laid out the duct and DHW lines, while the other seven were missing at least one page of the compliance report. (It should be noted here that the compliance documentation for high-rise buildings is very extensive. In a majority of these seven buildings, only one report (i.e., mechanical or ventilation) was missing.)

Table 2-1: Summary of Reasons for Rejecting a Building

Reason	# of Low-Rise Buildings	# of High-Rise Buildings
Total Collected	62	37
Incomplete Compliance Documentation[5]	17	7
Incomplete Plans	0	2
Alteration	0	1
Construction not Complete[6]	3	8
Building not Accessible[7]	0	1
Attached Single Family Building	2	0
Total Verified and Usable	40	18

2.3 On-Site Verification of Title 24 Documentation

The next step was to verify the building shell characteristics and the equipment installed in the 58 buildings for which complete and verified compliance documentation was collected. Recruitment letters were sent to the property managers and/or owners of these buildings. These recruitment letters were sent on the letterhead of the IOU that serves the building. Next, the project team contacted the property manager/owner in order to set up an appointment to survey the building. Of the 40 low-rise buildings contacted, eight refused to participate. Of the 18 low-rise buildings contacted, five refused to participate.

Therefore, the second phase of the data collection included on-site verification surveys of 32 low-rise and 13 high-rise buildings. The on-site surveys were conducted in order to verify that the following information gathered from the Title 24 documentation corresponded with what was installed in the building:

- ***General***
  - Floor area
- ***HVAC***
  - System type. Room, split or packaged air conditioning (AC) or heat pump (HP), or built-up.
  - Manufacturer and model number. This can be found on the nameplate.

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5 Most of these buildings had plans and permit information but were missing some or all of the compliance documentation. In these cases, it was not evident that anything was missing until a detailed review was completed.

6 Please note that the requirement was not that the building was occupied, instead, the building need only to have the building shell completed and all HVAC and water heating equipment installed.

7 When verifying that this building was constructed, the project team was told that the building was used for mentally handicapped persons and that access to the property was impossible.

  - Equipment efficiencies. Annual fuel utilization efficiency (AFUE), seasonal energy efficiency ratios (SEERs), energy efficiency ratios (EERs). If the efficiency rating was not on the sticker, the appliance efficiency was determined by using model numbers in appliance databases.
  - Manufacturer and model number of components. Components of interest include coils *(if applicable)*.

- ***Water Heaters***
  - System type. Individual or central boiler.
  - Manufacturer and model number. This can be found on the nameplate.
  - Equipment efficiencies. Energy factors (EFs) for gas water heaters less than 75kBtu, the efficiency for gas water heaters/boilers greater than 75kBtu or combined systems. If the efficiency rating was not on the sticker, the appliance efficiency was determined by using model numbers in appliance databases.
  - Tank size. *If applicable*
  - Re-circulation pumps. Number, size (volts, amps, HP, phase), pipe size.
  - Type of controls. *If applicable.*
  - Pipe insulation. R-value. *If applicable.*
  - Presence of additional measures such as heat traps and blankets. *If applicable.*

- ***Glazing***
  - Window efficiencies. The project team had the U-factors and the solar heat gain coefficients (SHGC) from the C-2Rs and high-rise residential compliance documents. ADM used low-e detectors and visually and manually check the type of frame (vinyl, aluminum, or wood) and the number of panes, and estimated the spacer width. This information helped us determine if these efficiencies were correct.
  - Window dimensions. To ensure accurate window areas, ADM measured the height and the width of each differently sized window, and sliding glass door, in the building. They also provided a count by window type, by size, and by orientation, and noted any that are not adjacent to conditioned space (e.g., stairwells).

- ***Building Shell***
  - Wall area
  - Wall, ceiling, and floor insulation. R-values were determined, where possible, as well as insulation type and thickness.
  - Frame type. The project team determined, where possible, steel stud versus wood stud partitions.

For the on-site data verification visit to a particular site, field surveyors were provided with a form that has the information extracted from the Title 24 documentation. Using this form, the surveyor verified either that the as-built value was the same as the value on the Title 24 documentation or entered the as-built value if it differed. In cases where some information was not possible to ascertain, the field surveyor noted so and the value on the compliance documentation was used as a default. The field surveyors also took photos of each site during the survey. Copies of the survey instruments are in Appendix A.

2.4 Develop the As-Permitted and As-Built Input Files

The purpose of this task is to develop simulation runs to analyze compliance under the Standards with which the building originally complied and under the 2001 Standards. The analysis includes 31 low-rise and 12 high-rise buildings.[8]

As-Permitted Simulations

The first task was to develop the input file that recreates the compliance documentation obtained from the building departments. For low-rise residential buildings, this was a straightforward process since the compliance documentation contains all of the inputs needed.[9] For high-rise residential buildings, simplifying assumptions about system zoning, controls, and schedules needed to be made in order to retain the overall usefulness of the simulations. It should be noted here that every permitted simulation complied since the documentation for each building must show compliance before construction is begun.[10]

Development of As-Permitted Input Files for Low-Rise Buildings

RER used MICROPAS for modeling the simulations for the low-rise multifamily buildings. The initial strategy was to collect only MICROPAS C-2R forms since they contain all of the information needed to develop the as-permitted input file making this subtask straightforward. However, due to the lack of complete compliance documentation found, the project team also began to collect other types of compliance documentation including EnergyPro and Comply24 C-2Rs.

Permitted compliance input files for the low-rise multifamily buildings were created using the RNC Interface.[11] The RNC Interface has the capability of reading data from a specified database, developing MICROPAS input files, and running simulations using the appropriate

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8 One low-rise building was not used in the analysis because it was an attached single family building. In addition, one high-rise building was not used in the analysis because of incomplete information.

9 This was true for all buildings except one where the compliance documentation collected was performed on a per residence basis instead of the entire building.

10 Insofar as all buildings obtained building permits, all buildings comply with Title 24 based on the documents filed with the building departments. Having said that, it is important to note that there were some cases where recreating the compliance documentation revealed that the building might not have originally complied.

11 RER, Inc. *Residential New Construction Study.* Prepared for Pacific Gas and Electric. September 2001.

version of MICROPAS. In developing the as-permitted input files, the RNC Interface can take in data from the database containing the compliance information collected from the building departments.

Development of As-Permitted Input Files for High-Rise Buildings

H-M-G used EnergyPro for modeling the simulations for the high-rise multifamily buildings. The data collection team attempted to obtain electronic input files for the high-rise buildings. For these cases, H-M-G verified the input as reasonable and representative of the design based on the data collected from the building departments. The project team then developed as-permitted input files for those buildings where the electronic file was not obtainable, but where the compliance documentation from the building department was complete. These compliance input files were designed to be consistent with the compliance documentation filed with the building departments during the building permit application process.

As-Built Simulations

Since buildings are not always built exactly according to the plans and/or compliance documentation, the results of the on-site surveys were used to replace those inputs that were changed. For example, if the compliance documentation states that R-30 was to be installed in the ceiling, but if during the on-site survey it was found that R-19 was installed, this field was changed in the input file and the as-built compliance results were calculated.

Development of As-Built Input Files for Low-Rise Buildings

As-built simulations for the low-rise multifamily buildings were completed by RER in the same manner that the permitted simulations were developed. In developing the as-built simulations, the RNC Interface simply read in data from the database containing the information obtained during the on-site verification.

Development of As-Built Input Files for High-Rise Buildings

H-M-G completed the as-built simulations for the high-rise multifamily buildings. Since simulations for high-rise residential buildings could not be performed using MICROPAS, H-M-G used EnergyPro for these buildings. EnergyPro allows the analysis of complex systems and construction types in compliance with the California Energy Commission's ACM guidelines and assumptions.

To model each building correctly, details of construction, based on the site visits, needed to be entered. However, even after making a site visit, there was some information that could not be verified. The best procedure in those cases was usually to assume that the original Title 24 documentation is correct.

2.5 Analyze Results

This task contains two subtasks: the baseline assessment and the compliance analysis. These subtasks are each briefly explained below.

Baseline Assessment

A major result of the analysis was the development of baseline characteristics of multifamily buildings as constructed in California. Summary statistics were developed by climate zone, multifamily building type, and by residential unit. However, please note that because of the small sample sizes in some climate zones and since population statistics were not developed, these summary statistics were not weighted or expanded to the population.

Also, note that, where possible, a common format across multifamily building types was developed in order to present sector-wide summary statistics. For example, the “percent of window area, as percent of wall space, with respect to orientation” is known in the Standards as the window wall ratio (WWR). Since envelopes for multifamily buildings are analyzed using a nonresidential ACM or a residential ACM depending upon the number of stories, some have requirements based on WWR and others, based on fenestration-to-floor area. In anticipation of the California Energy Commission amending the standards for multifamily buildings, the project team has reported both these ratios for all buildings, helping to establish a baseline correlation between the two metrics.

Compliance Analysis

Compliance analysis of each building was performed by comparing % Compliance Margins for the as-permitted and as-built cases. This analysis shows what the compliance margin is for both the as-permitted and as-built runs. The % compliance margin is the difference of the standards and proposed energy budgets (the margin) divided by the standard energy budget. Specifically,

$$\%\ Compliance\ Margin = \frac{(Standard\ Energy\ Budget - Proposed\ Energy\ Budget)}{(Standard\ Energy\ Budget)}$$

This definition is consistent with the method that most residential new construction programs use to define program compliance. For instance, a home must be 20% better than 1998 Title 24 (i.e., % Compliance Margin=20%) to qualify as an ENERGY STAR home. In addition, an analysis of reasons for buildings not complying relative to the compliance documentation filed with the building departments is also provided. That is, data on changes made to the specification on the plans filed at the time of the permitting process that caused a building to not comply was documented. Reasons for not complying are also presented on a building-by-building basis.

3

Current Building Practices for Multifamily Buildings

3.1 Introduction

This section discusses current building practices for multifamily buildings. In particular, building department compliance documentation and on-site verification surveys of low- and high-rise multifamily buildings were used to establish current building practices for building shell, HVAC systems, and water heating equipment. In addition, the date of the original compliance documentation and the date in which each building was occupied was also reviewed to better understand how long the construction process is for multifamily buildings.

3.2 Overview

The data collected are presented by climate zone and residence type. The following provides a description of the residence types and climate zones as well as an overview of the distribution of the sites included in the analysis.

Residence Type

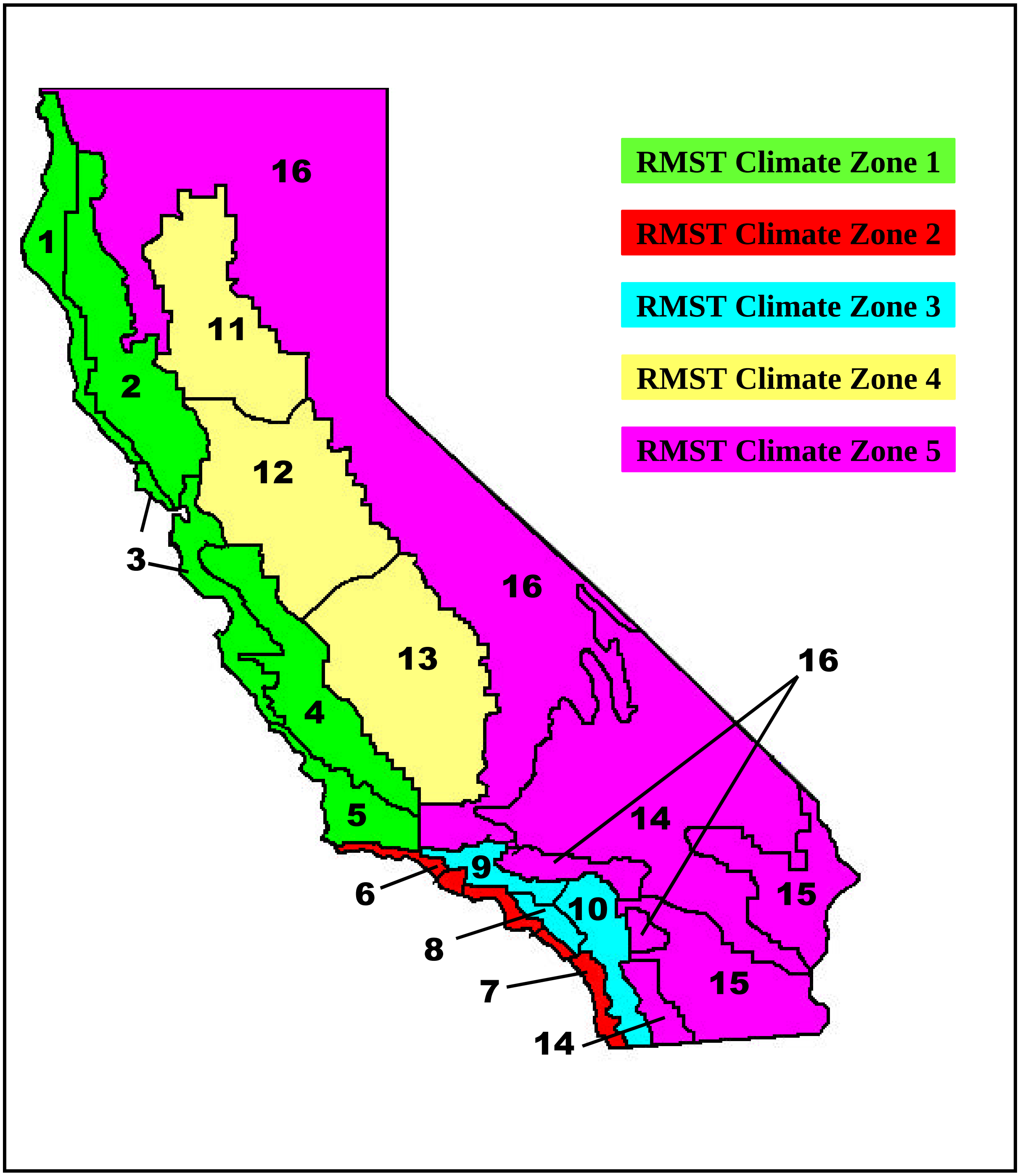
Average building characteristics are presented by low- and high-rise multifamily buildings. A multifamily building is defined as a residential building in which the dwelling units share at least a common floor or ceiling. Low-rise multifamily buildings are multifamily buildings that are two or three stories, while high-rise multifamily buildings are more than three stories.

CEC Climate Zone

As shown in Figure 3-1, there are 16 CEC climate zones in California. For this study, these zones were collapsed into five regions. The criterion for the aggregation of the climate zones was that the Title 24 requirements across these climate zones be the same or vary in only one component. Using this approach, climate zones were aggregated as follows:

- RMST Climate Zone 1 (CZ1) encompasses CEC Climate Zones 1, 2, 3, 4, and 5.
- RMST Climate Zone 2 (CZ2) encompasses CEC Climate Zones 6 and 7.
- RMST Climate Zone 3 (CZ3) encompasses CEC Climate Zones 8, 9, and 10.
- RMST Climate Zone 4 (CZ4) encompasses CEC Climate Zones 11, 12, and 13.
- RMST Climate Zone 5 (CZ5) encompasses CEC Climate Zones 14, 15, and 16.

Figure 3-1: CEC Climate Zones



Source: California Energy Commission.

Sites Included in the Analysis

Table 3-1 presents the distribution of surveyed sites by RMST climate zone and residence type. As shown, 31 low-rise buildings and 12 high-rise buildings are included in the analysis. Compliance documentation was collected for 62 low-rise buildings and 37 high-rise buildings, while on-site verification surveys were completed for 32 low-rise and 13 high-rise buildings. However, many sites were excluded due to incomplete compliance documentation or refusal to allow the on-site survey. (Please note that because of the small sample sizes in some climate zones and since population statistics were not developed, the summary statistics presented below were not expanded to the population.)

Table 3-1: Summary of Sites in the Analysis

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Overall	**43**	**2**	**14**	**11**	**13**	**3**
Low-Rise Multifamily	31	1	6	9	13	2
High-Rise Multifamily	12	1	8	2	-	1

3.3 Lag Time between Compliance Date and Occupied Date for Multifamily Buildings

Due to the large number of buildings, that originally complied under the 1998 Standards, found to be still under construction, an analysis of the lag time between compliance date and occupied date was conducted for the 31 low-rise and 12 high-rise buildings. Table 3-2 and Table 3-3 provide the date of the original compliance[1] documentation and the date that the building was first occupied for low-rise and high-rise multifamily buildings respectively, while Figure 3-2 illustrates the data presented in the tables. As shown, the original compliance dates and occupancy dates were available for 26 of the 31 low-rise buildings and 11 of the 12 high-rise buildings. The lag times between the compliance date and the occupied date averaged 18 months for the low-rise multifamily buildings and 24 months for the high-rise multifamily buildings.

[1] The compliance date refers to the date in which the original compliance analysis was completed. In most cases, the date that the building department approved the project was not available.

Table 3-2: Compliance and Occupied Dates – Low-Rise Multifamily Buildings

Site ID	Original Standard	Compliance Date	Occupied Date	# Months
99043	1998		2/2/2002	
99071	1995	8/28/1998	1/1/2000	16
99072	1995	12/4/1998	1/1/2000	13
99073	1995	3/11/1999	3/1/2001	24
99077	1995	2/3/1999	12/1/1999	10
99078	1995	5/31/1999	1/1/2001	19
99079	1995	6/22/1999	7/1/2000	12
99081*	1995	unknown	1/1/2001	
99082*	1995	unknown	11/1/2000	
99083	1998	10/21/1999	3/1/2001	16
99084	1995	4/26/1998	11/1/1999	18
99086	1995	1/6/1998	3/1/1999	14
99092	1995	4/29/1999	9/1/2000	16
99101*	1995	unknown	1/1/2000	
99103	1995	7/15/1998	8/1/2000	25
99104	1995	9/2/1998	8/1/2000	23
99111	1995	9/8/1998	1/1/2000	16
99112	1998	4/13/2000	12/1/2001	20
99113	1995	3/2/1999	5/1/2001	26
99114	1998	1/24/2000	11/1/2001	21
99120	1995	9/9/1998	9/1/2000	24
99121	1998	2/11/2000	6/1/2001	16
99122	1995	6/1/1999	10/1/2000	16
99123	1995	10/17/2000**	6/1/2001	7**
99124	1995	9/28/1998	7/1/2000	21
99126	1995	3/31/1999	6/1/2000	14
99127	1995	6/26/1999	12/1/2000	17
99128	1995	4/9/1999	7/1/2000	15
99129	1995	10/23/1997	12/1/1998	13
99141	1998	2/11/2000	6/1/2001	16
99142	1998	10/3/1999	5/1/2001	19

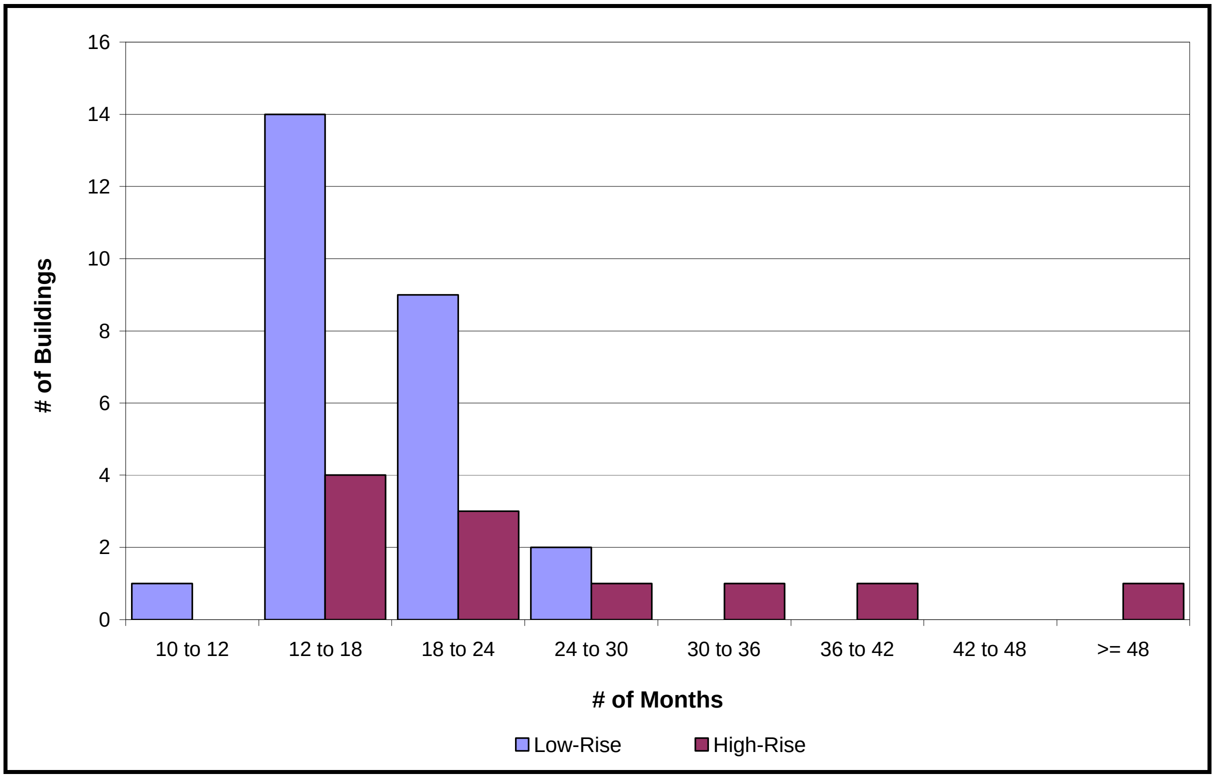
* The compliance documentation collected for these buildings were hand-copied and the dates were not included.

** The compliance documentation collected for this building was for a revision, not the original documentation.

Table 3-3: Compliance and Occupied Dates – High-Rise Multifamily Buildings

Site ID	Original Standard	Compliance Date	Occupied Date	# Months	Notes
99988	1995	5/11/1997	7/1/2001	50	Stand Alone 8-Story
99989	1998	9/27/2000	2/1/2002	16	Part of Complex
99990	1998	2/8/2000	3/1/2001	13	Part of Complex
99991	1995	9/16/1998	4/1/2000	19	Part of Complex
99992	1998	unknown	1/1/2001		Stand Alone 4-Story
99993	1998	8/16/1999	11/1/2002	39	Part of Complex
99994	1995	5/20/1999	4/1/2001	22	Part of Complex
99995	1995	9/23/1998	1/1/2000	15	Gut Remodel
99996	1998	4/11/2000	12/1/2002	32	Part of Complex
99997	1998	5/5/1999	7/1/2001	26	Stand Alone 4-Story
99998	1998	2/11/1999	7/1/2000	17	Part of Complex
99999	1998	9/25/2000	5/1/2002	19	Part of Complex

Figure 3-2: Distribution of Buildings by Lag Time



3.4 Reference for Evaluating Energy Efficiency Building Characteristics and Practices

Provided below is a brief overview of the Title 24 building standards for both low- and high-rise multifamily buildings.

Low-Rise Multifamily Buildings

Table 3-4 presents Prescriptive Package D values[2] for construction features affecting energy efficiency for the 16 CEC climate zones. These values provide a basis for evaluating the current construction practices. Values are given for ceiling insulation, wall insulation, glazing percent (versus total conditioned floor area), minimum glazing U-factors, and maximum allowable Solar Heat Gain Coefficients (SHGC) for the 1998 Standards.

Table 3-4: Prescriptive Package D Requirements by CEC Climate Zone

CEC CZ	Ceiling R-Value	Wall R-Value	Glazing Percent	Glazing U-factor	SHGC[3] (orientation)
1	38	21	16	0.65	
2	30	13	16	0.65	
3	30	13	20	0.75	
4	30	13	20	0.75	
5	30	13	16	0.75	
6	30	13	20	0.75	
7	30	13	20	0.75	
8	30	13	20	0.75	0.40 (W/E)
9	30	13	20	0.75	0.40 (W/E)
10	30	13	20	0.75	0.40 (W/E)
11	38	19	16	0.65	0.40 (W/E)
12	38	19	16	0.65	0.40 (W/E)
13	38	19	16	0.65	0.40 (W/E)
14	38	21	16	0.65	0.40 (W/E)
15	38	21	16	0.65	0.40 (S/W/E)
16	38	21	16	0.60	

2 *Contractor's Report 2001 Update Assembly Bill 970. CEC Volume 1 – Summary*. November 2000.

3 Prescriptive shading requirements are defined as Solar Heat Gain Coefficients values for the 1998 Standards.

Windows

Two values are used to rate window performance: U-factor and SHGC. U-factor is a measure of a window's thermal performance. The lower the U-factor, the greater a window's resistance to heat flow and the better its insulating value. SHGC measures how well a product transmits sunlight. SHGC is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward. The lower a window's SHGC, the less heat transmitted.

Since U-factors and SHGCs were not observed during the on-site visits, the window efficiency analysis focuses on the types of windows installed. After reviewing every possible combination of window type, RER found eight types of windows in the RMST database. These eight window types, listed below, are the focus of the analysis presented here.

- Clear glass, single-pane, metal frame.
- Clear glass, double pane, wood/vinyl frame.
- Clear glass, double pane, metal frame.
- Reflective/tinted glass, double pane, wood/vinyl frame.
- Reflective/tinted glass, double pane, metal frame.
- Low-E glass, double pane, wood/vinyl frame.
- Low-E glass, double pane, metal frame.

Space Heating

The energy efficiency of furnaces is expressed as a percentage of Annual Fuel Utilization Efficiency (AFUE). Equipment AFUEs increase as energy efficiency increases. Table 3-5 provides the minimum equipment efficiencies for space heating equipment in Prescriptive Package D of the 1998 Low-Rise Title 24 Standards, which follow the federal minimum standards.[4]

[4] Code of Federal Regulations. Title 10, Chapter II, Subpart C, Part 430, Section 430.32.

Table 3-5: Space Heating Standards

Equipment Type	Standard Efficiency	Efficiency Term
Heat pumps		
Split Systems	6.8	HSPF
Single Package Systems	6.6	HSPF
Gas Furnaces[5]	78%	AFUE
Hydronic System	75%	AFUE
Electric Furnaces	3.41	HSPF

Space Cooling

The cooling efficiency rating used to rate central air conditioners is the Seasonal Energy Efficiency Ratio (SEER). The higher the SEER rating, the more efficient the cooling equipment is. SEER ratings range from 9.9 to over 15. Table 3-6 provides the minimum equipment efficiencies for space cooling equipment in Prescriptive Package D of the 1998 Low-Rise Title 24 Standards, which follow the federal minimum standards.[6]

Table 3-6: Space Cooling Standards

Equipment Type	Standard Efficiency	Efficiency Term
Central Air Conditioners		
Split Systems	10	SEER
Single Package Systems	9.7	SEER
Heat pumps		
Split Systems	10	SEER
Single Package Systems	9.9	SEER

Water Heaters

The energy efficiency of water heaters is expressed as an energy factor rating (EF). Water heater EFs vary by storage tank size and fuel type.[7] Therefore, to standardize for tank size, the standard efficiency was calculated for each gas water heater in the sample. To conduct

5 Required efficiency for residential central gas furnaces that are less than 225 kBtu/hr.

6 Code of Federal Regulations. Title 10, Chapter II, Subpart C, Part 430, Section 430.32.

7 Code of Federal Regulations. Title 10, Chapter II, Subpart C, Part 430, Section 430.32.

an analysis of water heater efficiencies, RER computed the percent-above-standard for each water heater observed from the on-site surveys. The formula used for these calculations is:

$$\%AboveStd_i = \frac{(Eff_i - StdEff_i)}{StdEff_i}$$

where

Eff_i = Actual efficiency rating of unit *i*, and
$StdEff_i$ = $0.62 - (0.0019 \times (TankVolume_i))$.[8]

Using this approach standardizes for tank size and eliminates the need to conduct the analysis by tank size.

High-Rise Multifamily Buildings

The high-rise residential standards are a mix of requirements found in the nonresidential sections and the low-rise residential sections of the Standards. Table 3-7 provides a summary of the prescriptive envelope requirements listed in Table No. 1-J in Section 143. Before the AB 970 changes (2001 Title 24), the U-factor and relative solar heat gain (RSHG) were consistent across variations in glazing area up to a window wall ratio of 40% (i.e., maximum of 40 square feet of glass for each 100 square feet of wall area); above that, the prescriptive approach could not be used. Prescriptive HVAC requirements are also listed in the nonresidential sections (primarily Section 144), and the requirements for high-rise multi-family buildings are essentially the same requirements as for nonresidential buildings. For the lighting and water heating requirements, the nonresidential and high-rise residential portions list the requirements in Sections 123, 130 and 145. Section 145, on water heating, actually refers the reader to the Residential Standards, Section 151(f)8.

Most of the high-rise projects within this study were designed and permitted under the 1998 Standards, although three were permitted under the 1995 Standards. Little changed between the two versions other than the basis of RSHG switching from shading coefficient (SC) to solar heat gain coefficient (SHGC). Please note that Table 3-7 summarizes the 1998 prescriptive envelope requirements.

[8] This standard efficiency equation is applicable for residential gas water heaters with a tank size of more than or equal to 20 gallons and an input rating of less than or equal to 75,000 Btu/hr.

Table 3-7: High-Rise Residential Prescriptive Envelope Requirements

RMST CZ	CEC CZ	Ceiling R-Value	Wall R-Value	Glazing Percent	Glazing U-factor	RSHG (North/Non-North)
1	1	30	19	N/A	0.72	0.77/0.77
1	2-5	19	11	N/A	1.23	0.82/0.82
2	6-7	19	11	N/A	1.23	0.82/0.62
3	8-10	19	11	N/A	1.23	0.82/0.62
4	11-13	30	13	N/A	0.72	0.77/0.50
5	14-15	30	13	N/A	0.72	0.77/0.50
5	16	30	19	N/A	0.72	0.77/0.77

Windows

When used in high-rise residential buildings, windows use the nonresidential ratings (for U-factor and SHGC) as provided through the NFRC rating and labeling requirements. Windows that meet a U-factor of 1.23 are single glazed windows, and those with a U-factor of 0.72 or less are dual glazed.

