Residential New Construction Study

Project Year #2

Project Manager

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Executive Summary

ES.1 Introduction

This executive summary summarizes the second-year findings of the Residential New Construction – Year #2 Study (RNC) conducted by Regional Economic Research, Inc. (RER) under Pacific Gas & Electric (PG&E) management.[1] The RNC study was designed to investigate energy efficiency in newly constructed low-rise residential homes[2] across California. On-site surveys of 800 residential homes performed for the Statewide Residential Efficiency Market Share Tracking Study (RMST)[3] were used for this purpose. 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, and the key findings from the study including baseline characteristics, compliance analysis, and a comparison of these results to the results of the first year of the RNC project.

ES.2 Study Objectives

The objectives of the second year of the RNC study are to examine the status of Title 24 compliance for a representative sample of California residences, as-built, using the MICROPAS[4] Title 24 computer compliance tool and to assess the impacts of recent changes in Title 24 Standards, including the changes in construction practices and compliance behavior attributable to 1998 standards. The results from the RNC study are used to develop a baseline of common building practices in the residential new construction sector, assist residential new construction program managers to develop and maintain effective energy efficiency initiatives, and assess the energy savings potential for new energy-using technologies.

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1 The detailed results of this study can be found in *Residential New Construction Study - Year #2.* RER, Inc. August 2002. Prepared for Pacific Gas & Electric.

2 This includes detached single family homes and multifamily buildings that are three floors or less.

3 RER, Inc. *California Residential Efficiency Market Share Tracking - New Construction 2001.* July 2001. Prepared for Southern California Edison.

4 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.

ES.3 Overview of Approach

In order to describe common building practices and analyze Title 24 compliance for residential low-rise buildings, a software tool was developed that allows for the translation of data from 800 on-site surveys[5] into a MICROPAS input file. These input files were then processed using MICROPAS and the results were made available in a number of formats. These results, together with the detailed on-site data, were then analyzed to ascertain common building practices and complete the Title 24 compliance analysis.

There are six major elements to the approach, which are briefly described below.

Review the On-Site Survey Database

The initial task was to review the database containing the information from the 800 on-site surveys. These data were then used to establish current building practices. The database contains information regarding general building information such as household characteristics and site information, equipment information (lighting, appliances, and water heating equipment), HVAC information, building orientation and construction information, and multifamily-specific data including sketches.

The sample of 800 on-site surveys was stratified by residence type, RMST climate zone, utility, and six-month period. The 16 CEC climate zones were grouped into five RMST climate zones for the Residential Market Share Tracking Study. RER developed expansion weights to expand the on-site data to represent the total number of homes built within the three electric IOU territories between July 1, 1999 and June 30, 2000. The expansion weights are based on the number of households in each utility service area and RMST climate zone.

[5] Collected as a part of the Residential Market Share Tracking project.

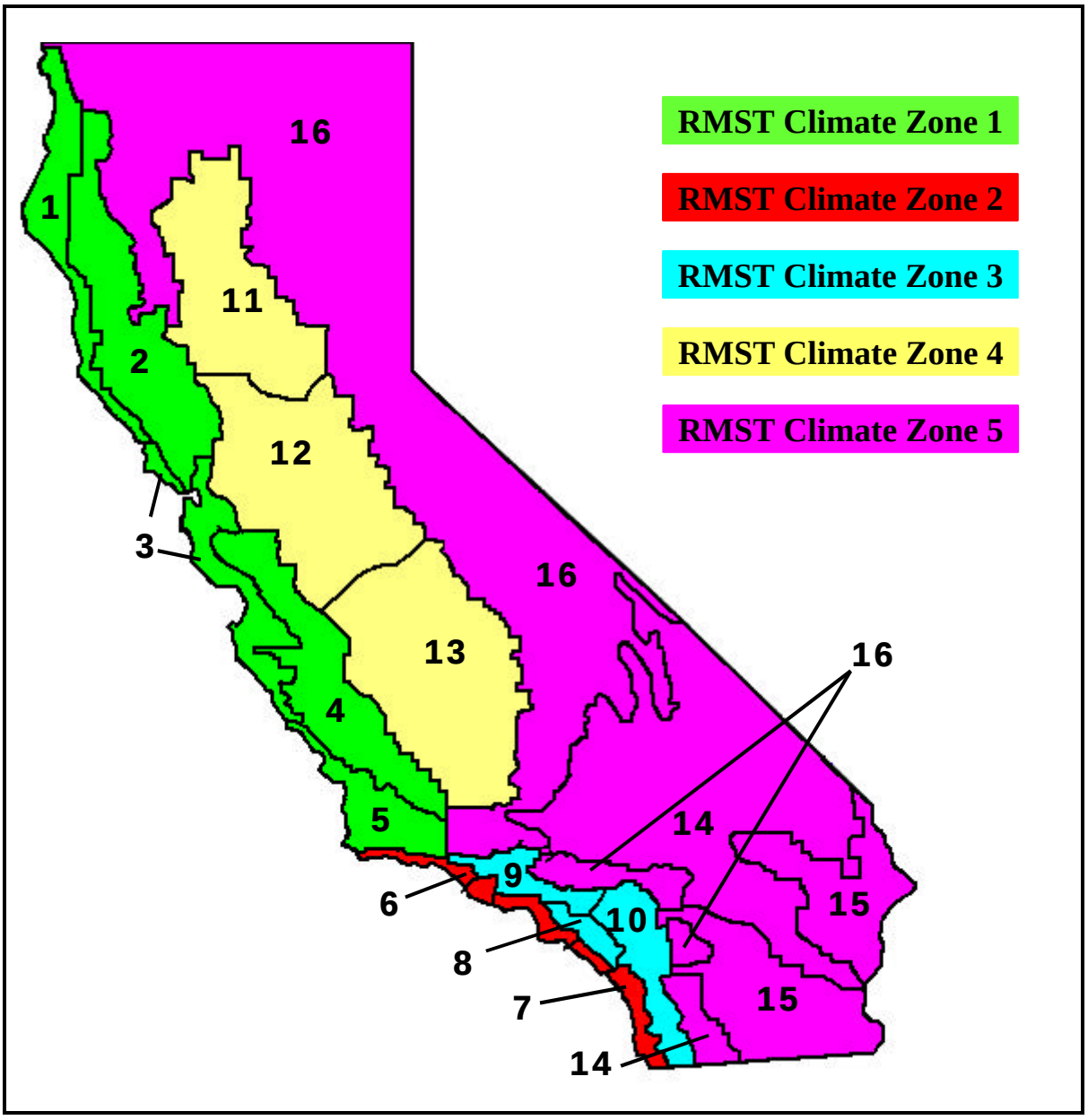
Table ES-1: Completed On-Site Surveys[6]

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Overall	**801**	**147**	**146**	**189**	**265**	**54**
SF (detached single family)	**575**	96	84	144	210	41
1 story	**259**	30	11	50	133	35
2 story	**309**	65	72	92	74	6
3 story	**7**	1	1	2	3	0
SF-A (low-rise single family attached)	**56**	17	12	14	6	7
1 story	**14**	1	1	1	4	7
2 story	**37**	12	10	13	2	0
3 story	**5**	4	1	0	0	0
MF (low-rise multifamily)	**127**	30	36	18	41	2
2 story	**68**	11	13	9	33	2
3 story	**59**	19	23	9	8	0
High-Rise	**22**	3	14	5	0	0
Other[7]	**21**	1	0	8	8	4

6 Note that high-rise buildings are not included in the distribution since they are not included in the analysis.

7 Other includes manufactured and mobile homes.

Figure ES-1: CEC Climate Zones



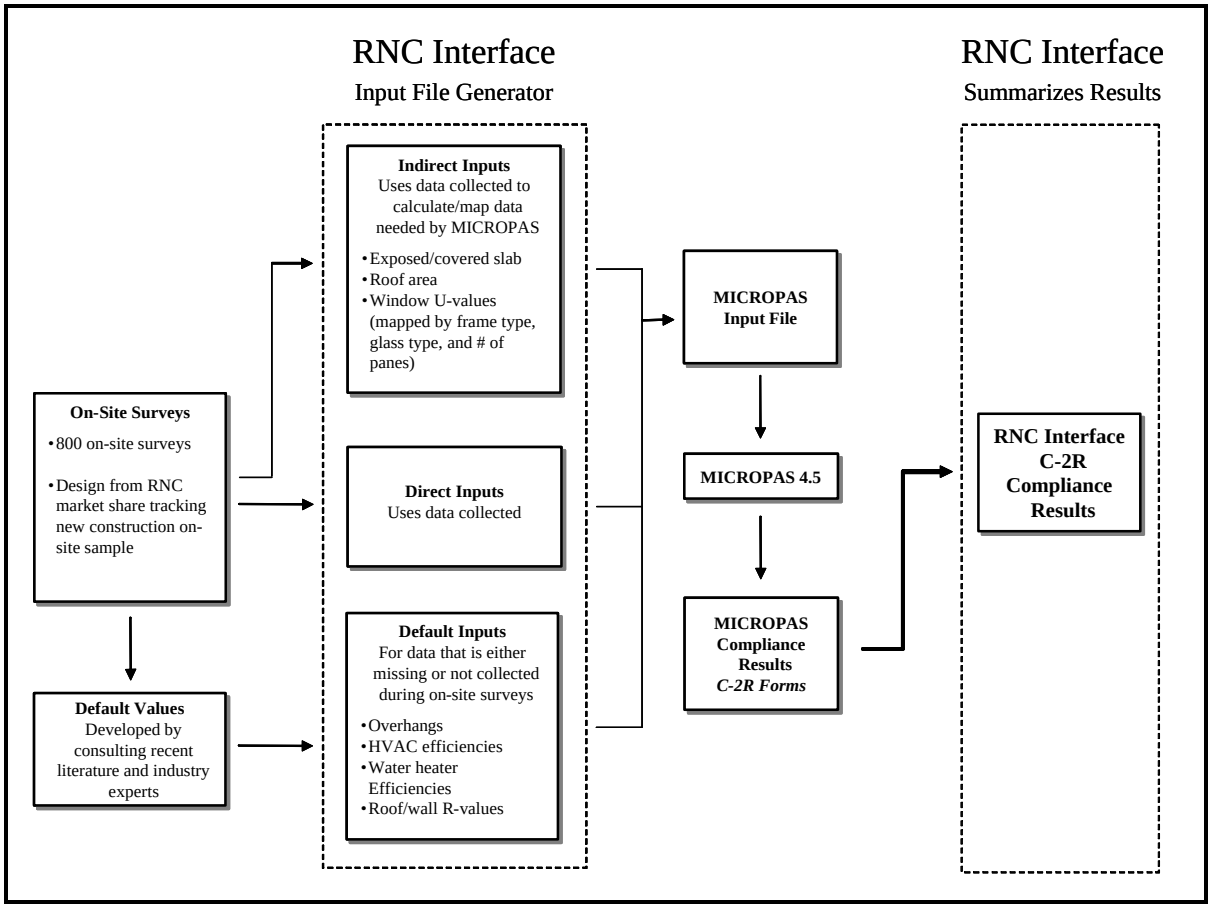
Create the RNC Interface

The RNC Interface is a software tool that uses data collected from the 800 on-site surveys to create MICROPAS input files and generate MICROPAS compliance runs from the RMST survey data of newly constructed residences. These runs are used to examine the compliance status for each residential building.[8] The RNC Interface is designed to support batch processing of the compliance analysis and is capable of outputting the compliance energy use

[8] Since the houses surveyed for the second year of this project were built between July 1999 and June 2000, nearly all of these homes would have had to comply with the 1998 low-rise residential building standards.

results and producing summary tables of energy use by end use and site. MICROPAS was chosen as the compliance tool because it is the tool of choice of energy consultants for performing low-rise residential compliance analysis.[9]

Figure ES-2: Overview of the RNC Interface Framework



Test the RNC Interface

Considerable effort was made to ensure that the RNC Interface produces accurate MICROPAS simulation results given the limitations of the available data and the design of the RNC Interface. To accomplish this task, a testing procedure was developed to evaluate the default parameters and underlying algorithms and structure of the RNC Interface. In particular, compliance forms for a sub-sample of RMST surveyed sites were gathered from building departments. For each sub-sampled site, data from the compliance documentation were used to populate an RMST survey form. These forms were then processed through the RNC Interface. The results were then compared to the compliance data on the original

[9] Interviews with MICROPAS developers indicate that more than 75% of energy professionals use their product. Further, two recent studies by RER indicate that more than 90% of energy compliance documentation was completed using MICROPAS.

compliance forms. Based on the analysis of the differences in the compliance results, additional changes were made to the RNC Interface. This procedure was repeated until an acceptable margin of error was reached. A final error band was then developed for use in analyzing the remaining RMST surveyed sites.

Complete the MICROPAS Compliance Analysis of the 800 Residences

Of the 800 sites, 725 were ultimately processed through the RNC Interface and the % Compliance Margin[10] was calculated for each site. The error band[11] established during the testing of the RNC Interface was then applied to the results. The sites were then grouped into four compliance categories: non-compliant, indeterminate, compliant, and overly compliant.

Identify Baseline Characteristics

Data from the on-site surveys were used to characterize common building practices in the residential sector. In particular, summaries of square footage, glazing areas, insulation levels, window types and efficiencies, and equipment efficiencies by residence type and climate zone were tabulated. These values were used to characterize the baseline practices in the residential new construction sector.[12]

Analyze the Compliance Results

Insofar as the performance method[13] was used for Title 24 compliance, it is problematic to isolate the particular reasons a home did or did not comply. This step characterized homes that comply and those that do not in order to discern the potential reasons homes might not comply with Title 24 requirements. In particular, summary tables of shell characteristics and equipment efficiencies were developed for homes that comply, do not comply, and overly comply. These results are presented and analyzed by residence type and climate zone and by

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[10] The % Compliance Margin represents the compliance margin expressed as a percentage of the standard energy budget. Specifically,

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

[11] The error band developed for this round of on-site surveys is -5% to +4%. This means that if the % Compliance Margin calculated by the RNC Interface is between -5% and +4%, the compliance of the home is indeterminate. Likewise, if the % Compliance Margin is less than -5%, then the home is not compliant with the 1998 building standards. A home with a % Compliance Margin greater than +4% is compliant.

[12] Note that the baseline characterization focused on water heating and HVAC equipment and building shell features. No attempt is made to characterize lighting and appliance features. These latter two categories are covered in the RMST New Construction 2001 report. RER, Inc. *California Residential Efficiency Market Share Tracking - New Construction 2001*. July 2001. Prepared for Southern California Edison.

[13] Builders/Title 24 consultants have the option of using the prescriptive method or the performance method in demonstrating compliance. The prescriptive method requires that the home have an exact list of measures installed. The performance method allows for trade-offs between measures and a Title 24 compliance software, such as MICROPAS, must be used.

percent glazing and window efficiency combinations. Based on this analysis, potential reasons for non-compliance are summarized and discussed.

ES.4 Summary of Findings

The following summarizes key findings from the second year of the residential new construction study. These include major findings from the baseline characteristics of newly constructed homes and the compliance analysis.

Baseline Characterization

Findings on efficiency levels and key differences in construction practice between detached single family homes and multifamily buildings, and differences among regions and project years are summarized below.

- ***Average HVAC equipment efficiencies in detached single family homes are slightly above the minimum equipment efficiency standards.*** The average efficiency of gas furnaces installed in detached single family homes is 80.5% AFUE, versus the 78% AFUE Standard value. The average efficiency of central air conditioners installed in detached single family homes is 10.6 SEER, versus the 10 SEER Standard value.
- ***Single family detached homes are more likely than multifamily buildings to have higher than standard efficiency air conditioners.*** Approximately 55% of detached single family homes have a higher than standard efficiency air conditioner (>10 SEER), compared to 19% of multifamily buildings.
- ***A large number of homes do not have cooling equipment.*** Approximately 54% of single family homes in RMST Climate Zone 1 and 34% of single family homes in RMST Climate Zone 2 do not have a cooling system, which is approximately 14% at the state level. Likewise, a significant number of multifamily buildings do not have cooling systems (27% statewide).
- ***The average duct leakage percentage for single family homes is significantly lower than for multifamily buildings.***[14] For detached single family homes, the average duct leakage percentage for those duct systems tested statewide was 13%, compared to 31% for multifamily buildings.
- ***Efficiency levels of water heating systems are generally above the Minimum Efficiency Standards for both single family homes and multifamily buildings.*** The average energy factor (EF) of water heating systems installed is 16% higher than required by the minimum efficiency standards for detached single family homes and 13% higher for multifamily buildings.

[14] A significance test at the 90% confidence level reveals that the estimates of the average percent duct leakage for single family homes is significantly lower than that for multifamily buildings at the state level.

- ***Dual-paned, vinyl-framed windows are typically installed in both detached single family homes and multifamily buildings.*** The predominant window type in detached single family homes and multifamily buildings is a vinyl-framed, dual-paned, clear glass window.
- ***Use of metal-framed windows is more extensive in multifamily buildings than in single family detached homes.*** While vinyl-framed, dual-paned, clear glass windows are predominantly used in both detached single family homes and multifamily buildings, metal windows are used more often in multifamily buildings (23.0% compared to 16.2% in detached single family homes).
- ***Use of metal-framed windows varies significantly by climate zone.***[15] For multifamily buildings, the percent of metal-framed windows ranges from a low of 0% in RMST Climate Zone 2 to highs of 56% and 32% in RMST Climate Zones 4 and 5, respectively. For single family homes, the percent of metal-framed windows also ranges significantly from 0% in RMST Climate Zone 2 to 36% in RMST Climate Zone 4.
- ***Ceiling and wall insulation levels are usually below prescriptive values.***[16] For those residences where ceiling and wall insulation R-values were obtained, the observed insulation levels were typically lower than prescriptive values, but always greater than or equal to the minimum R-values specified by the Standards.