The RSHG is a figure that combines the SHGC of the fenestration product itself (with or without high-performance glazing) and the building's projections (overhangs). The principle change in RSHG between 1995 and 1998 is the switch from reliance on the shading coefficient (SC) of the fenestration product, to the SHGC of the product as the starting point. The values in the 1995 RSHG column of Table 3-7 describe the same fenestration products as the values in the 1998 RSHG column. The only difference between glazing orientations through the 1998 Standards was a lower RSHG requirement for non-north orientations in CEC Climate Zones 6-15 (RMST CZ2-4 and part of CZ5). The lower RSHG could easily be met either by a standard tinted glass or, in the case of dual glazing, an average low-E coating on one of the panes.

Space Heating and Cooling

The HVAC equipment specified for a high-rise residential building complies prescriptively as long as the equipment just meets the relevant appliance standards. On a performance basis, the equipment is compared to similar, minimally complying equipment in a "standard" performance run. With few exceptions, whatever type of equipment is specified will also be the type of equipment assumed in the run that establishes the allowable energy use. Since there is such a wide range of equipment choices for high-rise residential heating and cooling, not all possible equipment types and efficiencies (as affected by size) are listed here. Rather, the most common types are discussed.

Package terminal air conditioner (PTAC) or heat pump (PTHP). PTHPs are used for heating and cooling, but when a PTAC is specified, it is generally coupled either with a hydronic heating system drawing heat from the water heater or a gas furnace. In the case of a proposed PTAC + hydronic system, the standard budget calculation assumes a four-pipe fan coil for the heating side. PTAC and PTHP systems are among the least efficient means for conditioning, but are often specified because they offer low first cost and ensure that the eventual tenant will be responsible for his/her own cooling or heating and cooling bills. There is, however, a range of efficiencies within this type: 9.7 seasonal energy efficiency ratio (SEER) to SEER 17, and 6.6 heating seasonal performance factor (HSPF) to HSPF 9.7.

"Four-pipe fan coil" systems. In large buildings, such as high-rise residential buildings, efficiency gains and even first cost savings can be achieved by providing a central chiller and boiler and distributing hot and cold water. Despite losses through the distribution systems, the equipment efficiency gains are large enough to result in major energy savings. The standard budget is calculated assuming a minimal efficiency four-pipe fan coil.

"Split DX" systems. Where there is space to place an outside condenser and coil for each residential unit, designers may specify split system air conditioners with a gas furnace ("gas packs"), or split system heat pumps. The minimum SEER rating for split systems is 10.0, and the range runs to about the same as with PTACs, though generally split systems are more efficient than package terminal units.

Water Heaters

The two primary types of water heating for high-rise residential, or any multifamily, buildings are individual water heaters (at each apartment) and central water heating with a hot water distribution system. Small water heaters (for individual apartments) for high-rise residential buildings have the same requirements as for low-rise multifamily or single family buildings.

Central water heaters (or boilers) with hot water distribution systems have an inherent efficiency advantage over numerous individual water heaters distributed throughout the building. This advantage shows up in the analysis because the standard water heating budget is calculated assuming individual water heaters for each residence, even if the intent for the building is to install a central boiler and hot water recirculation loop. However, some of the efficiency gains apparent from analysis with a CEC-approved program are artificial savings derived from the program's under-representation of distribution losses. Piping in recirculation systems is required to have insulation, but the pumps are not required to have controls. Controls that shut the pumps off when they are not needed (like what is required for nonresidential service water heating systems in Section 113(b)) substantially reduce the distribution systems losses and increases the overall system efficiency.

3.5 Current Building Practices in Multifamily Buildings

Summarized below are current construction practices for the following features:

- Square footage, number of stories, and equipment saturations,
- Fenestration,
- Space heating systems,
- Space cooling systems,
- Water heating,
- Shell features, and
- Ducts.

Square Footage, Number of Stories, and Number of Units

Table 3-8 presents a summary of the square footage and number of stories by RMST climate zone. Low-rise multifamily buildings surveyed vary in size from an average of 9,511 square feet in RMST Climate Zone 4 to an average of 22,194 square feet in RMST Climate Zone 1.

High-rise multifamily buildings surveyed range in size from an average of 59,912 square feet in RMST Climate Zone 3 to an average of 162,812 square feet in RMST Climate Zone 2.

Table 3-8: Square Footage and Number of Stories

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Low-Rise Multifamily Buildings *(n)*	*31*	*1*	*6*	*9*	*13*	*2*
Average Square Footage	14,324	22,194	20,250	15,505	9,511	18,590
Average Number of Stories	2.3	2.0	2.5	2.2	2.2	2.5
Average Number of Units in Building	21	24	33	21	14	27
Average Number of Units in Complex	224	468	302	237	173	138
High-Rise Multifamily Buildings *(n)*	*12*	*1*	*8*	*2*	-	*1*
Average Square Footage	133,233	114,268	162,812	59,912	-	62,208
Average Number of Stories	6	11	6	4	-	4
Average Number of Units in Building	138	107	170	68	-	53
Average Number of Units in Complex	461	212	486	649	-	139

Fenestration

Fenestration construction practices, as represented by percent glazing and window types, are discussed in this section.

Percent Glazing

For low-rise multifamily buildings, the percent glazing refers to the total glazing area of a home expressed as a percent of the total conditioned floor area. The 1998 Low-Rise Residential Standards use two values: 16% and 20%. For high-rise multifamily buildings, the percent glazing refers to the total glazing area of a home expressed as a percent of the total wall area. The 1995 and 1998 high-rise residential standards did not have "standard" or prescriptive percentages, but allowed whatever amount was proposed. Since the requirements for high-rise residential fenestration changed in the 2001 code (with assigned prescriptive U-factors and SHGCs for different ranges of window wall ratio, or WWR), the glazing percent is presented as a function of conditioned floor area (WFR) and as WWR for both low-rise and high-rise multifamily projects in the study.

In order to be able to compare the percent glazing for low-rise and high-rise buildings, the window floor ratio (WFR) and the window wall ratio (WWR) are provided in Table 3-9 and Table 3-10, respectively, by RMST climate zone. The following observations can be made from the table.

- The average WFR for low-rise and high-rise buildings is similar (12.7% and 13.8%, respectively). The same is true of the average WWRs, which are 18.5% and 22.3%, respectively.
- The statewide average WFR for low-rise multifamily buildings is 12.7%. These average WFR results suggest no evidence of significant differences across RMST climate zones.[9] It is also true that the buildings with the highest WFR are in those locations where there are likely to be the best views—overlooking San Francisco Bay and Lake Tahoe.
- The statewide average WWR for high-rise multifamily buildings is 22.5%. It is generally observed that the WWR decreases from the coastal (mild) climates to the inland (warmer) climates. The U-factor and SHGC requirements for windows become stringent as the window percentage increases in warmer climates, and there is an echo of that in the glazing percentages.

[9] The only exception to this is that a significance test at the 90% confidence level reveals that the average percent glazing for low-rise multifamily buildings in RMST Climate Zone 5 is significantly higher than the average percent glazing for low-rise multifamily buildings in RMST Climate Zone 1. However, please note that the sample size in RMST Climate Zone 1 was one low-rise multifamily building and the sample size in RMST Climate Zone 5 was two low-rise multifamily buildings.

Table 3-9: Percent Glazing (as % of Floor Area)

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Low-Rise Multifamily Buildings *(n)*	*31*	*1*	*6*	*9*	*13*	*2*
Average WFR	12.7%	11.9%	12.5%	12.9%	12.5%	14.7%
Title 24 Prescriptive		20% & 16%	20%	20%	16%	16%
High-Rise Multifamily Buildings *(n)*	*12*	*1*	*8*	*2*	-	*1*
Average WFR	13.8%	17.5%	13.8%	13.3%	-	11.4%

Table 3-10: Percent Glazing (as % of Wall Area)

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Low-Rise Multifamily Buildings *(n)*	*31*	*1*	*6*	*9*	*13*	*2*
Average WWR	18.5%	19.2%	18.4%	18.8%	18.2%	18.3%
High-Rise Multifamily Buildings *(n)*	*12*	*1*	*8*	*2*	-	*1*
Average WWR	22.3%	41.7%	20.6%	16.6%	-	28.2%

Window Types

Typical construction for window types—frame type, glass type, and number of panes—is presented in Table 3-11 for low-rise multifamily buildings and in Table 3-12 for high-rise multifamily buildings. The following results are shown.

- Metal-framed, clear glass windows are the predominant window type for low-rise multifamily buildings (77%). Dual-pane, metal-framed windows (42%) are more common than single-pane, metal-framed windows (35%).
- Metal-framed windows are also the predominant window type for high-rise multifamily buildings (66%). However, dual-pane, low-E, metal-framed windows (33%) are just as common as dual-pane, clear glass, metal-framed windows (33%) in high-rise multifamily buildings.

Table 3-11: Distribution of Predominant Window Types – Low-Rise Multifamily Buildings

Window Types (# of panes, frame type, glass type)	**Statewide** (31 Sites)	**RMST CZ1** (1 Site)	**RMST CZ2** (6 Sites)	**RMST CZ3** (9 Sites)	**RMST CZ4** (13 Sites)	**RMST CZ5** (2 Sites)
Dual-Pane, Vinyl-Framed, Clear Glass	19%	-	33%	11%	23%	-
Dual-Pane, Metal-Framed, Clear Glass	42%	100%	17%	56%	31%	100%
Single-Pane, Metal-Framed, Clear Glass	32%	-	50%	33%	31%	-
Dual-Pane, Vinyl-Framed, Low-E Glass	3%	-	-	-	8%	-
Dual-Pane, Metal-Framed, Low-E Glass	3%	-	-	-	8%	-

Table 3-12: Distribution of Predominant Window Types – High-Rise Multifamily Buildings

Window Types (# of panes, frame type, glass type)	**Statewide** (12 Sites)	**RMST CZ1** (1 Site)	**RMST CZ2** (8 Sites)	**RMST CZ3** (2 Sites)	**RMST CZ4** (0 Sites)	**RMST CZ5** (1 Site)
Dual-Pane, Vinyl-Framed, Clear Glass	17%	-	13%	50%	-	-
Dual-Pane, Metal-Framed, Clear Glass	33%	-	38%	50%	-	-
Single-Pane, Metal-Framed, Clear Glass	8%	-	13%	-	-	-
Dual-Pane, Vinyl-Framed, Low-E Glass	8%	-	-	-	-	100%
Dual-Pane, Metal-Framed, Low-E Glass	33%	100%	38%	-	-	-

Fenestration Average U-factors

The following tables for low-rise buildings use average U-factors obtained from the MICROPAS compliance runs. These results give a more comprehensive look at fenestration (as opposed to just windows). Results are presented in Table 3-14 for low-rise multifamily buildings. Table 3-13 provides a reference against which to evaluate the average U-factors computed in these tables.

For high-rise buildings, the U-factors are often different by window orientation due partly to the newer glass coatings used to give lower SHGCs without tinting, and the fact that these coatings also lower the U-factors. The site surveyors collected information on number of window panes, tints, low-E coatings, and frame type. This was compared to information gleaned from photographs and notes from the on-site surveys. Where the manufacturer and product were known, U-factors were used as specified by the manufacturer in their literature. Where the number of panes and coating or tint only was known, values from the NFRC database were used, choosing windows that most closely matched the description of the windows found at the site. Where more definitive information could not be found from the site surveys and the number of glazing layers matched the as-permitted model, the as-permitted U-factor was used.

Table 3-13: Default Window Thermal Performance Values

RMST Survey Fields and Descriptions			Default Values	
Frame Type	**Number of Panes**	**Glazing Type**	**U-factor**	**SHGC**
Vinyl	2	Clear	0.60	0.65
Vinyl	2	Tinted/Refl	0.60	0.53
Vinyl	2	Low-E	0.37	0.41
Vinyl	1	Clear	0.99	0.74
Metal	2	Clear	0.75	0.70
Metal	2	Tinted/Refl	0.75	0.59
Metal	1	Clear	1.28	0.80

The following results are shown in Table 3-14.

- The average glazing U-factor for low-rise multifamily buildings statewide is 0.827. The average U-factor varies by RMST climate zone from 0.715 in RMST Climate Zone 5 to 0.960 in RMST Climate Zone 2. The fact that RMST Climate Zone 2 has the worst average glazing U-factor is not surprising given that these CEC climate zones have the least stringent standards.
- The average glazing U-factor for high-rise buildings is 0.64. The average U-factor varies from 0.37 in RMST Climate Zone 5 to 0.69 in RMST Climate Zone 2. Similar to low-rise, it is not surprising that the glazing U-factor is the worst in RMST Climate Zone 2, since these CEC climate zones have less stringent standards and are the more moderate climates in the state.

Table 3-14: Average Glazing U-factors – Low-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (31 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (6 Sites)	RMST CZ3 (9 Sites)	RMST CZ4 (13 Sites)	RMST CZ5 (2 Sites)
Average U-factor	0.827	0.860	0.960	0.917	0.719	0.715
Title 24 Prescriptive		0.65\0.75	0.75	0.75	0.65	0.60/0.65
Higher Performance	26%	-	33%	11%	38%	-
Equal to Prescriptive	16%	-	17%	44%		-
Lower Performance	58%	100%	50%	44%	62%	100%

Table 3-15: Average Glazing U-factors – High-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (12 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (8 Sites)	RMST CZ3 (2 Sites)	RMST CZ4 (0 Sites)	RMST CZ5 (1 Site)
Average U-factor	0.64	0.42	0.70	0.66	-	0.37
Title 24 Prescriptive		0.72/1.23	1.23	1.23	0.72	0.72
Higher Performance	92%	100%	87%	100%	-	100%
Equal to Prescriptive	-	-	-	-	-	-
Lower Performance	8%	-	13%	-	-	-

Space Heating Systems

This section summarizes space heating systems characteristics for units installed in newly constructed multifamily residences. These characteristics include average system efficiencies, system type, and duct location.

Equipment Type and Location

Table 3-16 and Table 3-17 present a distribution of the space heating system equipment types and locations for low-rise and high-rise multifamily buildings, respectively. Results are as follows.

- Hydronic heating systems are the most common space heating equipment found in low-rise multifamily buildings (71%). There is also a fair amount of central heat pumps in low-rise multifamily buildings (16%).
- A similar result was found in high-rise multifamily buildings. Hydronic heating is the most commonly found heating source, with equal percentages of central and individual water heaters used for the hydronic systems (33% each). Central heat pumps are the next most common heating source in high-rise buildings (25%). There is one building with hydronic radiant floor heating.

Table 3-16: Space Heating Equipment Type – Low-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (31 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (6 Sites)	RMST CZ3 (9 Sites)	RMST CZ4 (13 Sites)	RMST CZ5 (2 Sites)
Equipment Type						
Central Furnace	3%	-	-	-	-	50%
Hydronic	71%	100%	33%	67%	92%	50%
Central Heat Pump	16%	-	33%	22%	8%	-
Wall Heat Pump	3%	-	17%	-	-	-
Electric Resistance	6%	-	17%	11%	-	-

Table 3-17: Space Heating Equipment Type – High-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (12 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (8 Sites)	RMST CZ3 (2 Sites)	RMST CZ4 (0 Sites)	RMST CZ5 (1 Site)
Equipment Type						
Central Heat Pump	25%	100%	25%	-	-	-
Hydronic with Central Boiler	33%	-	50%	-	-	-
Hydronic with Individual Water Heaters	33%	-	25%	100%	-	-
Hydronic Radiant Floor Heating	9%	-	-	-	-	100%
Furnace Central	-	-	-	-	-	-

Equipment Efficiency

Table 3-18 presents the percentage of sites with space heating equipment less than, equal to, and higher than the standard efficiency and a summary of gas space heating system efficiencies for low-rise multifamily buildings by system type. Table 3-19 presents the percentage of high-rise multifamily buildings with space heating equipment less than, equal to, and higher than the standard efficiency.[10] Key findings are highlighted below.

[10] It is worth noting that if gas furnaces or heat pumps are used, it is theoretically not possible to be below the prescriptive minimum, since the prescriptive minimum is set at the lowest possible efficiency allowed by state and federal appliance standards that govern equipment sold in California. As such, the three buildings in RMST Climate Zone 3 with equipment lower than the prescriptive have hydronic systems.

- Approximately 90% of the low-rise multifamily buildings surveyed have space heating equipment that is equal to or above standard efficiency.
- The average AFUE of the hydronic systems surveyed is 75.8%, which is slightly above the standard of 75% AFUE.
- Each high-rise multifamily building surveyed has space heating equipment that is equal to or above standard efficiency.

Table 3-18: Space Heating System Efficiency – Low-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (31 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (6 Sites)	RMST CZ3 (9 Sites)	RMST CZ4 (13 Sites)	RMST CZ5 (2 Sites)
Higher Performance	68%	100%	33%	44%	92%	50%
Equal to Prescriptive	23%	-	67%	22%	8%	50%
Lower Performance	10%	-	-	33%	-	-
Hydronic Systems						
Average Efficiency (AFUE)	0.758	0.759	0.773	0.755	0.757	0.760
# of Sites	22	1	2	6	12	1
Gas Furnaces						
Average Efficiency (AFUE)	0.780	-	-	-	-	0.780
# of Sites	1	-	-	-	-	1
Heat Pumps						
Average Efficiency (HSPF)	6.8	-	6.7	6.8	7.0	-
# of Sites	6	-	3	2	1	-
Electric Resistance Units[11]						
Average Efficiency (HSPF)	3.4	-	3.4	3.4	-	-
# of Sites	2	-	1	1	-	-

[11] The federal equipment standard for electric resistance heaters is 3.41 HSPF. Please note that the efficiencies used to calculate above and below prescriptive are based on the efficiencies set out in Prescriptive Package D. However, electric resistance heaters are not allowed under Prescriptive Package D and if they are installed, even at the federal equipment standard, that the space heating margin will be negative.

Table 3-19: Space Heating System Efficiency – High-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (12 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (8 Sites)	RMST CZ3 (2 Sites)	RMST CZ4 (0 Sites)	RMST CZ5 (1 Site)
Higher Performance	100%	100%	100%	100%		100%
Equal to Prescriptive	-	-	-	-	-	-
Lower Performance	-	-	-	-	-	-
Hydronic Systems						
Average Efficiency (AFUE)	80%	-	80.0	80.0	-	82.0
# of Sites	9	-	6	2	-	1
Heat Pumps						
Average Efficiency (HSPF)	6.6	6.5	7.2	-	-	-
# of Sites	3	1	2	-	-	-

Space Cooling System

Space cooling systems characteristics for units installed in newly constructed multifamily residences are discussed in this section. These characteristics include average system efficiencies, system type, and unit locations.

Equipment Type and Location

A distribution of the space cooling system equipment types and locations is presented in Table 3-20 for low-rise multifamily buildings and Table 3-21 for high-rise multifamily buildings. Key findings are highlighted below.

- Central air conditioners are the most common space cooling equipment found in low-rise multifamily buildings (71%). There is also a fair amount of central heat pumps in low-rise multifamily buildings (16%).
- Similarly, 67% of the high-rise multifamily buildings surveyed have central air conditioners while a fair amount has central heat pumps (25%).

Table 3-20: Space Cooling Equipment Types – Low-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (31 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (6 Sites)	RMST CZ3 (9 Sites)	RMST CZ4 (13 Sites)	RMST CZ5 (2 Sites)
Equipment Type						
Central Air Conditioner	71%	100%	33%	67%	92%	50%
Window/Wall Air Conditioner	6%	-	17%	11%	-	-
Central Heat Pump	16%	-	33%	22%	8%	-
Window/Wall Heat Pump	3%	-	17%	-	-	-
No Air Conditioner	3%	-	-	-	-	50%

Table 3-21: Space Cooling Equipment Types – High-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (12 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (8 Sites)	RMST CZ3 (2 Sites)	RMST CZ4 (0 Sites)	RMST CZ5 (1 Site)
Equipment Type						
Central Air Conditioner	67%	-	63%	100%	-	-
Central Heat Pump	25%	100%	25%	-	-	-
No Air Conditioner	13%	-	-	-	-	100%

Equipment Efficiency

Results for cooling system efficiencies are presented in Table 3-22 for low-rise multifamily buildings and Table 3-23 for high-rise multifamily buildings. Results are highlighted below.

- One low-rise multifamily building in RMST Climate Zone 4 has a central air conditioner with a 10.5 SEER and one low-rise multifamily building in RMST Climate Zone 3 has a packaged heat pump with a 10.0 SEER.[12] The remaining buildings have cooling equipment that just meet the prescriptive.
- Of the high-rise multifamily buildings with central space cooling equipment surveyed, all of them have equipment whose efficiency is higher than (75%) or equal to (25%) the standard efficiency.

[12] The prescriptive SEER for packaged heat pumps is 9.9 SEER.

Table 3-22: Cooling System Efficiency – Low-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (31 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (6 Sites)	RMST CZ3 (9 Sites)	RMST CZ4 (13 Sites)	RMST CZ5 (2 Sites)
Higher Performance	6%	-	-	11%	8%	-
Equal to Prescriptive	94%	100%	100%	89%	92%	100%
Lower Performance	-	-	-	-	-	-
Average Efficiency (SEER)*	10.0	10.0	10.0	10.0	10.0	10.0
# of Sites w/ Central Cooling	27	1	4	8	13	1

* The average SEER was calculated for the central cooling systems only.

Table 3-23: Cooling System Efficiency – High-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (12 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (8 Sites)	RMST CZ3 (2 Sites)	RMST CZ4 (0 Sites)	RMST CZ5 (1 Site)
Higher Performance	73%	-	88%	50%	-	-
Equal to Prescriptive	27%	100%	13%	50%	-	-
Lower Performance	0%	-	-	-	-	-
Average Efficiency (SEER)*	10.2	10.0	10.3	10.0	-	-
# of Sites w/ Central Cooling	11	1	8	2	-	0

* The average SEER was calculated for the central cooling systems only.

Water Heating

This section summarizes water heating equipment characteristics for units installed in newly constructed multifamily residences. These characteristics include average system efficiencies, system types, and fuel types.

Equipment Type, Fuel Type, and Use of Recirculation Pumps

Table 3-24 presents a summary of the water heating equipment types installed in multifamily buildings. Key findings are highlighted below.

- Approximately 87% of the low-rise multifamily buildings surveyed have individual storage gas water heaters for each dwelling unit.
- While one-third of the high-rise multifamily buildings surveyed have individual storage gas water heaters for each dwelling unit, more than half have a central boiler (58%).

Table 3-24: Water Heating Type

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Low-Rise Multifamily Buildings *(n)*	*31*	*1*	*6*	*9*	*13*	*2*
Boiler	3%	-	17%	-	-	-
Central System	3%	-	-	-	-	50%
Instantaneous	3%	-	-	-	8%	-
Storage/Standard	87%	100%	83%	89%	92%	50%
Storage/Standard – Large	3%	-	-	11%	-	-
Storage WH w/External Blankets	42%	0%	67%	56%	31%	0%
High-Rise Multifamily Buildings *(n)*	*12*	*1*	*8*	*2*	-	*1*
Boiler	58%	-	75%	-	-	100%
Instantaneous	8%	100%	-	-	-	-
Storage/Standard	33%	-	25%	100%	-	-

Equipment Efficiency

Table 3-25 presents a summary of water heating system efficiencies for low-rise multifamily buildings. Note that the efficiency results are presented relative to "minimum efficiency" rather than actual average efficiency values because the minimum efficiency varies by tank size and fuel type.[13] In addition, for those few systems where no information other than fuel type could be gathered due to water heater blanket or earthquake straps, the CEC default water heater data were used. The following are some key findings from these data.

- The statewide average % above standard efficiency for storage gas water heaters is approximately 9.8% for low-rise multifamily buildings and 10.6% for high-rise multifamily buildings.
- For multifamily buildings, whether low-rise or high-rise, the standard budget for water heating is based on a 50-gallon gas water heater with 0.58 EF in each unit. For those buildings with central water heaters (or boilers), there is an inherent efficiency advantage. There are losses associated with a distribution system from the central boiler to each unit, but these are not adequately accounted for in the current and previous standards. To determine an average % above efficiency for central water heating systems, requires using performance results only, and is somewhat deceptive for the reasons stated. When each dwelling unit has its own

[13] Please see Section 2.3 for the equations used to calculate the % above standard efficiency for storage gas water heaters.

water heater, the comparison of "as built" to standards is the same as described above.

This supports findings from other studies that available (i.e., standard practice) water heating systems are already more efficient than the Appliance Standard minimums. This might be due to high efficiency units being useful for meeting compliance requirements. In particular, the water heating budget and margins are often the most significant parts of the compliance margin for multifamily buildings, especially in those climate zones with mild weather.

Table 3-25: Storage Gas Water Heater Efficiency

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Low-Rise Multifamily Buildings *(n)*	*31*	*1*	*6*	*9*	*13*	*2*
Average % above standard	9.8%	8.5%	9.0%	8.9%	10.3%	15.8%
# of Sites	27	1	5	8	12	1
High-Rise Multifamily Buildings *(n)*	*12*	*1*	*8*	*2*	-	*1*
Average % above standard	10.6%	-	7.6%	13.5%	-	-
# of Sites	4	-	2	2	-	-

Building Shell Characteristics

Current building practices for ceiling insulation, wall insulation, radiant barriers, and metal framing are discussed and summarized below.

Ceiling Insulation

Table 3-26 summarizes current ceiling insulation practices. Note that these results are presented with respect to performance versus prescriptive values (higher performance, equal to prescriptive, lower performance).[14] Note also that both the low-rise and the high-rise residential standards require that a minimum of R-19 ceiling insulation be installed. Key findings are summarized below.

- Most of the ceiling insulation installed in the low-rise multifamily buildings surveyed is lower than the prescriptive R-value (81%). While some buildings were found to have insulation equal to the prescriptive R-value (19%), no insulation was found to be greater than the prescriptive. Given past studies and discussions with Title 24 consultants, this is not surprising. Since insulation does not play a major role in determining compliance, most builders are not inclined to install high performance insulation.

[14] Please reference Table 3-4 for a list of the standard R-values for ceiling insulation by CEC climate zone.

- Similarly, most of the ceiling insulation installed in the high-rise multifamily buildings surveyed is equal to or lower than the prescriptive R-value (75%).

Table 3-26: Ceiling Insulation – Average Insulation R-Value

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Low-Rise Multifamily Buildings *(n)*	*31*	*1*	*6*	*9*	*13*	*2*
Average R-Value	23.3	19.0	20.8	23.9	23.6	28.5
Higher Performance	-	-	-	-	-	-
Equal to Prescriptive	19%	-	17%	44%	-	50%
Lower Performance	81%	100%	83%	56%	100%	50%
High-Rise Multifamily Buildings *(n)*	*12*	*1*	*8*	*2*	-	*1*
Average R-Value	21.3	4.0[15]	20.4	24.5	-	40.0
Higher Performance	25%	-	13%	50%	-	100%
Equal to Prescriptive	67%	-	88%	50%	-	-
Lower Performance	8%	100%	-	-	-	-

Wall Insulation

Table 3-27 summarizes current wall insulation practices. Note that these results are presented with respect to performance versus prescriptive values (higher performance, equal to prescriptive, lower performance), per Table 3-4 for low-rise buildings and Table 3-7 for high-rise buildings. Key findings are summarized below.

- Similar to the ceiling insulation analysis shown above, wall insulation found in low-rise multifamily buildings is either equal to prescriptive (52%) or less than prescriptive (48%). R-13 wall insulation was installed in all but one low-rise multifamily building surveyed.
- The statewide average wall insulation in high-rise multifamily buildings (13.5) is close to the average in low-rise multifamily buildings (13.1). However, due to the less stringent prescriptive insulation values for high-rise multifamily buildings, two-thirds of these buildings have higher than prescriptive wall insulation.

[15] This site has an 8" concrete ceiling with no insulation.

Table 3-27: Wall Insulation – Average Insulation R-Value

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Low-Rise Multifamily Buildings *(n)*	*31*	*1*	*6*	*9*	*13*	*2*
Average R-Value	13.1	13.0	13.0	13.0	13.0	14.0
Higher Performance	-	-	-	-	-	-
Equal to Prescriptive	52%	100%	100%	100%	-	-
Lower Performance	48%	-	-	-	100%	100%
High-Rise Multifamily Buildings *(n)*	*12*	*1*	*8*	*2*	-	*1*
Average R-Value	13.5	11.0	13.3	13.0	-	19.0
Higher Performance	67%	-	75%	100%	-	-
Equal to Prescriptive	25%	100%	25%	-	-	-
Lower Performance	8%	-	-	-	-	100%

Duct Construction Location

Table 3-28 summarizes duct construction practices as characterized by duct location. Key findings are summarized below.

- The ducts in the low-rise multifamily buildings surveyed were found primarily in the attic (87%).
- Most of the ducts in the high-rise multifamily buildings surveyed were found in the walls and/or ceilings (75%).

Table 3-28: Duct Location

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Low-Rise Multifamily Buildings *(n)*	*31*	*1*	*6*	*9*	*13*	*2*
Attic	87%	100%	67%	78%	100%	100%
Conditioned Space	6%	-	17%	11%	-	-
Non-Ducted	6%	-	17%	11%	-	-
High-Rise Multifamily Buildings *(n)*	*12*	*1*	*8*	*2*	-	*1*
Attic	17%	100%	-	50%	-	-
Wall	8%	-	13%	-	-	-
Wall & Ceiling	67%	-	88%	50%	-	-
Non-Ducted	8%	-	-	-	-	100%

Lighting

Table 3-29 and Table 3-30 provide information on exterior lighting and compact fluorescent bulbs (CFLs) in bathrooms. Surveyors collected information on motion sensors and daylight timers on exterior lights. The first percentage under motion sensors refers to the percentage of buildings that have at least one motion sensor installed. Of the buildings with at least one motion sensor installed, the average percentage of exterior lights at that site with motion sensors was calculated. The same description is true of the daylight timers. Surveyors also collected information on the percentage of bulbs in all the bathrooms in each building that has CFLs. Key findings are summarized below.

- Only one low-rise and no high-rise multifamily buildings surveyed have motion sensors installed on exterior lights. The one site with motion sensors had them installed on 100% of the exterior lights.
- Approximately 55% of low-rise and 83% of high-rise multifamily buildings have daylight timers installed on at least some exterior lights. Of these sites, the daylight timers are installed on an average of 94% of the exterior lights in the low-rise multifamily buildings and of 100% of the exterior lights in the high-rise multifamily buildings.
- On average, just over half of the bathrooms have CFLs: 55% in low-rise and 67% in high-rise multifamily buildings.

Table 3-29: Lighting – Low-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (31 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (6 Sites)	RMST CZ3 (9 Sites)	RMST CZ4 (13 Sites)	RMST CZ5 (2 Sites)
Exterior Lights w/Motion Sensors						
% of Sites that Have at least One	3%	0%	0%	11%	0%	0%
Ave % Exterior Lights w/Motion Sensors	100%	-	-	100%	-	-
Exterior Lights w/Daylight Timers						
% of Sites that Have at least One	55%	0%	100%	78%	23%	50%
Ave % Exterior Lights w/Daylight Timers	94%	-	84%	100%	100%	100%
Ave % of Bathrooms w/CFLs Installed	55%	0%	50%	56%	62%	50%

Table 3-30: Lighting – High-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (12 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (8 Sites)	RMST CZ3 (2 Sites)	RMST CZ4 (0 Sites)	RMST CZ5 (1 Site)
Exterior Lights w/Motion Sensors						
% of Sites that Have at least One	0%	0%	0%	0%	-	0%
Ave % Exterior Lights w/Motion Sensors	-	-	-	-	-	-
Exterior Lights w/Daylight Timers						
% of Sites that Have at least One	83%	100%	75%	100%	-	100%
Ave % Exterior Lights w/Daylight Timers	100%	100%	100%	100%	-	100%
Ave % of Bathrooms w/CFLs Installed	67%	0%	63%	100%	-	100%

Laundry

Table 3-31 and Table 3-32 provide information on laundry rooms in multifamily buildings. Surveyors collected information regarding laundry facilities for both common area laundry rooms and equipment in individual dwelling units. Key findings are summarized below.

- Approximately 32% of low-rise and 8% high-rise multifamily buildings surveyed have a common laundry facility. On average, low-rise multifamily buildings with common laundry facilities have approximately 20 washers/dryers, while one high-rise multifamily building with a common laundry facility has six washers/dryers.
- Approximately 58% of low-rise and 92% high-rise multifamily buildings have washers/dryers in the individual dwelling units.

- Every high-rise multifamily building with washers/dryers in individual dwelling units are reported to have equipment in every dwelling unit and these are provided by the management. A similar result was found in low-rise multifamily buildings, where 98% of the units in buildings without a common laundry facility were reported to have a washer/dryer.

Table 3-31: Laundry – Low-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (31 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (6 Sites)	RMST CZ3 (9 Sites)	RMST CZ4 (13 Sites)	RMST CZ5 (2 Sites)
Sites w/Common Laundry						
% of Sites that Have	32%	0%	33%	33%	31%	50%
Ave # Washer/Dryer per complex	19	-	29	23	10	24
Sites w/Laundry in Individual Units						
% of Sites that Have	58%	100%	67%	56%	62%	0%
Ave % Units w/Washer/Dryer	98%	100%	100%	100%	96%	-
Washer/Dryer in unit Supplied	100%	100%	100%	100%	100%	-

Table 3-32: Laundry – High-Rise Multifamily Buildings

Analysis Parameter Description	Statewide (12 Sites)	RMST CZ1 (1 Site)	RMST CZ2 (8 Sites)	RMST CZ3 (2 Sites)	RMST CZ4 (0 Sites)	RMST CZ5 (1 Site)
Sites w/Common Laundry						
% of Sites that Have	8%	0%	0%	0%	-	100%
Ave # Washer/Dryer per complex	6	-	-	-	-	6
Sites w/Laundry in Individual Units						
% of Sites that Have	92%	100%	100%	100%	-	0%
Ave % Units w/Washer/Dryer	100%	100%	100%	100%	-	-
Washer/Dryer in unit Supplied	100%	100%	100%	100%	-	-

4

Analysis of Title 24 Compliance for Multifamily Buildings

4.1 Introduction

This section provides results of the compliance analysis for low-rise and high-rise multifamily buildings. The compliance documentation collected, the on-site verification surveys, and the features of the RNC Interface for low-rise buildings and EnergyPro for high-rise buildings made it possible to analyze the compliance of these multifamily buildings under several scenarios: as-permitted and as-built under the version of the Standard with which the building originally complied, and as-built under the 2001 Standards.

The remainder of this section provides an overview of the approach, a summary of the multifamily buildings used in the analysis, definitions of the compliance groups developed, and the results of the compliance analysis for both the low-rise and high-rise multifamily buildings.

4.2 Overview of the Approach

The first task was to develop an as-permitted input file that recreates the compliance documentation obtained from the building departments. It should be noted here that every permitted simulation will comply since the documentation for each building must show compliance before construction has begun.[1] Since buildings are not always built exactly according to the plans and/or compliance documentation, the results of the on-site verification surveys were used to replace those inputs that were changed and an as-built input file was created for each building.

[1] It will be assumed, insofar as all buildings obtained building permits, that all buildings comply with Title 24 based on the documents filed with the building departments. Having said that, it is important to note that there could be some cases where recreating the compliance documentation reveals that the building might not have originally complied. In these cases, it might not be possible to pinpoint specific reasons for non-compliance.

Compliance analysis of each building was then performed by comparing % Compliance Margins for the permitted and as-built cases. Since each building obtained a permit, the "permitted" runs each demonstrated compliance. The "as-built" cases, however, do not all comply. This analysis shows what the compliance margin is for both sets of runs. The compliance margin will be expressed as a percentage of the standard energy budget. Specifically,

$$\%\ Compliance\ Margin = \frac{(Standard\ Energy\ Budget - Proposed\ Energy\ Budget)}{(Standard\ Energy\ Budget)}$$

In addition, provided below is an analysis of reasons for buildings not complying relative to the compliance documentation filed with the building departments.

The final step was to analyze the as-built buildings under the 2001 Standards.

4.3 Buildings Included in the Analysis

Table 4-1 presents the distribution of sites included in the analysis by RMST climate zone and residence type. As explained in Section 2, 31 low-rise multifamily buildings and 12 high-rise buildings are included in the analysis. Compliance documentation was collected for 62 low-rise and 37 high-rise buildings, while on-site verification surveys were completed for 32 low-rise and 13 high-rise buildings. However, many sites were excluded due to incomplete compliance documentation or refusal to allow the on-site survey.

Table 4-1: Distribution of Usable Buildings

	Overall	**RMST CZ1**	**RMST CZ2**	**RMST CZ3**	**RMST CZ4**	**RMST CZ5**
Overall	**43**	**2**	**14**	**11**	**13**	**3**
Low-Rise Multifamily	31	1	6	9	13	2
High-Rise Multifamily	12	1	8	2	-	1

4.4 Definition of Compliance Groups

The following three compliance groups were used as the basis for analysis of the MICROPAS results for low-rise buildings and of the EnergyPro results for high-rise buildings.

- ***Non-Compliant.*** This category includes sites that, based on the analysis, are not compliant with Title 24 code.
- ***Compliant.*** This category includes sites that, based on the analysis, are compliant with Title 24 code.
- ***Overly Compliant.*** This category includes sites that, based on the analysis, are overly compliant with Title 24 code. In particular, these sites have a % Compliance Margin greater than 20%. This category was defined to assess the share of homes that would meet the existing ENERGY STAR® New Home Construction requirements.

4.5 Low-Rise Multifamily Buildings

The compliance documentation collected were originally intended to be for multifamily buildings that originally complied under the 1998 Standards. However, after review of the documentation, it was found that many of the buildings had not been completed yet. Therefore, compliance documentation for buildings that complied under either the 1995 or the 1998 Standards was included in the analysis. The remainder of this section summarizes the compliance of the buildings first under the Standards with which they originally complied, then under the 1998 and 2001 Standards.

Originally Complied – 1995 Standards

Of the 31 low-rise multifamily buildings surveyed, 24 originally complied under the 1995 standards. The results of the as-permitted and as-built compliance analysis of these buildings are presented below. Also explained below are the reasons for the differences between the results of these two runs, by building.

As-Permitted

Figure 4-1 presents the distribution of sites by compliance group as the reproduced compliance documentation complied with the 1995 standards.[2] As shown, the reproduced % Compliance Margin for one site is negative (-1.0%). This site originally complied using a "per residence" method in EnergyPro 1.0. However, for consistency, all sites were run through the RNC Interface using a "per building" method, so it was impossible to reproduce the exact compliance margin for this building.

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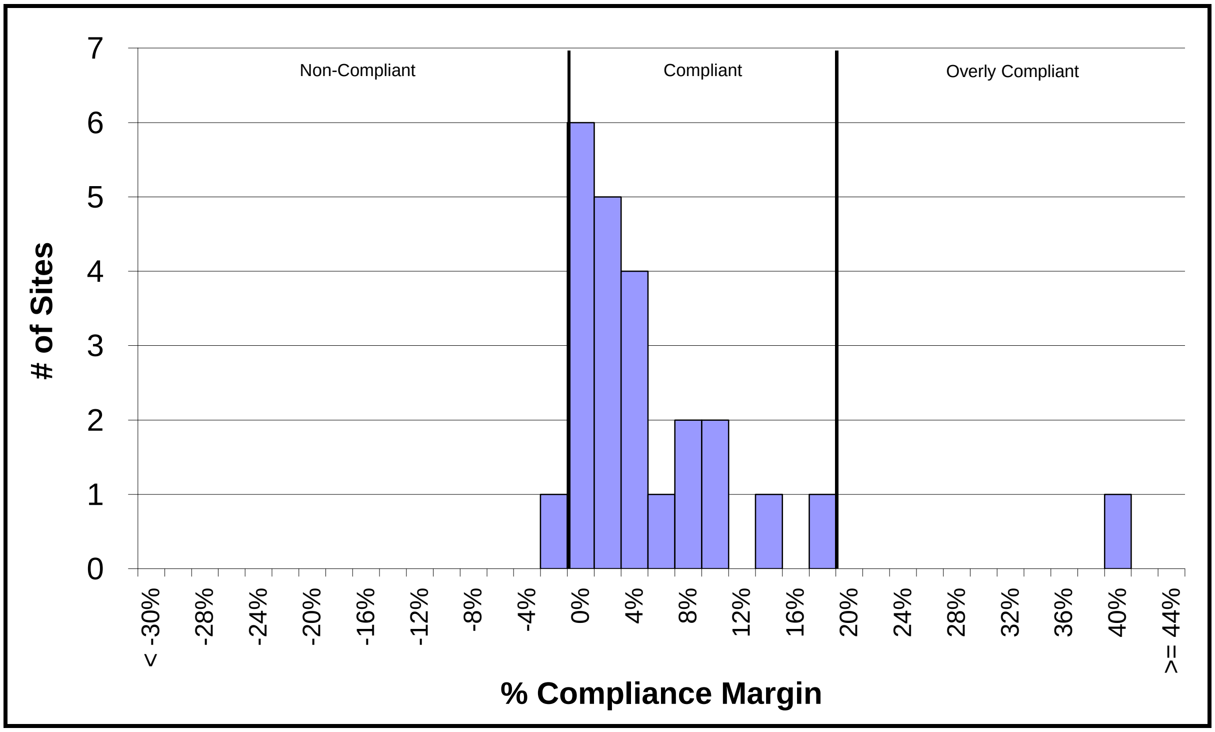
2 The reproduced results are exact for 20 of the 24 sites, while three are within 2%.

Also shown in Figure 4-1 is that most of the buildings originally complied by less than 6%. This is not surprising since most builders attempt to build as close to compliance as possible in order to not have to spend additional money on high efficiency measures. Also shown is that one building complied by nearly 42%.[3]

Figure 4-1: MICROPAS Results Summary – 1995 As-Permitted – Low-Rise Multifamily Buildings

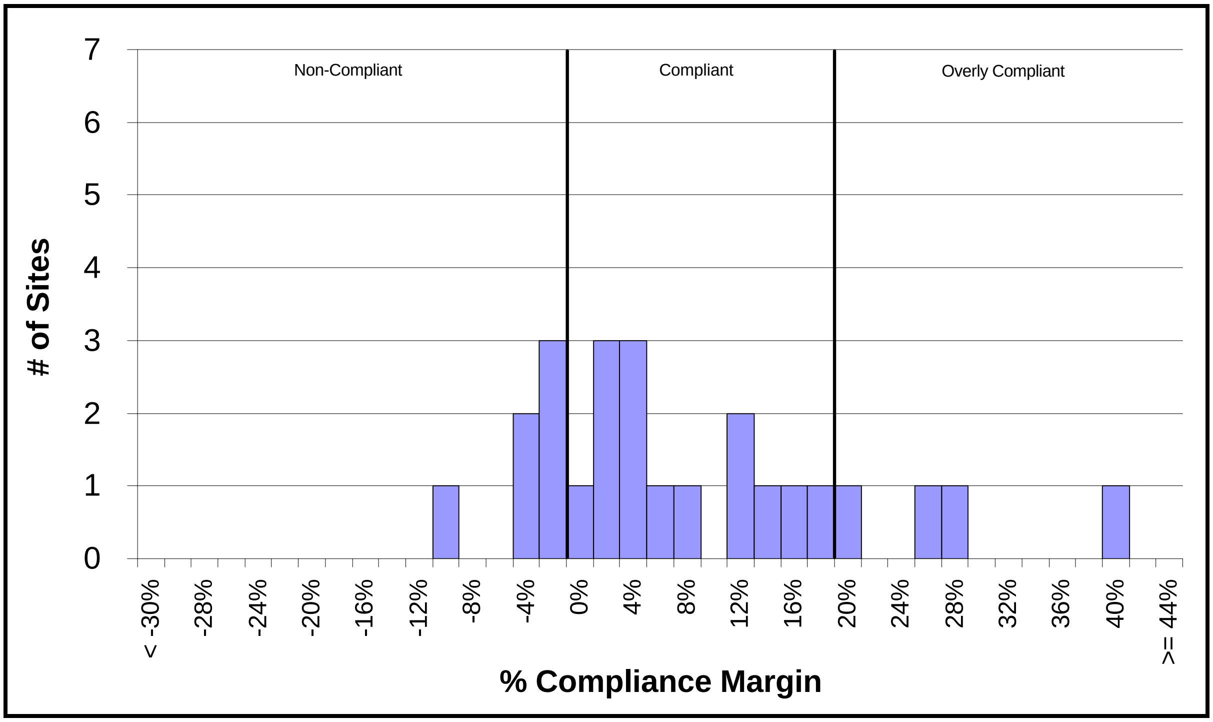


3 This site was overly compliant due to its large water heating margin.

As-Built

Figure 4-2 presents the distribution of how the as-built low-rise multifamily buildings complied with the 1995 Standards. As shown, six sites would not have complied with the 1995 Standards as-built. On the other hand, four buildings would have complied with the ENERGYSTAR Standards had they documented the measures actually installed on their compliance documentation. Reasons for the differences between the as-permitted and as-built results are discussed below.

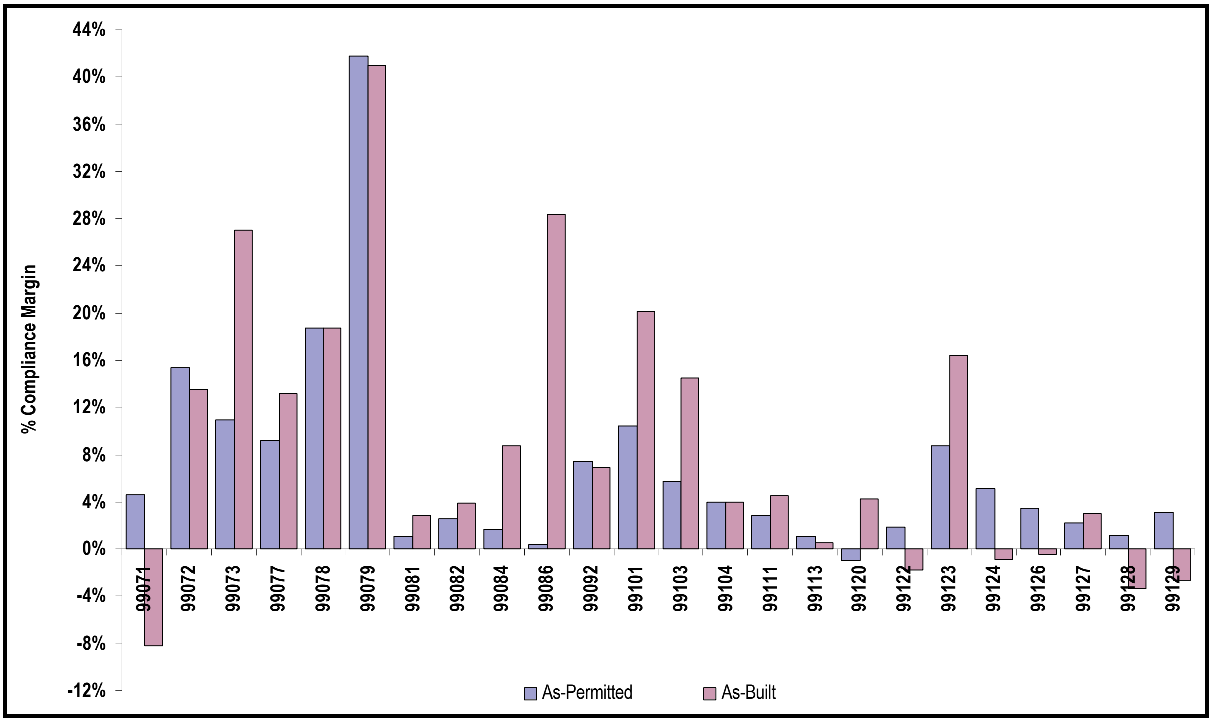
Figure 4-2: MICROPAS Results Summary – 1995 As-Built – Low-Rise Multifamily Buildings



Reasons for Differences between As-Permitted and As-Built

Figure 4-3 presents the % Compliance Margin for each low-rise multifamily building that originally complied under the 1995 Standards both as-permitted and as-built. As shown, the as-built % Compliance Margin is higher than the as-permitted % Compliance Margin for many sites. As explained below, this is primarily because more efficient windows were installed than had been indicated on the compliance documentation.

Figure 4-3: Comparison of As-Permitted Margin to As-Built Margin – Low-Rise Buildings – by Site



As expected, nearly every site was found to have something different than was listed on the compliance documentation. Reasons for the most dramatic changes in % Compliance Margin are listed below.[4]

- **As-built does not comply – six sites:**
  - **99071**

    Wrong climate zone used in the permit analysis (CEC CZ 7) – was changed to CEC Climate Zone 10
  - **99122**

    Water Heater Efficiency: EF 0.62 to EF 0.59
  - **99124**

    Water Heater Efficiency: EF 0.62 to EF 0.56
  - **99126**

    % Glazing: 11.2% to 12.4%

    Water Heater Distribution Type: standard to recirc/temp
  - **99128**

    Large glazing areas on two sides of the building

[4] Please see Appendix B for a detailed list of changes by building.

- **99129**
  % Glazing: 11.7% to 15.8%

- **As-built % Compliance Margin increased more than 5% – seven sites:**
  - **99073**
    Window Type: vinyl-framed, single-pane to vinyl-framed, dual-pane
  - **99084**
    Climate Zone: 8 to 6
  - **99086**
    Window Type: metal-framed, single-pane to metal-framed, dual-pane
    Ducts: attic to conditioned space
  - **99101**
    Window Type: metal-framed, single-pane to metal-framed, dual-pane
  - **99103**
    Window Type: metal-framed, single-pane to vinyl-framed, dual-pane
  - **99120**
    % Glazing: 24.7% to 14.8%
  - **99123**
    % Glazing: 14.4% to 11.9%

Originally Complied – 1998 Standards

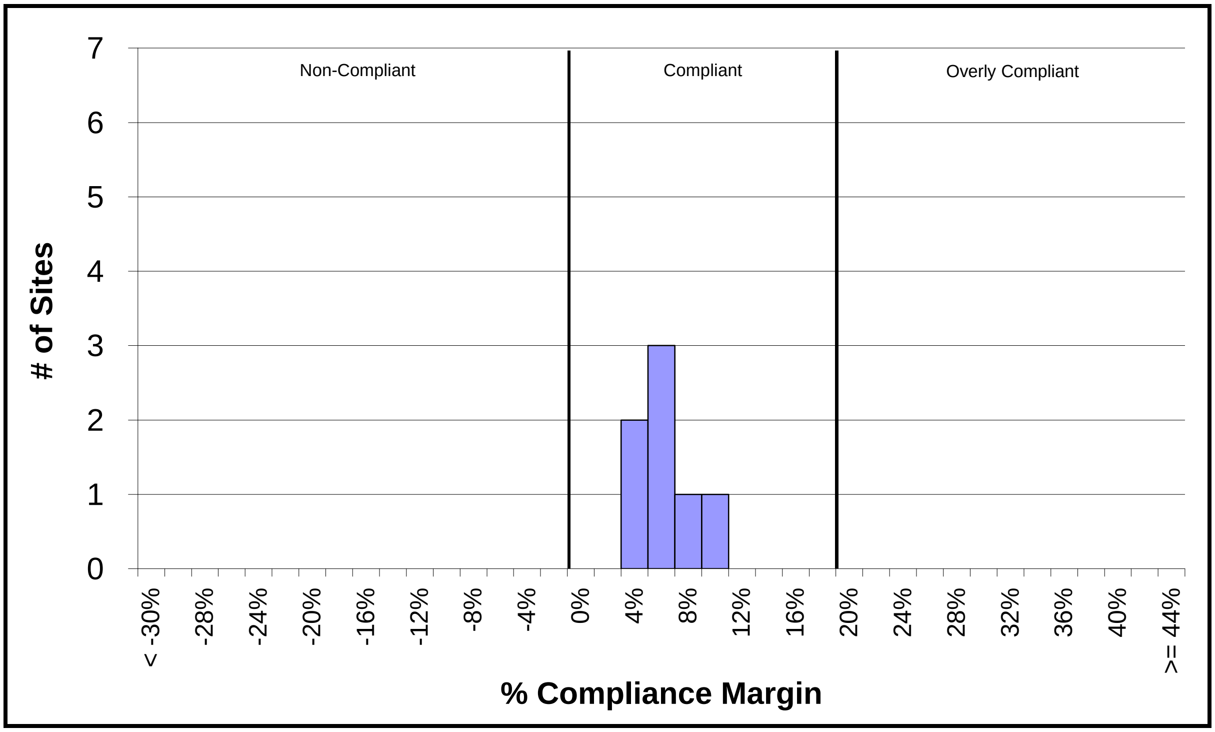
Of the 31 low-rise multifamily buildings surveyed, seven originally complied under the 1998 standards. The results of the as-permitted and as-built compliance analysis of these buildings are presented below. Also explained below are the reasons for the differences between the results of these two runs, by building.

As-Permitted

Table 4-4 presents the distribution of sites by compliance group as the reproduced compliance documentation complied with the 1998 standards.[5] As shown, each building complied with the 1998 Standards by between 4% and 10%.

[5] The reproduced results are exact for 20 of the 24 sites, while three are within 2%.

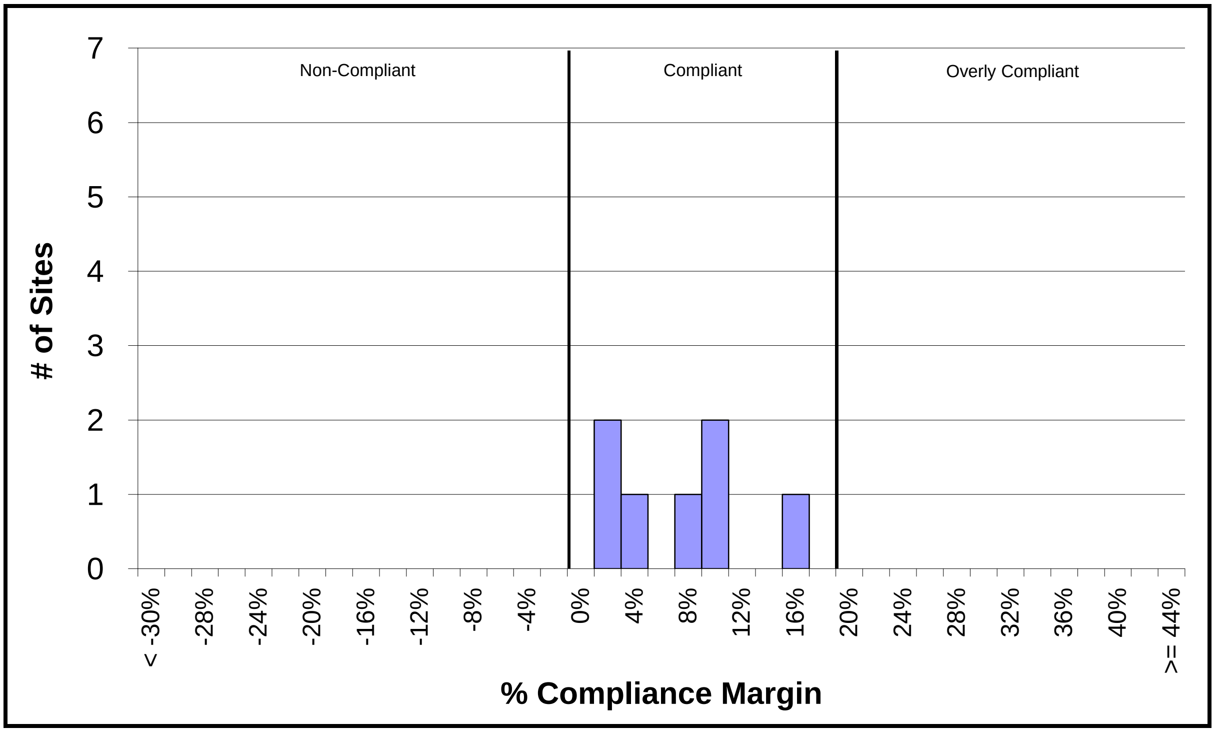
Figure 4-4: MICROPAS Results Summary – 1998 As-Permitted – Low-Rise Multifamily Buildings



As-Built

Table 4-2 presents the distribution of how the as-built low-rise multifamily buildings complied with the 1998 Standards. As shown, each building would have complied with the 1998 Standards, as-built, by between 2% and 16%.

Figure 4-5: MICROPAS Results Summary – 1998 As-Built – Low-Rise Multifamily Buildings



Reasons for Differences between As-Permitted and As-Built

As expected, nearly every site was found to have something different than what was listed on the compliance documentation. Reasons for the most dramatic changes in % Compliance Margin are listed below.

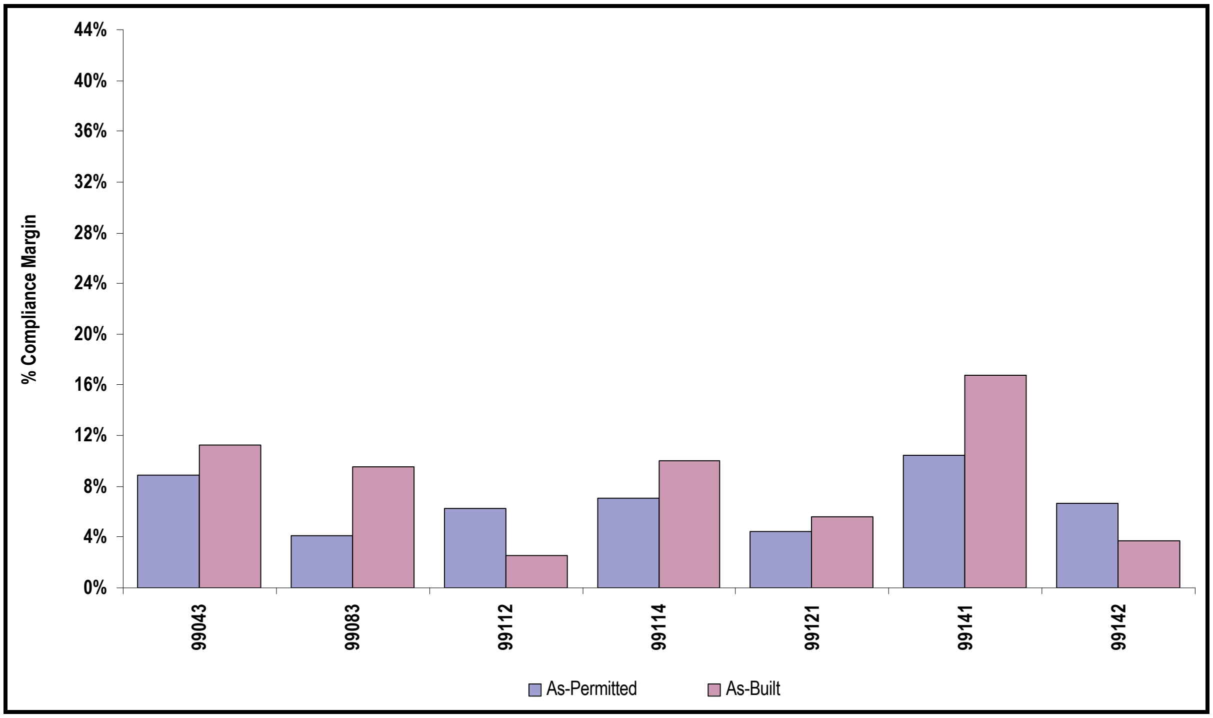
- **As-built % Compliance Margin decreased more than 3% – one site:**
  - **99112**

    Window Type: metal-framed, dual-pane to metal-framed, single-pane and removed most overhangs
- **As-built % Compliance Margin increased more than 5% – two sites:**
  - **99083**

    Window Type: metal-framed, single-pane to metal-framed, dual-pane
  - **99141**

    Window Type: vinyl-framed, single-pane to metal-framed, dual-pane

Figure 4-6: Comparison of As-Permitted Margin to As-Built Margin – Low-Rise Buildings – by Site



All Low-Rise Sites Run Under 1998 Standards

After each site was analyzed using the Standard under which it originally complied, all sites were analyzed using the 1998 Standards. This was done to provide a baseline in which to compare the compliance results of these buildings under the 2001 Standards.