Comparison of Homes Built in Project Year 1 and Project Year 2

A comparison between the results found in the first year[17] and the second year of the RNC project was conducted. While there were small changes in construction practices between Project Year #1 homes (built between July 1998 and June 1999) and the Project Year #2 homes (built between July 1999 and June 2000), there were no significant changes in the statewide average of any building characteristic.[18]

Analysis of Compliance

An assessment of the Title 24 compliance for low-rise residential buildings was conducted as part of the RNC study. The analysis is based on the MICROPAS simulation results using the

[15] A significance test at the 90% confidence level reveals that there is a significantly higher percentage of metal-framed windows installed in multifamily buildings in RMST Climate Zones 3 and 5 than in multifamily buildings in the remaining RMST climate zones.

[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.

[17] RER, Inc. *Residential New Construction Study.* May 17, 2001. Prepared for Pacific Gas & Electric.

[18] For detailed information on the differences between Project Year #1 homes and Project Year #2 homes by RMST Climate Zone, see Section 3.6 of the full report (RER, Inc. *Residential New Construction Study – Year #2.* August 2002. Prepared for Pacific Gas & Electric).

on-site survey data. In particular, 719 sites were processed through the RNC Interface[19] and the % Compliance Margin was calculated for each site. The primary objective of the analysis is to establish key characteristics of buildings that are compliant (compliant) and those that are not compliant with Title 24 standards (non-compliant). This was accomplished by examining the MICROPAS 5.1 results.

An error band was developed due to uncertainty with the compliance results. There is some uncertainty in the results due to the inability of the surveyors to capture all the detailed information required for the compliance runs. Application of the error band resulted in the following four compliance groups, which were used as the basis for analysis of the compliance results.

- ***Non-Compliant.*** This category includes sites that, based on the analysis, are not compliant with Title 24 code. In particular, these sites have a % Compliance Margin less than the lower end of the error band (i.e., <-5%).
- ***Indeterminate.*** This category includes sites that have a % Compliance Margin within the error band (-5% to 4%). As such, it is indeterminate as to whether these sites comply with the Title 24 codes.
- ***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., > 4% and < 24%).
- ***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 24%. This category was defined to assess the share of homes that would meet the existing ENERGY STAR New Home Construction requirements, given the error band.

Below is a summary of the results from the compliance analysis.

Figure ES-3 and Figure ES-4 summarize the distribution of sites by % Compliance Margin and compliance group for single family homes and multifamily buildings, respectively.

- ***Approximately 12% of sites are identified as non-compliant.*** The results from the RNC Interface compliance analysis indicate that 12% of all homes built in the study period were non-compliant. Most, however, fell within the compliant group (57%), and 13% fell in the overly compliant group.

[19] The RNC Interface, as explained in Section 2, uses on-site survey data to generate a MICROPAS 5.1 input file. MICROPAS 5.1 is a software tool used to determine compliance under the 1998 Low-Rise Residential Building Standards.

Figure ES-3: MICROPAS Results Summary – Detached Single Family Homes

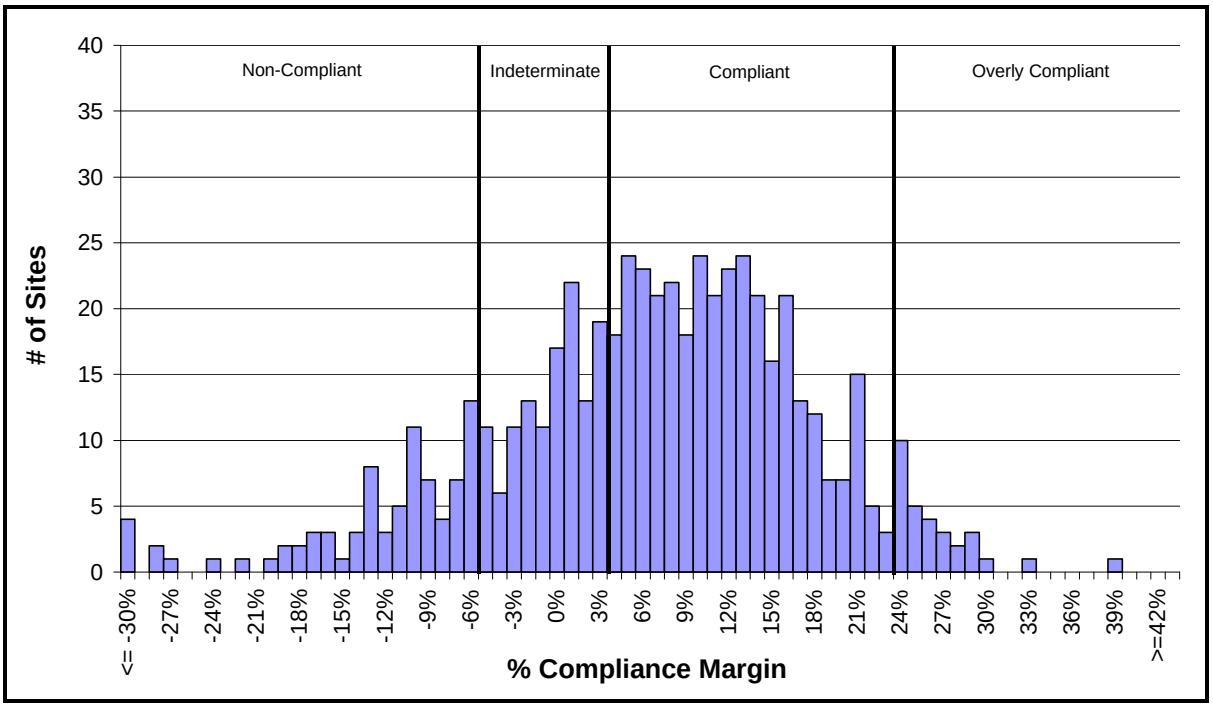
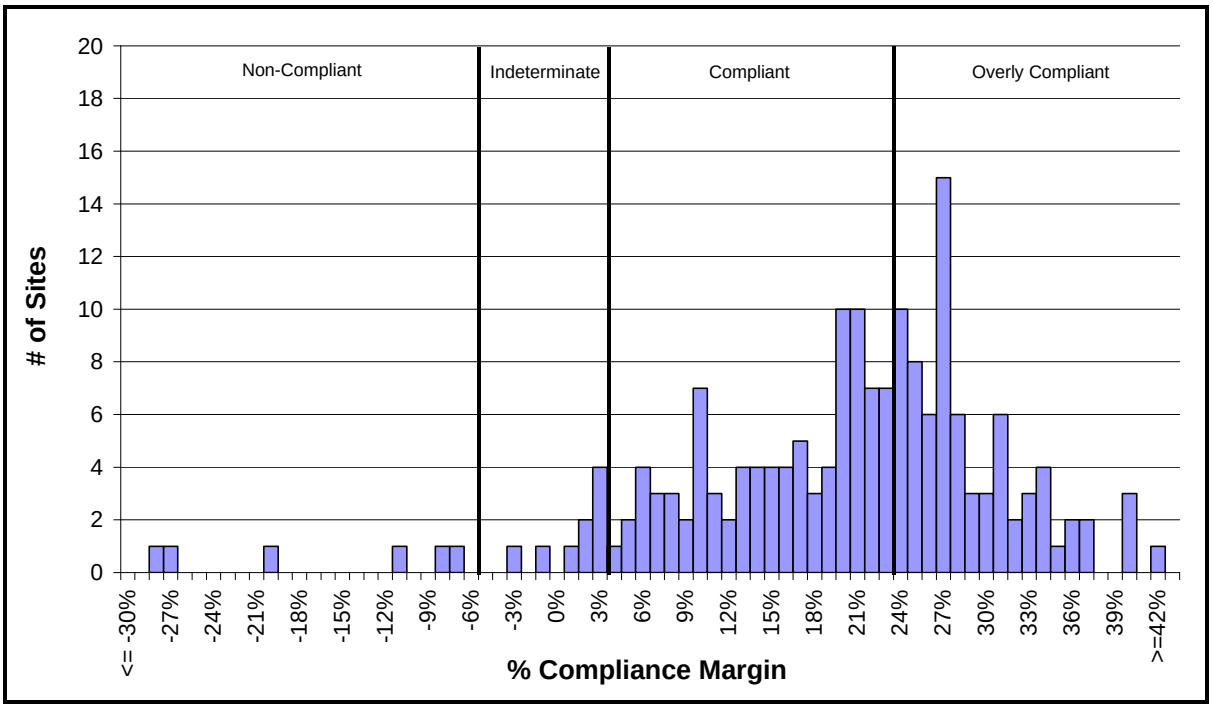


Figure ES-4: MICROPAS Results Summary – Multifamily Buildings



- ***Nearly 90% of homes have non-negative water heater margins.*** Approximately 93% of newly constructed homes with gas water heaters have water heaters with energy factors above the minimum standard values. This translates into positive water heating margins for these homes. This is most likely due to the relatively low cost associated with increasing the water heater efficiency in an effort to meet compliance.
- ***The percent glazing area has a substantial impact on compliance.*** Homes with large glazing percentages tend to be non-compliant, while homes with small glazing percentages tend to be compliant or overly compliant.
- ***Ceiling and wall insulation play a relatively minor role in compliance.*** The results of the analysis indicate that the impact of increases in wall and ceiling insulation levels on compliance is minimal. As such, when using performance-based methods to determine compliance, builders and Title 24 consultants do not typically use high efficiency insulation. This result is reflected in the fact that ceiling insulation installed in new homes is generally below the requirement. In addition, wall insulation installed is typically R-13, which is at the prescriptive level in some climate zones but below in others.
- ***Two-story homes are inherently more compliant than one-story homes.*** Approximately 70% of two-story detached single family homes are compliant or overly compliant compared to only 55% of one-story detached single family homes.
- ***Multifamily buildings are more compliant than detached single family homes.*** There are two primary reasons for this: 1) multifamily buildings, on average, have a lower glazing percentage than detached single family homes and 2) all multifamily buildings are either two-story or three-story buildings which are inherently more compliant than one-story homes.
- ***RMST Climate Zone 2 (southern coast) has the highest percentage of compliant homes.*** Approximately 95% of sites in RMST Climate Zone 2 fall in either the compliant or overly compliant groups. In fact, RMST Climate Zone 2 is the most compliant of the RMST climate zones with an average % Compliance Margin of 17.5%. Only 1% of sites in RMST Climate Zone 2 fall in the non-compliant group and only 4% fall in the indeterminate group.
- ***RMST Climate Zone 5 (desert and mountains) has the highest percentage of non-compliant homes.*** Approximately 39% of sites in RMST Climate Zone 5 fall in the non-compliant group and 31% are indeterminate. In fact, RMST Climate Zone 5 is the most non-compliant of the RMST climate zones with an average % Compliance Margin of -5.3%.

ES.5 Compliance Variations Among Climate Zones Across Project Years

Table ES-2 presents the average % Compliance Margin by project year and RMST climate zone for both detached single family homes and multifamily buildings. When comparing the compliance analysis results found in the second year of this project to the results found in the first year of this project, several questions arise. Are the compliance analysis results significantly different? If so, are the changes in average % Compliance Margin attributable to changes in building practices or to changes in the standards?

Table ES-2: Average % Compliance Margin by Project Year, RMST Climate Zone, and Residence Type

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Detached Single Family Homes						
Project Year #1 - 1995	4.8%	6.8%	6.7%	10.2%	-1.0%	-0.5%
Project Year #2 - 1998	6.2%	11.4%	14.7%	6.1%	4.1%	-6.2%
Attached Single Family & Multifamily Buildings						
Project Year #1 - 1995	14.9%	11.0%	17.5%	21.7%	13.6%	9.6%
Project Year #2 - 1998	21.6%	22.3%	22.1%	22.3%	22.0%	3.3%

To answer these questions accurately, it is not enough to simply look at the differences in the % Compliance Margins from the two reports. Remember that the homes used in the first year of the project were analyzed using MICROPAS 4.5, which uses the 1995 low-rise residential building standards, whereas homes used in the second year of the project were analyzed using MICROPAS 5.1, which uses the 1998 low-rise residential building standards. Therefore, the compliance of the homes used for the second year of the project were analyzed using MICROPAS 4.5. These results were then used in two comparisons to help understand the differences in the results between Project Year #1 and Project Year #2, by RMST climate zone.

- ***"Project Year #1 – Using the 1995 standards" results vs. "Project Year #2 – Using the 1995 standards" results.*** Comparing the % Compliance Margins between these sets of results makes it possible to analyze how the differences in building practices between the two project years affected the average % Compliance Margin.
- ***"Project Year #2 – Using the 1995 standards" results vs. "Project Year #2 – Using the 1998 standards" results.*** Comparing the % Compliance

Margins between these sets of results makes it possible to analyze how the changes in the standards affected the average % Compliance Margin.

The following subsections summarize the findings of this analysis for detached single family homes and attached single family and multifamily buildings.

Detached Single Family Homes

The analysis conducted for detached single family homes concludes that a combination of the changes in average building characteristics and changes to the standards were responsible for the significant changes in the average % Compliance Margin across RMST Climate Zones. Specifically, a decrease in the average % glazing[20] and the changes to the water heating portion of the standards were the primary reasons for the significant increase in the average % Compliance Margin in RMST Climate Zone 2. In RMST Climate Zones 1 and 4 however, the change in the space heating and water heating portions of the standards was the primary reason for the significant increase. While, increases in the average % glazing[21] in RMST Climate Zones 3 and 5 was the primary reason for the significant decrease in their % Compliance Margins.

Attached Single Family Homes and Multifamily Buildings

The analysis conducted for attached single family and multifamily buildings concludes that both building practices and changes to the standards were responsible for the significant changes in the average % Compliance Margin across RMST Climate Zones. Specifically, a decrease in the average % glazing[22] and the changes to the space heating and water heating portions of the standards were the primary reasons for the significant increase in the average % Compliance Margin in RMST Climate Zone 1. While in RMST Climate Zones 2 and 4 the change in the standards was the primary reason for the significant increase.

[20] Note that for this second year of the project, the on-site surveyors were given different protocols when gathering glazing information in order to improve the accuracy of their measurements.

[21] See Footnote 20.

[22] See Footnote 20.

1

Introduction

1.1 Overview

The work presented in this report is part of a two-year study conducted by Regional Economic Research, Inc. (RER) under Pacific Gas & Electric (PG&E) management. The report investigates energy efficiency in newly constructed low-rise residential homes throughout California.[1] 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.

Section 2 provides an overview of the development of the tool used to complete the compliance analysis, the RNC Interface. Section 3 summarizes the baseline construction practices of low-rise residential buildings built between July 1, 1999 and June 30, 2000 in California, while Section 4 presents the results of the Title 24 compliance analysis[2] of these homes. Section 5 provides a summary of the key results. This section provides a review of the objectives of this project, a discussion of the approach taken along with key findings from each of the various sections of this report, and a brief discussion on the next steps in the project.

1.2 Objectives

The study makes extensive use of on-site surveys of residential homes performed for the Statewide Residential Efficiency Market Share Tracking Study (RMST).[3] The objective of the study is to examine the status of Title 24 compliance for a representative sample of California residences as constructed (as-built) using the MICROPAS Title 24 computer compliance tool. The study results will be used to track common building practices in the residential new construction sector, to assist residential new construction program managers

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

2 As described in detail in Section 2, MICROPAS 5.1, compliance software used to perform compliance analysis under the 1998 low-rise residential standards, was used to develop the results in Section 4.

3 *California Residential Efficiency Market Share Tracking – New Construction 2001.* RER, Inc. July 2001. Prepared for Southern California Edison.

to develop and maintain effective energy efficiency initiatives, and to assess the energy savings potential for new energy using technologies.

1.3 Overview of Approach to Assess Baseline Building Practices and Title 24 Compliance in the Residential Sector

The objective of this phase of the project is to describe common building practices and analyze Title 24 compliance for residential low-rise buildings. To accomplish this task, RER developed a software tool that allows the data from 800 on-site surveys[4] to be translated into a MICROPAS input file. These input files are then processed by MICROPAS and the results are made available in a number of formats. RER 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 on-site survey database, update the RNC interface to analyze the new fields added to the on-site survey form, develop a new error band, complete the MICROPAS compliance analysis of the 800 residences, identify baseline characteristics, and analyze the compliance results.

1.4 Organization of the Report

The remainder of the report is organized as follows:

- Section 2 presents an overview of the development and testing of the Residential New Construction Interface (RNC Interface) to MICROPAS.
- Section 3 discusses and summarizes the current building practices in low-rise residential buildings.
- Section 4 discusses the analysis of Title 24 compliance in low-rise residential 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: Sample C-2R form
  - Appendix B: Summary of the effort to collect C-2R forms
  - Appendix C: On-Site Survey Forms (first year and second year)
  - Appendix D: Duct Blaster Test Survey Forms (first year and second year)
  - Appendix E: Creating the RNC Interface

[4] Residential Market Share Tracking project being conducted by Regional Economic Research, Inc. for Southern California Edison, 2000-2002.

2

The RNC Interface

2.1 Introduction

This section briefly describes the development and testing of the RNC Interface created to generate MICROPAS Title 24 standard compliance analyses (compliance runs) based on survey data collected for the California Residential Efficiency Market Share Tracking (RMST) Study.[1] The primary purpose of the RNC Interface is to generate MICROPAS compliance runs from the RMST survey data of newly constructed residences. These runs are used to examine the compliance status for each residential building and to explore the energy conservation potential of some key energy saving technologies. MICROPAS was chosen as the compliance tool because it is the tool of choice among energy consultants for performing low-rise residential compliance analysis.[2] The interface was designed to do the following:

- Translate the on-site survey data into MICROPAS input files,
- Run MICROPAS in a batch mode,
- Facilitate the use of either MICROPAS 4.5, 5.1, or 6.0,
- Extract the MICROPAS compliance results, and
- Provide a platform for the technical potential analysis.

The following sections provide an overview of the RNC Interface, a brief description on how the RNC Interface was tested, and a discussion of the RNC Interface error band developed for use in analyzing the compliance of individual surveyed residences and modifications made to last year's on-site survey instrument to improve the MICROPAS simulations.

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1 *California Residential Efficiency Market Share Tracking – New Construction 2001.* RER, Inc. July 2001. Prepared for Southern California Edison.

2 Interviews with MICROPAS developers indicate that more than 75% of energy professionals use their product. Further, two recent studies by RER indicate that more than 90% of energy compliance documentation was completed using MICROPAS.

2.2 Overview of the RNC Interface

The RNC Interface uses the data collected from on-site surveys to create a MICROPAS input file. This is accomplished by first manipulating the data,[3] then "writing" it to a file in the required MICROPAS input format. The RNC Interface then passes the input file through MICROPAS 5.1. The interface produces results in the same format as the C-2R forms used for compliance documentation. A copy of a C-2R form is contained in Appendix A.

MICROPAS Version 4.5, 5.1, and 6.0

It was recognized early on that the RNC Interface needed to be able to generate results for two versions of MICROPAS: MICROPAS4 (v4.5) for the 1995 Standards and MICROPAS5 (v5.1) for the 1998 Standards. The Residential Standards are normally revised on a three-year cycle. However, during the first year of the project, emergency revisions were made to the Standards under AB 970.[4] Therefore, the capability to generate results for a third version of MICROPAS, MICROPAS6 (v6.0), was added to the interface. The current standards are the AB 970 Standards, which were implemented in January 2002 for all low-rise residential homes and superceded the 1998 Standards.

Developing MICROPAS Inputs from the RMST On-Site Survey Data

The RMST on-site survey database contains detailed information on HVAC and water heating equipment and building envelope characteristics. Some of these data were taken directly out of the database and written to the MICROPAS input file. However, the on-site survey did not collect all of the information needed to create a valid MICROPAS input file. Where possible, changes were made to the survey instrument for Project Year #2 to collect additional information in order to limit the number of defaults required[5]. Even with the changes, some of the information needed to create the input file was not able to be collected at some sites or had to be manipulated in order to be utilized in the MICROPAS run. As such, the transformation of RMST survey data to MICROPAS inputs can be characterized in the following three categories.

- ***Direct Inputs.*** These values, types, etc., are mapped directly from the RMST survey database into the MICROPAS input file. Examples of direct inputs include square footage, heating and cooling equipment efficiencies, and roof and wall insulation values.
- ***Default Inputs.*** These values, types, etc., are required MICROPAS inputs, including MICROPAS run parameters, for which no equivalent direct or indirect

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[3] For information on how the RNC Interface manipulates the data, please see Appendix E, subsection "Developing MICROPAS Inputs from the RMST On-Site Survey Data."

[4] Assembly Bill 970 is a measure passed by the California State Legislature in January 2001. *Contractor's Report 2001 Update Assembly Bill 970. CEC Volume 1 – Summary.* November 2000.

[5] See Section 2.5 for more information on the changes to the on-site survey instrument.

survey data value exists. Examples of default inputs include slab thickness and thermal performance characteristics.

- ***Direct Defaults.*** These are defaults for direct values that are required MICROPAS inputs, but for which no value was entered on the survey form (missing data). Examples of direct defaults include roof insulation, wall insulation, and HVAC and water heating equipment efficiencies[6].

Direct inputs are inserted directly into the MICROPAS input files. The methods and sources used to develop *default inputs* and *direct defaults* include the use of algorithms and mapping tables, the MICROPAS User's Guide, consultation with industry experts, building department C-2R forms, and on-site survey data. Each input type is used by the RNC Interface to generate the MICROPAS input files.

Features of the RNC Interface

The ability to do batch compliance runs for a large number of sites from outside MICROPAS, and to be able to easily extract the results for these runs, is critical to performing the runs efficiently. The RNC Interface controls the execution of each MICROPAS run, then imports the run results into an Access database table automatically as each run is completed. In addition to performing batch runs, the RNC Interface has several other useful capabilities:

- Select individual or multiple sites,
- Select the version of MICROPAS (4.5, 5, or 6),
- Select whether to run a Cardinal,[7]
- Select the weather data set to use – FullYear or ReducedYear,[8] and
- Specify the source input database (this feature was used for the testing phase to read in building department C-2R data).

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6 Please note that in many cases, detailed information on central water heaters in multifamily buildings was not obtainable. The focus of the RMST on-site surveys was to survey the residence and not the entire building. Also, home owners/renters were contacted to obtain permission to perform the on-site survey and not the apartment managers office. Therefore, it was impossible for the surveyors to gain access to the central water heating equipment in many cases. Please see Section 4.10 for information on this may affect the compliance results.

7 A Cardinal run is actually four runs—a run is performed for the home facing each of the four cardinal directions (North/East/South/West) and compliance is determined by the run with the smallest margin.

8 "MICROPAS can be run using full-year weather data (365 days) or reduced-year data (42 days). The reduced-year run performs only one-eighth of the calculations of the full-year run. Because of the reduced calculation time, the reduced-year weather data is used for most compliance work … Very small differences in results may occur between reduced and full year calculations." *MICROPAS4 User's Manual.*

2.3 Testing the RNC Interface

Considerable effort was made in Project Year #1 to ensure that the RNC Interface produced accurate MICROPAS simulation results given the limitations of the available data and the design of the RNC Interface. RER developed a testing procedure to evaluate the default parameters, underlying algorithms, and structure of the RNC Interface. Building department compliance forms (C-2Rs) were collected for a sample of the sites surveyed and the data was mapped to the Project Year #1 on-site database.[9] These data then were passed through the RNC Interface. The error band used for Project Year #1 was calculated by comparing the compliance margins from these runs to the compliance margins from the C-2R forms.

Since the second year RMST on-site survey form was changed to improve data availability, it was necessary to re-implement the testing procedure. Data from the Project Year #1 C-2Rs were mapped to the Project Year #2 on-site survey database. Additional fields from the C-2Rs, such as roof area and overhangs, could be mapped since these fields were added to the Project Year #2 on-site survey. The error band for Project Year #2 then was calculated in the same manner as Project Year #1.

2.4 RNC Interface Error Band

Establishing the error band for the RNC Interface was necessary because there is uncertainty in the compliance runs generated by the RNC Interface. As such, it is problematic to determine compliance/non-compliance from the results of the RNC Interface runs. Therefore, a margin of error for the estimated % Compliance Margin was developed using data from the test phase of the project. This error band is ultimately used to define three compliance categories:

- Non-compliant,
- Indeterminate, and
- Compliant.

The error band for the compliance margins is developed using the difference estimator method described below. Using the comparison of the test sites, an error band of -5% to +4% around the RNC Interface compliance estimates was calculated. This implies that if the RNC Interface compliance run using the on-site data for a single site estimated a 12% compliance margin, then there is 90% confidence that the "true" compliance margin is between 6% and 16% (12% - 5% = 7%, 12% + 4% = 16%).[10]

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[9] For details on the testing procedure, please see Appendix E.

[10] Note that all test sites used to calculate the Error Band are detached single family homes.

Difference Estimator Method

The difference estimator method was used to develop an error band for the % Compliance Margin from the RNC Interface. This was accomplished by comparing the compliance runs from the RNC Interface and the building department C-2R data for the test sites. In particular, the difference estimator (DE), the average difference of the two versions, and the standard deviation of the difference estimator were calculated. Specifically, % Compliance Margin as calculated for the building department C-2R compliance data (% Compliance Margin_{BD}) and for the RNC Interface compliance runs (% Compliance Margin_{RER}) was determined as follows:

$$\%\ Compliance\ Margin_{i,BD} = \frac{Standard\ Design_{i,BD} - Proposed\ Design_{i,BD}}{Standard\ Design_{i,BD}}$$

where

$Standard\ Design_{BD}$ = Total energy use (space heating, space cooling, and water heating) for a home with Prescriptive Package D features (standard design) from the building department compliance records (*BD*).

$Proposed\ Design_{BD}$ = Total energy use (space heating, space cooling, and water heating) for home *i* with proposed construction plan features (proposed design) from the building department compliance records (*BD*).

and

$$\%\ Compliance\ Margin_{i,RER} = \frac{Standard\ Design_{i,RER} - Proposed\ Design_{i,RER}}{Standard\ Design_{i,RER}}$$

where

$Standard\ Design_{i,RER}$ = Total energy use (space heating, space cooling, and water heating) for a home with Prescriptive Package D features (standard design) from the RNC Interface (*RER*).

$Proposed\ Design_{i,RER}$ = Total energy use (space heating, space cooling, and water heating) for home *i* with proposed construction plan features (proposed design) from the RNC Interface (*RER*).

The difference estimator (*DE*) is defined as:

$$DE = \frac{\sum_i \%\ Complaince\ Margin_{Ri,ER} - \%\ Compliance\ Margin_{i,BD}}{n}$$

The standard deviation (*StdDev*) of the difference estimator is defined as:

$$StdDev\ (DE) = \sqrt{\frac{\sum (\%\ Complaince\ Margin_{BD} - (\%\ Complaince\ Margin_{RER} + DE))^2}{(n-1)}}$$

Error Band Analysis and Results

A summary of key parameters in the error band analysis is presented in Table 1. In particular, the difference estimator is -0.29%, which implies that, on average, the % Compliance Margins generated from the RNC Interface are 0.29% lower than the % Compliance Margin generated from the building department C-2R forms. The standard deviation of the difference estimator is calculated as 0.029 – slightly lower than Year #1. To compute the 90% confidence interval, the standard deviation is multiplied by 1.645, which is 0.0476 or 4.76%. Lastly, since the RNC Interface compliance runs are, on average, 0.29% lower than the building department C-2R compliance runs, 5.17% is both added and subtracted from -0.29% to define the error band. As mentioned above, the resulting error band is -5% to +4%.

Table 1: Summary of the RNC Interface Error Band Analysis

Statistic	Year #1	Year #2
Difference Estimator	0.73%	-0.29%
Standard Deviation	0.0314	0.0289
90% Confidence Interval	± 5.17%	± 4.76%
Lower Error Band	-4.44%	-5.05%
Upper Error Band	5.90%	4.47%

2.5 Modifications of the RMST On-Site Survey Designed to Improve the MICROPAS Simulations

Several modifications were made to the second year RMST on-site survey form. These changes improved data availability and quality for the MICROPAS analysis. Additional changes were made to capture data requested by CEC personnel and other statewide RNC program managers.

- ***Lighting Systems.*** Although not an issue for compliance analysis, detailed information on kitchen lighting and diffuser types, bathroom lighting (especially in bathrooms with toilets), and ceiling fan lighting systems was added to the survey form and collected during the second year of on-sites.
- ***Miscellaneous Appliances.*** A count of ceiling fans that do not have lights has been added.
- ***HVAC Systems.*** Detailed information on HVAC system location and an estimate of the distance between the HVAC system and water heating system were added. For better consistency with MICROPAS5, the HVAC system equipment types have been expanded to simplify specification of a combination space/water heating system.
- ***Water Heating Equipment.*** Many significant changes were made to this page of the survey form. Up to two different water heaters can be specified on a single page and a "quantity" field was added. It is now easier and more direct to specify a combination space/water heating type unit. Control types and features reflecting the various credits/debits available in MICROPAS were added. Finally, additional fields needed to record performance and efficiency information for large water heaters and water heaters used in hydronic systems have been added.
- ***Duct Systems.*** Information on the location of supply and return ducts was gathered. Duct and duct-sealing types were expanded. A field for recording the duct sealing tape UL label information and brand name was also added. Although, these data were gathered last year, there was no dedicated field to capture the data.
- ***Building Construction and Orientation.*** Most changes were made in this area to enhance the MICROPAS runs. To address door shading, RER added a field to specify shading conditions for doors located in recessed entryways or under patio covers. To address the roof area issue discussed in the previous section, the roof area (ceiling-below-roof) was recorded directly during the on-site visit. In addition, roof insulation type was added to make better use of ceiling insulation levels specified in inches. However, the most significant change to the building construction area of the survey form was made to address the issue of slab floor areas and raised floors above garages for two-story homes. Ground floor area was directly estimated including, for slab floors, an estimate of the percent of the slab floor that is exposed (i.e., not carpeted). The second story floor area above an unconditioned garage was also collected.
- ***Windows, Glass Doors, and Skylights.*** This section of the survey form was also changed. In particular, interior and exterior shading details were separated and expanded to better reflect MICROPAS options. In addition, glass type options were revised to reflect the use of the ETEKT+ AE1600 Low-E Coating Detectors,[11] which can be used to detect after-market window films as well as

[11] ETETKT+ Low-E Coating Detectors were obtained from Electronic Design to Market, Inc. (www.edtm.com). These meters detect the presence of metal surface coatings on the outer or inner sides of single-paned or dual-paned glass windows.

low-E coatings. The final revision involved deleting fields that were to be used to collect information from the AAMA Permanent Label that is supposed to be affixed to every AAMA-rated window. Unfortunately, these labels are usually removed before the homeowner's final walk-through and these fields were never used during the first year's survey.

One of the most significant changes is that the surveyors used the ETEKT+ Low-E meters to determine if low-E or after-market films have been applied to the windows. Surveyors also measured the home's three largest windows and then used those measurements as the basis for estimating the areas of other windows (surveyors do not measure all the windows due to time and budget constraints).

- ***Recruitment and Survey Process Changes.*** An estimate of total conditioned floor area is now being obtained from the customer at the time of recruitment. This estimate will be used as yet another quality control check for the on-site surveys.

3

Current Building Practices for Low-Rise Residential Buildings

3.1 Introduction

This section discusses current building practices for low-rise residential buildings. In particular, on-site survey data from 801 homes, which were of first occupied between July 1, 1999 and June 30, 2000, were used to establish current building practices for building shell, HVAC systems, and water heating equipment.

The remainder of this section provides an overview of the on-site sample design, a discussion of the prescriptive requirements of Title 24, and a discussion of current building practices by climate zone and residence type.

3.2 Overview of On-Site Survey Sample Design

This section presents an overview of the sample design for the Residential Efficiency Market Share Tracking (RMST) on-site survey.[1] The overview includes a discussion on the sample frame, sample sampling plan, sample selection, and sample weights.

RMST On-Site Sample Frame

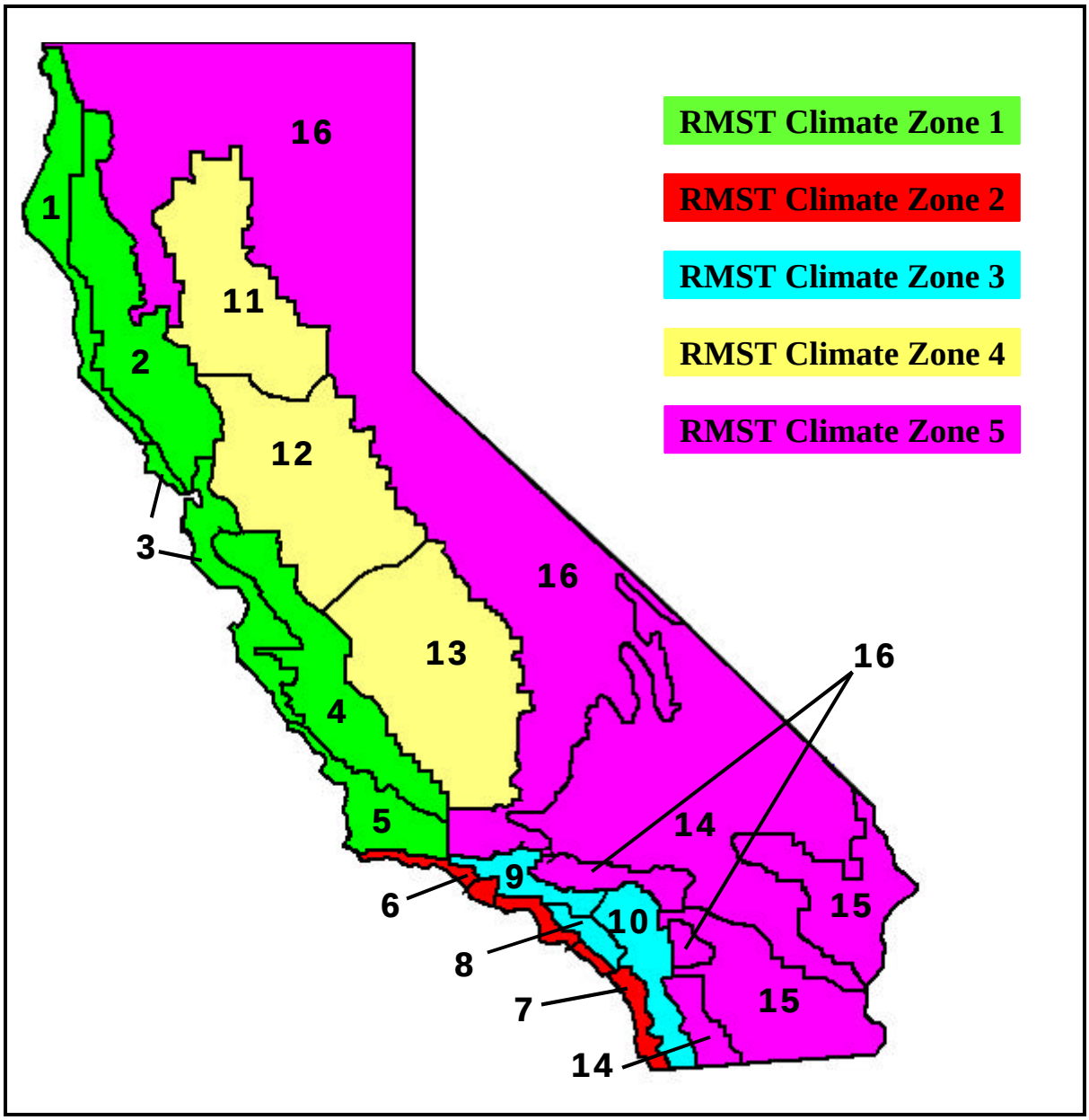
The RMST new construction sample frame was developed using customer frame data provided to RER by California's investor-owned utilities (IOUs). For purposes of developing the new construction sample frame, RER defines newly constructed homes as those first occupied between July 1, 1999 and June 30, 2000. Further, it was essential that the frame data include information on residence type and CEC climate zone.