As-Permitted

Similar to the analysis above, all 31 sites were analyzed under the 1998 Standards. The distribution of sites by compliance group and RMST climate zone and the average % Compliance Margin by RMST climate zone are presented below.

Distribution of Sites by Compliance Groups and RMST Climate Zones

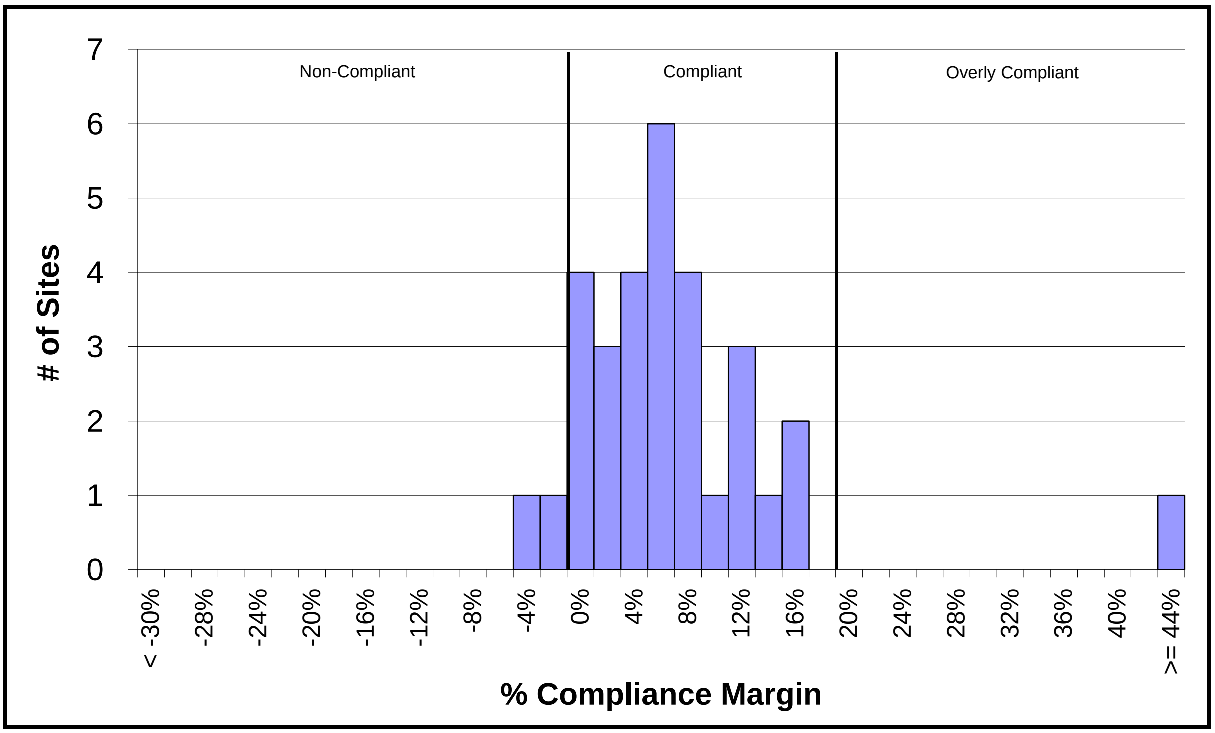
Table 4-2 and Figure 4-7 present the distribution of low-rise multifamily buildings by compliance groups and RMST climate zones. Key findings are summarized below.

- Approximately 93% of the sites (29) are identified as compliant (i.e., they are in the compliant or overly compliant compliance groups). Note that one site falls into the overly compliant group.
- Approximately 6% of the sites (2) are identified as non-compliant (i.e., they are in the non-compliant group).

Table 4-2: Distribution of Sites – 1998 As-Permitted – Low-Rise Multifamily Buildings

Compliance Group	Totals	Percent	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Non-Compliant	2	6%	0	0	0	2	0
Compliant	28	90%	1	5	9	11	2
Overly Compliant	1	3%	0	1	0	0	0
# Sites in the Sample	31		1	6	9	13	2
Overall Percentage		100%	3%	19%	29%	42%	6%

Figure 4-7: MICROPAS Results Summary – 1998 As-Permitted – Low-Rise Multifamily Buildings



Average % 1998 As-Permitted Compliance Margin by RMST Climate Zone

Table 4-3 summarizes the relationship between average as-permitted % Compliance Margin and RMST climate zones. As shown, the buildings in RMST Climate Zone 2 (Southern Coast) have the highest average % Compliance Margin (17%), while the average % Compliance Margin ranges from 4% to 9% in the remaining RMST climate zones.

Table 4-3: Average % Compliance Margin – 1998 As-Permitted

RMST CZ	CEC CZ	Low-Rise
CZ1	1, 2, 3, 4, 5	9%
CZ2	6, 7	17%
CZ3	8, 9, 10	8%
CZ4	11, 12, 13	4%
CZ5	14, 15, 16	9%

As-Built

The on-site verification surveys were used to change the data given on the compliance documentation to reflect what was actually installed at the building.

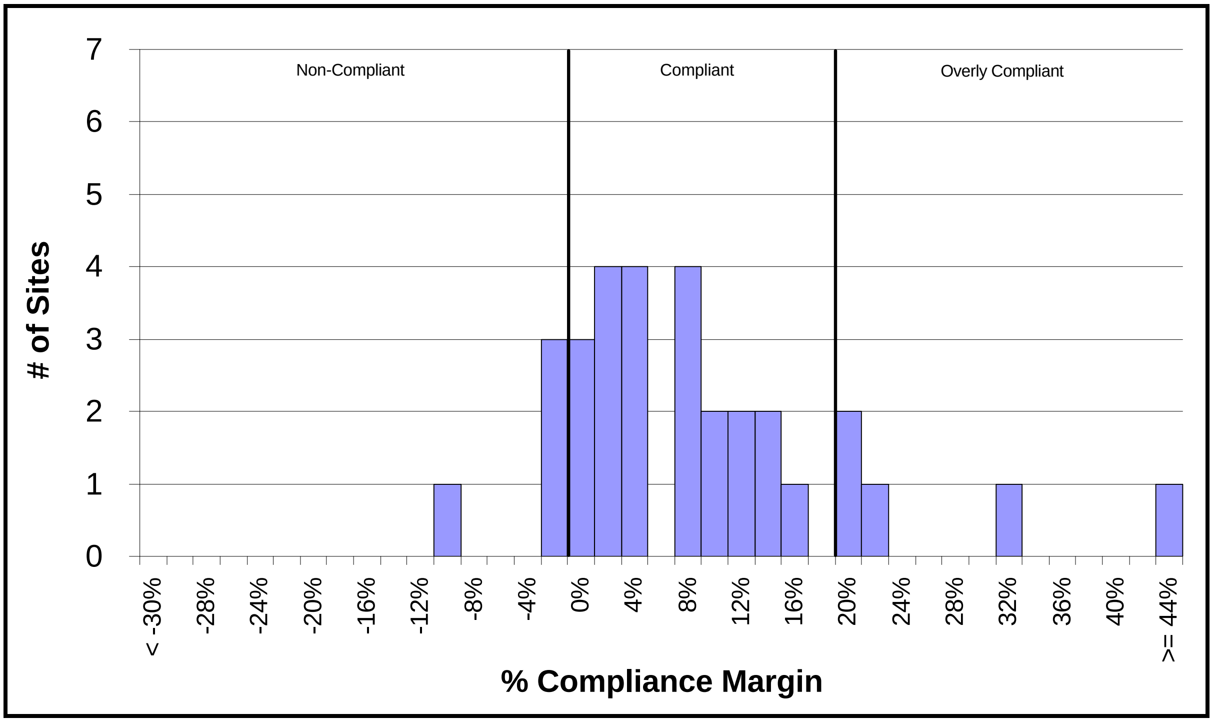
Distribution of Sites by Compliance Groups and RMST Climate Zones

Figure 4-8 provides the distribution of sites by % Compliance Margin as they complied using the as-built characteristics. As shown, four sites are non-compliant while five sites are overly compliant. As explained above, one typical reason for sites performing better as-built than as-permitted is due to installing more efficient windows than those designated on the compliance documentation. Many sites installed dual-pane windows rather than single-pane windows, while one site installed vinyl-framed windows instead of metal-framed windows. Further analysis on why each site did better or worse can be found below.

Table 4-4: Distribution of Sites – 1998 As-Built – Low-Rise Multifamily Buildings

Compliance Group	Totals	Percent	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Non-Compliant	4	13%	0	0	0	4	0
Compliant	22	71%	1	4	6	9	2
Overly Compliant	5	16%	0	2	3	0	0
# Sites in the Sample	31		1	6	9	13	2
Overall Percentage		100%	3%	19%	29%	42%	6%

Figure 4-8: MICROPAS Results Summary – As-Built 1998 Standards – Low-Rise Multifamily Buildings



Average 1998 As-Built % Compliance Margin by RMST Climate Zone

Table 4-5 provides the average as-built % Compliance Margin, under the 1998 Standards, by RMST climate zone. As shown, the buildings in RMST Climate Zone 2 (Southern Coast) also have the highest average as-built % Compliance Margin (20%), while RMST Climate Zone 4 (Central Valley) has the lowest average as-built % Compliance Margin (3%)

Table 4-5: Average % Compliance Margin – 1998 As-Built

RMST CZ	CEC CZ	Low-Rise
CZ1	1, 2, 3, 4, 5	11%
CZ2	6, 7	20%
CZ3	8, 9, 10	13%
CZ4	11, 12, 13	3%
CZ5	14, 15, 16	10%

Differences between 1995 and 1998 Standards

Of the 24 sites that originally complied under the 1995 Standards, 17 have a higher % Compliance Margin under the 1998 Standards than they did under the 1995 Standards (average difference = 3.8%). This is primarily due to the change in the low-rise residential building standards between 1995 and 1998 that altered how the water heating standard budget is calculated. In the 1995 Standards, homes that had a water heater blanket installed received a credit. However, in the 1998 Standards, the "*prescriptive water heating requirements do not include the blanket. The proposed water heater will be compared to a minimally complying water heater (0.53 EF). The effect is that the applicant who formerly modeled water heating with an R-12 wrap will receive the same credit they have been receiving and no blanket will be required as long as it is 0.58 EF or higher*."[6]

The other seven sites had a higher % Compliance Margin under the 1995 Standards than they do under the 1998 Standards (average difference = -4.4%). Three of these sites are in CEC Climate Zone 7 (RMST Climate Zone 2), one is in CEC Climate Zone 11 (RMST Climate Zone 4), and two are in CEC Climate Zone 12 (RMST Climate Zone 4). Each site in CEC Climate Zone 7, the site in CEC Climate Zone 11, and one site in CEC Climate Zone 12 have higher water heating margins under 1998 than under 1995, as explained above, but both the heating and the cooling margins decreased enough to cause the overall margin to decrease from 1995 to 1998. The decrease in the % Compliance Margin of the remaining site in CEC Climate Zone 12 was due to a decrease in the credit given for insulated water heating pipes.

As-Built Compliance Analysis – 2001 Standards

Once each site was analyzed as-built under the 1998 Standards, it was analyzed under the 2001 Standards.

Distribution of Sites by Compliance Groups and RMST Climate Zones

Figure 4-9 provides the distribution of sites by % Compliance Margin as they would have complied as-built under the 2001 Standards. As shown, 12 of the 31 buildings would have complied, while the others would not have complied under the 2001 Standards. Not surprisingly, of the six buildings in RMST Climate Zone 2 (Southern Coast), only one would not have complied.[7] The changes made to the 2001 low-rise residential standards were primarily changes that involved the cooling budgets. Since the cooling budgets in RMST Climate Zone 2 are such a small percentage of the overall budget, these changes did not make compliance in these CEC climate zones (6 and 7) much more difficult.

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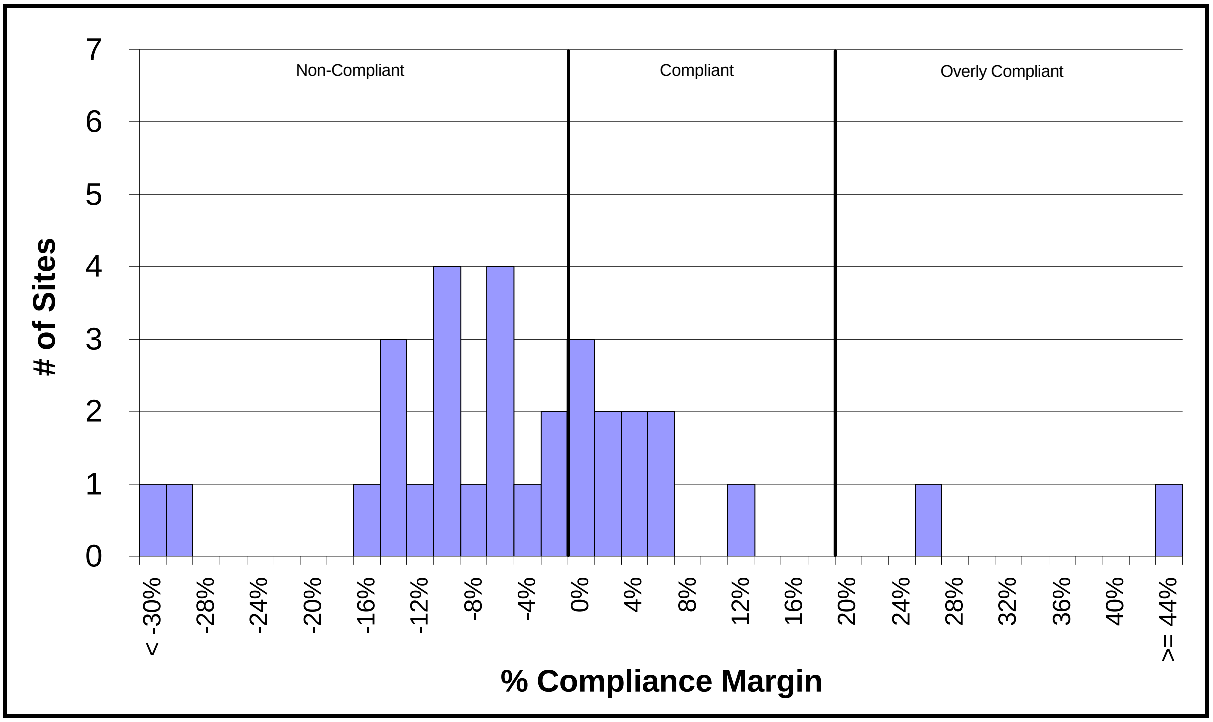
6 http://www.energy.ca.gov/title24_1998_standards/summary_changes.html

7 This building would have nearly reached compliance having a % Compliance Margin of –0.5%.

Figure 4-9: MICROPAS Results Summary – As-Built 2001 Standards – Low-Rise Multifamily Buildings



Average 2001 As-Built % Compliance Margin by RMST Climate Zone

Table 4-6 provides the average as-built % Compliance Margin under the 2001 Standards by RMST climate zone. Not surprisingly, the buildings in RMST Climate Zone 2 (Southern Coast) also have the highest average 2001 as-built % Compliance Margin (12%), while RMST Climate Zone 4 (Central Valley) and RMST Climate Zone 5 (Mountains & Deserts) have the lowest average as-built % Compliance Margins (-9% and -7%, respectively)

Table 4-6: Average % Compliance Margin – 2001 As-Built

RMST CZ	CEC CZ	Low-Rise
CZ1	1, 2, 3, 4, 5	1%
CZ2	6, 7	12%
CZ3	8, 9, 10	-2%
CZ4	11, 12, 13	-9%
CZ5	14, 15, 16	-7%

4.6 High-Rise Multifamily Buildings

This section reports on the relationships between compliance groups by examining the distribution of sites by compliance groups and examining the average percent Compliance Margin. For all sites, an EnergyPro simulation model of the building was created using data on the compliance documentation. Throughout the rest of this report, we refer to these as the "as-permitted" model. A second EnergyPro model was then created for each building using data on construction of the buildings from the on-site visits collected by ADM. These models are henceforth referred to as the "as-built" models. The study included 21 sites for which Title24 compliance data were obtained. Of the 21 sites, ADM were able to perform site verification surveys of 12 sites. For this report, only the 12 sites with completed on-site data are included in the analysis.

Originally Complied

Presented below are the results of the as-permitted and as-built compliance analysis of these buildings. Also explained below are the reasons for the differences between the results of these two runs, by building.

<u>As-Permitted</u>

The analysis included 12 sites for which plans, permit data, and site survey data had been obtained from ADM. Of the 12 sites surveyed, all 12 originally complied with the version of the standards effective at the time building permits were obtained. Generally, that was the 1998 Standards, but for four projects, it was the 1995 Standards. There were virtually no changes affecting high-rise residential buildings between these two versions of the Standards.[8] Therefore, the as-permitted analysis for each building was run against the Standards under which it was originally permitted.

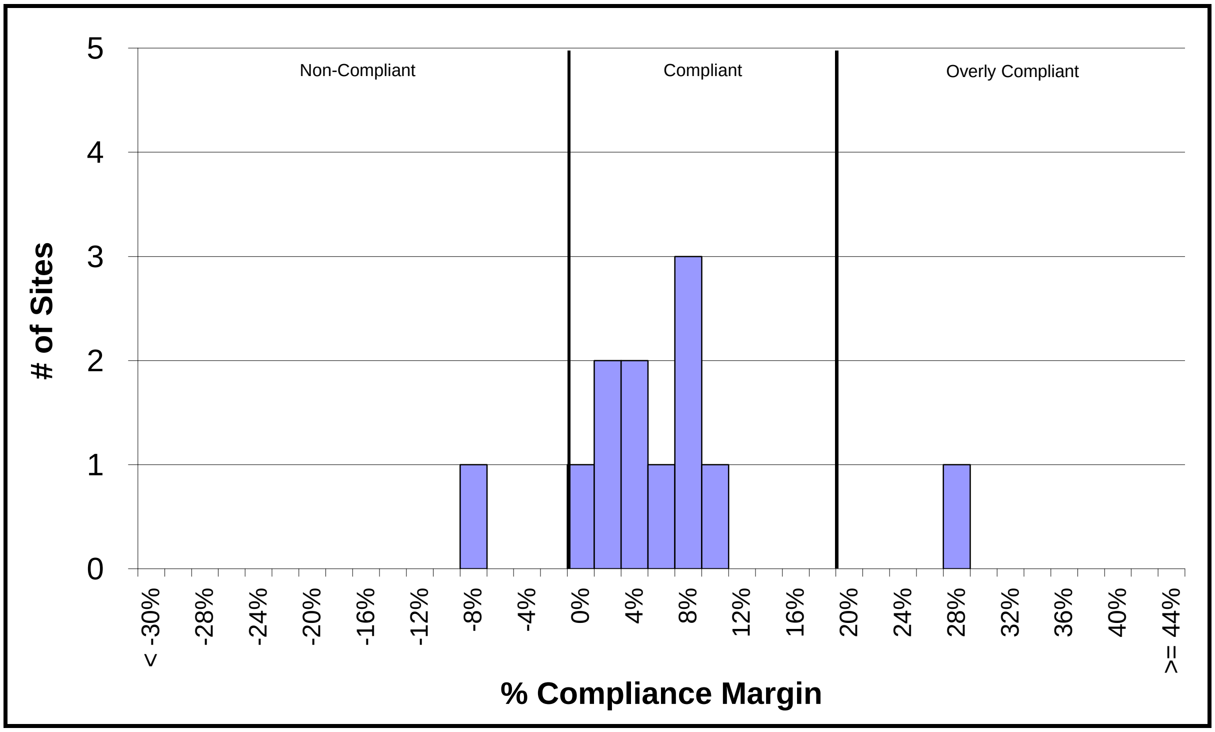
Figure 4-1 presents the distribution of sites by compliance groups.[9] The compliance percentages are based on reproduced compliance documentation for the version of the standards under which they were permitted. Compliance documents were available in electronic format for 10 of the 12 buildings, and were recreated for the remaining two sites. The models for these two sites are simplified models that mimic the site conditions to the extent of information available. As shown, the reproduced % compliance margin for one site is negative (-8.0%). This site originally complied using a "prescriptive" method embedded

8 The Standards changed from referencing Shading Coefficient to referencing Solar Heat Gain Coefficient; which is a change that did not make a difference. The Standards also added a requirement for insulation below concrete floors that had open space (e.g., a parking garage) under them in high-rise residential buildings.

9 For a definition of "compliance groups," see Section 2.

in EnergyPro 1.0.[10] However, since, for consistency, all sites were run using the "performance" method, the exact compliance margin could not be reproduced.

Figure 4-10: EnergyPro Results Summary – As-Permitted – High-Rise Multifamily Buildings



As-Built

The as-built simulation models were constructed based on the as-permitted models, with changes made per the field verification notes. The version of EnergyPro approved for use with the Standards at the time the buildings complied was used. For almost all of the buildings, the field staff could provide adequate information for window areas, HVAC equipment data, and central water heating plant details. The field verifiers could not collect sufficient information to verify the following items:

- Window U-factor and SHGC, and
- Envelope insulation levels.

[10] The prescriptive compliance model in EnergyPro used for the 1995 standards uses two separate methods for calculating U-factors. Whereas the proposed assembly uses a layer-by-layer approach to calculate U-factors, the 'standard' assembly uses a U-factor based upon a look-up table for construction types in the standards. This introduces differences in the standard and proposed budgets in spite of using the same construction assembly.
The prescriptive method for mechanical compliance is based upon meeting the load requirements, and over-sizing equipment is allowed. For the performance method, this over-sizing results in a 'penalty' as its energy usage is higher than that of a equipment sized to load for the 'standard' case

For windows, U-factor and SHGC values were estimated based on field notes describing window features, as well as photographs of the buildings. In case of the unavailability of physical evidence of the manufacturer and model of windows, the team used CEC default values based on generic descriptions matching what the field staff found.

For envelope insulation, verification of wall/roof thickness was used as a proxy, and insulation values derived. When better information was not available, the as-permitted values were used.

Figure 4-11: EnergyPro Results Summary – As-Built – High-Rise Multifamily Buildings

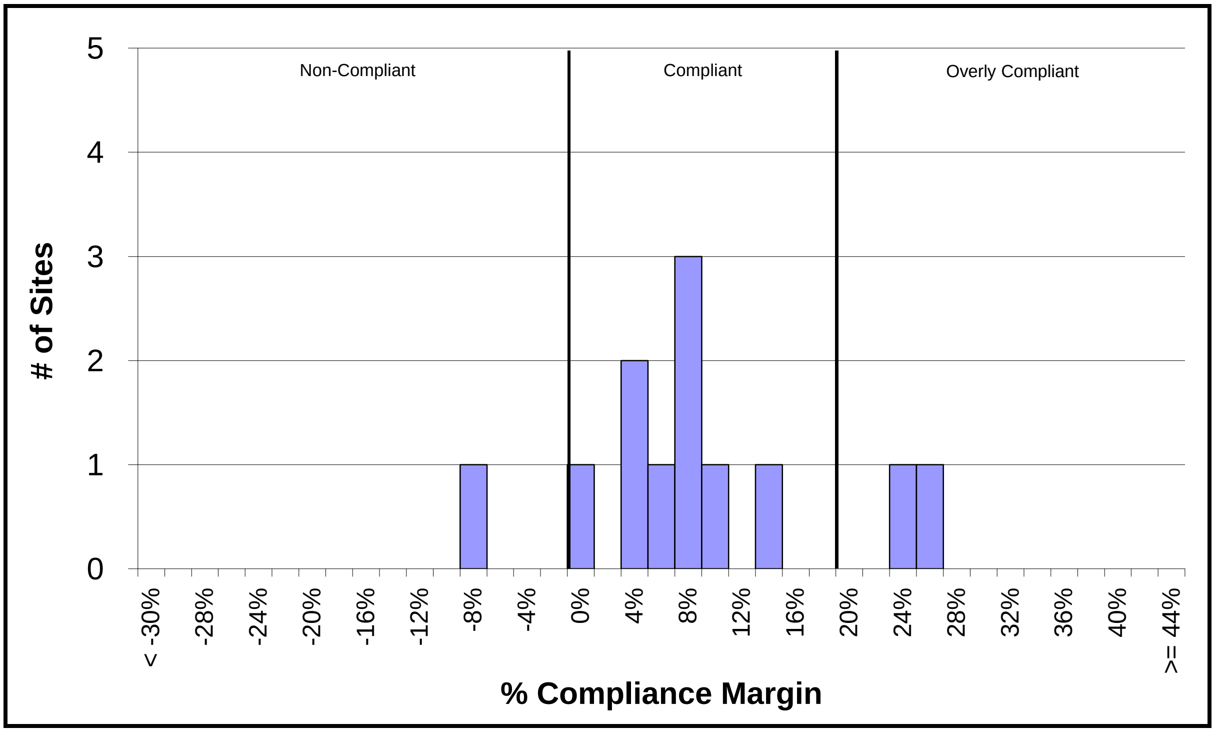


Table 4-7: Average % As-Built Compliance Margin – by RMST Climate Zone

RMST CZ	CEC CZ	High-Rise
CZ1	1, 2, 3, 4, 5	28%
CZ2	6, 7	9%
CZ3	8, 9, 10	4%
CZ4	11, 12, 13	-
CZ5	14, 15, 16	8%

Reasons for Differences between As-Permitted and As-Built

As expected, the "as-built" condition of nearly every site was found to have something different from what was listed on the compliance documentation. Descriptions of deviations responsible for the most dramatic changes in % Compliance Margin are listed by site below.

- **As-built does not comply – one site:**
  - **99988 –** Both the as-permitted and as-built models are simplified models of the building, based on available information. The envelope areas and HVAC system details match the totals as reported to the building departments and verified on-site, respectively. The main reason for non-compliance of the as-built model is the fan load, which remains constantly higher than assumed in the Title 24 standard budget runs due mostly to oversizing compared to ACM (Alternative Compliance Manual) standard assumptions. The wall areas were reduced by 12% and window areas reduced by 35% for the as-built model compared to the as-permitted model, resulting in an overall reduction in envelope gains and losses. This further increases the difference in equipment capacities for the as-built model vs. the Title 24 assumptions, and results in greater margin of non-compliance.
- **As-built % Compliance Margin increased more than 5% – three sites:**
  - **99995 –** The overall building window/wall ratio (WWR) changed from 51% in the "as-permitted" model to 38% in the "As-Built" model. This significant reduction in WWR results in significantly lower heat gains and losses from the envelope and is reflected in the lower energy consumption of the As-Built model when compared to the as-permitted model.
  - **99996 –** There are three major changes that affect the compliance margin of the two models.
    a) Window Type: Metal-framed, dual-pane in the as-permitted model to metal-framed dual-pane low-e windows in the as-built model. This results in lower solar gains and lower cooling loads.
    b) HVAC System: Four-pipe fan coil in the as- permitted model to heat pump in the as-built model. The higher efficiency of the heat pumps when

compared to the four-pipe fan coil system results in greater compliance margins.

c) Water Heater Efficiency: Standard 50-gallon individual water heaters in the as-permitted case to 82% efficient gas fired central water heaters in the as-built case. This is perhaps the largest difference between the two models, as the difference in the efficiency of the individual water heaters to that of the central water heater. Fifty-gallon water heaters with an EF of .058 typically have a recovery efficiency around 0.76-0.78. Recovery efficiency for small water heaters is roughly equivalent to thermal efficiency for boilers. Also, the standards do not correctly account for recirculation losses, resulting in a large apparent reduction in the water heating budget.

- **99997 –** There are two major differences between the as-permitted and as-built models.

  a) Window Type: Metal-framed, single-pane in the as- permitted model to metal-framed, dual-pane in the as-built model. This resulted in lower U-factors and SHGC, reducing heating and cooling loads.

  b) HVAC System: The as-permitted model used a split DX system with a gas furnace for heating (80% AFUE), while the as-built model used a heat pump with 7.40 HSPF. This resulted in apparent heating energy savings. Also, the cooling efficiency increased from SEER 10 in the as-permitted model to a SEER 12 in the as-built model.

- **As-Built Percent Compliance Margin reduced more than 5% – one site:**

  - **99998 –** On-site verification of the HVAC equipment showed that although the total number of HVAC units was the same as in the as- permitted model, the units were serving different residential zones than shown on the original compliance documentation, changing the sizing requirements for the units. The units installed were also of a larger cooling capacity, resulting in higher cooling and fan energy usage than the units submitted for permit requirements.

Figure 4-12: Comparison of As-Permitted Margin to As-Built Margin – High-Rise Buildings – by Site

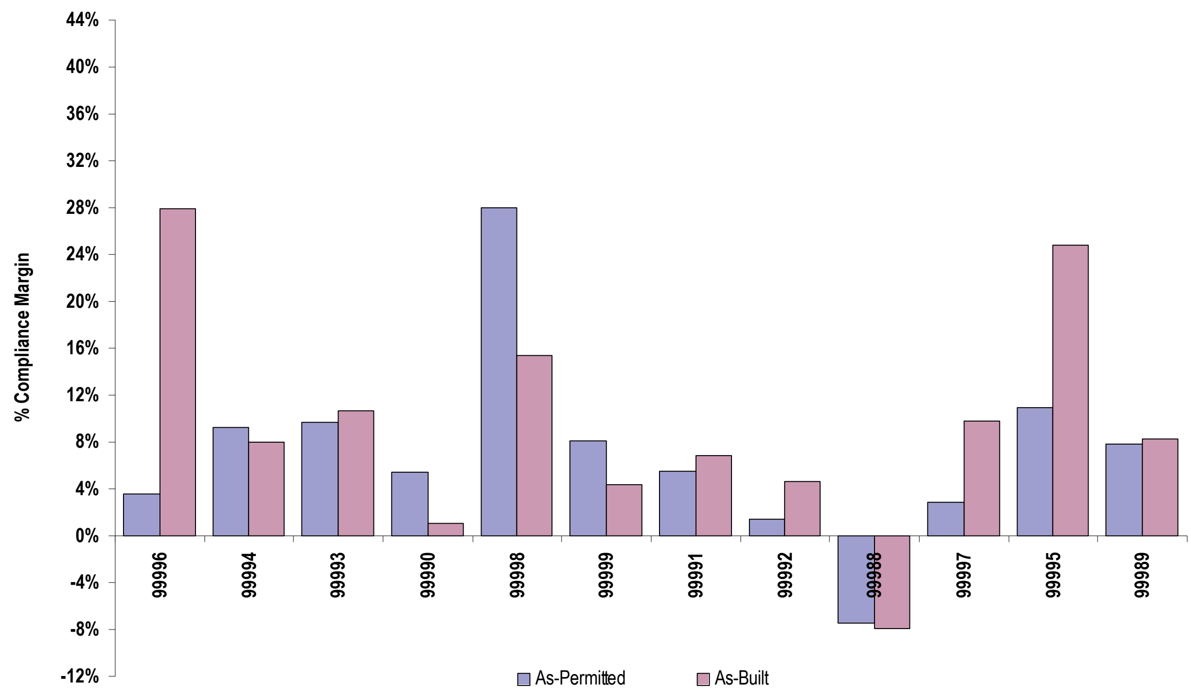
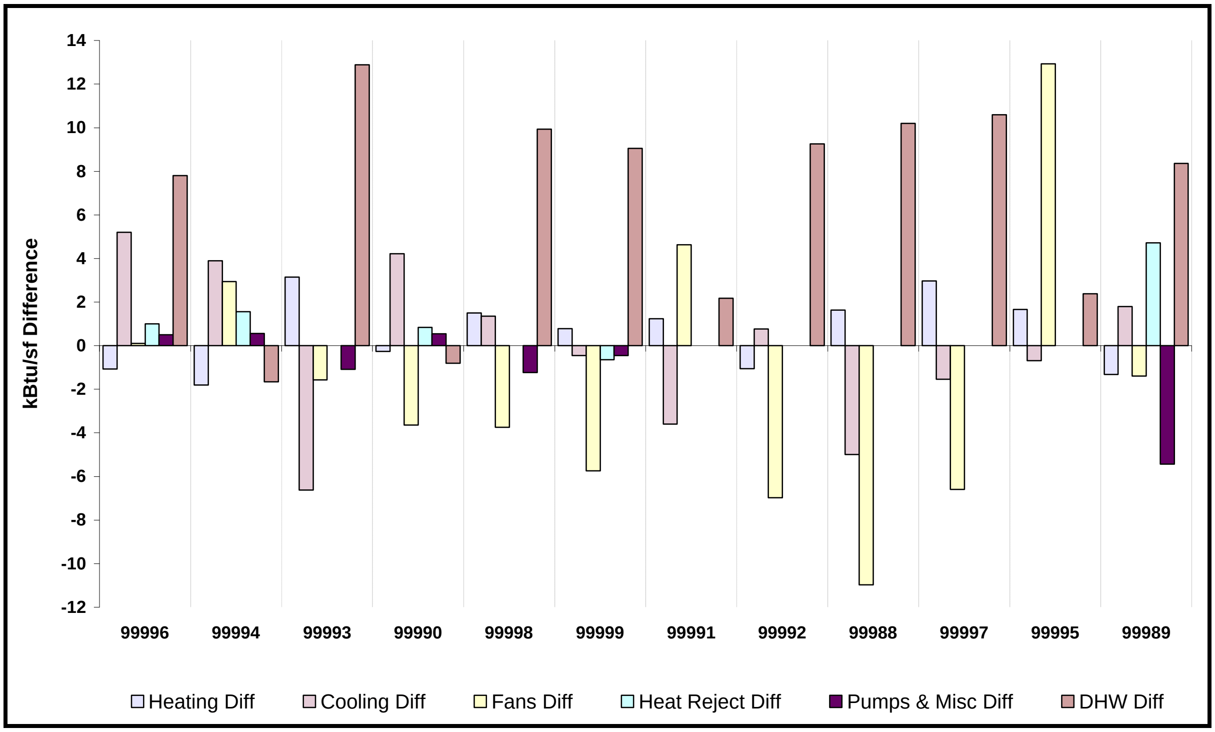


Figure 4-13 further explains the compliance margins in the as-built models by showing the difference across the six end-use categories: heating load, cooling load, indoor fan usage, heat rejection loads at the cooling towers, pumps and miscellaneous loads, and domestic hot water energy consumption.

For almost all of the 12 buildings, the variation in the compliance margins for domestic hot water energy is higher than for other end uses. This is because most of these 12 buildings have centralized water heaters with distribution systems, which are compared within the compliance programs to the Title 24 assumption of individual, minimally compliant water heaters in each unit. The standard case uses the same building geometry as the proposed case in the as-built model, but uses Title 24 default values for insulation, HVAC equipment type, efficiency etc. This 'standard' case is then used as a benchmark to derive compliance margins.

The HVAC system type assumed in the standard cases are based upon the building occupancy and equipment specified in the proposed case, as specified by the ACM released by the California Energy Commission.[11] For the 12 buildings analyzed, the ACM rules resulted in the as-built models having different systems in the standard case versus the proposed case. This difference is reflected most in the fan loads (as apart from the cooling and heating loads).

Figure 4-13: As-Built Compliance Margin – High-Rise Buildings – By End-Use Category and Site



As-Built Compliance Analysis – 2001 Standards

Once the 12 sites were analyzed under the standards they originally were permitted under using the as-built data, the as-built cases were analyzed under the 2001 Standards. As shown Figure 4-14, seven sites would not have complied had they been built under the 2001 Standards.

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11 California Energy Commission. *Alternative Calculation Method (ACM) Approval Manual for the 2001 Energy Efficiency Standards for Residential Buildings.* P400-01-012. Sacramento, CA. April 5, 2001.

Figure 4-14: EnergyPro Results Summary – As-Built 2001 Standards – High-Rise Multifamily Buildings

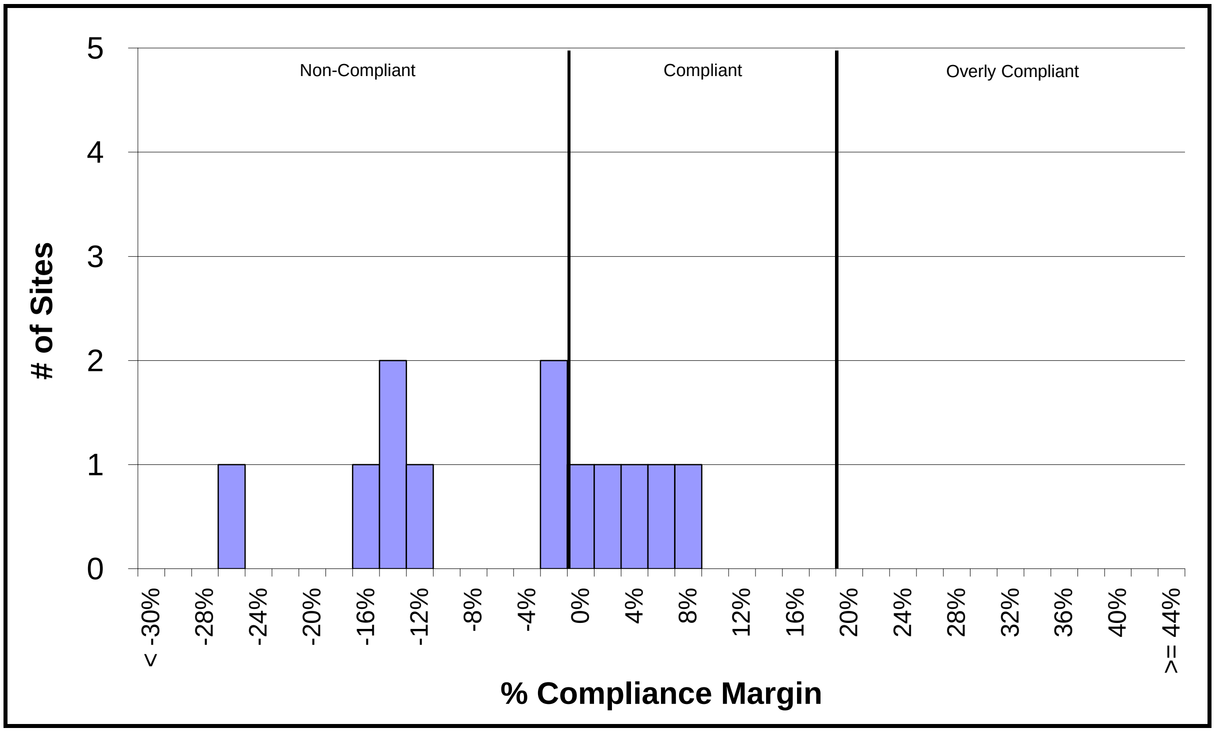

Table 4-8: Average % Compliance Margin – by RMST Climate Zone

RMST CZ	CEC CZ	High-Rise
CZ1	1, 2, 3, 4, 5	6%
CZ2	6, 7	-4%
CZ3	8, 9, 10	-13%
CZ4	11, 12, 13	-
CZ5	14, 15, 16	1%

5

Summary of Results

5.1 Introduction

This section summarizes key findings discussed in the baseline characterization and compliance analysis sections of this report.

5.2 Building Characteristics

This section summarizes the building practices for newly constructed multifamily buildings based on the analyzed sample of 31 low-rise and 12 high-rise multifamily buildings. It should be noted that no attempt was made to develop weights for the sample that would reflect all newly constructed multifamily buildings and that the sample is relatively small.[1] As such, the summaries presented in this section should be viewed as an indicator of construction practices and not necessarily represent statewide practices.

Low-Rise Multifamily Buildings

Due to the small number of sites (31) in the sample, statewide trends in construction cannot be adequately predicted. However, these provide a snapshot of the construction practices in low-rise multifamily buildings. Key building characteristics findings from the low-rise multifamily buildings surveyed are presented below.

- ***The average size of the low-rise multifamily buildings surveyed is approximately 14,000 square feet.*** The average building is 2.3 floors and contains 21 dwelling units. Further, the average number of dwelling units per complex of the 31 low-rise complexes surveyed is 224 dwelling units.

[1] Insofar as there is limited data relating to number of newly constructed multifamily buildings (as opposed to multifamily units published by CIRB), the study team agreed early on in the study not to develop estimates of statewide multifamily building new construction activity.

- ***Nearly all of the low-rise multifamily buildings surveyed had less glazing area than the prescriptive requirement.*** The only building that had a glazing percent[2] (16.9%) higher than the prescriptive is located in CEC Climate Zone 11, where the prescriptive glazing percentage is 16%. The average glazing percentage of the buildings surveyed statewide was 12.7%.
- ***Metal-framed, clear glass windows are the predominant window type found in the low-rise multifamily buildings surveyed (77%).*** Dual-pane, metal-framed windows (42%) are more common than single-pane, metal-framed windows (35%) in the surveyed buildings.
- ***Approximately 71% of the low-rise multifamily buildings surveyed have a hydronic heating system.*** There is also a fair amount of central heat pumps in the low-rise multifamily buildings surveyed (16%).
- ***Central air conditioners are the most common space cooling equipment found in the low-rise multifamily buildings surveyed (71%).*** There is also a fair amount of central heat pumps in low-rise multifamily buildings (16%). Of the 31 buildings surveyed, two have cooling systems that are higher than the prescriptive efficiency, while the other 25 buildings that have central cooling have systems that meet the prescriptive efficiency.
- ***Nearly all of the low-rise multifamily buildings surveyed have storage gas water heaters installed.*** Twenty-seven of the 31 buildings had individual storage gas water heaters for each dwelling unit. On average, these water heaters are 10% above standard.[3]
- ***Ceiling and wall insulation levels in the low-rise multifamily buildings surveyed are usually below prescriptive values.***[4] For those buildings surveyed, the insulation levels were typically lower than prescriptive values, but always greater than or equal to the minimum R-values specified in the mandatory requirements section of the Standards.
- ***The ducts in the low-rise multifamily buildings surveyed were found primarily in the attic (87%).*** Of the remaining buildings, two were found to have ducts in conditioned space and two did not have ducts.
- ***Just over half of the bathrooms in the low-rise multifamily buildings surveyed have CFLs.*** Furthermore, exterior lights with motion sensors were found only in one of the low-rise multifamily buildings surveyed, while exterior lights with daylight timers were found at just over half of the buildings.

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2 The percent glazing here refers to the window area to floor area ratio (WFR).

3 See Section 3.3 for an explanation of how % above standard is calculated for storage gas water heaters.

4 The prescriptive values, the minimum values allowed by Prescriptive Package D in the 1998 standards, for both ceiling and wall insulation vary by CEC climate zone.

- ***Approximately 32% of the low-rise multifamily buildings surveyed have a common laundry facility and 58% have individual laundry equipment in the dwelling unit.*** In the buildings that have a common laundry facility, there are an average of 19 washer/dryers per complex. In those buildings that have individual washer/dryers, all the equipment was supplied by the management.

High-Rise Multifamily Buildings

High-rise residential buildings are typically found in places where the land is at a premium, and real estate values encourage vertical growth. For this reason, high-rise buildings in California tend to be concentrated in the major coastal cities. In the sample of 12 buildings, eight are from RMST Climate Zone 2, which includes CEC Climate Zones 6 and 7, a thin band along the coast from Santa Barbara through Los Angeles to San Diego. Few high-rise multifamily buildings were found outside the major coastal areas. Due to the small number of sites (12) in the sample, the statewide trends in construction cannot be adequately predicted. However, these give a snapshot of the construction practices in the portions of the state where high-rise buildings are most prevalent.

Key building characteristics findings from the high-rise multifamily buildings surveyed are presented below.

- ***The average size of the high-rise multifamily buildings surveyed is just over 130,000 square feet.*** The average building is six floors and contains 138 dwelling units. Further, the average number of dwelling units per complex of the 12 low-rise complexes surveyed is 461 dwelling units.
- ***The average WWR for the high-rise multifamily buildings surveyed is 22%.*** The window to wall area ratio[5] by building ranged from 14% to 42%.
- ***Metal-framed windows are the predominant window type for the high-rise multifamily buildings (66%) surveyed.*** It is interesting to note that dual-pane, low-E, metal-framed windows (33%) are as common as dual-pane, clear glass, metal-framed windows (33%) in the high-rise multifamily buildings surveyed.
- ***Of the high-rise multifamily buildings surveyed, hydronic heating is the most commonly found heating source, with equal percentages of central and individual water heaters used for the hydronic systems (33% each).*** Heat pumps are the next most common heating source in high-rise buildings (25%). There is one building with hydronic radiant floor heating.

[5] The standards for high-rise residential buildings refers to the window area to wall area ratio (WWR), instead of percent glazing by floor area.

- ***The heating systems installed in each of the high-rise multifamily buildings surveyed have higher than prescriptive efficiencies.***
- ***Central air conditioners are the most common space cooling equipment found in the high-rise multifamily buildings surveyed (67%).*** There is also a fair amount of heat pumps in high-rise multifamily buildings (25%). Of the 12 buildings surveyed, one does not have cooling equipment installed. Also, none of the buildings surveyed had unitary air conditioners.
- ***Just over half of the high-rise multifamily buildings surveyed have a central boiler.*** Seven of the 12 buildings were found to have a central boiler, while four have individual storage gas water heaters for each dwelling unit. On average, these individual water heaters are nearly 11% above standard.[6]
- ***Ceiling and wall insulation levels in the high-rise multifamily buildings surveyed are commonly equal to or just above prescriptive values.***[7] Of those buildings surveyed, the ceiling insulation levels in eight of the buildings were equal to the prescriptive value, while three buildings had ceiling insulation greater than prescriptive. The wall insulation found was even more likely to be above prescriptive – eight had wall insulation that is greater than prescriptive and three had wall insulation equal to prescriptive.
- ***The ducts in the high-rise multifamily buildings surveyed were found primarily (67%) in the wall or ceiling (interstitial space between apartments).*** Of the remaining buildings, two were found to have ducts in the attic, one had ducts only in the walls, and one did not have ducts.
- ***Eight of the 12 high-rise multifamily buildings surveyed have CFLs in the bathrooms.*** Furthermore, exterior lights with motion sensors were not found in any of the high-rise multifamily buildings surveyed, while exterior lights with daylight timers were found at 10 of the 12 buildings.
- ***Only one of the high-rise multifamily buildings surveyed has a common laundry facility, while the other 11 buildings have individual laundry equipment in the dwelling unit.*** In those buildings that have individual washer/dryers, all the equipment was supplied by the management.

[6] See Section 3.3 for the explanation of how % above standard is calculated for storage gas water heaters.

[7] The prescriptive values, the minimum values allowed by Prescriptive Package D in the 1998 standards, for both ceiling and wall insulation vary by CEC climate zone.

5.3 Analysis of Compliance

The following is a summary of the results from the compliance analysis of low-rise and high-rise multifamily buildings.

Overview of Compliance Groups

The following four compliance groups were used as the basis for compliance analysis.

- ***Non-Compliant.*** This category includes sites that, based on the analysis, are not compliant with Title 24 code. In particular, these sites have a negative Compliance Margin less than the lower end of the error band.
- ***Compliant.*** This category includes sites that, based on the analysis, are compliant with Title 24 code. In particular, these sites have a % Compliance Margin greater than the upper end of the error band (i.e., >=0% and < 20%).
- ***Overly Compliant.*** This category includes sites that, based on the analysis, are overly compliant with Title 24 code. In particular, these sites have a % Compliance Margin greater than 20%. This category was defined to assess the share of buildings that would meet the existing ENERGY STAR® New Home Construction requirements, given the error band.

Low-Rise Multifamily Buildings

Below is a summary of the results from the compliance analysis of the 30 low-rise multifamily buildings.

- ***As-permitted[8] – one building was overly compliant.*** Approximately 97% of the buildings (30) are identified as compliant (i.e., they are in the compliant or overly compliant compliance groups) and 3% of the buildings (1) are identified as non-compliant.[9]
- ***As-built[10] – four buildings were overly compliant.*** Approximately 81% of the buildings (24) are identified as compliant (i.e., they are in the compliant or overly compliant compliance groups). One of these four building was overly compliant as-permitted. The remaining three buildings had more efficient windows installed than was documented on the C-2R.

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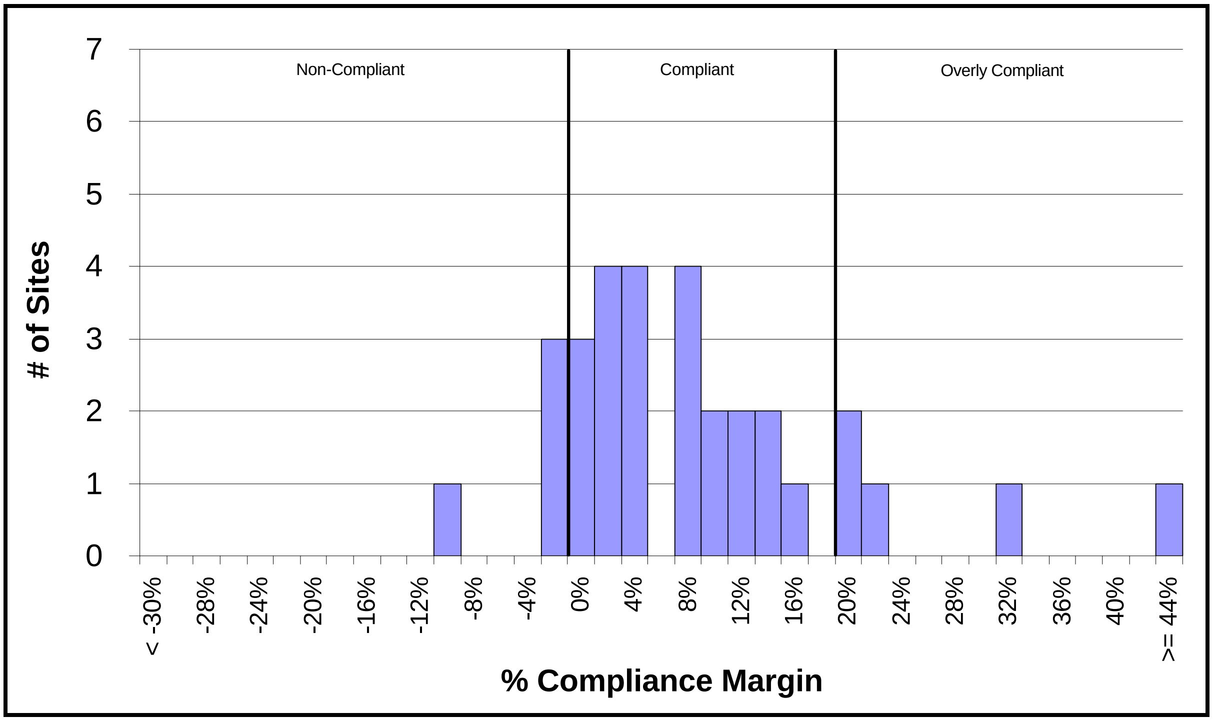
8 Under the Standards with which the building originally complied.

9 This site originally complied using a "per residence" method in EnergyPro 1.0. However, for consistency, all sites were run through the RNC Interface using a "per building" method, so it was impossible to reproduce the exact compliance margin for this building.

10 Under the Standards with which the building originally complied.

- ***As-built[11] – six buildings were non-compliant.*** Of the six sites found to be non-compliant as-built, three were built with more glazing area than was documented on the C-2R and two had less efficient water heaters installed than was documented on the C-2R. Another building originally complied using CEC Climate Zone 7, but was actually built in CEC Climate Zone 10, which is a climate zone with more stringent requirements.
- ***As-built under the 1998 Standards – five buildings were overly compliant.*** As shown in Figure 5-1, four buildings were non-compliant and twenty-two buildings were compliant.

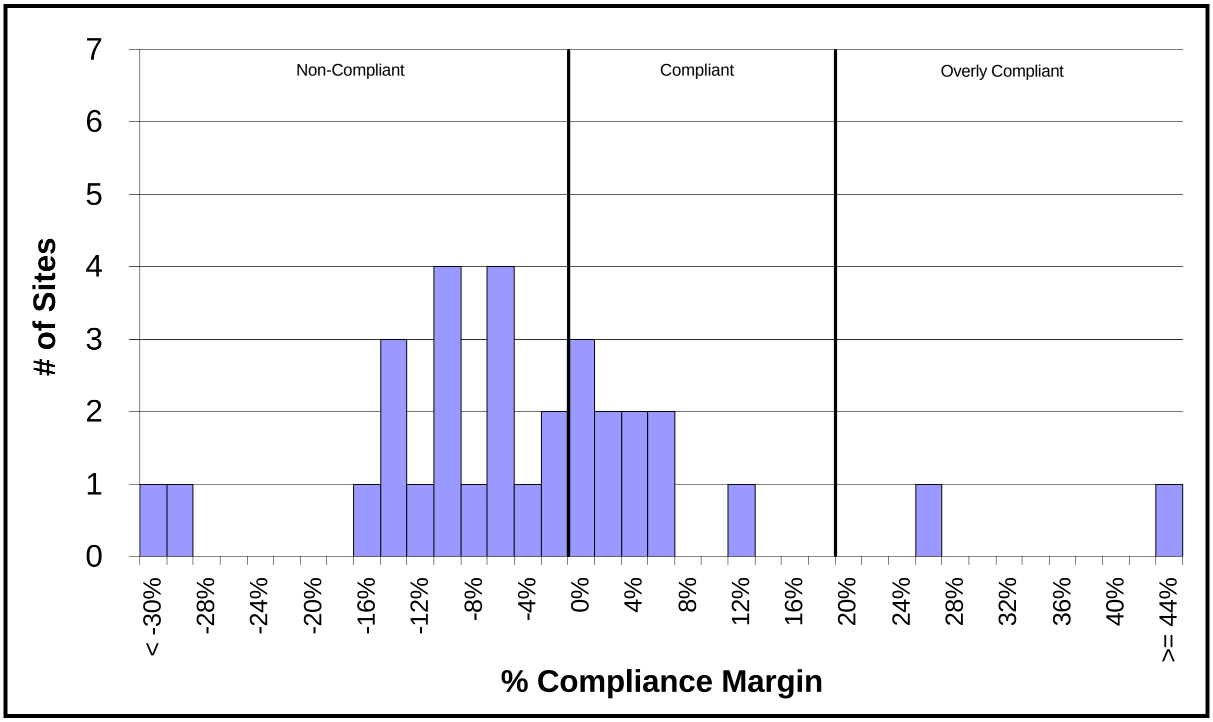
Figure 5-1: MICROPAS Results Summary – As-Built 1998 Standards – Low-Rise Multifamily Buildings



- ***The low-rise multifamily buildings in RMST Climate Zone 2 (Southern Coast) have the highest average as-built % Compliance Margin (20%).*** In addition, the buildings in RMST Climate Zone 4 (Central Valley) have the lowest average as-built % Compliance Margin (3%).
- ***As-built under the 2001 Standards – 19 buildings would have been non-compliant.*** As shown in Figure 5-2, only 12 as-built buildings would have complied under the 2001 Standards.

[11] Under the Standards with which the building originally complied.

Figure 5-2: MICROPAS Results Summary – As-Built 2001 Standards – Low-Rise Multifamily Buildings



- ***The low-rise multifamily buildings in RMST Climate Zone 2 (Southern Coast) have the highest average as-built % Compliance Margin (12%).*** Meanwhile, the average % compliance margin of the low-rise multifamily buildings in RMST Climate Zones 3 (Southern Inland), 4 (Central Valley), and 5 (Mountains & Deserts) was negative (-2%, -9%, and -7% respectively).

High-Rise Multifamily Buildings

Below is a summary of the results from the compliance analysis of the 12high-rise multifamily buildings.

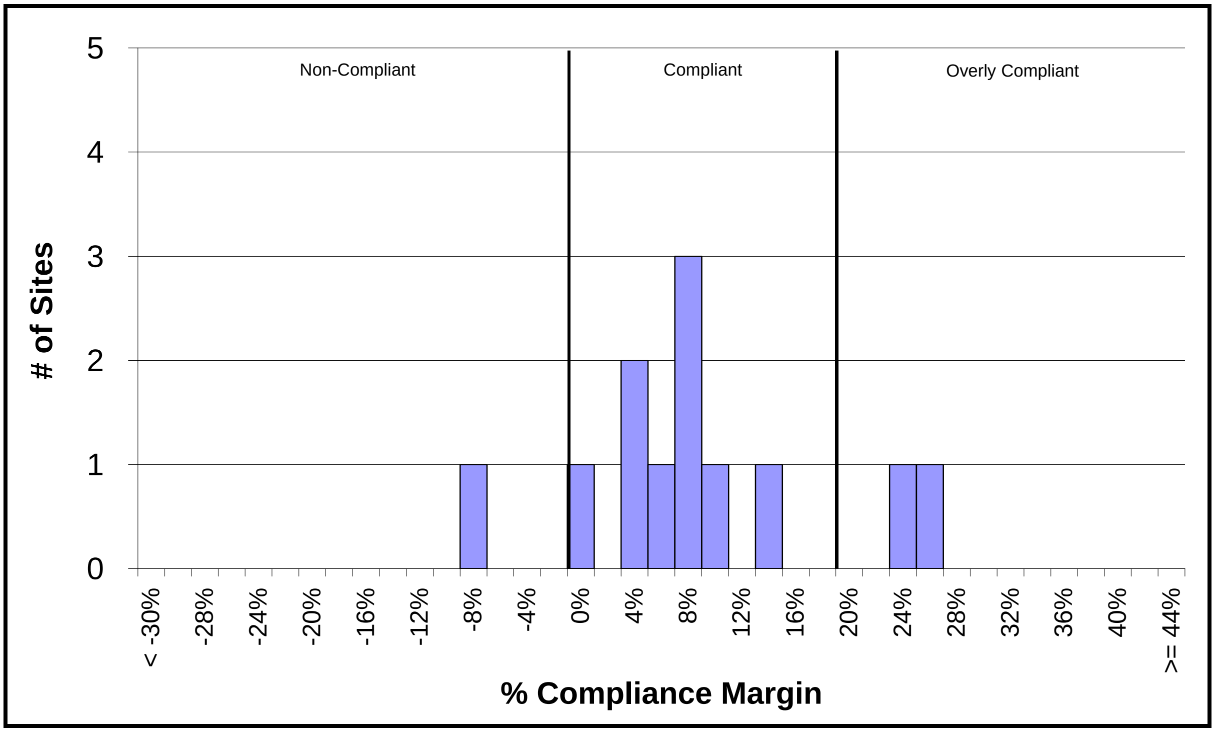
- ***As-permitted[12] – one building was overly compliant.*** Eleven of the 12 buildings are identified as compliant (i.e., they are in the compliant or overly compliant groups) and one of the buildings was identified as non-compliant.[13]

12 Under the Standards with which the building originally complied.

13 This site originally complied using a "prescriptive" method embedded in EnergyPro 1.0.[13] However, since, for consistency, all sites were run using the "performance" method, the exact compliance margin could not be reproduced.