- ***Residence Type.*** Each utility has a residence type indicator in their billing frame. These definitions vary widely and, at best, could be aggregated only into single family and multifamily designators. Common area accounts were omitted from the sample frame.

[1] See Section 2 of the *California Residential Efficiency Market Share Tracking – New Construction 2001* report for details of the sample design. Prepared by Regional Economic Research, Inc. for Southern California Edison. July 11, 2001.

- ***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.

In addition to residence type and climate zone indicators, the frame data contained an identifier that allowed the gathering of usage data, such as premise identifier, meter number, or account number.

Sampling Plan and Sample Selection

Next, RER developed the sampling plan for the on-site survey. The sample was stratified by residence type, CEC climate zone, and utility.[2] RER allocated the sample targets proportionally with some over sampling for the SDG&E service territory, for a total completed sample size of 801.[3] With the sampling plan complete, RER randomly selected the primary and secondary members of the sample-by-sample stratum.

Table 3-1 presents a summary of the combined frame used for developing the new construction survey sampling plan and the completed sample for the three electric IOU territories.

Table 3-1: On-Site Survey Sample Frame and Completed Targets

Res. Type and Climate Zone	PG&E		SCE		SDG&E	
	Sample Frame	Completed Targets	Sample Frame	Completed Targets	Sample Frame	Completed Targets
SF.CZ1	19,223	96	0	-	0	-
SF.CZ2	0	-	5,427	31	4,673	53
SF.CZ3	0	-	21,366	126	1,532	18
SF.CZ4	40,095	198	1,833	-	0	-
SF.CZ5	441	3	4,611	36	59	2
SF Total	**59,759**	**297**	**33,237**	**193**	**6,264**	**73**
MF.CZ1	8,236	47	0	-	0	-
MF.CZ2	0	-	1,355	19	3,077	29
MF.CZ3	0	-	2,233	28	593	4
MF.CZ4	6,210	47	18	-	0	-
MF.CZ5	83	-	254	9	6	-
MF Total	**14,529**	**94**	**3,860**	**56**	**3,676**	**33**
All Total	**74,288**	**391**	**37,097**	**249**	**9,940**	**106**

SF = Single Family
MF = Multifamily (Includes Attached Single Family and Multifamily Buildings)

[2] The RMST sample design also stratified the sample by six-month period.

[3] The completed targets in Table 3-1 do not sum to 801 because some of the sites surveyed were outside of the three electric IOU service territories.

Table 3-2 presents the distribution of surveyed sites by RMST climate zone, residence type, and number of stories. As shown, 22 high-rise buildings and 21 manufactured/mobile homes were surveyed. These sites are not included in the analysis.

Table 3-2: Completed On-Site Surveys[4]

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Overall	**801**	**147**	**146**	**189**	**265**	**54**
SF (detached single family)	**575**	96	84	144	210	41
1 story	**259**	30	11	50	133	35
2 story	**309**	65	72	92	74	6
3 story	**7**	1	1	2	3	0
SF-A (low-rise single family attached)	**56**	17	12	14	6	7
1 story	**14**	1	1	1	4	7
2 story	**37**	12	10	13	2	0
3 story	**5**	4	1	0	0	0
MF (low-rise multifamily)	**127**	30	36	18	41	2
2 story	**68**	11	13	9	33	2
3 story	**59**	19	23	9	8	0
High-Rise	**22**	3	14	5	0	0
Other[5]	**21**	1	0	8	8	4

4 Note that high-rise buildings are not included in the distribution since they are not included in the analysis.

5 Other includes manufactured and mobile homes.

RMST On-Site Survey Expansion Weights

RER developed expansion weights to expand the on-site data to represent to the total number of homes built within the three electric IOU territories between July 1, 1999 and June 30, 2000. The expansion weights are based on the number of households in each utility service area and CEC climate zone shown in Table 3-3.[6] In particular, the expansion weights for HVAC equipment are based on utility and climate zone, while the expansion weights for water heaters and windows are based solely on utility.

Table 3-3: New Homes Built Between July 1, 1999 and June 30, 2000

CEC Climate Zone	PG&E	SCE	SDG&E	All
CZ:1	27,459	-	-	**27,459**
CZ:2	-	6,782	7,750	**14,532**
CZ:3	-	23,599	2,125	**25,724**
CZ:4	46,305	1,851	-	**48,156**
CZ:5	524	4,865	65	**5,454**
Total	**74,288**	**37,097**	**9,940**	**121,325**

Specifically, expansion weights were calculated as follows:

$$Weight_{i,U,CZ,HT,SA} = \frac{N_{U,CZ,HT,SA}}{n_{U,CZ,HT,SA}}$$

where

$N_{U,CZ,HT,SA}$ = the total number of houses built between July 1, 1999 and July 30, 2000, by utility, climate zone, housing type, and semi-annual classification, and

$n_{U,CZ,HT,SA}$ = the number of completed sample points for houses built between July 1, 1999 and July 30, 2000, by utility, climate zone, housing type, and semi-annual classification.

[6] New construction frames from the various utilities include both single family and multifamily homes.

3.3 Reference for Evaluating Energy Efficiency Building Characteristics and Practices

The following sections provide a description of the prescriptive requirements of Title 24 and the different bases that can be used to analyze the data—statewide, CEC climate zones, RMST climate zones, glazing performance groups, and utility service areas. These reference points provide a backdrop for the analysis of typical building characteristics and practices in the residential new construction sector. Further, as will be discussed in Section 4, the statewide, utility, and climate zone breakouts provide useful insights for the compliance analysis.

Building Shell Prescriptive Requirements by CEC Climate Zone

Prescriptive Package D values[7] for construction features affecting energy efficiency are presented in Table 3-4 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-values, and maximum allowable Solar Heat Gain Coefficients (SHGC) for the 1998 Standards.

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

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

CEC CZ	Ceiling R-Value	Wall R-Value	Glazing Percent	Glazing U-Value	SHGC[8] (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	

Windows. Two values are used to rate window performance: U-value and SHGC. U-value is a measure of a window's thermal performance. The lower the U-value, 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-values and SHGCs were not observed during the on-site visits, the analysis of window efficiency 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.

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

- Clear glass, single pane, wood/vinyl frame.
- 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.

Equipment Minimum Standards

The parameters used to measure energy efficiency and the current energy efficiency standards for furnaces, air conditioners, water heaters, and windows are presented below.

Furnaces

The energy efficiency of furnaces is expressed as a percentage of Annual Fuel Utilization Efficiency (AFUE). Equipment AFUEs increase as energy efficiency increases. The federal minimum AFUE standard for furnaces is 78%.[9,10] Units must have at least a 90% AFUE to qualify for the ENERGY STAR® label.

Air Conditioners

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. SEER ratings range from 9.9 to over 15. Standard efficiency for central air conditioners is 10 SEER.[11,12] To qualify for the ENERGY STAR label, central air conditioners must have at least a 12 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.[13] Therefore, to standardize for tank size, the standard efficiency was calculated for each gas water heater in the sample. To conduct 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:

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

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

11 Required efficiency for residential central air conditioners that are less than 65 kBtu/hr.

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

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

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

where

Eff_i = Actual efficiency rating of unit *i*, and
$StdEff_i$ = $0.62 - (0.0019 \times (TankVolume_i))$.[14]

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

Region/Climate Zone Basis Options for Comparison of Construction Practices

The most straightforward way to examine current building practices and compliance is to use a statewide average for all parameters. However, due to variations across the state in weather, local building code requirements, wages, customer preferences, influence of existing RNC programs, and other issues, looking at construction techniques on only a statewide average basis would be inadequate. Therefore, both the statewide and climate zone averages are presented to allow these regional differences to be sorted out. Possible region/climate zone breakouts for use in evaluating and analyzing energy efficiency are described below and compared in Table 3-5.

- ***CEC Climate Zones.*** These 16 standard climate zones defined by the CEC are utilized for all compliance calculations, as shown in Figure 3-1. This would be the most detailed breakout to use. However, because the RMST sample for some of these climate zones is quite thin (not many new homes built in several climate zones), meaningful trends could not be discerned for those climate zones.
- ***RMST Climate Zones.*** The RMST climate zones were used to develop the RMST survey sample. These subgroups are based on CEC climate zones with similar prescriptive performance characteristics, regional proximity, and utility service areas.
- ***Performance Groups.*** These are based on the Prescriptive Package D requirements for glazing percent and window shading, as shown in Table 3-5. These are the same breakouts used in a recent CEC report on multifamily buildings.[15] Performance groups are defined as follows:
  - **16% Glazing, No Shading (*16%-NS*).** CEC Climate Zones 1, 2, 5, and 16 are in this group, which has prescriptive values of 16% glazing area and no shading requirements.

[14] 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.

[15] Regional Economic Research, Inc. July 2000. *Low-Rise Multifamily Building New Construction Characteristics Study*. Prepared for the California Energy Commission. P400-00-012.

- **16% Glazing, With Shading (*16%-WS*).** CEC Climate Zones 11, 12, 13, 14, and 15 are in this group, which has prescriptive values of 16% glazing area and shading requirements.
- **20% Glazing, No Shading (*20%-NS*).** CEC Climate Zones 3, 4, 6, and 7 are in this group, which has prescriptive values of 20% glazing area and no shading requirements.
- **20% Glazing, With Shading (*20%-WS*).** CEC Climate Zones 8, 9, and 10 are in this group, which has prescriptive values of 20% glazing area and shading requirements.

- ***Utility Service Areas.*** This would be the most difficult to use as the basis for analysis because the utility service areas for the IOUs (PG&E, SCE, SCG, and SDG&E) span multiple CEC climate zones and overlap in some areas.

For continuity with the RMST study, results for this report are presented on a statewide and RMST climate zone basis. However, other regional bases are used as needed to further examine a particular building practice or compliance issue.

Table 3-5: Comparison of Regions Used as Basis – Analyzing Results

RMST Climate Zones	CEC Climate Zones	CEC Climate Zone Reference City	Prescriptive Glazing Performance Groups	Utility Service Areas
1	CZ1	Arcata	16%-NoShading	PG&E
	CZ2	Santa Rosa	16%-NoShading	PG&E
	CZ3	Oakland	20%-NoShading	PG&E
	CZ4	Sunnyvale	20%-NoShading	PG&E/SCG
	CZ5	Santa Maria	16%-NoShading	PG&E/SCG
2	CZ6	Los Angeles	20%-NoShading	SCE/SCG
	CZ7	San Diego	20%-NoShading	SDG&E
3	CZ8	El Toro	20%-WithShading	SCE/SCG/SDG&E
	CZ9	Pasadena	20%-WithShading	SCE/SCG
	CZ10	Riverside	20%-WithShading	SCE/SCG/SDG&E
4	CZ11	Red Bluff	16%-WithShading	PG&E
	CZ12	Sacramento	16%-WithShading	PG&E
	CZ13	Fresno	16%-WithShading	PG&E/SCG
5	CZ14	China Lake	16%-WithShading	SCE/SCG/SDG&E
	CZ15	El Centro	16%-WithShading	SCE/SCG/SDG&E
	CZ16	Mount Shasta	16%-NoShading	PG&E/SCE/SCG

3.4 Current Building Practices in the Residential Sector

In this section, "typical construction practices," as reflected in the RMST survey data, are compared wherever possible to Prescriptive Package D values and minimum equipment efficiencies from the Residential Standards. These comparisons are made at the state, RMST climate zone, and residence type[16] level in order to discern regional variations in construction practices. Current construction practices for the following features are summarized below.

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

Note that for some equipment and shell characteristics, information based on observed data as well as data for the entire sample are presented. The data for the entire sample can include default data developed for use in the Title 24 compliance analysis.

Square Footage, Number of Stories, and Equipment Saturations

Table 3-6 and Table 3-7 present a summary of the square footage, number of stories, and equipment saturations by RMST climate zone for single family detached homes and multifamily buildings, respectively. Single family detached homes vary in size from an average of 2,109 square feet in RMST Climate Zone 4 to 2,756 square feet in RMST Climate Zone 2. Not surprisingly, almost all of the water heaters and central furnaces are natural gas or propane. Further, the saturation of central air conditioners increases sharply in hot dry RMST Climate Zones 3, 4, and 5.

Multifamily buildings range in size from 13,602 square feet in RMST Climate Zone 5 to 26,702 square feet in RMST Climate Zone 3. As with single family homes, natural gas and propane are the predominate fuels for water heaters and central furnaces. Again, the saturation of cooling systems increases substantially in RMST Climate Zones 3, 4, and 5.

[16] Note that in most tables and discussions, attached single family and multifamily residences are combined. However, due to interest in multifamily building codes, the results for some features have been broken out into attached single family residences and multifamily residences separately.

Table 3-6: Square Footage, Number of Stories, and Equipment Saturations – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average Square Footage	2,329	2,434	2,756	2,502	2,109	2,125
Average Number of Stories	1.5	1.7	1.9	1.7	1.4	1.2
Heating Equipment Saturation						
Central Furnace	98.2%	94.7%	98.4%	100.0%	98.5%	100.0%
Central Heat Pump	-	-	-	-	-	-
Electric Resistance	-	-	-	-	-	-
Hydronic	1.6%	4.4%	1.6%	-	1.5%	-
Radiant Heat	0.2%	0.9%	-	-	-	-
Wall Furnace	-	-	-	-	-	-
Wall Heat Pump	-	-	-	-	-	-
Water Loop Heat Pump	-	-	-	-	-	-
Cooling Equipment Saturation						
Central Air Conditioner	85.9%	46.2%	66.1%	100.0%	98.5%	100.0%
Central Heat Pump	-	-	-	-	-	-
Evaporative Cooler	-	-	-	-	-	-
Hydronic	0.2%	-	-	-	0.5%	-
No Air Conditioner	13.8%	53.8%	33.9%	-	1.0%	-
Window/Wall Air Conditioner	-	-	-	-	-	-
Window/Wall Heat Pump	-	-	-	-	-	-
Water Loop Heat Pump	-	-	-	-	-	-
Water Heater Saturation						
Electric	0.2%	-	-	-	0.5%	-
Gas	93.9%	92.9%	97.6%	96.7%	92.1%	92.0%
Propane	5.9%	7.1%	2.4%	3.3%	7.4%	8.0%
Solar	-	-	-	-	-	-

Table 3-7: Square Footage, Number of Stories, and Equipment Saturations – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average Square Footage	21,536	24,872	22,526	26,702	14,285	13,602
Average Number of Stories	2.3	2.5	2.5	2.2	2.1	1.6
Heating Equipment Saturation						
Central Furnace	38.5%	32.0%	46.6%	54.1%	24.5%	100.0%
Central Heat Pump	6.8%	3.7%	18.1%	3.4%	4.6%	-
Electric Resistance	10.1%	28.6%	5.2%	-	-	-
Hydronic	37.8%	27.9%	25.7%	25.6%	69.3%	-
Radiant Heat	0.6%	-	-	3.2%	-	-
Wall Furnace	2.3%	3.5%	2.9%	3.2%	-	-
Wall Heat Pump	4.0%	4.3%	1.6%	10.4%	1.6%	-
Water Loop Heat Pump	-	-	-	-	-	-
Cooling Equipment Saturation						
Central Air Conditioner	28.3%	14.3%	31.3%	46.2%	24.5%	100.0%
Central Heat Pump	6.8%	3.7%	18.1%	3.4%	4.6%	-
Evaporative Cooler	-	-	-	-	-	-
Hydronic	31.1%	12.3%	22.9%	19.0%	69.3%	-
No Air Conditioner	27.3%	62.8%	20.8%	17.7%	-	-
Window/Wall Air Conditioner	2.5%	2.6%	5.2%	3.2%	-	-
Window/Wall Heat Pump	4.0%	4.3%	1.6%	10.4%	1.6%	-
Water Loop Heat Pump	-	-	-	-	-	-
Water Heater Saturation						
Electric	0.4%	-	1.8%	-	-	-
Gas	99.2%	100.0%	98.2%	100.0%	98.4%	100.0%
Propane	0.5%	-	-	-	1.6%	-
Solar	-	-	-	-	-	-

Fenestration

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

Percent Glazing

Percent glazing refers to the total glazing area of a home expressed as a percent of the total conditioned floor area. The Residential Standards use two values: 16% and 20%.[17] Average percent glazing values are presented in Table 3-8 and Table 3-9 by RMST climate zone. The following observations can be made from these tables.[18]

- The average glazing percentage for detached single family homes is 17.4%, compared to 10.0% for attached single family homes and 9.0% for multifamily buildings.
- The average glazing percentage for detached single family homes is less than the prescriptive value in RMST Climate Zones 2, and 3.
- RMST Climate Zone 5 has the highest average percent glazing for both detached single family homes (18.5%) and multifamily buildings (10.9%). RMST Climate Zones 1 and 3 have the highest average percent glazing for attached single family homes (10.5% and 10.4% respectively).
- RMST Climate Zones 4 and 5 have the largest number of detached single family homes with percent glazing values more than the prescriptive value (lower performance).

Table 3-8: Percent Glazing – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Higher Performance	58%	63%	87%	73%	42%	34%
Equal to Prescriptive	1%	1%	2%	1%	0%	-
Lower Performance	42%	36%	11%	26%	57%	66%
Prescriptive		16% & 20%	20%	20%	16%	16%
Average % Glazing	17.4%	18.0%	16.5%	18.0%	16.8%	18.5%

[17] See Table 3-5 for more information.

[18] Note that for this second year of the project the on-site surveyors were given different protocols when gathering glazing information in order to improve the accuracy of their measurements.

Table 3-9: Percent Glazing – Attached Single Family Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Higher Performance	100%	100%	100%	100%	100%	100%
Equal to Prescriptive	-	-	-	-	-	-
Lower Performance	-	-	-	-	-	-
Prescriptive		20% & 16%	20%	20%	16%	16%
Average % Glazing	10.0%	10.5%	10.1%	10.4%	7.8%	9.3%

Table 3-10: Percent Glazing – Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Higher Performance	97%	100%	100%	100%	95%	50%
Equal to Prescriptive	-	-	-	-	-	-
Lower Performance	3%	-	-	-	5%	50%
Prescriptive		20% & 16%	20%	20%	16%	16%
Average % Glazing	9.0%	9.4%	8.3%	9.7%	8.7%	10.9%

Figure 3-2 and Figure 3-3 offer a more in-depth look at percent glazing values. Percent glazing values for all sites are presented versus CEC and RMST climate zone. These results suggest the following.

- Most detached single family homes in CEC climate zones with a prescriptive glazing percentage of 20% have glazing percentages below prescriptive.
- Nearly all multifamily buildings have glazing percentages below prescriptive.
- A handful of attached single family buildings have glazing percentages above prescriptive values.

Figure 3-2: Percent Glazing Values by CEC and RMST Climate Zone – Detached Single Family Homes

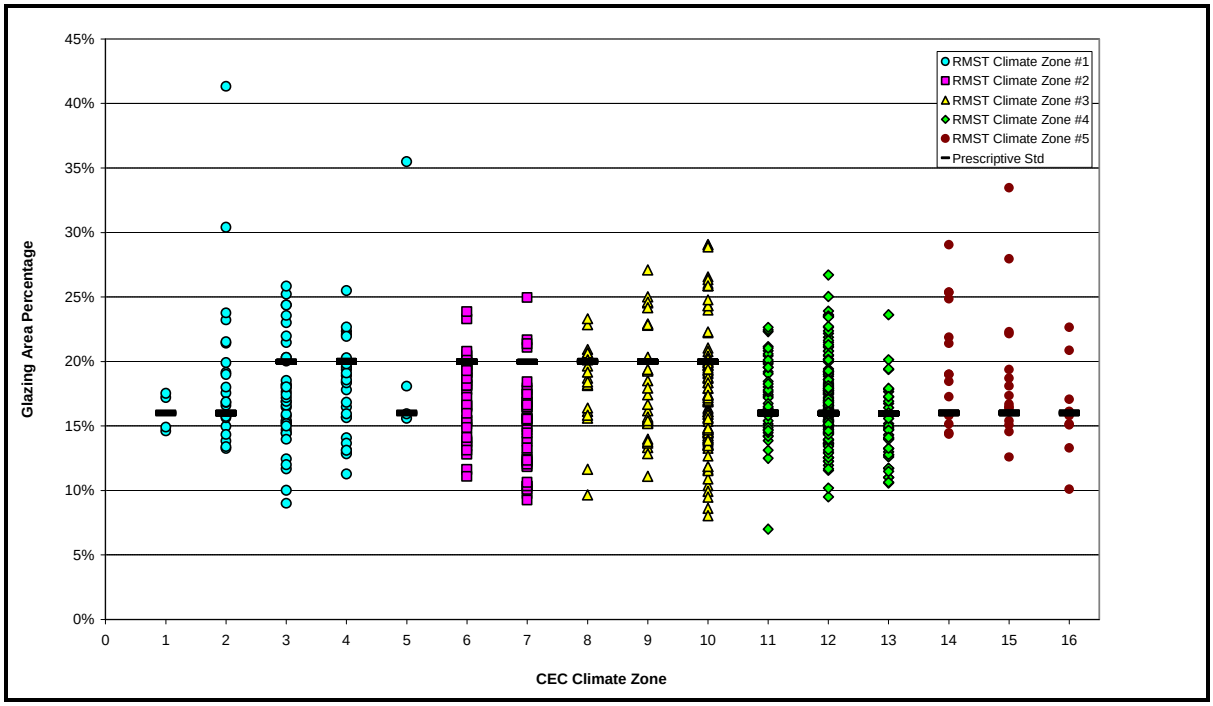
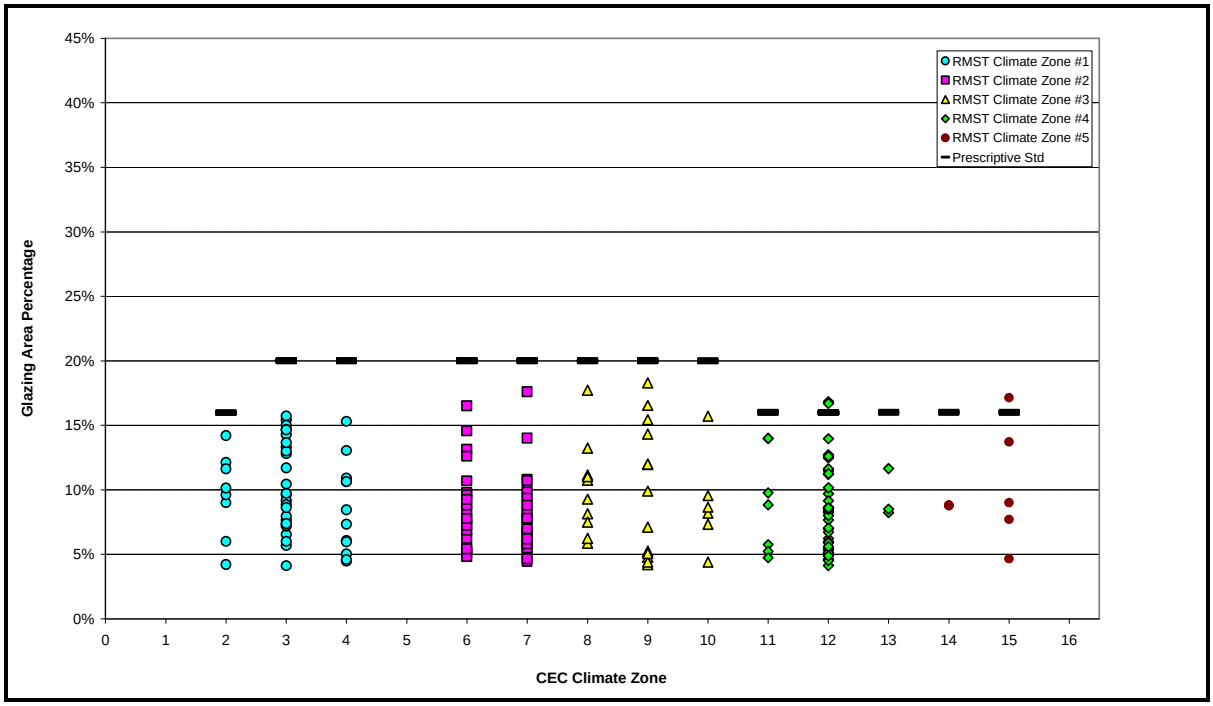


Figure 3-3: Percent Glazing Values by CEC and RMST Climate Zone – Attached Single Family and Multifamily Buildings



Window Types

Typical construction for window types—frame type, glass type, and number of panes—is presented in Table 3-11 for detached single family homes and Table 3-12 for multifamily buildings. These following results are shown.

- The predominant window type for all building types is vinyl-framed, dual-paned, clear glass (75% for detached single family homes, 79% for attached single family homes, and 70% multifamily buildings).
- A large percentage of detached single family homes in RMST Climate Zone 4 (36%) have dual-paned metal-framed windows.
- Attached single family homes in both RMST Climate Zones 1 and 4 also have a large percentage of dual-paned metal-framed windows (26% and 28%, respectively).
- While most windows in multifamily buildings are vinyl-framed, dual-paned, clear glass windows, there are a large number of homes in RMST Climate Zones 4 and 5 with metal-frame windows in (60% and 50%, respectively). It is important to note here that nearly all of the metal-framed windows in RMST Climate Zone 4 are dual-paned, while all of the metal-framed windows in RMST Climate Zone 5 are single-paned.

Table 3-11: Distribution of Window Types – Detached Single Family Homes

Window Types (# of panes, frame type, glass type)	**Statewide**	**RMST CZ1**	**RMST CZ2**	**RMST CZ3**	**RMST CZ4**	**RMST CZ5**
2-paned Vinyl, Clear Glass	75.2%	86.2%	98.7%	97.3%	48.0%	96.8%
2-paned Metal, Clear Glass	13.6%	5.5%	-	0.5%	30.0%	3.2%
2-paned Vinyl, Low-E	7.7%	7.4%	-	0.7%	15.1%	-
2-paned Metal, Low-E	2.6%	0.9%	-	-	5.8%	-
1-paned Vinyl, Clear Glass	0.4%	-	-	0.8%	0.5%	-
1-paned Metal, Clear Glass	-	-	-	-	-	-
2-paned Vinyl, Tinted/Reflective	0.5%	-	1.3%	0.7%	0.5%	-
2-paned Metal, Tinted/Reflective	-	-	-	-	-	-

Table 3-12: Distribution of Window Types – Attached Single Family Buildings

Window Types (# of panes, frame type, glass type)	**Statewide**	**RMST CZ1**	**RMST CZ2**	**RMST CZ3**	**RMST CZ4**	**RMST CZ5**
2-paned Vinyl, Clear Glass	79.3%	62.5%	100.0%	93.4%	54.1%	100.0%
2-paned Metal, Clear Glass	12.4%	25.7%	-	-	27.6%	-
2-paned Vinyl, Low-E	6.4%	11.9%	-	-	18.3%	-
2-paned Metal, Low-E	-	-	-	-	-	-
1-paned Vinyl, Clear Glass	2.0%	-	-	6.6%	-	-
1-paned Metal, Clear Glass	-	-	-	-	-	-
2-paned Vinyl, Tinted/Reflective	-	-	-	-	-	-
2-paned Metal, Tinted/Reflective	-	-	-	-	-	-

Table 3-13: Distribution of Window Types – Multifamily Buildings

Window Types (# of panes, frame type, glass type)	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
2-paned Vinyl, Clear Glass	69.8%	80.3%	90.4%	100.0%	37.4%	50.0%
2-paned Metal, Clear Glass	24.4%	16.8%	-	-	57.2%	-
2-paned Vinyl, Low-E	0.9%	2.9%	-	-	-	-
2-paned Metal, Low-E	-	-	-	-	-	-
1-paned Vinyl, Clear Glass	2.1%	-	9.6%	-	-	-
1-paned Metal, Clear Glass	2.0%	-	-	-	2.7%	50.0%
2-paned Vinyl, Tinted/Reflective	-	-	-	-	-	-
2-paned Metal, Tinted/Reflective	0.9%	-	-	-	2.7%	-

Fenestration Average U-Values

The following tables use average U-values as 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 3-15 for detached single family homes and Table 3-16 for multifamily buildings. Table 3-14 provides a reference against which to evaluate the average U-values computed in these tables.

Table 3-14: Default Window Thermal Performance Values

RMST Survey Fields and Descriptions				Default Values	
Frame Type	Number of Panes	Glazing Type	Grids/ Muntins	U-Value	SC/SHGC
Vinyl	2	Clear	Yes	0.60	0.88/0.65
Vinyl	2	Tinted/Refl	Yes	0.60	0.74/0.53
Vinyl	2	Low-E	Yes	0.37	0.58/0.41
Metal	2	Clear	Yes	0.75	0.88/0.70
Metal	2	Tinted/Refl	Yes	0.75	0.74/0.59

The following results are shown in Table 3-15 and Table 3-16.

- The average U-value for detached single family homes is approximately 0.59. U-values range from 0.58 to 0.60 across RMST climate zones.

- There is more variation in average U-values across climate zones for multifamily buildings. RMST Climate Zone 3 has the lowest average U-value at 0.613, while the sites in RMST Climate Zone 5 have an average U-value of 0.816.
- Nearly all of the windows in both detached single family homes and multifamily buildings in RMST Climate Zones 2 and 3 are vinyl framed.
- For detached single family homes, nearly 36% in RMST Climate Zone 4 have metal-framed windows, while close to 5% of the homes in RMST Climate Zones 1 and 5 do.
- For multifamily buildings, RMST Climate Zone 4 has the highest percentage of homes with metal-framed windows (58.4), while in RMST Climate Zones 1 and 5 the percentages are 19.7% and 31.8%, respectively.

Table 3-15: Average Window U-Values – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Higher Performance	85%	95%	100%	99%	68%	90%
Equal to Prescriptive	1%	3%	-	1%	1%	3%
Lower Performance	14%	1%	-	1%	31%	8%
Average U-Value	0.595	0.583	0.589	0.592	0.604	0.598
% of Sites w/Metal Frames	16.2%	6.4%	0.0%	0.5%	35.9%	3.2%

Table 3-16: Average Window U-Values – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Higher Performance	75%	82%	90%	97%	40%	68%
Equal to Prescriptive	6%	18%	-	-	-	-
Lower Performance	20%	-	10%	3%	60%	32%
Average U-Value	0.645	0.616	0.638	0.613	0.689	0.816
% of Sites w/Metal Frames	23.0%	19.7%	0.0%	0.0%	58.4%	31.8%

Space Heating Systems

A summary of space heating systems characteristics for units installed in newly constructed homes is discussed in this section. These characteristics include average system efficiencies,

system type, and duct location. Note that efficiency results focus exclusively on gas-fueled systems because there are so few electric systems in the sample.

Equipment Type and Location

A distribution of the space heating system equipment types and locations are presented in Table 3-17 for detached single family homes and Table 3-18 for multifamily buildings. Results are as follows.

- Detached single family space heating systems are predominantly furnaces (98.2%), with a small number of radiant heating units located in RMST Climate Zone 1 (0.9%) and hydronic systems in RMST Climate Zones 1, 2, and 4 (4.4%, 1.6%, and 1.5%, respectively). Most space heating system units (76% statewide) are located in the attic.
- Heating equipment types in multifamily buildings are much more diverse. Statewide, central furnaces and hydronic systems are nearly tied at approximately 38% each. There are also many more heat pumps (10.8%) and even some electric resistance heating (10.1%) being used, though these are only in RMST Climate Zones 1 and 2. Heat pumps are probably more popular in multifamily residences because they eliminate the need to pipe gas to all units.
- RMST Climate Zone 4 has the largest percentage of hydronic systems (69%) for multifamily homes.

Table 3-17: Space Heating Equipment Type and Location – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Equipment Type						
Central Furnace	98.2%	94.7%	98.4%	100.0%	98.5%	100.0%
Central Heat Pump	-	-	-	-	-	-
Electric Resistance	-	-	-	-	-	-
Hydronic	1.6%	4.4%	1.6%	-	1.5%	-
Radiant Heat	0.2%	0.9%	-	-	-	-
Wall Furnace	-	-	-	-	-	-
Wall Heat Pump	-	-	-	-	-	-
Water Loop Heat Pump	-	-	-	-	-	-
Equipment Location						
Attic	76.4%	46.7%	87.5%	90.0%	79.4%	74.9%
Garage	10.6%	31.5%	1.8%	5.8%	5.9%	11.6%
Conditioned Space	0.5%	2.1%	1.6%	-	-	-
Other	12.5%	19.8%	9.1%	4.2%	14.7%	13.5%

Table 3-18: Space Heating Equipment Type and Duct Location – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Equipment Type						
Central Furnace	38.5%	32.0%	46.6%	54.1%	24.5%	100.0%
Central Heat Pump	6.8%	3.7%	18.1%	3.4%	4.6%	-
Electric Resistance	10.1%	28.6%	5.2%	-	-	-
Hydronic	37.8%	27.9%	25.7%	25.6%	69.3%	-
Radiant Heat	0.6%	-	-	3.2%	-	-
Wall Furnace	2.3%	3.5%	2.9%	3.2%	-	-
Wall Heat Pump	4.0%	4.3%	1.6%	10.4%	1.6%	-
Water Loop Heat Pump	-	-	-	-	-	-
Equipment Location						
Attic	27.2%	18.4%	25.8%	54.9%	16.1%	77.7%
Garage	6.1%	3.9%	2.0%	-	16.4%	-
Conditioned Space	22.8%	35.7%	14.4%	19.8%	18.3%	-
Other	43.9%	41.9%	57.8%	25.3%	49.3%	22.3%

Equipment Efficiency

Table 3-19 and Table 3-20 present a summary of gas space heating system efficiencies for detached single family homes and multifamily buildings, respectively. Key findings are highlighted below.