- ***As-built[14] – two buildings were overly compliant.*** As shown in Figure 5-3, 11 of the 12 buildings are identified as compliant (i.e., they are in the compliant or overly compliant groups). Of the two buildings that were found to be overly compliant, one had less window area installed than was documented on the C-2R and the other had more efficient windows, a higher efficiency HVAC system, and a central water heating system (as opposed to individual water heaters) installed than were documented on the C-2R.
- ***As-built[15] – one building was non-compliant.*** The main reason for non-compliance is the fan load, which remains constantly higher than assumed in the Title 24 standard budget runs due mostly to oversizing compared to ACM (Alternative Compliance Manual) standard assumptions.
- ***As-built under the 2001 Standards – seven buildings would have been non-compliant.*** As shown in Figure 5-4, only five as-built buildings would have complied under the 2001 Standards.

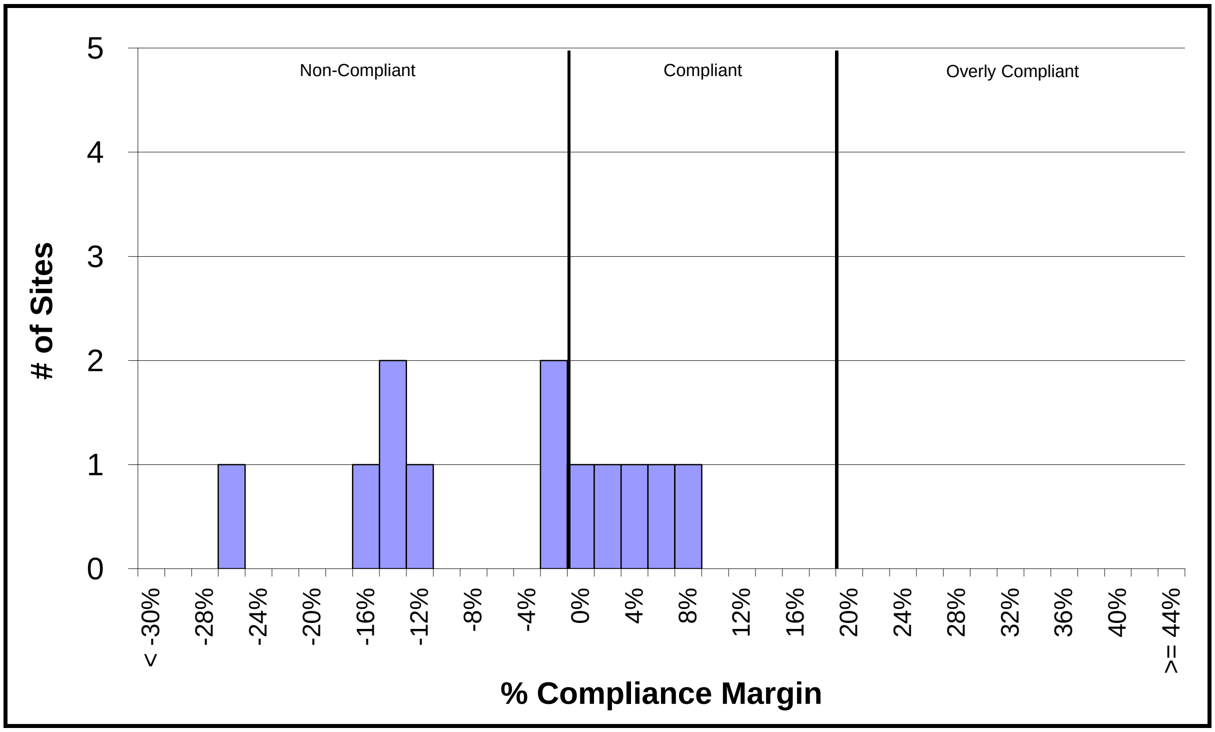
Figure 5-3: EnergyPro Results Summary – As-Built – High-Rise Multifamily Buildings



14 Under the Standards with which the building originally complied.

15 Under the Standards with which the building originally complied.

Figure 5-4: EnergyPro Results Summary – As-Built 2001 Standards – High-Rise Multifamily Buildings



5.4 Conclusions

The results of this study indicate that both low-rise and high-rise multifamily builders will need to modify the typical methods used for compliance and/or make changes to the standard construction practices used under the 1998 Standards, in order to just meet the 2001 Standards. For instance, a large number of buildings are able to comply with the 1998 standards without taking compliance credit for high efficiency measures (e.g., those buildings already employing measures like dual-paned windows and high efficiency water heaters). In some climate zones the homes, as they were constructed, will not comply with the 2001 standards. In other climate zones, the homes as they were constructed will comply with the 2001 standards, but will not have the typically large compliance margins seen under the 1998 Standards. Both situations indicate that the energy consultants and builders, in most regions, will no longer be able to continue business as usual, which should present a good opportunity for managers of residential new construction energy efficiency programs to enlist energy consultants and builders in their programs. The key findings that support these conclusions are summarized below:

Low-Rise Multifamily Buildings

Implementation of the 2001 Standards has tempered the "excess" compliance margins—usually attributed to the use of lower-than-prescriptive glazing percentages and higher-than-standard efficiency water heaters—that are normally associated with multifamily buildings. Nearly two-thirds of low-rise buildings surveyed that complied under the 1998 Standards would not comply under the tighter energy budgets of the 2001 Standards. As such, changes to either the standard compliance practices or standard construction practices are likely to occur. However, the extent of the change required is likely to vary greatly by climate zone[16].

- In RMST Climate Zone 2, the 2001 average compliance margin is still very positive (12%) so existing practices can still be used to achieve compliance.
- In RMST Climate Zones 1 and 3, the 2001 average compliance margins are just slightly negative (-1% and -2% respectively), so a change to compliance practice might be all that is needed to achieve compliance. For example, using the performance parameters for the actual windows that will be installed rather than CEC default values might be enough to achieve compliance.
- In RMST Climate Zones 4 and 5, the 2001 average compliance margins are more severely negative (-9% and -7% respectively), due to the emphasis of the 2001 Standards on reducing cooling energy. As such, a change to both compliance practices and construction practices will likely be needed to achieve compliance.

In addition, low-rise residential multifamily buildings will generally not be impacted by the change proposed for the 2005 Standards to evaluate central water heating systems against a boiler-based system rather than against individual storage water heaters. This is because the most common hydronic heating system for low-rise multifamily units is a combination space/domestic water heating system that utilizes an individual storage water heater and fan coil for each dwelling unit. However, there are other proposed changes particularly the time dependent valuation of energy usage to the 2005 standards that will impact the low-rise residential buildings. The impact of all proposed changes on low-rise residential buildings is currently being evaluated.

The data from this study suggests that builders of low-rise multifamily units typically use individual unit water heaters as opposed to central systems. Further, builders typically install individual unit water heaters that are more efficient than the existing standards and construct buildings with lower than prescriptive glazing percentages. These factors offer builders the opportunity to trade-off this compliance margin benefit for lower than prescriptive requirements for insulation, windows, and space conditioning.

[16] Note that for climate zones with relatively large cooling loads, such as the inland valley, compliance under the 2001 standards is substantially harder to achieve than compliance under the 1998 standards.

A review of the sample of homes in this study suggests that in some cases trade-offs could be taking place as evidenced by lower than prescriptive insulation, a high occurrence of single-pane metal windows, and some occurrences of electric resistance space heating systems. However, in other cases the compliance margin benefit from high efficiency water heating and relative low glazing percentages results in relatively high compliance margins. In either case, the common practice of installing high efficient individual unit water heaters and constructing buildings with lower than prescriptive glazing percentages enable builders of low-rise multifamily buildings to easily comply with the prevailing Title 24 (1995 or 1998) standards. However, the 2001 standards for the inland climate zones are more difficult to attain than the prevailing 1995 or 1998 standards.

High-Rise Multifamily Buildings

Conclusions are more difficult to draw from the high-rise analysis due to the small number of sites (12) and lack of sites in RMST CZ4. However, since fewer high-rise multifamily are built, and most of these tend to be located along the coast (RMST CZ1 and CZ2), the results may still provide a good characterization of high-rise multifamily residences. Key findings for high-rise multifamily buildings include:

- More than half of the high-rise buildings surveyed have central water heating systems, so high-rise buildings will be significantly impacted by the change proposed for the 2005 Standards to evaluate central water heating systems against a central boiler-based system, rather than against individual storage water heaters.
- There are other proposed changes particularly the time dependent valuation of energy usage to the 2005 standards that will also impact the high-rise residential buildings. The impact of all proposed changes on high-rise residential buildings is currently being evaluated.
- Regarding the issue of trading off the extra energy budget resulting from the use of central water heating systems, this does not seem to be an issue for high-rise buildings: insulation typically meets or exceeds prescriptive values, heating efficiencies are higher than minimum appliance standards, and dual-paned windows are most common and half of those are even low-e.
- Exterior lighting is generally controlled in accordance with the non-residential and high-rise lighting Standards via daylighting controls.

Common Issues

Key findings applicable to the entire multifamily segment include:

- For both low-rise and high-rise multifamily buildings, there is some evidence of specifying CEC minimum default window performance parameters on the compliance documentation, but installing windows that are better than these defaults. This supports anecdotes from other sources that Title 24 energy consultants do this to give the builder maximum flexibility during construction.

- Results from the building characteristics analysis show that low-rise and high-rise[17] multifamily residences are distinctly different in building envelope configuration, glazing percentages, and predominant space heating, space cooling, and water heating system types.
- CFLs are not present in the bathrooms of all multifamily buildings, as required by the Standards, but are implemented more often in high-rise buildings (two-thirds) than low-rise buildings (less than one-half).
- Laundry equipment in the low-rise and high-rise buildings surveyed, whether located in a common area facility or within the individual dwelling units, is always supplied by the management.

[17] Note that some of the four-story high-rise buildings surveyed have similar building characteristics to the low-rise buildings surveyed.

Appendix A

On-Site Verification Survey Instruments

Low-Rise On-Site Verification Survey Instrument

C2R File ID #

PG&E Statewide Multifamily Low-Rise Residential On-Site Survey Form

Regional Economic Research, Inc. and ADM

Version: April 16, 2002

Contact Information:

Contact Name:			
Street Address:			
City:			
Zip Code:			
Phone Number:	( )		
County:		CEC Climate Zone #:	

Photo Information

Camera ID #		# of photos	

* Please take at least one photograph of each orientation of the building.

Survey Tracking Information:

	Date:	Initials
Field Verification Survey Executed:	__ / __ / __	__ __ __
Survey Received from Surveyor:	__ / __ / __	__ __ __
Survey Received at RER:	__ / __ / __	__ __ __
Data Entry Complete:	__ / __ / __	__ __ __

Builder/Development Information

Development/Complex Name:	
Month/Year the building was first occupied:	month ____ / year ______
Builder's Name:	

General Site Information

This verification form is applicable only to Low-Rise Multifamily buildings - those buildings where residential units share walls, roofs, and floors. Attached single-family residences - those buildings where the residential units do not shared either floor or roof with other residential units – are not to be surveyed. High-rise residential buildings – those with >3 floors – are to be surveyed using the High-Rise Residential survey form.

Building Characteristics

Site Activity Type	**AP** = Apartments, general **SR** = Senior apartments **CT** = Condos/townhomes **LI** = Low-income housing **OT** = Other (describe) ______________________	**AP SR CT LI OT**
Building footprint/shape	**R** = Rectangular **L** = L-shaped **T** = T-shaped **C** = Courtyard **H** = H-shaped **M** = Multiple footprints **O** = Other (describe) ___________	**R L T C H M O**
Residential unit configuration	**B** = Back-to-back **S** = Straight-through **H** = Hallway (interior) **P** = Perimeter units (arranged around a central area) **O** = Other (describe) _______________________________	**B S H P O**
Number of floors (occupied space only, i.e. excluding parking garage)		
Total conditioned floor area of the building?		ft^2
-- % of building that is not residential units (i.e. laundry facilities, rec. rooms, etc.)		%
Floor-to-floor height, ft		ft
Floor-to-ceiling height, ft		ft
Total number of residential units in this bldg?		

Complex Information

Total # of residential-unit *buildings* in the complex?	
Total number of *residential units* in the complex?	
Do all buildings in this complex have the same footprint/configuration? *(if only 1 building – N/A)*	**Y N N/A**
Laundry Rooms	
Does the complex have a central laundry?	**Y N**
If yes, approximately how many washers and dryers are there total?	
Is the laundry housed in a separate building?	**Y N**
Do individual apartments have washer/dryers installed?	**Y N**
If yes, approximately wht % of the units?	
If there is a washer/dryer in each unit, are these supplied by the apartment complex?	**Y N**
Lighting	
Do the exterior lights managed by the complex have motion sensors? If so, approximately what	%
Do the exterior lights managed by the complex have daylight timers? If so, approximately what	%
Were Compact Fluorescent light bulbs (CFLs) installed in the bathrooms of each unit?	**Y N**

Notes: ____

____

____

____

____

Building/Site Sketch – Plan View

Page __ of __

Sketch an outline (i.e. external walls) of the site for each floor of the building. Include dimensions and note location of garages. Draw an arrow to indicate true North versus the "Front" of the building, as aligned to the Front of the building as indicated on the C2R form. Note other external walls as Left, Right, and Back. Indicate areas with vaulted ceilings. Indicate glazing locations. Show any trees or adjacent structures that provide significant shading. Use multiple sheets if needed and number accordingly. ***Indicate ALL dimensions needed to verify building envelope dimensions on the C2R.***

Notes: ____

____

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____

Building/Site Sketch – Elevation View

Page __ of __

Sketch an elelvation view of the site for each side of the building. Include dimensions and note location of garages. Indicate the "Front" of the building, as aligned to the Front of the building as indicated on the C2R form. Note other external walls as Left, Right, and Back. Indicate garages and non-residential areas. Indicate glazing locations. ***Indicate ALL dimensions needed to verify building envelope dimensions on the C2R.***

Notes: ____

____

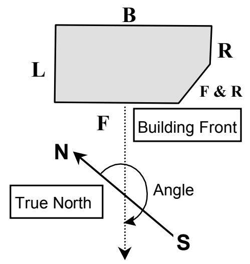
____

____

____

Building Orientation and Construction

Front Wall Orientation



Front orientation angle: (0-360°) ______________

NOTE: The "Front" of the building as indicated here must be aligned consistent with the "Front" as indicated on the C2R form.

External Walls and Doors

Wall orientation (reference: facing the Front wall)	**Front**	**Left**	**Back**	**Right**
Gross wall area, ft² (*inc. windows, doors, etc.*)				
Demising wall area (wall between cond. and uncond. space), ft²				
Wall surface type: S=Stucco W=Wood siding V=Vinyl siding M=Metal siding B=Brick/Block OT=Other*				
Exterior wall construction type: WF24 = 2X4 Wood Framed; WF26 = 2X6 Wood Framed; MF24 = 2X4 Metal Framed; MF26 = 2X6 Metal Framed; WFOM = Wood Foam Panel; BLO = Concrete Block; BRI = Brick; OT = Other*				
Wall insulation R-Value (from insulation certificate if available)				
Number of wooden doors				
Number of insulated metal doors				
Number of uninsulated metal doors				
Door Shading: patio cover or recessed entry? **Y**es or **N**o	**Y N**	**Y N**	**Y N**	**Y N**

Roof Construction Type

Total Roof Area, ft²		_______________ ft²
Roof Type	FAT=Framed w/Attic-Crawl Space MET=Metal Decking CON=Concrete Decking FNO=Framed w/o Attic-Crawl Space OT=Other ________________________________	
-- External Roof Surface	T=Tile (Clay, Concrete, etc.) C=Composition B=Built-up S= Shingle/Shake OT=Other*	
-- External Roof Color	W=White L=Light M=Medium D=Dark	
Radiant barrier?		**Y N**
Insulation R-value	Indicate R-value (use θ only if uninsulated)	
	Insulation type: **B** = Batt/Blanket **L** = Loose-fill **OT** = Other ___________	
	Indicate inches of insulation in roof cavity	

* Note "Other" construction types in comments block.

Floor Construction Type

Floor construction type	**S** =Slab **C** =Crawl **U** =Unheated Basement **G** =Garage **ADB** =Cond. space below
Raised floor insulation R-value	Indicate R-value (use θ only if uninsulated)

Windows, Glass Doors, and Skylights – Summary

C-2R Window Identifier	C-2R Area	OnS Total Area	Areas Match?	Windows Installed Not On Plans	Windows On Plans Not Installed	Window Sizes Do Not Match C-2R
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						
35						
36						
37						
38						
39						
40						

Windows, Glass Doors, and Skylights – Detailed

Item # (use multiple sheets if necessary)							
C-2R Window Identifier							
Unit Type	**W** = Window **D** = Door **S** = Skylight						
Exterior Shading / Overhangs	(ie. Overhang, Awning, PatioCover, RecessedEntry, etc.) **Height** (Distance from top of Window to Overhang)						
	Depth (Distance Wall to end of Overhang)						
Style	**S=**Slider **F=**Fixed **A=**Art Glass **D=**Double-Hung **B**=Bay/Bow **C**=Casement **W**=Awning						
Frame type	**M**=Metal **W**=Wood **V**=Vinyl **OT**=Other*						
Layers of glazing	**S**=Single **D**=Double **T**=Triple						
Muntins/grids?	**I**=Internal/between panes **E**=External **B**=Both						
Glass Type	**C**=Clear **T**=Tinted **R**=Reflective **LowE**: **LN**=Near **LF**=Far						
-- Was this an after-market film/treatment?		**Y N**	**Y N**	**Y N**	**Y N**	**Y N**	**Y N**
Size of Window	**Height** (inches)						
	Width (inches)						
	Area (square feet)						
Number of units installed							
Total Area (Multiply Area by # units installed)							

Item # (use multiple sheets if necessary)							
C-2R Window Identifier							
Unit Type	**W** = Window **D** = Door **S** = Skylight						
Exterior Shading / Overhangs	(ie. Overhang, Awning, PatioCover, RecessedEntry, etc.) **Height** (Distance from top of Window to Overhang)						
	Depth (Distance Wall to end of Overhang)						
Style	**S=**Slider **F=**Fixed **A=**Art Glass **D=**Double-Hung **B**=Bay/Bow **C**=Casement **W**=Awning						
Frame type	**M**=Metal **W**=Wood **V**=Vinyl **OT**=Other*						
Layers of glazing	**S**=Single **D**=Double **T**=Triple						
Muntins/grids?	**I**=Internal/between panes **E**=External **B**=Both						
Glass Type	**C**=Clear **T**=Tinted **R**=Reflective **LowE**: **LN**=Near **LF**=Far						
-- Was this an after-market film/treatment?		**Y N**	**Y N**	**Y N**	**Y N**	**Y N**	**Y N**
Size of Window	**Height** (inches)						
	Width (inches)						
	Area (square feet)						
Number of units installed							
Total Area (Multiply Area by # units installed)							

* Describe Other frame type in comments block

Notes:

Windows, Glass Doors, and Skylights – Detailed (cont.)

Item # (use multiple sheets if necessary)							
C-2R Window Identifier							
Unit Type	**W** = Window **D** = Door **S** = Skylight						
Exterior Shading / Overhangs	(ie. Overhang, Awning, PatioCover, RecessedEntry, etc.) **Height** (Distance from top of Window to Overhang)						
	Depth (Distance Wall to end of Overhang)						
Style	**S=**Slider **F=**Fixed **A=**Art Glass **D=**Double-Hung **B**=Bay/Bow **C**=Casement **W**=Awning						
Frame type	**M**=Metal **W**=Wood **V**=Vinyl **OT**=Other*						
Layers of glazing	**S**=Single **D**=Double **T**=Triple						
Muntins/grids?	**I**=Internal/between panes **E**=External **B**=Both						
Glass Type	**C**=Clear **T**=Tinted **R**=Reflective **LowE**: **LN**=Near **LF**=Far						
-- Was this an after-market film/treatment?		**Y N**	**Y N**	**Y N**	**Y N**	**Y N**	**Y N**
Size of Window	**Height** (inches)						
	Width (inches)						
	Area (square feet)						
Number of units installed							
Total Area (Multiply Area by # units installed)							

Item # (use multiple sheets if necessary)							
C-2R Window Identifier							
Unit Type	**W** = Window **D** = Door **S** = Skylight						
Exterior Shading / Overhangs	(ie. Overhang, Awning, PatioCover, RecessedEntry, etc.) **Height** (Distance from top of Window to Overhang)						
	Depth (Distance Wall to end of Overhang)						
Style	**S=**Slider **F=**Fixed **A=**Art Glass **D=**Double-Hung **B**=Bay/Bow **C**=Casement **W**=Awning						
Frame type	**M**=Metal **W**=Wood **V**=Vinyl **OT**=Other*						
Layers of glazing	**S**=Single **D**=Double **T**=Triple						
Muntins/grids?	**I**=Internal/between panes **E**=External **B**=Both						
Glass Type	**C**=Clear **T**=Tinted **R**=Reflective **LowE**: **LN**=Near **LF**=Far						
-- Was this an after-market film/treatment?		**Y N**	**Y N**	**Y N**	**Y N**	**Y N**	**Y N**
Size of Window	**Height** (inches)						
	Width (inches)						
	Area (square feet)						
Number of units installed							
Total Area (Multiply Area by # units installed)							

* Describe Other frame type in comments block

Notes:

Heating, Cooling, Fans, and Ducts

Heating and Cooling Systems

System ID	# ___		#___	
System Information				
System Type: **C** = Central Unit** **EV** = Evaporative Cooler **RT** = Room Unit, Thru-the-wall **RW** = Room Unit, Window **FR** = Free-standing Room Unit **FL** = Floor Furnace Unit **WF** = Wall Furnace w/fan **WG** = Wall Furnace, gravity **HF** = Hydronic (Fan Coil)** **HR** = Hydronic (Radiant) **BB** = Baseboard/Radiant Heater **S** = Shared central system **P** = Portable Unit **OT** = Other* ____________	C RT FR WF HF BB P	EV RW FL WG HR S OT	C RT FR WF HF BB P	EV RW FL WG HR S OT
% of Residence Served by this System				
Location: **G**=Garage **A**=Attic/Ceiling **S**=Cond. Space **M**= Mech. Room/Closet **OT**=Other _____________	**G A S** **M OT**		**G A S** **M OT**	
For **C and **HF** System Types: Estimated straight-line distance from blower to water heating unit in ft	__ __ **ft**		__ __ **ft**	
Heating Equipment				
Manufacturer				
Model Number (include dash numbers)				
Number of units:				
Equipment Type: **F** = Furnace **HP** = Heat Pump **RH** = Radiant Heater **ER** = Elec. Resistance **HW** = WaterHtgSyst (pg10) **BB** = Baseboard Heater **N** = None **OT** = Other* **Fuel Type:** **E** = Electricity **G** = Natural Gas **P** = Propane (LPG) **F** = Fuel Oil **W** = Wood **OT** = Other* ________	**F** **HP** **RH** **ER** **HW** **BB** **N** **OT**	**E** **G** **P** **F** **W** **OT**	**F** **HP** **RH** **ER** **HW** **BB** **N** **OT**	**E** **G** **P** **F** **W** **OT**
Input Capacity (Check units, either kBtuh or kW)	__________ ❑ kBtuh ❑ kW		__________ ❑ kBtuh ❑ kW	
Efficiency | Efficiency Units (A=AFUE H=HSPF E=EER C=COP)		**A H E C**		**A H E C**
HP only: -- *Supplemental Heating Capacity (kW)*				
-- *Soft start? (Y/N)*	**Y N**		**Y N**	
Cooling Equipment				
Manufacturer				
Model Number (include dash numbers)				
Number of Units:				
Type: **AC** = A/C (Std DX) **ID** = Indirect/Direct Evap **HP** = Heat Pump **N** = None **EV** = Direct Evap **OT** = Other ____________	**AC** **HP** **EV**	**ID** **N** **OT**	**AC** **HP** **EV**	**ID** **N** **OT**
Output Capacity (kBtuh)				
Efficiency | Efficiency Units (S=SEER E=EER P=% Sat. Eff)		**S E P**		**S E P**
Condenser Type: **A**=Air **E**=Evap **G**=Ground W=Water	**A E G W**		**A E G W**	
TXValve Present?	**Y N**		**Y N**	

* Describe Other types in comments block.

Heating and Cooling Systems (cont.)

System ID	# ___	#___
Fans/Ventilation (Ducted systems only)		
Indoor Fan, hp		
Supply Air Rate (CFM)		
Fan Type: **C**=Constant **T**=2-speed **V**=Variable	**C T V**	**C T V**

Duct Systems

Do the residential units in this building have ducts? *If no, then you are done with ducts for this set of plans.*	**Y N**	
Are the ducts laid out as per plans?	**Y N**	
Duct Length: (measure distance between HVAC equipment and farthest register)		
	Supply	**Return**
Predominant Location of Supply Registers: **F**=Floor **C** =Ceiling **I**=Interior Walls **P**=Perimeter **OT**=Other*	**F C** **I P OT**	**F C** **I X OT**
Location of Ducts (indicate all that apply): **A**=Attic **CR** =Crawlspace **CS**=Conditioned Space **W**=Wall Cavity **B**=Basement **OT**=Other*	**A CR** **CS W B OT**	**A CR** **CS W B OT**
Duct Types (indicate all that apply): **PF**=Plastic Flexduct **MF**=Metal Flexduct **M**=Sheet Metal **P**=Panned Joist **D**=Ductboard **U**=Unfinished wall cavity **OT**=Other*	**PF MF** **M P D U OT**	**PF MF** **M P D U OT**
Duct Size: Please indicate the approx. diameter of the ducts in inches.		
Duct Sealant Types (indicate all that apply): **M**=Mastic **BT**=Butyl Tape **MT**=Metal Tape **CT**=Cloth tape **D**=Duct tape **C**=Mech. clamps **OT**=Other*	**M BT** **MT CT D C OT**	**M BT** **MT CT D C OT**
--- Aerosol sealing used (check for certificate)**?**	**Y N**	**Y N**
--- For tapes, list **UL Label/Brand Name** if visible (e.g. UL181B-FX, UL723)		
Duct Insulation R-Value (–7 if insulation not labeled, 0 if uninsulated)	**-7 0 4.2 6 8**	**-7 0 4.2 6 8**

* Describe Other types in comments block.

Notes:

Water Heating Equipment

Item #	___	___
Manufacturer		
Model Number (include dash numbers)		
Energy Factor (EF)		
Location: **G**=Garage **A**=Attic **S**=Cond. Space **O**=Outside closet **M**= Mech. Room/Closet **OT**=Other ________________	**G A S O M OT**	**G A S O M OT**
Quantity		
Equipment type: **S** = Standard (Storage) Water Heater **I =** Instantaneous (Tankless) **HP** = Heat Pump Water Heater **B** = Boiler **C** = Central plant, shared service **OT** = Other _________________	**S I HP B C OT**	**S I HP B C OT**
Fuel Type: **E** = Electricity **G** = Natural Gas **P** = Propane (LPG) **S** = Solar w/back-up **F** = Fuel Oil **N**=Not Heated	**E G P S F N**	**E G P S F N**
-- Solar Backup Type (if relevant): **E** = Electricity **G** = Natural Gas **P** = Propane (LPG) **OT**=Other _________	**E G P OT**	**E G P OT**
Service type: **D** = DHW only **S** = Space heating only **C** = Combined (provides both DHW and space heating)	**D S C**	**D S C**
If this is a Combo unit – What is the pump input? (Watts)		
Does the water heater serving this dwelling also serve others? Y=Yes N=No	**Y N**	**Y N**
Tank Capacity/Volume (Gallons)		
Rated Input Capacity		
-- Units for Rated Input Capacity: **B** = kBtuh **W** = kW	**B W**	**B W**
Pilot Input (Btu)		
Recovery Efficiency/AFUE(fraction)		
Standby Loss (fraction)		
What is the R-value of the external insulation jacket? *If no blanket – Enter 0*		
Are hot water heater pipes insulated? **Y**=Yes **N**=No	**Y N**	**Y N**
-- Is pipe insulation R-4 or greater? **Y**=Yes **N**=No	**Y N**	**Y N**
Is water heater less than 8' away from all DHW fixtures? **Y**=Yes **N**=No	**Y N**	**Y N**
Does the system utilize hot water reclaim/recovery? **Y**=Yes **N**=No	**Y N**	**Y N**
Hot water recirculation system present? **Y**=Yes **N**=No	**Y N**	**Y N**
-- Recirculation pump power (hp) *Enter **0** for no pump*	_____ hp	_______ hp
-- Recirc Pump Control type (circle all that apply): **C** = Continous **TP** = Temperature **TM** = Timer **D =** Demand **OT** = Other ________________	**C TP TM D OT**	**C TP TM D OT**
Heat trap present? Y=yes, N=no	**Y N**	**Y N**
Low-flow fixtures (showerheads, faucets, etc.)? **Y**=yes, **N**=no	**Y N**	**Y N**

DHW Piping

Diameter of Supply pipe at source (leaving boiler or tank)	**1"** **11/4"** **11/2"** **2"** **21/2"** Other? ______in
Supply Pipe insulated *at source*? (Y/N)	
Supply pipe insulated *at the far end* (Y/N)	
Diameter of Return pipe at end (near boiler or tank)	**1/2"** **3/4"** **1"** **11/2"** Other? ______in
Return Pipe insulated *at source*? (Y/N)	
Return pipe insulated *at the far end* (Y/N)	
Recirculation Pump power (hp) *Enter 0 for no pump*	
Pump Manufacturer/Model #	
Recirculation Pump Control Type: (select all that apply) **C** = Continuous, **T** = Temperature, **TM** = Timer, **D** = Demand, **O** = Other _____________	
Controls Manufacturer/ Model #	
Recirculation Loop as shown on Plans? (Y/N)	
If recirculation loop NOT as shown on plan, estimate total length of all recirculation piping (supply and return) in each of the following conditions:	
Underground	ft.
Unconditioned Space (e.g. attic, outdoors)	ft.
Conditioned Space (e.g. wall cavity, plenum between conditioned spaces)	ft.
Other (Describe)	ft.