- The average statewide and RMST climate zone efficiencies are above the minimum standard efficiency of 78% AFUE. The statewide average for both detached single family homes and multifamily buildings is approximately 80.5% AFUE.
- Penetration of high efficiency space heating units (>90% AFUE) is very low—2.8% for detached single family homes. RMST Climate Zone 4 has the largest percentage of both detached single family homes and multifamily buildings with high efficiency space heating units (5.2% and 11.8%, respectively).
- Space heating system efficiencies were collected for a slightly larger percentage of detached single family homes than for multifamily buildings—82% versus 76%, respectively. This was due primarily to the inaccessibility of HVAC units in multifamily (typically rental) units. In these situations, the units are usually locked

up and accessible only to the property manager and not to the occupant (and hence not to the surveyor).

Table 3-19: Gas Space Heating System Efficiency – Detached Single Family Homes

Analysis Parameter Description	Statewide Average	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average Efficiency (AFUE)*	80.52	80.73	80.12	80.11	80.81	80.45
>= 78% and <= 80% AFUE*	91.9%	90.5%	92.0%	96.2%	90.2%	89.4%
> 80% and <= 90% AFUE*	5.3%	5.7%	8.0%	3.8%	4.6%	10.2%
> 90% AFUE*	2.8%	3.8%	-	-	5.2%	0.5%
% of sites with observed data	82.4%	94.6%	91.1%	83.4%	75.1%	77.3%
% of sites with default values	17.6%	5.4%	8.8%	16.6%	24.9%	22.7%
Default AFUE	80.00	80.00	80.00	80.00	80.00	80.00
Average AFUE including defaults	80.43	80.69	80.11	80.09	80.61	80.34

* Of observed data.

Table 3-20: Gas Space Heating System Efficiency – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide Average	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average Efficiency (AFUE)*	80.53	80.07	80.00	80.74	81.66	80.00
>= 78% and <= 80% AFUE*	94.4%	94.1%	100.0%	94.8%	88.2%	100.0%
> 80% and <= 90% AFUE*	2.0%	5.9%	-	-	-	-
> 90% AFUE*	3.6%	-	-	5.2%	11.8%	-
% of sites with observed data	76.0%	92.7%	47.0%	84.0%	83.5%	68.2%
% of sites with default values	24.0%	7.3%	53.0%	16.0%	16.4%	31.8%
Default AFUE	80.00	80.00	80.00	80.00	80.00	80.00
Average AFUE including defaults	80.40	80.07	80.00	80.62	81.39	80.00

* Of observed data.

Space Cooling System

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

Equipment Type and Location

A distribution of the space cooling system equipment types and locations is presented in Table 3-21 for detached single family homes and Table 3-22 for multifamily buildings. Key findings are highlighted below.

- For detached single family homes, the predominant space cooling system is a conventional central air conditioner (85.9%). However, 13.8% of the homes do not have air conditioning and a small number of sites have a hydronic system (0.2%).
- Space cooling equipment is typically installed in the attic of detached single family homes (81.6%).
- For multifamily buildings, a much more diverse range of equipment types is used. Unlike detached single family homes, central air conditioners are not the predominant system (28.3%). Instead, approximately 31% of multifamily buildings have a hydronic system installed. In addition, 27.3% of multifamily buildings statewide do not have air conditioning.
- Unlike detached single family homes, some multifamily buildings have window/wall cooling units—2.5% have window/wall air conditioners and 4.0% have window/wall heat pumps.

Table 3-21: Space Cooling Equipment Types – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Equipment Type						
Central Air Conditioner	85.9%	46.2%	66.1%	100.0%	98.5%	100.0%
Central Heat Pump	-	-	-	-	-	-
Evaporative Cooler	-	-	-	-	-	-
Hydronic	0.2%	-	-	-	0.5%	-
No Air Conditioner	13.8%	53.8%	33.9%	-	1.0%	-
Window/Wall Air Conditioner	-	-	-	-	-	-
Window/Wall Heat Pump	-	-	-	-	-	-
Water Loop Heat Pump	-	-	-	-	-	-
Equipment Location						
Attic	81.6%	64.9%	87.5%	90.0%	80.3%	74.9%
Garage	7.3%	18.8%	2.0%	5.8%	6.0%	11.6%
Other	11.1%	16.3%	10.5%	4.2%	13.8%	13.5%

Table 3-22: Space Cooling Equipment Types – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Equipment Type						
Central Air Conditioner	28.3%	14.3%	31.3%	46.2%	24.5%	100.0%
Central Heat Pump	6.8%	3.7%	18.1%	3.4%	4.6%	-
Evaporative Cooler	-	-	-	-	-	-
Hydronic	31.1%	12.3%	22.9%	19.0%	69.3%	-
No Air Conditioner	27.3%	62.8%	20.8%	17.7%	-	-
Window/Wall Air Conditioner	2.5%	2.6%	5.2%	3.2%	-	-
Window/Wall Heat Pump	4.0%	4.3%	1.6%	10.4%	1.6%	-
Water Loop Heat Pump	-	-	-	-	-	-
Equipment Location						
Attic	36.5%	35.0%	28.9%	71.4%	19.7%	77.7%
Garage	8.4%	5.8%	-	-	20.0%	-
Other	55.1%	59.2%	71.1%	28.6%	60.3%	22.3%

Equipment Efficiency

Results for cooling system efficiencies are presented in Table 3-23 for detached single family homes and Table 3-24 for multifamily buildings. Results are highlighted below.

- For detached single family homes, statewide and RMST climate zone average efficiencies are higher than the minimum efficiency (10 SEER).
- Higher than standard efficiency is the result of sizeable penetration of high efficiency equipment (>11 SEER) for detached single family homes (24.3% statewide), especially in RMST Climate Zone 4 (40.7%).
- For multifamily buildings, average efficiencies are lower than detached single family homes and much closer to the minimum standard (10.07 versus 10.64).
- Space cooling system efficiencies were collected for a larger percent of detached single family homes than for multifamily buildings (69.4% and 52.9%, respectively). This was due primarily to the inaccessibility of HVAC units in multifamily (typically rental) units. In these situations, the units are usually locked up and accessible only to the property manager and not to the occupant (and hence not to the surveyor).

Table 3-23: Central Air Conditioner Efficiency – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average Efficiency (SEER) *	10.64	10.48	10.24	10.22	10.95	10.48
<= 10 SEER*	44.7%	29.0%	64.3%	58.6%	36.6%	63.3%
> 10 and <= 11 SEER*	31.1%	60.6%	30.2%	39.4%	22.7%	14.9%
> 11 and <= 12 SEER*	21.1%	7.6%	5.5%	2.0%	35.2%	21.1%
> 12 and <= 13 SEER*	2.6%	-	-	-	4.9%	0.6%
> 13 and <= 14 SEER*	0.6%	2.7%	-	-	0.6%	-
> 14 SEER*	-	-	-	-	-	-
% of sites w/ observed efficiency	69.4%	42.0%	58.5%	67.7%	87.5%	57.9%
% of sites w/ default efficiency	30.6%	58.0%	41.5%	32.3%	12.5%	42.0%
Default SEER	10.00	10.00	10.00	10.00	10.00	10.00
Average SEER for all sites (including defaults)	10.45	10.20	10.14	10.15	10.83	10.28

* Of observed data.

Table 3-24: Space Cooling System Efficiency – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average Efficiency (SEER) *	10.07	10.08	10.02	10.04	10.10	10.05
<= 10 SEER*	81.2%	59.3%	91.6%	66.2%	93.3%	56.8%
> 10 and <= 11 SEER*	16.4%	40.7%	8.4%	33.8%	1.9%	43.2%
> 11 and <= 12 SEER*	1.4%	-	-	-	2.8%	-
> 12 and <= 13 SEER*	1.0%	-	-	-	1.9%	-
> 13 and <= 14 SEER*	-	-	-	-	-	-
> 14 SEER*	-	-	-	-	-	-
% of sites w/ observed efficiency	52.9%	28.4%	47.3%	41.0%	89.6%	95.3%
% of sites w/ default efficiency	47.1%	71.6%	52.7%	59.0%	10.4%	4.7%
Default SEER	10.00	10.00	10.00	10.00	10.00	10.00
Average SEER for all sites (including defaults)	10.04	10.02	10.01	10.02	10.09	10.05

* Of observed data.

Multiple HVAC Systems and Thermostat Types

Multiple HVAC systems and thermostat type can have a significant impact on energy use. A summary of the percent of homes with multiple units and thermostat types is presented in Table 3-25 for detached single family homes and Table 3-26 for attached single family and multifamily buildings. Results are highlighted below.

- Approximately 10% of detached single family homes have two HVAC units. Multiple HVAC systems are even more prevalent in RMST Climate Zone 2 (21.9%).
- Digital thermostats are the most common thermostat type (92.7% statewide). A small number of electromechanical thermostats are still being used (5.3% statewide), especially in RMST Climate Zones 5 and 2 (19.1% and 12.2%, respectively).[19]
- No home automation systems were found.
- For multifamily buildings, only 0.9% of the residences two HVAC units.

[19] The installation of electromechanical thermostats has decreased since the first year of the study, however, when the statewide average for detached single family homes was 26%.

- Digital thermostats are also the most common thermostat type for multifamily buildings (74.6% statewide). There are also a large number of electromechanical thermostats installed in multifamily buildings (21.3%), while 2.6% were found to have hybrid thermostats installed.

Table 3-25: Multiple HVAC Systems and Thermostat Types – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Number of HVAC Systems						
1	90.1%	90.1%	78.1%	85.8%	93.8%	100.0%
2	9.9%	9.9%	21.9%	14.2%	6.2%	-
Thermostat Types						
Digital	92.7%	94.7%	87.9%	95.4%	93.5%	80.9%
Electromechanical	5.3%	5.3%	12.2%	4.6%	1.8%	19.1%
Hybrid	1.9%	-	-	-	4.7%	-
Home Automation System	-	-	-	-	-	-
None	-	-	-	-	-	-
Other	-	-	-	-	-	-

Table 3-26: Multiple HVAC Systems and Thermostat Types – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Number of HVAC Systems						
1	99.1%	98.3%	98.3%	100.0%	100.0%	100.0%
2	0.9%	1.7%	1.7%	-	-	-
Thermostat Types						
Digital	74.6%	59.0%	76.1%	79.1%	86.4%	95.3%
Electromechanical	21.3%	38.3%	23.9%	17.7%	4.0%	4.7%
Hybrid	2.6%	-	-	-	9.5%	-
Home Automation System	-	-	-	-	-	-
None	-	-	-	-	-	-
Other	1.4%	2.6%	-	3.2%	-	-

Water Heating

A summary of water heating equipment characteristics for units installed in newly constructed homes is discussed in this section. These characteristics include average system efficiencies, system types, and fuel types.

Equipment Type, Fuel Type, and Use of Recirculation Pumps

Distributions of water heating equipment types and the use of recirculation pumps and fuel types are presented in Table 3-27 and Table 3-29 for detached single family homes and Table 3-28, Table 3-30, and Table 3-31 for attached single family and multifamily buildings. Key findings are highlighted below.

- For detached single family homes and attached single family homes, the conventional storage-type water heater is the most predominant system type (99.2% and 94.2% respectively). For detached single family homes, natural gas fueled units are most common (93.3%), followed by propane (5.9%), while all of the storage-type water heaters in attached single family homes surveyed were natural gas fueled units.
- Of detached single family homes statewide, 8.0% utilize recirculation pumps in their water heating systems. Recirculation pumps are used primarily in RMST Climate Zones 1 and 2 (22.8% and 12.8%, respectively).
- For multifamily buildings, the conventional gas fueled storage-type water heater is also the predominant system type (73.8%). However, 23.9% of all multifamily

buildings have central water heaters. Specifically, while 42.7% of three-story multifamily buildings have central water heaters, only 8.1% of two-story multifamily buildings have these.

- Of attached single family homes and multifamily buildings statewide, 9.2% utilize recirculation pumps in their water heating systems. This is only slightly higher than reported for detached single family homes (8.0%).
- Statewide, 99.2% of the detached single family homes have water heaters that are gas fueled. Small percentages of electric instantaneous water heaters were found in RMST Climate Zone 4 (0.5%).
- Statewide, only 1.0% of detached single family homes had two water heaters.

Table 3-27: Water Heating Fuel Type and Presence of Recirculation Pumps – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Style/Fuel Type						
Boiler	0.6%	3.2%	-	-	-	-
Storage/Standard – NatGas	93.3%	89.6%	97.6%	96.7%	92.1%	92.0%
Storage/Standard – Propane	5.9%	7.1%	2.4%	3.3%	7.4%	8.0%
Instantaneous – Electric	0.2%	-	-	-	0.5%	-
Systems w/Recirculating Pumps	8.0%	22.8%	12.8%	2.1%	4.9%	-

Table 3-28: Water Heating Fuel Type and Presence of Recirculaiton Pump – Attached Single Family and Multifamily Buildings

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
SF-A (single family attached)						
1 story						
Central System	9.0%	0.0%	0.0%	0.0%	20.9%	0.0%
Storage/Standard – NatGas	91.0%	100.0%	100.0%	100.0%	79.1%	100.0%
2 story						
Boiler	3.0%	8.8%	0.0%	0.0%	0.0%	-
Central System	3.0%	8.8%	0.0%	0.0%	0.0%	-
Storage/Standard – NatGas	94.0%	82.3%	100.0%	100.0%	100.0%	-
3 story						
Storage/Standard – NatGas	100.0%	100.0%	100.0%	-	-	-
MF (multifamily buildings)						
2 story						
Central System	8.1%	10.2%	19.4%	27.1%	0.0%	0.0%
Storage/Standard – NatGas	90.7%	89.8%	80.6%	72.9%	97.7%	100.0%
Storage/Standard – Propane	1.2%	0.0%	0.0%	0.0%	2.3%	0.0%
3 story						
Boiler	2.5%	6.2%	0.0%	0.0%	0.0%	-
Central System	42.7%	72.4%	6.9%	62.9%	25.6%	-
Storage/Standard – ElecResist	1.2%	0.0%	3.6%	0.0%	0.0%	-
Storage/Standard – NatGas	53.6%	21.3%	89.6%	37.1%	74.4%	-
Systems w/Recirculating Pumps	9.2%	24.0%	4.8%	-	2.2%	-

Table 3-29: Water Heaters – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Natural Gas	93.9%	92.9%	97.6%	96.7%	92.1%	92.0%
Propane	5.9%	7.1%	2.4%	3.3%	7.4%	8.0%
Electric	0.2%	-	-	-	0.5%	-
Solar	-	-	-	-	-	-
sites w/1 Water Heater	99.0%	98.9%	100.0%	100.0%	98.1%	100.0%
sites w/2 Water Heaters	1.0%	1.1%	-	-	1.9%	-

Table 3-30: Water Heaters – Attached Single Family Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Natural Gas	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Propane	-	-	-	-	-	-
Electric	-	-	-	-	-	-
Solar	-	-	-	-	-	-

Table 3-31: Water Heaters – Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Natural Gas	98.8%	100.0%	97.5%	100.0%	98.1%	100.0%
Propane	0.6%	-	-	-	1.9%	-
Electric	0.5%	-	2.5%	-	-	-
Solar	-	-	-	-	-	-

Equipment Efficiency

A summary of water heating system efficiencies is presented in Table 3-42 for detached single family homes and Table 3-33 for 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. 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. Key findings from these data include the following.

- The average % above minimum efficiency values for sites with actual data is 13.4% for multifamily buildings and 15.6% for detached single family buildings.

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, especially in those climate zones with mild weather.

Table 3-32: Gas Water Heater Efficiency – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average % above standard*	15.6%	14.4%	15.5%	16.0%	16.0%	15.8%
% sites w/actual data	79.8%	86.2%	73.0%	83.0%	75.2%	89.3%
% sites w/default values	18.1%	10.6%	23.9%	16.4%	22.8%	7.8%
% sites w/CEC default values	2.1%	3.2%	3.1%	0.6%	2.0%	2.9%
Average % above std inc. defaults	15.1%	13.8%	14.9%	15.7%	15.5%	15.0%

* Of observed data.

Table 3-33: Gas Water Heater Efficiency – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average % above standard*	13.4%	14.2%	11.2%	14.9%	13.6%	13.1%
% sites w/actual data	62.8%	44.8%	66.8%	63.0%	78.0%	90.5%
% sites w/default values	15.0%	14.1%	21.7%	12.1%	13.4%	9.3%
% sites w/CEC default values	22.1%	41.1%	11.5%	24.9%	8.6%	0.1%
Average % above std inc. defaults	10.7%	8.3%	10.6%	11.4%	12.8%	13.3%

* Of observed data.

Water Heater Efficiency and Water Heater Blanket

Under the 1995 Standards, a significant credit could be obtained by adding an external insulating blanket to an already high efficiency water heater using the performance compliance method. However, this credit was removed from the 1998 Standards. Results for this aspect of water heating are shown in Table 3-34 for detached single family homes and Table 3-35 for multifamily buildings. Key findings are summarized below.

- For detached single family homes, 64.7% of water heaters have EFs better than the standard minimum and do not have blankets. However, a substantial number (33.2%) are high efficiency and have blankets.
- All RMST climate zones have some high efficiency units with blankets, but RMST Climate Zone 4 has the largest percentage with 51.5% of water heaters that are high efficiency and also have blankets.
- For multifamily buildings, using high efficiency water heaters without blankets is the predominant practice (70.4%).
- Nearly 8% of multifamily buildings statewide have high efficiency water heaters with blankets.

Table 3-34: Water Heater Efficiency and Blanket Status – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
EF < Std EF, No blanket	0.2%	1.1%	-	-	-	-
EF = Std EF, No blanket	0.8%	3.2%	-	-	-	2.9%
EF > Std EF, No blanket	64.7%	84.4%	65.9%	72.1%	47.0%	89.3%
EF < Std EF, Blanket present	-	-	-	-	-	-
EF = Std EF, Blanket present	1.1%	-	3.1%	0.6%	1.5%	-
EF > Std EF, Blanket present	33.2%	11.3%	31.0%	27.3%	51.5%	7.8%

Table 3-35: Water Heater Efficiency and Blanket Status – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
EF < Std EF, No blanket	-	-	-	-	-	-
EF = Std EF, No blanket	21.8%	41.1%	9.8%	24.9%	8.6%	-
EF > Std EF, No blanket	70.4%	55.2%	85.2%	62.0%	79.6%	100.0%
EF < Std EF, Blanket present	-	-	-	-	-	-
EF = Std EF, Blanket present	-	-	-	-	-	-
EF > Std EF, Blanket present	7.8%	3.7%	5.0%	13.1%	11.8%	-

Building Shell Characteristics

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

Ceiling Insulation

Current ceiling insulation practices are summarized in Table 3-36 for detached single family homes and Table 3-37 for attached single family and multifamily buildings. Note that these results are presented with respect to performance versus prescriptive values (higher performance, equal to prescriptive, lower performance). Note also that the Residential Standards require a minimum of R-19 ceiling insulation to be installed. Key findings are summarized below.

- Actual ceiling insulation values were gathered for only 24% of detached single family homes statewide. However, this value was as high as 61% in RMST Climate Zone 1 and as low as 0% in RMST Climate Zone 5. Default values used for the MICROPAS runs were developed for each CEC climate zone from the actual values.
- For detached single family homes, 45% statewide have ceiling insulation levels that are lower than the prescriptive values.
- Approximately 1% of the detached single family homes statewide have ceiling insulation levels that exceed the prescriptive values, all of these are located primarily in RMST Climate Zone 1.
- Actual ceiling insulation values were gathered for only 15% of multifamily buildings statewide.

Table 3-36: Ceiling Insulation – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average R-Value*	30.7	29.6	30.0	30.0	31.7	-
Average % difference from Prescriptive*	-9.4%	-2.7%	0.0%	0.0%	-16.5%	-
Higher Performance*	1%	2%	-	-	-	-
Equal to Prescriptive*	54%	85%	100%	100%	20%	-
Lower Performance*	45%	13%	-	-	80%	-
% of sites w/actual data	24%	61%	3%	2%	28%	-
% of sites w/default values	76%	39%	97%	98%	72%	100%
Average % difference from Prescriptive	-23.9%	0.0%	-36.7%	-36.7%	-21.1%	0.0%
Average % difference from Prescriptive inc defaults	-20.5%	-1.6%	-35.5%	-35.9%	-19.8%	0.0%

* Of observed data.

Table 3-37: Ceiling Insulation – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average R-Value*	27.7	30.0	-	19.0	20.4	-
Average % difference from Prescriptive*	-10.3%	0.0%	-	-36.7%	-46.3%	-
Higher Performance*	-	-	-	-	-	-
Equal to Prescriptive*	77%	100%	-	-	-	-
Lower Performance*	23%	-	-	100%	100%	-
% of sites w/actual data	15%	35%	-	3%	10%	-
% of sites w/default values	85%	65%	100%	97%	90%	100%
Average % difference from Prescriptive	-22.5%	0.0%	-36.7%	-36.7%	-21.1%	0.0%
Average % difference from Prescriptive inc defaults	-20.7%	0.0%	-36.7%	-36.7%	-23.6%	0.0%

* Of observed data.

Wall Insulation

Wall insulation practices are summarized in Table 3-38 for detached single family homes and Table 3-39 for attached single family and multifamily buildings. Both tables show that very little actual data on wall insulation were gathered for either detached single family homes or multifamily buildings (only 18% and 12%, respectively). A high reliance on default values was the result, and defaults were set at prescriptive values. The Residential Standards require a minimum of R-13 wall insulation and there is limited space for insulation in a 2×4 stud frame.

Table 3-38: Wall Insulation – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average R-Value*	15.6	18.0	19.0	13.0	14.4	19.0
Average % difference from Prescriptive*	-4.4%	34.9%	46.2%	0.0%	-24.3%	-9.5%
Higher Performance*	26%	75%	100%	-	2%	-
Equal to Prescriptive*	15%	15%	-	100%	14%	-
Lower Performance*	59%	10%	-	-	85%	100%
% of sites w/actual data	18%	30%	2%	1%	28%	3%
% of sites w/default values	82%	70%	98%	99%	72%	97%
Average % difference from Prescriptive	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Average % difference from Prescriptive inc defaults	-0.8%	10.4%	0.7%	0.0%	-6.8%	-0.3%

* Of observed data.

Table 3-39: Wall Insulation – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average R-Value*	17.9	18.8	-	-	13.0	-
Average % difference from Prescriptive*	33.2%	44.4%	-	-	-31.6%	-
Higher Performance*	78%	92%	-	-	-	-
Equal to Prescriptive*	7%	8%	-	-	-	-
Lower Performance*	15%	-	-	-	100%	-
% of sites w/actual data	12%	31%	-	-	6%	-
% of sites w/default values	88%	69%	100%	100%	94%	100%
Average % difference from Prescriptive	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Average % difference from Prescriptive inc defaults	3.8%	13.8%	0.0%	0.0%	-2.0%	0.0%

* Of observed data.

Radiant Barrier and Framing Practices

Radiant barriers and framing materials can also have a significant impact on energy use. A summary of this information is included in Table 3-40 for detached single family homes and Table 3-41 for attached single family and multifamily buildings. Key findings are summarized below.

- Radiant barriers are installed in only 3.5% of detached single family homes statewide. RMST Climate Zone 4 has the highest penetration of radiant barriers (6.8%).
- Metal framing was not used in detached single family homes statewide and in only 1.8% of multifamily buildings. Multifamily buildings with metal framing are concentrated primarily in RMST Climate Zone 1 (4.5%), but there are a few sites in RMST Climate Zone 2 (1.8%).

Table 3-40: Radiant Barrier and Framing Practices – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Radiant barriers installed						
No	96.5%	100.0%	98.1%	97.9%	93.2%	100.0%
Yes	3.5%	-	1.9%	2.1%	6.8%	-
Framing						
Metal	-	-	-	-	-	-
Wood	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 3-41: Radiant Barrier and Framing Practices – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Radiant barriers installed						
No	98.7%	100.0%	100.0%	100.0%	95.2%	100.0%
Yes	1.3%	-	-	-	4.8%	-
Framing						
Metal	1.8%	4.5%	1.8%	-	-	-
Wood	98.2%	95.5%	98.2%	100.0%	100.0%	100.0%

HVAC Duct System

Duct leakage and duct construction practices, material types, sealant types, and location are summarized and discussed below.

Duct Leakage Rate

Duct blaster tests[20] to determine duct leakage rates were conducted for a sub-sample of 100 of the 800 RMST surveyed sites. Of these sites, 84 were valid MICROPAS sites. Test results are contained in Table 3-42 for detached single family homes and Table 3-43 for attached single family and multifamily buildings. Results are presented in four numeric

[20] Duct leakage rates are obtained from duct blaster tests by isolating the duct system, sealing all other outlets such as registers and plenums, pressurizing the duct system, and in this configuration, recording air flow through the duct system, which is the measured leakage rate. Duct blaster tests were conducted at 25 KPa, as described in Appendix C of the RMST report.

categories of leakage. A fifth category notes those duct systems that could not be pressurized in order to perform the duct blaster test. Key findings are summarized below.

- Overall, 13.5% of detached single family homes and 15.5% of multifamily buildings had tight duct systems (leakage was low enough that they would qualify for RNC programs).
- A considerable number of duct systems in detached single family homes had leakage rates greater than 300 cfm (17.0%).
- For detached single family homes, duct systems tested in RMST Climate Zone 1 were on average the leakiest at 288 cfm,[21] while those in RMST Climate Zone 5 were the tightest (141 cfm).
- The average leakage rate for multifamily buildings is 229 cfm—just slightly higher than that for detached single family homes (210).

Table 3-42: Summary of Duct Blaster Tests – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Number of Sites	70	14	12	17	22	5
Average Leakage Rate (valid tests)	210	288	237	212	164	141
Leakage Categories (All Sites):						
<=110 cfm (RNC programs)	13.5%	-	6.7%	-	31.7%	19.6%
> 110 and <=300 cfm	69.6%	69.9%	59.2%	80.4%	63.4%	80.6%
> 300 and <=500 cfm	13.9%	22.2%	34.0%	13.9%	4.9%	-
> 500 cfm	3.1%	7.9%	-	5.7%	-	-

[21] The average leakage rate in RMST Climate Zone 1 is not significantly greater than the average leakage rates in the remaining RMST climate zones except for RMST Climate Zone 5.

Table 3-43: Summary of Duct Blaster Tests – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Number of Sites	24	6	6	6	6	-
Average Leakage Rate (valid tests)	229	272	265	201	184	-
Leakage Categories (All Sites):						
<=110 cfm (RNC programs)	15.5%	19.0%	-	34.8%	-	-
> 110 and <=300 cfm	53.2%	38.0%	62.1%	40.0%	80.9%	-
> 300 and <=500 cfm	27.0%	28.7%	37.9%	25.2%	19.1%	-
> 500 cfm	4.3%	14.4%	-	-	-	-

In addition, duct blaster test results for those customers who indicated their home was built under an RNC program were examined. Only three detached single family homes fit this category and of these two had duct leakage rates less than 110 cfm, which is consistent with RNC program requirements. However, the duct leakage rate for the other home was approximately 185 cfm.

Percent Duct Leakage

An estimate of percent duct leakage requires that the total supply fan system flow rate be known. Percent duct leakage is the ratio of the measured duct leakage rate over the total supply fan system flow rate. However, since this information was difficult to collect on-site, supply fan flows were estimated by utilizing cooling and heating capacity data, Title 24 Residential Standards sizing rules, and the following logic:

- For HVAC systems where cooling capacities were available from the on-site survey, a value of 400 CFM per ton was used to estimate total supply CFM.
- For HVAC systems where heating capacities were available from the on-site survey, a value of 21.7 CFM per kBtuh was used to estimate total supply CFM.
- For HVAC systems where neither cooling nor heating capacities were available from the on-site survey, the following process was followed:
  - Default ft^2/ton and ft^2/kBtuh values were calculated for each building type (single family detached homes and multifamily buildings) by computing and averaging these values for those residences that had capacities.
  - If the residence had a cooling system, the default ft^2/ton value and floor area of the residence were used to compute a default cooling capacity, and a value of 400 CFM per ton was used to estimate total supply CFM.

- If the residence did not have a cooling system, the default ft^2/kBtuh value and floor area of the residence were used to compute a default heating capacity, and a value of 21.7 CFM per kBtuh was used to estimate total supply CFM.

The results of this process are displayed in Table 3-44, which presents the average percent duct leakage by RMST climate zone. These results suggest no evidence of significant differences across RMST climate zones.[22] The results also reveal that single family homes have a significantly lower percent duct leakage than multifamily residences.[23] This is a major deviation from the common perception that duct leakage for multifamily residences would be less than that in single family homes due to smaller duct run lengths. Instead, these results suggest that although duct runs are shorter, duct construction/sealing for multifamily buildings is possibly of lower quality. This might also suggest that building cavities and other such unfinished air flow paths are used more often in multifamily buildings than in single family detached homes.

Table 3-44: Average Percent Duct Leakage by Utility

	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Single Family Homes	**13.3%**	**15.4%**	**12.4%**	**12.9%**	**13.7%**	**8.9%**
	(0.0093)	*(0.0235)*	*(0.0145)*	*(0.0173)*	*(0.0196)*	*(0.0215)*
	n = 70	*n = 14*	*n = 12*	*n = 17*	*n = 22*	*n = 5*
Multifamily Buildings	**30.7%**	**28.0%**	**34.9%**	**31.6%**	**28.2%**	**-**
	(0.0315)	*(0.0404)*	*(0.0762)*	*(0.09)*	*(0.0462)*	-
	n = 24	*n = 6*	*n = 6*	*n = 6*	*n = 6*	*n = 0*

Standard errors in parentheses.

Duct Construction Type and Location

Duct construction practices as characterized by duct construction type and duct location are summarized in Table 3-45 for detached single family homes and Table 3-46 for attached single family and multifamily buildings. Key findings are summarized below.

[22] The only exception to this is that a significance test at the 90% confidence level reveals that the average percent duct leakage for multifamily homes in RMST Climate Zone 5 is significantly lower than the average percent duct leakage for multifamily homes in RMST Climate Zones 1 and 4.

[23] A significance test at the 90% confidence level reveals that the estimates of the average percent duct leakage for single family homes are significantly less than the average percent duct leakage for multifamily buildings at the state level and for each RMST climate zone.

- As expected, nearly all detached single family homes (99.0%) used ducted systems.
- More non-ducted systems are utilized by multifamily buildings, primarily in RMST Climate Zone 1 (40.7%). This is primarily due to the absence of cooling systems for a high percentage of sites (see *Space Cooling Systems*).
- Flex duct installed in the attic is the dominant construction practice for both detached single family homes and multifamily buildings (95.5% and 63.5%, respectively). Both residence types use primarily plastic flex ducts (90.8% and 58.6%, respectively) and only approximately 5% metal flex ducts.
- Nearly 13% of detached single family homes have metal duct work, while approximately 10% of multifamily buildings do.
- Unfinished wall cavities are not permitted under the standards. However, unfinished wall cavities were used as part of the duct system in a small percent of both detached single family homes (1.9% in RMST Climate Zone 2) and multifamily buildings (3.3% in RMST Climate Zone 3 and 2.5% in RMST Climate Zone 4).

Table 3-45: Duct Construction Types and Locations – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
System Type						
Ducted	99.0%	96.8%	98.4%	100.0%	99.5%	100.0%
Non-Ducted	1.0%	3.2%	1.6%	-	0.5%	-
Construction Types						
Plastic Flex	90.8%	89.5%	97.9%	85.6%	91.7%	97.4%
Metal Flex	4.7%	3.1%	0.5%	13.5%	1.5%	2.6%
Metal	15.9%	26.9%	40.8%	10.8%	10.0%	4.4%
Panned	0.2%	1.2%	-	-	-	-
Unfinished Wall Cavity	0.2%	-	-	0.8%	-	-
Other	0.2%	-	1.9%	-	-	-
Not Accessible	3.6%	3.3%	0.5%	0.6%	6.8%	-
Duct Location						
Attic	94.1%	78.8%	94.6%	97.5%	98.0%	98.2%
Wall	8.5%	15.0%	18.6%	3.3%	6.2%	8.4%
Crawlspace	5.8%	24.0%	1.6%	0.9%	2.3%	1.8%
Conditioned Space	1.1%	4.7%	0.5%	1.0%	-	-
Basement	0.4%	1.0%	-	-	0.5%	-
Other Location	0.4%	1.2%	1.9%	-	-	-

Table 3-46: Duct Construction Types and Locations – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
System Type						
Ducted	81.3%	59.3%	92.1%	83.1%	95.4%	100.0%
Non-Ducted	18.7%	40.7%	7.9%	16.9%	4.6%	-
Construction Types						
Plastic Flex	58.6%	48.9%	65.9%	71.4%	52.6%	63.5%
Metal Flex	4.9%	-	-	4.1%	12.5%	4.7%
Metal	14.0%	29.2%	15.1%	3.4%	7.5%	22.3%
Panned	-	-	-	-	-	-
Unfinished Wall Cavity	1.4%	-	-	3.3%	2.5%	-
Other	8.0%	-	16.6%	13.4%	5.1%	-
Ducts Not Accessible	29.7%	39.4%	25.1%	14.1%	34.8%	31.8%
Duct Location						
Attic	61.3%	66.4%	58.8%	82.5%	44.2%	100.0%
Wall	35.3%	29.2%	30.0%	18.4%	54.6%	16.8%
Crawlspace	6.0%	6.9%	4.1%	3.0%	9.0%	-
Conditioned Space	1.9%	-	7.8%	-	-	-
Basement	-	-	-	-	-	-
Other Location	9.4%	-	22.4%	9.3%	7.5%	-

Duct Sealant Methods and Tape Types

Duct sealant and tape certification types are summarized in Table 3-47 for detached single family homes and Table 3-48 for attached single family and multifamily buildings. Note that two or more sealing methods may have been used on each residence. Consequently, percentages in the table by RMST climate zone will add to more than 100%. Note also that, regarding the tape certifications listed in this table, these listings were compiled from the brand names recorded from the sealant tapes observed by the RMST surveyors. Key findings are summarized below.

- Butyl tape is the most utilized sealant method for both building types: 54.6% for detached single family homes and 40.6% for multifamily buildings.

- Most detached single family homes and multifamily buildings use multiple sealing methods, typically butyl tapes, metal tapes, and sometimes mastic.
- For detached single family homes, the highest percentage of mastic sealing occurs in RMST Climate Zone 4 (34%). This could be an indication of the influence of PG&E RNC programs and the actions of other market actors like Beutler and Consol that emphasize and encourage tight ducts.
- Regarding duct tape UL 181 certification, which is required by the Standards, most tapes for which a rating could be identified were UL 181 rated. However, a small percentage of tapes still being used are not UL 181 certified—overall 0.6% for detached single family homes and 0.8% for multifamily buildings.