Notes:

Comments and Observations

Page #	Item	Comments

High-Rise On-Site Verification Survey Instrument

File ID #

PG&E Statewide Multifamily High-Rise Residential On-Site Survey Form

H-M-G and ADM

Version: December 20, 2002

Contact Information:

Contact Name:			
Street Address:			
City:			
Zip Code:			
Phone Number:	**( )**		
County:		**CEC Climate Zone #:**	

Photo Information

Camera ID #		# of photos	

* Please take at least one photograph of each orientation of the building.

Survey Tracking Information:

	Date:	Initials
Field Verification Survey Executed:	__ / __ / __	__ __ __
Survey Received from Surveyor:	__ / __ / __	__ __ __
Survey Received at RER:	__ / __ / __	__ __ __
Data Entry Complete:	__ / __ / __	__ __ __

Builder/Development Information

Development/Complex Name:	
Month/Year the building was first occupied:	month ____ / year ______
Builder's Name:	

General Site Information

This verification form is applicable only to High-Rise Multifamily buildings—those with >3 floors. For buildings that have 3 or less floors, use the Low-Rise Residential survey form.

Building Characteristics

Site Activity Type	**AP** = Apartments, general **SR** = Senior apartments **CT** = Condos/townhomes **LI** = Low-income housing **OT** = Other (describe) ______________________	**AP SR CT** **LI OT**
Building footprint/shape	**R** = Rectangular **L** = L-shaped **T** = T-shaped **C** = Courtyard **H** = H-shaped **M** = Multiple footprints **O** = Other (describe) ___________	**R L T C** **H M O**
Is this building part of a larger complex?		**Y N**
Number of floors (occupied space only, i.e. excluding parking garage)		
Total conditioned floor area of the building?		ft^2
-- % of building that is not residential units (i.e. laundry facilities, rec. rooms, etc.)		%
Floor-to-floor height, ft		ft
Floor-to-ceiling height, ft		ft
Total number of residential units in this bldg?		

Complex Information

Total # of residential-unit *buildings* in the complex?	
Total number of *residential units* in the complex?	
Do all buildings in this complex have the same footprint/configuration? *(if only 1 building – N/A)*	**Y N N/A**
Laundry Rooms	
Does the complex have a central laundry?	**Y N**
If yes, approximately how many washers and dryers are there total?	
Is the laundry housed in a separate building?	**Y N**
Do individual apartments have washer/dryers installed?	**Y N**
If yes, approximately wht % of the units?	
If there is a washer/dryer in each unit, are these supplied by the apartment complex?	**Y N**
Lighting	
Do the exterior lights managed by the complex have motion sensors? If so, approximately what %?	%
Do the exterior lights managed by the complex have daylight timers? If so, approximately what %?	%
Were Compact Fluorescent light bulbs (CFLs) installed in the bathrooms of each unit?	**Y N**

Notes: ____

____

____

____

____

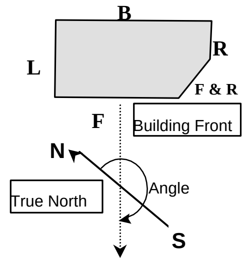
____

____

____

Building Orientation and Construction

Front Wall Orientation



Front orientation angle: (0-360°) ______________

NOTE: The "Front" of the building as indicated here must be aligned consistent with the "Front" as indicated on the PERF1 form.

External Walls and Doors

Wall orientation (reference: facing the Front wall)	Front	Left	Back	Right
Gross wall area, ft^2 (*inc. windows, doors, etc.)*				
Demising wall area (wall between cond. and uncond. space), ft^2				
Wall surface type: S=Stucco W=Wood siding V=Vinyl siding M=Metal siding B=Brick/Block OT=Other*				
Exterior wall construction type: WF24 = 2X4 Wood Framed, WF26 = 2X6 Wood Framed, MF24 = 2X4 Metal Framed, MF26 = 2X6 Metal Framed, WFOM = Wood Foam Panel, BLO = Concrete Block, BRI = Brick, OT = Other*				
Wall insulation R-Value (from insulation certificate if available)				
Number of wooden doors				
Number of insulated metal doors				
Number of uninsulated metal doors				
Door Shading: patio cover or recessed entry? **Y**es or **N**o	**Y N**	**Y N**	**Y N**	**Y N**

Roof Construction Type

Total Roof Area, ft^2		______________ ft^2
Roof Type	FAT=Framed w/Attic-Crawl Space MET=Metal Decking CON=Concrete Decking FNO=Framed w/o Attic-Crawl Space OT=Other ______________________________	
-- External Roof Surface	T=Tile (Clay, Concrete, etc.) C=Composition B=Built-up S= Shingle/Shake OT=Other*	
-- External Roof Color	W=White L=Light M=Medium D=Dark	
Radiant barrier?		**Y N**
Insulation R-value	Indicate R-value (use θ only if uninsulated)	
	Insulation type: **B** = Batt/Blanket **L** = Loose-fill **OT** = Other ___________	
	Indicate inches of insulation in roof cavity	

* Note "Other" construction types in comments block.

Floor Construction Type

Floor construction type	**S** =Slab **C** =Crawl **U** =Unheated Basement **G** =Garage **ADB** =Cond. space below
Raised floor insulation R-value	Indicate R-value (use θ only if uninsulated)

Window Specifications

Item # (use multiple sheets if necessary)	____#	____#	____#	____#
Window Size (Length/Width) *in Feet:*				
Window Frame Type: 1=metal, 2=wood, 3=vinyl, 4=fiberglass, 5=other ___________				
Layers of Glazing: 1=single, 2=double, 3=triple				
Glazing Type: 1=clear, 2=light tinted, 3=dark tinted, 4=reflective				
Low-E Coating (Y/N)/Surface No.	/	/	/	/
Manufacture Name:				
Model #:				
Window Spacer Type				
Window Spacer Width				

Item # (use multiple sheets if necessary)	____#	____#	____#	____#
Window Size (Length/Width) *in Feet:*				
Window Frame Type: 1=metal, 2=wood, 3=vinyl, 4=fiberglass, 5=other ___________				
Layers of Glazing: 1=single, 2=double, 3=triple				
Glazing Type: 1=clear, 2=light tinted, 3=dark tinted, 4=reflective				
Low-E Coating (Y/N)/Surface No.	/	/	/	/
Manufacture Name:				
Model #:				
Window Spacer Type				
Window Spacer Width				

Wall/Window Areas

Wall Orientation (reference: facing the Front Wall)		**Front**	**Left**	**Back**	**Right**
Wall Area (sq. ft.)					
Window #	Count				
Window #	Count				
Window #	Count				
Window #	Count				

Notes:

Packaged Systems *(Y / N)*

Item # (use multiple sheets if necessary)	____#	____#	____#
Cooling System Type:			
Make:			
Model:			
Quantity:			
SEER/EER:	/	/	/
Heating System Type:			
Quantity:			
Fuel Type: (1=electric, 2=gas)			
Heating Equipment Efficiency:			

	Packaged Cooling Systems		Heating System Types
HP	Heat Pump	FC	Furnace
PTAC	Packaged Terminal Air Conditioner	HP	Heat Pump
PSZ	Packaged Single Zone	EH	Electrical Heat
PVAV	Packaged Variable Air Volume	N/A	Not Applicable

Built-Up Air Distribution Systems *(Y / N)*

Item # (use multiple sheets if necessary)	____#	____#	____#
Air Distribution System Type:			
Quantity:			
Number of Apartments Serviced by Each Unit:			
Supply Fan HP:			
Supply Fan Efficiency:			
Supply Fan Make/Model #:	/	/	/
Return Fan HP:			
Return Fan Efficiency:			
Return Fan Make/Model #:	/	/	/

SZS	Single Zone System	TPFC	Two Pipe Fan Coil System
MZS	Multi Zone System	FPFC	Four Pipe Fan Coil System
DDS	Dual Duct System	WSHP	Hydronic Heat Pump System
CVS	Constant Volume Reheat Fan System	INDUC	Ceiling Induction Unit
VAV	Variable Air Volume System	FPHS	Floor Panel Heating System
CVAV	Ceiling Bypass VAV System	HVS	Heating and Ventilating System

Built-Up Air Distribution Systems *(Y / N)*

Are the ducts laid out as per plans?	**Y N**	
Duct Length: (measure distance between HVAC equipment and farthest register)		
	Supply	**Return**
Duct Location: (indicate all that apply) C=Conditioned Space, P=Plenum, W=Wall Cavity, U=Unconditioned, O=Other ______________		
Duct Type: (indicate all that apply) PF=Plastic Flexduct, MF=Metal Flexduct, M=Sheet Metal, P=Panned Joist, D=Ductboard, U=Unfinished Wall Cavity, O=Other ______________		
Duct Sealant Type: (indicate all that apply) M=Mastic, BT=Butyl Tape, MT=Metal Tape, CT=Cloth Tape, D=Duct Tape, C=Mech. Clamps, O=Other ______________		
Duct Insulation R-Value: (-7 if insulation if not labeled, 0 if not insulated)	**-7 0 4.2 6 8**	**-7 0 4.2 6 8**

Heating Equipment (Built-Up) *(Y / N)*

Item # (use multiple sheets if necessary)	____#	____#	____#
Heating Equipment Type:*			
Make:			
Model:			
Fuel Type:**			
Efficiency (%):			
Quantity:			
Output Capacity (kBtu/hr):			

***Heating equipment type:**
1=None, 2=Gas Furnace, 3=Electric Furnace, 4=Hot Water Boiler, 5=Steam Boiler
**** Heating fuel type:**
1=Electricity, 2=Gas, 3=Oil, 4=LPG, 5=Wood, 6=Solar, 7=Coal/Coke, 8=Purchased Steam, 9=Purchased Chilled Water, 10=Other ____________________

Cooling Equipment (Built-Up) *(Y / N)*

Item # (use multiple sheets if necessary)	____#	____#	____#
Cooling Equipment Type:*			
Make:			
Model:			
Fuel Type:**			
COP:			
Quantity:			
Output Capacity (tons):			

***Cooling equipment type:**
1=Centrifugal Chiller, 2=Recriprocating Chiller, 3=Screw Compressor, 4=Absorption Chiller, 5=Reciprocating DX Compressor, 6=Hydronic Heat Pump, 7=Other ____________________
**** Cooling fuel type:**
1=Electricity, 2=Gas, 3=Oil, 4=LPG, 5=Wood, 6=Solar, 7=Coal/Coke, 8=Purchased Steam, 9=Purchased Chilled Water, 10=Other ____________________

HVAC Circulation Pumps *(Y / N)*

Item # (use multiple sheets if necessary)	____#	____#	____#
Service Type: 1=Chilled, 2=Hot Water, 3=Chilled/Hot Water			
Motor Type: 1=Fixed Speed, 2=Variable Speed			
Pump Power (HP):			
Pump Efficiency:			
Pump Make/Model #	/	/	/
Quantity:			

Notes:

Cooling Towers (Built-Up) *(Y / N)*

Item # (use multiple sheets if necessary)	____#	____#	____#
Tower Capacity:			
Tower Efficiency:			
Fan Horsepower:			
Fan Efficiency:			
Fan Quantity:			
Pump Horsepower:			
Pump Efficiency:			
Pump Quantity:			

Air Cooled Condenser (Built-Up) *(Y / N)*

Item # (use multiple sheets if necessary)	____#	____#	____#
Type: 1=Air, 2=Evaporative, 3=Air with Pre-Cooler			
Fan Horsepower:			
Fan Quantity:			
Fan Efficiency:			

Water Heating Equipment *(Y / N)*

Item # (use multiple sheets if necessary)	____#	____#	____#
Fuel Type: 1=Electricity, 2=Gas, 3=Oil, 4=LPG, 5=Wood, 6=Solar, 7=Coal/Coke, 8=Purchased Steam, 9=Purchased Hot Water, 10=Other _____________			
Water Heating Equipment Type: 1=Space Heating Boiler, 2=Individual Water Heater Tank, 3=Instantaneous (tankless), 4=Purchased Steam Heat Exchanger, 5=Heat Pump Water Heater, 6=Boiler (water heating only)			
Water Heater Location: 1=Unconditioned Space, 2=Conditioned Space within Same Building, 3=Separate Building, 4=Exterior, 5=Other _______________			
Quantity:			
Capacity (kBtu/hr or kW) of EACH heater:			
Equipment Efficiency: (EF for <75 kBtu, Recovery Efficiency for >75 kBtu systems)			
Manufacturer:			
Model #:			
Service Type: 1=DHW only, 2=Combined Hydronics			
Storage Tank Capacity (gallons)			
Is the hot water tank insulated? Y/N			
Are hot water pipes from the heater to the tank insulated? Y/N			

Notes:

DHW Piping

Diameter of supply pipe at source (leaving boiler or tank):		**1” 1¼” 1½” 2” 2½” Other? ___ in.**
Supply pipe insulated *at source?* (Y/N)		
Supply pipe insulated *at the far end?* (Y/N)		
Diameter of return pipe at source (leaving boiler or tank):		**½” ¾” 1” 1½” Other? ___ in.**
Return pipe insulated *at source?* (Y/N)		
Return pipe insulated *at the far end?* (Y/N)		
Recirculation pump power (HP): *Enter 0 for no pump*		
Pump manufacturer/model #:		/
Recirculation pump control type: (select all that apply) C=Continuous, T=Temperature, TM=Timer, D=Demand O=Other _______________		
Controls manufacturer/model #:		/
Recirculation loop as shown on plans? (Y/N)		
If recirculation loop NOT as shown on plan, estimate total length of all recirculation piping (supply and return) in each of the following conditions:		
	Underground	ft.
	Unconditioned Space (e.g., attic, outdoors)	ft.
	Conditioned Space (e.g., wall cavity, plenum between conditioned spaces)	ft.
	Other (describe)	ft.

Notes:

Comments and Observations

Page #	Item	Comments

Appendix B

Detailed List of As-Built Differences

Site Name	Site ID	As Complied	As Built - 98	RER CZ	CEC CZ	Changed from…	Glazing %	Changed to…	Window Original	Changed to…	Overhangs	Roof Insulation	Heating Eff	Cooling Eff
Milpitas1	99043	8.9%	11.2%	1	4		11.2%	11.9%						
Escondido1	99071	4.6%	0.9%	3	10	7							Increased	
Chula Vista2	99072	15.4%	12.4%	2	7									
San Diego1	99073	10.9%	21.4%	2	7		14.4%	12.2%	VS	VD				
San Diego2	99077	9.2%	13.5%	2	7				MS	VD				
Oceanside	99078	18.8%	14.8%	2	7									
Chula Vista3	99079	41.8%	49.6%	2	7									
Irvine1	99081	1.1%	1.5%	3	8				MS	MS				
Irvine2	99082	2.5%	5.4%	3	8		14.8%	14.8%	MS	MD				
Irvine3	99083	4.1%	9.6%	3	8				MS	MD				
Newport Beach	99084	1.7%	9.2%	2	6	8								
Brea1	99086	0.4%	32.9%	3	8				MS	MD				
West Covina1	99092	7.4%	15.7%	3	9									
Temecula1	99101	10.4%	22.4%	3	10				MS	MD				
San Diego3	99103	5.7%	21.6%	3	10				MS	VD				
Riverside1	99104	4.0%	5.4%	3	10									
Rocklin1	99111	2.9%	8.6%	4	11		11.3%	10.9%	VD	VS	Add on doors			Increased
Rocklin2	99112	6.3%	2.5%	4	11		13.0%	11.6%	MD	MS	Deleted Most			
Rocklin3	99113	1.1%	0.0%	4	11		18.3%	16.9%				30 to 19		
Rosville1	99114	7.0%	10.1%	4	11		13.0%	12.9%	MD	VD				
Davis2	99120	-1.0%	8.8%	4	12		24.7%	14.8%	VD	VS				
Davis1	99121	4.4%	5.6%	4	12		12.2%	11.5%						
Fairfield1	99122	1.8%	3.8%	4	12									
Lafayette1	99123	8.7%	3.2%	4	12		14.4%	11.9%						
Vacaville1	99124	5.2%	-0.1%	4	12		10.3%	9.7%						
Sacramento2	99126	3.5%	0.8%	4	12		11.2%	12.4%						
Folsom1	99127	2.2%	4.7%	4	12		10.0%	8.8%			Increased			
Davis3	99128	1.2%	-0.4%	4	12		15.7%	15.4%	VD	VD				
Sacramento3	99129	3.1%	-8.7%	4	12		11.7%	15.8%						
Lancaster1	99141	10.5%	16.7%	5	14				VS	MD				
Palmdale1	99142	6.6%	3.7%	5	14	11	16.3%	15.7%						

Site Name	Site ID	WH Eff	Changed to…	WH Jacket	Changed to…	WH Distribution Type	Changed to…	WH Tank Size	Changed to…	Other
Milpitas1	99043	0.57	0.6	R-12	R- 0					Has Second WH Energy Factor from .52 to .56
Escondido1	99071			R-12	R-0					Floor R-val from 13 to 19, Hvac to HP
Chula Vista2	99072							50	40	
San Diego1	99073			R-N/A	R-16					HVAC Duct Loc from Attic to Conditioned Space
San Diego2	99077									
Oceanside	99078			R-N/A	R-12					
Chula Vista3	99079							200	115	
Irvine1	99081									WH Rated Input from 50,000 to 40,000
Irvine2	99082							50	40	Ceiling Height from 9 to 8
Irvine3	99083			R-N/A	R-19.2					Ceiling Height from 9 to 8, WH Rated Input from 50k to 40k
Newport Beach	99084									
Brea1	99086					Recirc/Nocontrol	Recirc/Temp			HVAC from Attic to Conditioned Space
West Covina1	99092									WH Energy Recovery Factor from .76 to .746
Temecula1	99101									
San Diego3	99103									
Riverside1	99104									
Rocklin1	99111	0.53	0.6			Standard	PipeInsul			Hvac Duct Loc from conditioned space to Attic
Rocklin2	99112					Standard	PipeInsul			Floor Area 5424 to 6560
Rocklin3	99113			R-12	R-16					
Rosville1	99114									
Davis2	99120	0.62	0.53					40	50	Ceiling Height from 9 to 9'10, windows clear to lowE
Davis1	99121									
Fairfield1	99122	0.62	0.59							Rated input 36,000 to 40,000
Lafayette1	99123									Ceiling Height from 8 to 9
Vacaville1	99124	0.62	0.56							Ceiling Height from 9 to 8'9"
Sacramento2	99126					Standard	Recirc/Temp			
Folsom1	99127									WH Energy Recovery Factor from .76 to .752
Davis3	99128	0.62	0.59							WH Rated Input from 36,000 to 40,000
Sacramento3	99129									Ceiling Height from 9 to 8'10
Lancaster1	99141									
Palmdale1	99142									Hvac changed to Furnace

Appendix C

Sample Design

C.1 Overview

The major objective of the Statewide Multifamily New Construction Energy Efficient Baseline Study of New Buildings is to identify opportunities for increased energy efficiency in multifamily residential buildings. To identify these opportunities, RER will conduct a survey of multifamily buildings. In the next sections, we will discuss the nuances of identifying the appropriate sample of buildings. RER will use a number of sources to determine exactly which buildings should be sampled. These sources include building industry data as well as information collected from building departments in different California localities. The key point to note is that designing the sample involves a process of balancing available data with the data obtained from building departments willing (and able) to share their records.

C.2 Sampling Unit

The aim of the project is to identify the opportunities for increased energy efficiency in the following types of multifamily residential buildings:

- Multifamily up to three stories (low-rise), and
- Multifamily more than three stories (high-rise).

Multifamily buildings are buildings with contain units that share at least a common floor or a common ceiling.[1] In addition, these units may have common walls.

RER will calculate compliance with Title 24 building standards and energy savings from the implementation of energy efficient measures on a building-by-building basis, not on individual units within a building.[2] Therefore, for this study, the sampling unit is the building. Data collection is further complicated because most construction industry records (such as records on issuance of permits) are available on a unit basis, not a building basis.

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[1] Multifamily definitions are consistent with MICROPAS compliance standard definitions.

[2] Please note that compliance is typically analyzed on a per building basis, though it can be calculated on a per-unit basis also.

C.3 Data Sources

In this section, we will discuss the sources of data for determining the sample frame and the sample population. We discuss the types of data that are required, the sources for this information, and the limitations of the data. We emphasize that no one source provides all the information that is required for sample selection and sample frame. However, robust estimates can be developed by using a number of sources in combination.

Data Required for Construction of Sample Frame

It is necessary to obtain the number of single family attached buildings, low-rise multifamily and high-rise multifamily buildings that were constructed and occupied in 2001 in California. This data will enable us to weight the on-site survey results for the state of California.

Data Required for Sample Selection

In order to determine which buildings should be surveyed, the following pieces of information are necessary.

- Building address for identification purposes.
- Number of stories in the building. This data is useful in determining whether the building is a low or high-rise building.
- The year built or year effective. While the year built is a record of when the building was built, year effective is likely to be closer to the date that residents moved into the building (i.e., it takes into account changes made to the building before occupancy).

Data Sources Considered

RER has conducted an exhaustive review of possible sources of data, and may use the following data sources for sample selection and/or sample frame determination.

- ***Construction Industry Research Board (CIRB) Data for California.*** The CIRB compiles building permit data (on a unit basis) by county by year. CIRB 2001 data would include information on the number of permits for residential units (not buildings) issued by county in the year 2001. There are three constraints to using these data.
  - First, the data do not clearly identify all units “constructed and occupied” in 2001, only units for which permits were issued. According to sources at the CIRB, there is an approximate lag of three months between issuance of a permit and completion of a unit. RER would need to develop a methodology for dealing with this lag.

- Second, CIRB data are categorized only into single or multifamily residences. Multifamily residences are defined as "duplexes, three to four unit structures, apartment-type structures with five units or more, and units in structures of more than one unit that do not meet CIRB definitions of single family housing." While this definition is similar to RER's definition of multifamily residences, it does not differentiate between low-rise and high-rise buildings.
- Lastly, the CIRB data have limited information on the address of the unit constructed. Since no address information is available, RER cannot directly identify buildings that should be sampled. (Again, RER believes CIRB data are for number of residential units, not buildings.)

While these major constraints do exist, CIRB data are still useful because they provide a big picture of counties and their construction trends in 2001. These data are invaluable in determining counties that should be sampled further.

- ***Parcel Quest Data from CD-Data.*** CD-Data collects tax assessor data from all California counties and sells these data in a package called Parcel Quest. Data from the county tax assessor are input to the Parcel Quest database between two weeks and four months after the tax assessment has been made. There are three constraints to using these data.
  - Since the tax assessor data are independently collected by the counties, different counties provide different data fields. Therefore, some counties' data are more complete. Only about 16 of the 58 California counties have data complete enough to use in calculating population frame.
  - Parcel Quest does not provide data on Imperial, Kern, King, Napa, Riverside, Santa Clara, Siskiyou, Tulare, and Ventura counties.

  Parcel Quest data are available for purchase for $175 per county (if data are purchased for four counties or more). The exception to this is Los Angeles County, which is separated into three regions. Data cost $175 for each region. Data are provided on a CD-ROM that can be read by Parcel Quest proprietary software (included in the price of the CD), which allows for customized searches and customized formatting of results. Parcel Quest software can also export data to other computer programs.

- ***Data from the Meyers Group.*** The Meyers Group collects data for 25 counties in California and only tracks California condominiums. In addition, the Meyers Group data do not include information on the number of floors in a building.
- ***Data from Realfacts.com.*** Realfacts.com collects data on investment grade (grade A and grade B) rental complexes that are not subsidized and are not senior citizen housing units. Since data are collected only for rental properties with more than 50 units in Northern California and more than 100 units in the rest of California, it will not be useful in determining the population frame.
- ***Data from Research Conducted by ADM.*** ADM has conducted research on "friendly" building departments (i.e., building departments that are more reliable in providing information). These building departments are not located by county but

by place within a county. Unfortunately, these areas may not necessarily have had multifamily construction. For example, Carlsbad, Poway, and Vista are friendly localities within San Diego County, but downtown San Diego likely had the most multifamily building construction activity. Downtown San Diego is not considered a friendly locality.

- ***Utility Billing Frame Data for the Residential Market Share Tracking (RMST) Project.*** Utility data were collected as part of the RMST project. These data include building type (single family detached or multifamily), address (including apartment number), and initial read date. While these data do not explicitly identify individual residential units as multifamily low-rise and multifamily high-rise, the address field can be used to group observations into low-rise or high-rise buildings.
- ***Data from the Census Bureau.*** The Manufacturing and Construction Division of the Census Bureau provides estimates on the number of multifamily residential buildings built each year for four U.S. regions (Northeast, Midwest, South, and West). These estimates include information on number of units per building and number of stories per building. Unfortunately, these estimates are based on a national sample and California-specific data are not available. Further discussions with the Census Bureau have revealed that California-only data can be formally requested from the Chief of the Manufacturing and Construction Division at the Census Bureau. This formal request may result in their providing California-only data or it may result in a decline of the request. Unfortunately, this process is likely to be time consuming.
- ***Other Data from the Utilities.*** Other data records from the California utilities may prove to be useful in determining low-rise and high-rise multifamily buildings built in California in 2001. For example, utility data can be used to identify master metered residential buildings and the number of floors that these buildings have.

C.4 Sample Frame

Determining the sample frame includes first identifying the total number of multifamily buildings constructed in 2001. Ideally, the sample frame would be used for sample selection. Unfortunately, extensive research to date has not found any one source of information that would allow RER to calculate the total number of multifamily buildings and then break that number out by building type and climate zone.

The one suggested solution to this problem is to use data from the utility billing frame database in the following way.

- Clarify the difference between the two multifamily indicators used by SoCalGas and PG&E and better understand the definition of multifamily as used by SDG&E and SCE.

- Calculate the number of apartment units (meters) per building using the address field. This can be done easily using SAS.
- Flag buildings higher than 20 meters per building. (The number meters per building used will be agreed upon by the project team.)
- Flag residential buildings that are master metered. These buildings are likely to be multifamily residential buildings.
- Manually look up this flagged list. Apartment numbers can be used as a proxy for determining the number of stories in a building.
- Review small commercial accounts from each utility to identify possible master metered accounts.

Each of the four IOUs in California should have these data available by the end of February 2002 for homes that first took service between July 2000 and December 2001.

While these data may become available in February 2001, using the utility billing frame database is not ideal. It requires more time to analyze the data in order to extract the necessary information. In addition, using this methodology to obtain the sample frame still involves using an algorithm and, therefore, final estimates may not be precise.

Sample Frame Stratification

After the sample frame has been determined, it must be stratified in two ways: first, by type of building (i.e., single family attached buildings, low-rise multifamily buildings and high-rise multifamily buildings), and second, since energy efficiency savings vary by climate, the sample frame must be stratified by climate zone. RER has developed climate zone groupings as shown below.

- RMST Climate Zone 1 encompasses CEC Climate Zones 1, 2, 3, 4 and 5.
- RMST Climate Zone 2 encompasses CEC Climate Zones 6 and 7.
- RMST Climate Zone 3 encompasses CEC Climate Zones 8, 9 and 10.
- RMST Climate Zone 4 encompasses CEC Climate Zones 11, 12 and 13.
- RMST Climate Zone 5 encompasses CEC Climate Zones 14, 15 and 16.

C.5 Sample Allocation

The project scope is to conduct 50 on-site surveys at low-rise multifamily residential buildings and 50 on-site surveys at high-rise multifamily residential buildings. Since energy efficiency is a function of climate, this sample of surveys should be representative of the distribution of low-rise and high-rise buildings by climate zone.

In ideal circumstances, the sample frame of multifamily residential buildings would be used to determine the allocation of buildings by climate zone. Unfortunately, data on the sample frame and its stratification are not readily available. However, the RMST sample frame for multifamily buildings can be used as a proxy for the sample frame and, as such, provides a basis for allocating the required sample across climate zones. The following two sections discuss how this database could be use to allocate the 50 low-rise and 50 high-rise multifamly sites across climate zones.

Low Rise Multifamily Building Sample Allocation

Using data obtained from the RMST multifamily frame, RER calculated the distribution of all multifamily units (not buildings) by climate zone. RER used this distribution to calculate the distribution of on-site surveys for low-rise multifamily residential buildings as shown in Table C-1.

Table C-1: Distribution of Low Rise Buildings

Climate Zone	Utility Frame Distribution[1]	Suggested Distribution for On-Site Surveys
RMST Climate Zone 1	35.2%	34% n = 17
RMST Climate Zone 2	19.7%	20% n = 10
RMST Climate Zone 3	16.8%	16% n = 8
RMST Climate Zone 4	26.6%	26% n = 13
RMST Climate Zone 5	1.7%	4% n = 2

[1] Based on data from third and fourth quarters of 1999 and first and second quarters of 2000.

High Rise Multifamily Building Sample Allocation

Using data obtained from the RMST Year 1 and Year 2 on-site surveys, RER calculated the distribution of high-rise multifamily units (not buildings) by climate zone. RER then calculated the distribution of on-site surveys of high-rise multifamily residential buildings as shown in Table C-2. Note that this suggests that little or no high-rise buildings were built in Climate Zones 4 and 5.

Table C-2: Distribution of High Rise Buildings

Climate Zone	RMST Year 1 Distribution	RMST Year 2 Distribution	Average RMST Distribution	Suggested Distribution for On-Site Surveys
RMST Climate Zone 1	30.0%	13.6%	21.8%	22% n = 11
RMST Climate Zone 2	50.0%	59.1%	54.5%	56% n = 28
RMST Climate Zone 3	16.7%	27.3%	22.0%	22% n = 11
RMST Climate Zone 4	3.3%	0.0%	1.7%	0% n = 0
RMST Climate Zone 5	0.0%	0.0%	0.0%	0% n = 0

[1] Based on data from third and fourth quarters of 1999 and first and second quarters of 2000

C.6 Sample Selection

Ideally, the sample would be selected at random from a database of eligible buildings. Since no such database exists, RER developed a more practical approach for sample selection.

Given that no one source of data can be used to obtain all these pieces of information for all California counties, RER used a combination of data sources and the following methodology.

Step 1: Map CEC Climate Zones to RMST Climate Zones to California Counties. RER will accomplish this by using the CEC ZIP code to climate zone and ZIP code to county mapping database.

Step 2: Quantify Multifamily Building Activity for all Counties and Building Departments. In this step, the CIRB data are used to determine the construction activity (number of building permits issues in 2001) of multifamily buildings by county and building department. Note that these are building permits and not number of completed multifamily buildings.

Step 3: Identify Counties with the Most Building Activity by RMST Climate Zone. RER will identify counties with substantial building activity within each of the five RMST climate zone groupings. Building departments within these counties will be targeted to meet the completed sample targets using the following approach.

- ***For counties where sufficient Parcel Quest data are available (address, number of stories).*** Three counties are the prime targets insofar as the Parcel Quest data will allow us to have identified low- and high-rise multifamily buildings with addresses prior to visiting the building departments. Table C-3 presents a summary of the building departments that are likely to be visited in order to complete the sample targets. Note that the building departments under the Parcel Quest column heading are provided only as a guide. The actual building departments visited will depend on the results of the analysis of the Parcel Quest data. That is, the Parcel Quest data will provide specific addresses for high-rise multifamily buildings built in 2001. The following counties are included in this category.

- Alameda
- San Francisco
- San Mateo
- San Bernardino
- Sacramento
- El Dorado

Note also that some counties overlap climate zones. However, it is unlikely that building departments within the counties overlap climate zones. Further, for some cases, such as San Francisco, there is an added bonus in that ADM has identified the particular building department as cooperative.

- ***Counties where insufficient Parcel Quest data are available, but have ADM-friendly building departments.*** There are instances where data are required from counties, but no Parcel Quest data are available to help identify sites prior to visiting the building department. In these cases, RER has identified building departments with relatively high building activity that ADM has identified as cooperative. ADM will target these sites in these counties. Note that Parcel Quest might be able to provide data on addresses, which will aid in the search at the building department. The following counties are included in this category.
  - Santa Clara
  - Orange
  - Los Angeles
- ***Counties where no Parcel Quest Data is available and no ADM-friendly building departments exist.*** There are cases where there are counties with relatively high building activity, but no Parcel Quest data or ADM-friendly building departments exist. In these case, particular building departments are identified that will be visited. Again, some Parcel Quest data might be available to assist in the search at the building department. The following counties are included in this category.
  - Santa Clara
  - Orange
  - Los Angeles
  - San Diego

Table C-3 summarizes the sampling approach described above. Included in Table C-3 are low-rise and high-rise targets by climate zone. The targets for each climate zone are further broken out proportionally to the building activity in number of units for each of the targeted counties.

Table C-3: Building Departments to be Sampled by County and RMST Climate Zone

Low Rise[1]	High Rise[1]	County	Parcel Quest	ADM Friendly	Other (i.e., High construction)	Have site addresses?
RMST Climate Zone 1						
3	2	Alameda[3]	Oakland (2,1) Fremont (1,0) Berkeley (-,-)	Hayward (-,-)		✓ ✓ ADM
4	3	San Francisco	San Francisco (4,3)	San Francisco (4,3)		✓
1	1	San Mateo[4]	Foster City (-,-) Belmont (0,0) San Mateo (1,0)			ADM ✓ ✓
9	5	Santa Clara[5]		Mountain View (-,-)	San Jose (8,3) Santa Clara (1,0)	✓ ✓ ADM
17	**11**	**TOTAL FOR RMST CLIMATE ZONE 1**				
RMST Climate Zone 2						
2	5	Orange		Uninc. Orange (1,2) Newport Beach (0,1)	San Clemente (1,1)	ADM ADM
3	9	San Diego			San Diego (2,6) Chula Vista (1,2)	RER RER
5	14	Los Angeles		Uninc. Los Angeles (2,1)	Los Angeles (2,10) Long Beach (1,2)	ADM ADM
10	**28**	**TOTAL FOR RMST CLIMATE ZONE 2**				
RMST Climate Zone 3						
1	2	San Bernardino	Rancho Cucamonga (1,2)			RER
2	2	Orange		Uninc. Orange (1,1) Irvine (0,1)	Fullerton (1,0)	ADM ADM
5	7	Los Angeles		Uninc. Los Angeles (2,3)	Pasadena (1,2) Santa Clarita (1,2) Burbank (1,2)	ADM ADM ADM
8	**11**	**TOTAL FOR RMST CLIMATE ZONE 3**				
RMST Climate Zone 4						
3	0	El Dorado[2]	El Dorado (3,0)			✓
3	0	Placer			Rocklin (3,0)	✓
4	0	Solano[7]	Vacaville (2,0) Fairfield (2,0)			ADM ✓
3	0	Alameda[6]	Dublin (2,0) Pleasanton (-,-)			✓ ADM
13	**0**	**TOTAL FOR RMST CLIMATE ZONE 4**				
RMST Climate Zone 5						
2	0	El Dorado[2]	Uninc. El Dorado (2,0)			ADM
2	**0**	**TOTAL FOR RMST CLIMATE ZONE 5**				

1 Distributions of low rise and high rise buildings per climate zone are derived using Table C-1 and Table C-2. However, distributions within climate zones (i.e., by county) are based on multifamily unit data from CIRB.

2 Four low rises in El Dorado County were identified. Five more are needed. RER assumes ADM will locate one additional low rise during on-site surveys. This should be from unincorporated El Dorado.

3 One high rise in Alameda County was identified. Two are needed. RER assumes ADM will locate one additional high rise during on-site surveys. This can come from Oakland, Fremont, Berkeley, or Hayward.

4 We have not been able to identify one high rise in San Mateo County. RER assumes ADM will locate one high rise during on-site surveys. This can come from Foster City, Belmont, or San Mateo.

5 We have identified only three high rises in Santa Clara County. RER assumes ADM will locate one additional high rise during on-site surveys. This can come from San Jose, Santa Clara, or Mountain View.

6 We have only identified two low rises in Alameda County. RER assumes ADM will locate one additional low rise during on-site surveys. This can come from Dublin or Pleasanton

7 We have only identified one low rise in Solano County. Four are needed. RER assumes ADM will locate three additional low rises during on-site surveys. These can come from Vacaville or Fairfield.

It is important to note that the counties suggested in Table C-3 represent 76% of the total multifamily unit permits issued in 2001 (using data from CIRB). There were 41,433 permits issued for multifamily units in 2001, and 31,856 were located in one of the 11 counties mentioned above.

C.7 Sample Design Issues

In designing the sample as described above, RER identified a number of issues.

- There is no single source of data. Therefore, the team must compile information from a number of sources to create a sample representative of the population.
- Since RER has been unable to determine the sample frame (population), expansion weights cannot be calculated and the technical potential savings will not be weighted up to the population. Instead, technical potential savings will be presented as an average per square foot.
- RER will survey the counties and building departments listed in Table C-3 only if Title 24 records are available from these building departments. The project team decided earlier to conduct on-site surveys only at buildings for which Title 24 records are available. ADM will ascertain availability of Title 24 records prior to visiting buildings.

C.8 Preliminary Lists of Sample Sites

The following tables contain preliminary lists of sample sites by county. Please not that in cases were there is more than one buildnig in the project/complex, only one building will be included in the analysis.

Table C-4: Alameda

CEC Zone	RMST Climate Zone	Source	Type	Builder	Project Name	Project Address	Project City	Project County	Project State	Project Zip	Number Units	Number stories
3	1	MF stats -- Mary Kay	Unknown	Master Builders	Smith S C & Sippey Michael B	897 Colusa	Berkeley	Alameda	CA	94707	4	?
3	1	MF stats -- Mary Kay	Unknown	unknown	Creekside Plaza LLC	2161 Allston	Berkeley	Alameda	CA	94704	60	?
3	1	MF stats -- Mary Kay	Unknown	unknown	Civic Center Driver APTS. LP. Building 3	39370 Civic Center Drive	Fremont	Alameda	CA	94538	102	?
3	1	MF stats -- Mary Kay	Townhouse	Olson-Hayward, LLC	740 City Walk Place	740 City Walk Place	Hayward	Alameda	CA	94541	4	?
3	1	MF stats -- Mary Kay	Townhouse			752 City Walk Pl.					5	?
3	1	MF stats -- Mary Kay	Condominium	Signature Properties	Durant Square	10970 International Blvd.	Oakland	Alameda	CA	94603-3865	16	?
3	1	MF stats -- Mary Kay	Townhouse	Signature Properties	Durant Square	10970 International Blvd.	Oakland	Alameda	CA	94603-3865	32	?
3	1	MF stats -- Mary Kay	Unknown	unknown	California College of Arts and Crafts	5276 Broadway	Oakland	Alameda	CA	94618	67	?
3	1	Parcel Quest	Low Rise	unknown	unknown	1155 San Pablo	Berkeley	Alameda	CA	94706	16	low
3	1	Parcel Quest	Low Rise	unknown	unknown	35477 Monterra Cr	Union City	Alameda	CA	94587-8076	84	low
3	1	Parcel Quest	Low Rise	unknown	unknown	Dyer Street (mailing address is 4174 glenwood tr, #3, union city, ca 94587-3939)	Union City	Alameda	CA	94587	39	low
3	1	Parcel Quest	Low Rise	unknown	unknown	Avila Terraza 6S (mailing address is 1017 avila terraza)	Fremont	Alameda	CA	94536	40	low
3	1	MF stats -- Mary Kay	Low Rise	unknown	John F & C Kathain, owners	1573 165th Ave.	San Leandro	Alameda	CA	94578-3115	4	low
3	1	MF stats -- Mary Kay	High Rise	COD Builders	Dreyer's Site Residential Lofts	311 Oak Street	Oakland	Alameda	CA	94607	220	high
12	4	Parcel Quest	Low Rise	unknown	unknown	7600 Southfront Road, # 3	Livermore	Alameda	CA	94550	67	low
12	4	MF stats -- Mary Kay	Low Rise	Toll Bros.	4718-4730 Sandyford Ct.	4718-4730 Sandyford Ct.	Dublin	Alameda	CA		7	low
12	4	MF stats -- Mary Kay	High Rise	Wermers	Shea Properties	4700 Tassajara Rd.# 3	Dublin	Alameda	CA	94588	117	high
12	4	MF stats -- Mary Kay	High Rise	"	"	4850 Tassajara Rd. #2					44	high
12	4	MF stats -- Mary Kay	High Rise	"	"	4600 Tassajara Rd #4					35	high
12	4	MF stats -- Mary Kay	High Rise	"	"	4900 Tassajara Rd. #1					44	high
12	4	MF stats -- Mary Kay	Low Rise	"	"	4750 Tassajara Rd					105	low

Table C-5: El Dorado

CEC Zone	RER Zone	Source	Type	Builder	Project Name	Project Address	Project City	Project County	Project State	Project Zip	Number Units	Number stories
16	5	ParcelQuest	Low Rise	unknown	unknown	7505 Grizzly Flat	Somerset	El Dorado	CA	?	2	low
12	4	ParcelQuest	Low Rise	unknown	unknown	2291 Loch Way	El Dorado Hills	El Dorado	CA	95762	2	low
12	4	ParcelQuest	Low Rise	unknown	unknown	5180 Stampede Lange	Shingle Springs	El Dorado	CA	95682	2	low
12	4	ParcelQuest	Low Rise	unknown	unknown	4373 Barnett Ranch	?	El Dorado	CA	?	2	low

Table C-6: Placer

CEC Zone	RER Zone	Source	Type	Builder	Project Name	Project Address	Project City	Project County	Project State	Project Zip	Number Units
11	4	MF stats -- Mary Kay	Condominium	Horton, D.R., INC.	1001 Boardwalk Way	1001 to 1039 Boardwalk Way	Rocklin	Placer	CA		3 each
11	4	MF stats -- Mary Kay	Condominium	Horton, D.R., INC.	Park Place Condominiums	1200 to 1207 Reading Way	Rocklin	Placer	CA		3 each
11	4	MF stats -- Mary Kay	Condominium	Horton, D.R., INC.	Park Place Condominiums	1301 to 1307 St Charles Way	Rocklin	Placer	CA		3 each
11	4	MF stats -- Mary Kay	Unknown	Horton, D.R., INC.	901 Marvin Gardens WY	901 to 931 Marvin Gardens WY	Rocklin	Placer	CA		3 each
12	4	MF stats -- Mary Kay	Unknown	unknown	Terraces @ Highland Reserve Apartments	700 Gibson Dr.	Roseville	Placer	CA	95678	273
11	4	MF stats -- Mary Kay	Low Rise	Stamas Corporation	101 to 1601 Sammy Way, Building 1-16	101 to 1601 Sammy Way, Buildir	Rocklin	Placer	CA	95677	8 each

Table C-7: San Francisco

CEC Zone	RER Zone	Source	Type	Builder	Project Name	Project Address	Project City	Project County	Project State	Project Zip	Number Units	Number stories
3	1	MF stats -- Mary Kay	Unknown	unknown	unknown	unknown	San Francisco	San Francisco	CA		6	?
3	1	MF stats -- Mary Kay	Condomini	unknown	Rowland Associates	Rowland St.	San Francisco	San Francisco	CA		3	?
3	1	MF stats -- Mary Kay	Unknown	unknown	17th/Valencia Assoc LLC	601 Valencia St	San Francisco	San Francisco	CA	94110	24	?
3	1	MF stats -- Mary Kay	Unknown	unknown	SF Housing DEV Corporation	4445 33rd Street	San Francisco	San Francisco	CA	94116	30	?
3	1	MF stats -- Mary Kay	Condomini	unknown	Benjamin LIU, owner	437 19th Avenue	San Francisco	San Francisco	CA	94121	3	?
3	1	MF stats -- Mary Kay	Unknown	unknown	300 Linden St. LLC	401 Hayes St.	San Francisco	San Francisco	CA	94102	14	?
3	1	MF stats -- Mary Kay	Unknown	unknown	Albert K.C. Wang	3129 Geary BL	San Francisco	San Francisco	CA		3	?
3	1	MF stats -- Mary Kay	Condomini	unknown	Will P.K NG	1500 Taylor St.	San Francisco	San Francisco	CA	94133	3	?
3	1	MF stats -- Mary Kay	Low Rise	unknown	QU MON YEE	unknown	San Francisco	San Francisco	CA		3	low
3	1	MF stats -- Mary Kay	Low Rise	unknown	Eileen Long	807 Shotwell St.	San Francisco	San Francisco	CA	94110	3	low
3	1	MF stats -- Mary Kay	Low Rise	unknown	Robert Miller	691 Tennessee St.	San Francisco	San Francisco	CA		25	low
3	1	MF stats -- Mary Kay	Low Rise	unknown	Raul Arriza, owner	600 Portola Dr.	San Francisco	San Francisco	CA	94127	15	low
3	1	MF stats -- Mary Kay	Low Rise	unknown	Caledonia Partners	363 Valencia St	San Francisco	San Francisco	CA	94103	8	low
3	1	MF stats -- Mary Kay	Low Rise	unknown	Esquivel Santana	2902 22nd Street	San Francisco	San Francisco	CA		14	low
3	1	Parcel Quest	Low Rise	unknown	unknown	229 Brannan, 3H	San Francisco	San Francisco	CA	94107	2	low
3	1	Parcel Quest	Low Rise	unknown	unknown	1960 to 1970 Sutter, 5-15	San Francisco	San Francisco	CA	94105	2 each	low
3	1	Parcel Quest	Low Rise	unknown	unknown	1960 Sutter, 6	San Francisco	San Francisco	CA	94105	4	low
3	1	Parcel Quest	Low Rise	unknown	unknown	1800 washington Street, #315	San Francisco	San Francisco	CA	94109	3	low
3	1	Parcel Quest	Low Rise	unknown	unknown	1670 Kirkwood	San Francisco	San Francisco	CA	94132	9	low
3	1	MF stats -- Mary Kay	Low Rise	unknown	T. Egan, owner	1047 Mississippi St.	San Francisco	San Francisco	CA	94107	9	low
3	1	MF stats -- Mary Kay	High Rise	unknown	Signe M. Perine	880 Corbett Ave.	San Francisco	San Francisco	CA		4	high
3	1	MF stats -- Mary Kay	High Rise	unknown	85 Sycamore st	85 Sycamore St.	San Francisco	San Francisco	CA	94110	3	high
3	1	MF stats -- Mary Kay	High Rise	unknown	801 Greenwich St	801 Greenwich St.	San Francisco	San Francisco	CA	94133	8	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Walter & Tina Jordan, owners	772 South Van Ness Ave.	San Francisco	San Francisco	CA	94110	4	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Raymond Chan, owner	741 Ellis St.	San Francisco	San Francisco	CA	94109	9	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Angues MacCarthy	707 Guerrero St.	San Francisco	San Francisco	CA	94110	3	high
3	1	MF stats -- Mary Kay	High Rise	unknown	George Lak, owner	6900 Geary Bl	San Francisco	San Francisco	CA	94121	17	high
3	1	MF stats -- Mary Kay	High Rise	unknown	175 Russ St. Assoc. LLC	68 Harriet St	San Francisco	San Francisco	CA		16	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Tennessee St. Lofts	601 Mariposa St	San Francisco	San Francisco	CA	94107	18	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Mulling, owner	5951 California St.	San Francisco	San Francisco	CA	94121	3	high
3	1	MF stats -- Mary Kay	High Rise	unknown	New Golden Stat Plumbing CO	4809 Mission St.	San Francisco	San Francisco	CA	94112	3	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Armax, INC.	445 Bryant St.	San Francisco	San Francisco	CA	94107	10	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Wing Chan, owner	4228 California St.	San Francisco	San Francisco	CA	94118	3	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Fred Willmann	380 10th Street	San Francisco	San Francisco	CA	94103	30	high
3	1	MF stats -- Mary Kay	High Rise	unknown	One Ball LLC	348 Hyde St.	San Francisco	San Francisco	CA	94109	12	high
3	1	MF stats -- Mary Kay	High Rise	unknown	3037 22nd Street	3037 22nd Street	San Francisco	San Francisco	CA	94110	3	high
3	1	MF stats -- Mary Kay	High Rise	unknown	The Bennan Living Trust	2738 Haight St.	San Francisco	San Francisco	CA	94102	30	high
3	1	MF stats -- Mary Kay	High Rise	unknown	2122 V Taraval St.	2122 V Taraval St.	San Francisco	San Francisco	CA	94116	3	high
3	1	MF stats -- Mary Kay	High Rise	"	"	2051 Harrison St.	San Francisco	San Francisco	CA	94110	20	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Harrison Development LLC	2001 and 2095 Harrison St	San Francisco	San Francisco	CA	94110	22 each	high
3	1	MF stats -- Mary Kay	High Rise	unknown	175 Russ St. Assoc. LLC	173 Russ St.	San Francisco	San Francisco	CA		16	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Philip and Mary Tom, owner	1276 18th Ave.	San Francisco	San Francisco	CA	94122	3	high
3	1	MF stats -- Mary Kay	High Rise	unknown	1217 Ocean Ave.	1217 Ocean Ave.	San Francisco	San Francisco	CA	94112	9	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Mol Casbar, owner	119 Lyon St.	San Francisco	San Francisco	CA	94117	3	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Raul Arrzaza	1078 Potrero Ave.	San Francisco	San Francisco	CA	94110	3	high
3	1	MF stats -- Mary Kay	High Rise	unknown	1050 Mississippi St.	1050 Mississippi St.	San Francisco	San Francisco	CA	94107	3	high
3	1	MF stats -- Mary Kay	High Rise	unknown	Mark Nelson Development	1001 Bine St.	San Francisco	San Francisco	CA	94118	4	high

Table C-8: San Mateo

CEC Zone	RER Zone	Source	Type	Builder	Project Name	Project Address	Project City	Project County	Project State	Project Zip	Number Units	Number stories
3	1	MF stats -- Mary Kay	Unknown	BPD Construction	Norfolk Properties LLC	511 Bayshore Blvd.	San Mateo	San Mateo	CA	94401	4	?
3	1	MF stats -- Mary Kay	Unknown	Newgen Builders, INC	Chamberlain Group	540 El Camino Real	San Mateo	San Mateo	CA	94402	21	?

Table C-9: Santa Clara

CEC Zone	RER Zone	Source	Type	Builder	Project Name	Project Address	Project City	Project County	Project State	Project Zip	Number Units	Number stories
4	1	MF stats -- Mary Kay	Unknown	unknown	Gary & Jean Walton	7500 TO 7520 Eigleberry St.	Gilroy	Santa Clara	CA	95020	5 each	?
3	1	MF stats -- Mary Kay	Unknown	unknown	Joe & Victoria Rocha-Owner	550 E Eighth St.	Gilroy	Santa Clara	CA	95020	4	?
4	1	MF stats -- Mary Kay	Unknown	Jim Baer Premier Properties	2825 El Camino Real	2825 El Camino Real	Palo Alto	Santa Clara	CA	94306	6	?
4	1	MF stats -- Mary Kay	Unknown	Roem Builders	2555 Alum Rock Av.	2555 Alum Rock Av.	San Jose	Santa Clara	CA	95116	55	?
4	1	MF stats -- Mary Kay	Townhouse	Bovis Lend Leas	367 Santana Heights	367 Santana Heights	San Jose	Santa Clara	CA		6-9 each	?
4	1	MF stats -- Mary Kay	Townhouse	Bovis Lend Leas	367 Santana Heights	367 Santana Heights B#A to B#11B	San Jose	Santa Clara	CA		6-11 each	?
4	1	MF stats -- Mary Kay	Townhouse	unknown	Avalon Bay Community	754 The Alameda (B#5 to B#7)	San Jose	Santa Clara	CA	95126	5-8 each	?
4	1	MF stats -- Mary Kay	Unknown	unknown	Barbaccia	150 Palm Valley Blvd	San Jose	Santa Clara	CA		57	?
4	1	MF stats -- Mary Kay	Unknown	Green Calley Co	Barry Swenson Bui	4855 San Felipe Rd	San Jose	Santa Clara	CA	95135	119	?
4	1	MF stats -- Mary Kay	Unknown	L & D Construct	First Community H	2580 S Bascom Ave.	San Jose	Santa Clara	CA	95124	90	?
4	1	MF stats -- Mary Kay	Unknown	unknown	Legacy Partners	475 W San Carlose St. (Bldg 1a)	San Jose	Santa Clara	CA	95110	17	?
4	1	"	"	"	"	475 W San Carlos St. (Bldg 3)	San Jose	Santa Clara	CA	95110	9	?
4	1	"	"	"	"	475 W San Carlos St. (Bldg 1a)	San Jose	Santa Clara	CA	95110	6	?
4	1	"	"	"	"	475 W San Carlos St. (Bldg 4)	San Jose	Santa Clara	CA	95110	5	?
4	1	"	"	"	"	475 W. San Carlos St. (Bldg 5)	San Jose	Santa Clara	CA	95110	8	?
4	1	MF stats -- Mary Kay	Unknown	Ovisco INC	Mike Oveyssi, owner	348 S Clover Ave.	San Jose	Santa Clara	CA	95128	64	?
4	1	MF stats -- Mary Kay	Unknown	unknown	Moorpark Place LLC	3704 Moorpark Ave.	San Jose	Santa Clara	CA	95117	5	?
4	1	MF stats -- Mary Kay	Unknown	unknown	Western Pacific	597 King George Ave	San Jose	Santa Clara	CA	95136	5	?
4	1	MF stats -- Mary Kay	Unknown	unknown	Western Pacific	549 - 573 King George Ave.	San Jose	Santa Clara	CA	95136	6 each	?

Table C- (cont'd): Santa Clara

CEC Zone	RER Zone	Source	Type	Builder	Project Name	Project Address	Project City	Project County	Project State	Project Zip	Number Units	Number stories
4	1	MF stats -- Mary Kay	Low Rise	PCI Inc.	Crossings At Montague	755 E. Capitol Ave., Building A, C, E, I, O, M	Milpitas	Santa Clara	CA	95035	24 each	low
4	1	MF stats -- Mary Kay	Low Rise	PCI Inc.	Crossings At Montague	755 E Capitol Ave., Building B, D	Milpitas	Santa Clara	CA	95035	32 each	low
4	1	MF stats -- Mary Kay	Low Rise	PCI Inc.	Crossings At Montague	755 E. Capitol Ave., Building F	Milpitas	Santa Clara	CA	95035	12	low
4	1	MF stats -- Mary Kay	Low Rise	Segue Construction	20 Descanso Dr. B#1	20 Descanso Dr. B#1	San Jose	Santa Clara	CA	95112	89	low
4	1	"	"	"	"	20 Descanso Dr. B#2	San Jose	Santa Clara	CA	95112	48	low
4	1	"	"	"	"	20 Descanso Dr. B#3	San Jose	Santa Clara	CA	95112	34	low
4	1	"	"	"	"	20 Descanso Dr. B#5	San Jose	Santa Clara	CA	95112	52	low
4	1	"	"	"	"	20 Descanso Dr. Bldg 4	San Jose	Santa Clara	CA	95112	38	low
4	1	MF stats -- Mary Kay	Low Rise	Branagh INC	2855 The Villages P	2855 The Villages P	San Jose	Santa Clara	CA	95135	31	low
4	1	"	"	"	"	2855 The Villages P	San Jose	Santa Clara	CA	95135	22	low
4	1	"	"	"	"	2855 The Villages P	San Jose	Santa Clara	CA	95135	26	low
4	1	MF stats -- Mary Kay	Low Rise	Bovis Lend Leas	300 S Winchester BL (Bld 3)	300 S Winchester BL (Bld 3)	San Jose	Santa Clara	CA	95128	98	low
4	1	MF stats -- Mary Kay	Low Rise	unknown	Barbaccia Properties	150 Palm Valley Blvd	San Jose	Santa Clara	CA		52	low
4	1	MF stats -- Mary Kay	Low Rise	unknown	Bascom Hacsc Asso-owner	2565 S Bascom Ave.	San Jose	Santa Clara	CA		125	low
4	1	MF stats -- Mary Kay	Low Rise	Segue Construct	Irvine Apartments	80 Descanso Dr. Building #2	San Jose	Santa Clara	CA	95112	40	low
4	1	"	"	"	"	80 Descanso Dr. Bldg 1	San Jose	Santa Clara	CA	95112	46	low

Table C- (cont'd): Santa Clara

CEC Zone	RER Zone	Source	Type	Builder	Project Name	Project Address	Project City	Project County	Project State	Project Zip	Number Units	Number stories
4	1	"	"	"	"	80 Descanso Dr. Bldg 1	San Jose	Santa Clara	CA	95112	79	low
4	1	"	"	"	"	80 Descanso Dr. B#3	San Jose	Santa Clara	CA	95112	80	low
4	1	MF stats -- Mary Kay	Low Rise	unknown	Legacy Partners	475 W. San Carlos St. (Bldg 10)	San Jose	Santa Clara	CA	95110	10	low
4	1	"	"	"	"	475 W San Carlos St. (Bldg 1B)	San Jose	Santa Clara	CA	95110	12	low
4	1	"	"	"	"	475 W. San Carlos St. (bldg 6, 8, 9)	San Jose	Santa Clara	CA	95110	8 each	low
4	1	"	"	"	"	475 W. San Carlos St. (bldg 7)	San Jose	Santa Clara	CA	95110	6	low
4	1	MF stats -- Mary Kay	Low Rise	unknown	Legacy Partners-Owners	250 Josepha St. (bldg11)	San Jose	Santa Clara	CA	95110	20	low
4	1	MF stats -- Mary Kay	Low Rise	Core Builders	Lenzen Housing	790 Lenzen Av	San Jose	Santa Clara	CA	95126	88	low
4	1	MF stats -- Mary Kay	Low Rise	Douglas and Ross Construction	3445 Lochinvar Ave.	3445 and 3465 Lochinvar Ave.	Santa Clara	Santa Clara	CA	95051	20 each	low
4	1	MF stats -- Mary Kay	High Rise	Bovis Lend Leas	367 Santana Heights	367 Santana Heights	San Jose	Santa Clara	CA		12	high
4	1	"	"	"	"	367 Santana Heights B#1A	San Jose	Santa Clara	CA		27	high
4	1	"	"	"	"	367 Santana Heights B#1B and #3B	San Jose	Santa Clara	CA		18 each	high
4	1	"	"	"	"	367 Santana Heights B#3A	San Jose	Santa Clara	CA		27	high
4	1	"	"	"	"	367 Santana Heights B#5	San Jose	Santa Clara	CA		24	high
4	1	MF stats -- Mary Kay	High Rise	unknown	Avalon Bay Community	754 The Alameda (B#4) 4101-4113	San Jose	Santa Clara	CA	95126	52	high
4	1	"	"	"	"	754 The Alameda (B#3) STE 3010-3112	San Jose	Santa Clara	CA	95126	58	high
4	1	"	"	"	"	754 The Alameda (B#2) STE 2101-2118	San Jose	Santa Clara	CA	95126	72	high
4	1	"	"	"	"	754 The Alameda (B#1) STE 1201-1209	San Jose	Santa Clara	CA	95126	18	high
4	1	MF stats -- Mary Kay	High Rise	unknown	Federal Realty Inc.	334 Santana Row (Bldg 4)	San Jose	Santa Clara	CA		100	high

Table C-10: Solano

CEC Zone	RER Zone	Source	Type	Builder	Project Name	Project Address	Project City	Project County	Project State	Project Zip	Number Units	Number stories
12	4	ParcelQuest	?		Rolling Oaks Apartments, Inc.	3700 Lyon Road	Fairfield	Solano	CA		292	?