Table 3-47: Duct Sealant Methods and Tape Types – Detached Single Family Homes

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Duct Sealant Methods[24]						
Butyl Tape	54.6%	59.2%	82.8%	45.3%	54.0%	37.5%
Metal Tape	28.2%	64.4%	51.4%	16.8%	16.5%	7.3%
Mastic	19.2%	15.4%	15.5%	1.2%	33.9%	10.2%
Clamp	4.1%	10.7%	5.3%	1.9%	2.9%	-
Duct Tape	24.6%	9.7%	3.0%	50.1%	15.6%	59.9%
Cloth Tape	2.7%	-	2.6%	0.8%	4.9%	3.2%
Other Sealant Method	0.2%	-	-	-	0.5%	-
Ducts Not Accessible	4.0%	3.3%	1.0%	2.1%	6.8%	-
Duct Tape Types						
UL 181 - DK UL 723 - DK	92.1%	80.0%	72.6%	97.0%	98.2%	100.0%
UL 181 - DK UL 723 - Yes	0.4%	2.3%	-	-	-	-
UL 181 - No UL 723 - No	0.4%	-	2.3%	0.7%	-	-
UL 181 - No UL 723 - Yes	0.2%	-	-	0.9%	-	-
UL 181 - Yes UL 723 - DK	3.3%	3.9%	16.1%	0.8%	1.8%	-
UL 181 - Yes UL 723 - No	2.2%	8.7%	4.5%	0.5%	-	-
UL 181 - Yes UL 723 - Yes	1.4%	5.1%	4.5%	-	-	-

[24] Although identification of aerosol sealing was part of the RMST survey, no homes using this sealing method were found.

Table 3-48: Duct Sealant Methods and Tape Types – Attached Single Family and Multifamily Buildings

Analysis Parameter Description	Statewide	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Duct Sealant Methods[25]						
Butyl Tape	40.6%	34.7%	63.7%	32.9%	33.4%	27.1%
Metal Tape	26.8%	41.2%	28.3%	7.6%	26.7%	22.3%
Mastic	6.0%	3.3%	3.9%	-	13.5%	-
Clamp	2.2%	9.5%	-	-	-	-
Duct Tape	10.7%	-	-	33.2%	10.7%	41.1%
Cloth Tape	-	-	-	-	-	-
Other Sealant Method	-	-	-	-	-	-
Ducts Not Accessible	35.8%	39.4%	30.0%	33.9%	39.0%	31.8%
Duct Tape Types						
UL 181 - DK UL 723 - DK	94.8%	90.5%	92.4%	100.0%	97.8%	100.0%
UL 181 - DK UL 723 - Yes	0.6%	2.0%	-	-	-	-
UL 181 - No UL 723 - No	0.4%	-	1.8%	-	-	-
UL 181 - No UL 723 - Yes	0.4%	-	1.8%	-	-	-
UL 181 - Yes UL 723 - DK	0.5%	1.7%	-	-	-	-
UL 181 - Yes UL 723 - No	1.0%	2.0%	2.0%	-	-	-
UL 181 - Yes UL 723 - Yes	2.2%	3.9%	2.0%	-	2.2%	-

Lighting and Consumer Appliances

Typical installation practices for lighting and refrigerators, clothes washers, and dishwashers are outside the scope of this study and are not presented. However, this information is available from the RMST study.[26]

[25] Although identification of aerosol sealing was part of the RMST survey, no homes using this sealing method were found.

[26] Regional Economic Research, Inc. *California Residential Efficiency Market Share Tracking - California Lamp Report 2001Volume 1.* Prepared for Southern California Edison. October 12, 2001.

3.5 Summary of Current Construction Practices

Current building practices in the low-rise residential sector are summarized below. In particular, findings on efficiency levels and key differences in construction practice between detached single family homes and multifamily buildings and regions are summarized. Table 3-49 and Table 3-50 provide a high-level summary of the results found in the second year of the RNC project, for both detached single family homes and multifamily buildings.

Statewide

The following is a summary of construction practices that appear to be statewide practices (i.e., independent of region).

- The average AFUE of space heating systems installed in detached single family homes is 80.5, which is slightly higher than required by the Minimum Efficiency Standards. The average SEER of the space cooling systems is also higher than required by the Minimum Efficiency Standards at 10.6.
- The average EF of water heating systems installed is 16% higher than required by the Minimum Efficiency Standards for detached single family homes and 13% higher for multifamily buildings.
- The predominant window for both detached single family homes and multifamily buildings is vinyl-framed, dual-paned, clear glass.

Regional Construction Practices

A number of differences in building practices among RMST climate zones were detected during the analysis. Table 3-49 and Table 3-50 summarize some of the key characteristics, by RMST climate zone, for detached single family homes and multifamily buildings, respectively.

- Ceiling and wall insulation is usually below prescriptive values in those climate zones with the most extreme prescriptive values. Wall insulation of R-13 is usually used. Ceiling insulation is usually the Standards minimum of R-19 for multifamily buildings. However, this varies for detached single family homes.
- For single family homes, the percent of metal-framed windows ranges from a low of 0% in RMST Climate Zone 2 to a high of 36% in RMST Climate Zone 4.
- Approximately 14% of detached single family homes statewide do not have a cooling system. Specifically, 54% of detached single family homes in RMST Climate Zone 1 and 34% in RMST Climate Zone2 do not have a cooling system. Also, a large number of multifamily buildings do not have cooling systems (27% statewide). RMST Climate Zone 1 is most extreme with 63% of sites not having a cooling system. Unlike detached single family homes, some multifamily buildings in RMST Climate Zone 3 do not have cooling systems (18%).

- For detached single family homes, duct systems tested in RMST Climate Zone 1 were on average the leakiest with an average rate of 15% (288 cfm), while those in RMST Climate Zone 5 were the tightest with an average rate of 9% (141 cfm).[27]

Table 3-49: Summary of Key Characteristics by RMST Climate Zone – Detached Single Family Homes

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Building Shell						
Average Square Footage	2,329	2,434	2,756	2,502	2,109	2,125
Average Number of Stories	1.5	1.7	1.9	1.7	1.4	1.2
Windows						
Average % Glazing	17%	18%	16%	18%	17%	18%
Prescriptive % Glazing		20% & 16%	20%	20%	16%	16%
Average U-value	0.595	0.583	0.589	0.592	0.604	0.598
Air Conditioners						
Average SEER of Observed Data	10.64	10.48	10.24	10.22	10.95	10.48
> 10 SEER	55%	71%	36%	41%	63%	37%
% of sites w/No Air Conditioner	14%	54%	34%	0%	1%	0%
Gas Furnaces						
Average AFUE of Observed Data	80.52	80.73	80.12	80.11	80.81	80.45
> 80% AFUE	8%	9%	8%	4%	10%	11%
Gas Water Heaters						
Avg. % Above Std Energy Factor	16%	14%	15%	16%	16%	16%
% of sites w/Blankets	34%	11%	34%	28%	53%	8%
Ducts						
Average Leakage (cfm)	210	288	237	212	164	141
Average % Leakage	13%	15%	12%	13%	14%	9%
Radiant Barriers						
% of sites w/ a Radiant Barrier	3.5%	-	1.9%	2.1%	6.8%	-

[27] A significance test conducted at a 90% confidence level shows that the average leakage rate for RMST Climate Zone 5 is significantly less than the average leakage rates for both RMST Climate Zones 1 and 4.

Table 3-50: Summary of Key Characteristics by RMST Climate Zone – Attached Single Family and Multifamily Buildings

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Building Shell						
Average Square Footage	21,536	24,872	22,526	26,702	14,285	13,602
Average Number of Stories	2.3	2.5	2.5	2.2	2.1	1.6
Windows						
Average % Glazing	9%	10%	9%	10%	9%	10%
Prescriptive % Glazing		20% & 16%	20%	20%	16%	16%
Average U-value	0.645	0.616	0.638	0.613	0.689	0.816
Air Conditioners						
Average SEER of Observed Data	10.07	10.08	10.02	10.04	10.10	10.05
> 10 SEER	19%	41%	8%	34%	7%	43%
% of sites w/No Air Conditioner	27%	63%	21%	18%	-	-
Gas Furnaces						
Average AFUE of Observed Data	80.53	80.07	80.00	80.74	81.66	80.00
> 80% AFUE	6%	6%	0%	5%	12%	0%
Gas Water Heaters						
Avg. % Above Std Energy Factor	13%	14%	11%	15%	14%	13%
% of sites w/Blankets	8%	4%	5%	13%	12%	0%
Ducts						
Average Leakage (cfm)	229	272	265	201	184	-
Average % Leakage	31%	28%	35%	32%	28%	-
Radiant Barriers						
% of sites w/ a Radiant Barrier	1.3%	-	-	-	4.8%	-

Building Type

A number of differences in building practices were also found between detached single family homes and multifamily buildings.

- Glazing percentages in multifamily buildings are much smaller than for detached single family homes.[28]
- While vinyl-framed, dual-paned, clear glass windows are predominantly used in both detached single family homes and multifamily buildings, metal-framed windows are used more often in multifamily buildings (23% compared to 16% in detached single family homes).
- Of detached single family homes, 24 % have a higher than standard efficiency air conditioners (>11 SEER) compared to none of the multifamily buildings.
- Space cooling system efficiencies were collected for a larger percentage of detached single family homes than for multifamily buildings (69% and 53%, respectively). This was due primarily to the inaccessibility of HVAC units in multifamily (typically rental) units.

Building Characteristics

Percent Glazing

The average glazing percentage for all building types is less than the prescriptive values. RMST Climate Zones 2 and 3 have the largest number of sites with percent glazing values less than the prescriptive value, but also have the largest prescriptive value (20%).

Window Types

The predominant window type for all building types is vinyl-framed, dual-paned, clear glass. However, a large number of detached single family homes (notably in RMST Climate Zone 4 (36%)) and multifamily buildings (particularly in RMST Climate Zones 4 and 5 (58% and 32%, respectively)) are still be built using metal-framed windows.

Space Heating Systems

Space heating systems are predominantly central gas furnaces with efficiencies slightly above 80% AFUE. Hydronic systems in detached single family homes, 1.6% statewide, are located in RMST Climate Zones 1, 2, and 4. Penetration of high efficiency (≥90%) space heating units is low for detached single family homes (2.8%) and multifamily buildings (3.6%). For detached single family homes, high efficiency units are concentrated in RMST Climate Zones 1 and 4 (4% and 5%, respectively).

Heating equipment types in multifamily buildings are much more diverse than in detached single family homes. Central furnaces and hydronic systems both have saturations of approximately 38% statewide. There are also more heat pumps (11%) and even some

[28] A significance test conducted at a 90% confidence level shows that the average glazing percentage in detached single family homes is significantly greater than the average glazing percentage in multifamily buildings.

electric resistance heating (10%), primarily in RMST Climate Zone 1. Heat pumps are probably more popular in multifamily residences because they eliminate the need to pipe gas to all units.

Space Cooling Systems

Space cooling systems are predominantly central air conditioners. A large number of new homes do not have air conditioners—14% of detached single family homes and 27% of multifamily buildings, primarily in RMST Climate Zones 1, 2 and 3. Penetration of high efficiency (>11 SEER) space cooling units is approximately 24% statewide for detached single family homes. These units are concentrated in RMST Climate Zones 4 and 5 (41% and 22%, respectively).

Water Heating Systems

Standard practice water heaters are already more efficient than the Appliance Standards minimums (average 16% higher). This percentage is fairly consistent across RMST climate zones. This is because high efficiency water heaters are cost-effective, are readily available, and offer better performance (hence fewer customer complaints).

Building Shell Characteristics

Most detached single family homes (45% statewide) are constructed using ceiling insulation with efficiency levels that are lower than the prescriptive values, while only 1% of homes use above prescriptive ceiling insulation levels. A similar result was found regarding wall insulation. However, it is important to note that wall insulation values were collected for less than one-fourth of the sites.

Miscellaneous Practices

Number of HVAC Systems. Of detached single family homes, 10% have multiple (two or more) HVAC units. These are primarily in RMST Climate Zones 2 and 3 (22% and 14%, respectively).

Thermostat Type. Digital thermostats are the most common thermostat type with 93% for single family homes and 75% for multifamily buildings. However, a small number of electromechanical thermostats are still used—5% and 21% statewide for single family and multifamily, respectively.

Radiant Barriers. Radiant barriers are installed in approximately 3.5% of detached single family homes and 1.3% of the multifamily buildings statewide. RMST Climate Zone 4 has the highest penetration of radiant barriers for detached single family homes (6.8%).

3.6 Comparison of Homes Built in Project Year #1 and Project Year #2

Table 3-51 and Table 3-52 provide a summary of the results reported in the first year of the RNC project,[29] for both detached single family homes and multifamily buildings, by RMST climate zone. In addition, Table 3-53 provides a high-level comparison of key building characteristics between Project Year #1 homes and Project Year #2 homes. Note that the homes used in the analysis for Project Year #1 were built between July 1, 1998 and June 30, 1999, while the homes used in the analysis for Project Year #2 were built between July 1, 1999 and June 30, 2000.

Below is a brief comparison of the baseline characteristics of the homes analyzed during the two years of this project. In general, construction practices did not change significantly from Project Year #1 to Project Year #2. Interviews with builders and Title 24 consultants, who stated that they made only minor changes, if any, in construction practices during this period, reinforces this. Many claimed that the changes made to the standards did not make Title 24 compliance more difficult and, therefore, did not cause them to change their practices.

Percent Glazing

The average glazing percentage for detached single family homes in RMST Climate Zones 1 and 4 remained fairly constant from Project Year #1 to Project Year #2. Meanwhile, the average glazing percentage for detached single family homes in RMST Climate Zone 2 has decreased from 19% to 16%, which is below the prescriptive % glazing of 20%. On the other hand, detached single family homes in RMST Climate Zones 3 and 5 have increased from 16% to 18% and 17% to 18%, respectively. While the average for RMST Climate Zone 3 is still below the prescriptive % glazing of 20%, the average for RMST Climate Zone 5 is now even higher above the prescriptive % glazing of 16%.[30]

Space Heating Systems

The average AFUE of gas furnaces in detached single family homes did not change much between Project Year #1 and Project Year #2. The statewide average was 80.4% in Project Year #1 and 80.5% in Project Year #2. The average AFUE of gas furnaces in multifamily buildings increased from 80.0% to 80.5% from Project Year #1 to Project Year #2.[31]

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[29] Regional Economic Research, Inc. *Residential New Construction Study*. Prepared for Pacific Gas & Electric. May 17, 2001.

[30] As noted above, for this second year of the project the on-site surveyors were given different protocols when gathering glazing information in order to improve the accuracy of their measurements.

[31] A significance test conducted at a 90% confidence level shows the increase in the average AFUE from Project Year #1 to Project Year #2 was not a significant increase.

Space Cooling Systems

A larger percent of new homes are being built with air conditioners. In Project Year #1, approximately 20% of detached single family homes and 38% of multifamily buildings were built without cooling equipment installed, compared to just 14% and 27%, respectively, in Project Year #2. For detached single family homes, RMST Climate Zones 2 and 5 had the largest percentage increase in homes with cooling equipment. In addition, the penetration of high efficiency (>10 SEER) space cooling units statewide for detached single family homes has increased from 55% to 65% and from 19% to 26% for multifamily buildings.

Water Heating Systems

There was not much change in the efficiencies of the gas water heaters installed in new homes between Project Year #1 and Project Year #2.[32] The statewide average % above standard remained at 16% for detached single family homes and 13% for multifamily buildings. The use of water heater blankets has remained relatively constant. There was a small increase in the percentage of detached single family homes with a water heater blanket (32% to 34%) and a decrease in the percentage of multifamily buildings with a water heater blanket (14% to 8%).

Ducts

The percentage duct leakage in detached single family homes was nearly the same in Project Year #1 and Project Year #2, 14% and 13%, respectively. The same result was found in multifamily buildings—28% in Project Year #1 and 31% in Project Year #2.

Radiant Barriers

The percentage of radiant barriers installed increased for both detached single family homes and multifamily buildings between Project Year #1 and Project Year #2. Specifically, 2.3% of detached single family homes had radiant barriers in Project Year #1, compared to 3.5% in Project Year #2. Likewise, none of the multifamily buildings in the sample for Project Year #1 had radiant barriers installed, but in Project Year #2, approximately 1.3% had radiant barriers.

[32] Note that the homes used in the analysis for Project Year #1 were built between July 1, 1998 and June 30, 1999, while the homes used in the analysis for Project Year #2 were built between July 1, 1999 and June 30, 2000.

Table 3-51: Summary of Key Characteristics by RMST Climate Zone – Detached Single Family Homes – Project Year #1

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Building Shell						
Average Square Footage	2,232	2,324	2,353	2,436	1,952	2,179
Average Number of Stories	1.6	1.7	1.9	1.7	1.3	1.2
Windows						
Average % Glazing	17%	18%	19%	16%	17%	17%
Prescriptive % Glazing		16% & 20%	20%	20%	16%	16%
Average U-value	0.586	0.576	0.592	0.594	0.584	0.591
Air Conditioners						
Average SEER of Observed Data	10.53	10.39	10.19	10.17	10.95	10.87
> 10 SEER	65%	72%	45%	66%	66%	63%
% of sites w/No Air Conditioner	20%	51%	52%	1%	5%	9%
Gas Furnaces						
Average AFUE of Observed Data	80.39	80.28	80.05	80.22	80.81	80.35
> 80% AFUE	8%	4%	6%	7%	13%	12%
Gas Water Heaters						
Avg. % Above Std Energy Factor	16%	16%	16%	17%	15%	17%
% of sites w/Blankets	32%	22%	22%	30%	47%	19%
Ducts						
Average Leakage (cfm)	218	216	241	221	182	331
Average % Leakage	14%	14%	17%	12%	11%	19%
Radiant Barriers						
% of sites w/ a Radiant Barrier	2.3%	0.9%	-	-	6.2%	2.4%

Table 3-52: Summary of Key Characteristics by RMST Climate Zone – Attached Single Family and Multifamily Buildings – Project Year #1

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Building Shell						
Average Square Footage	15,463	16,979	14,911	15,060	13,852	10,792
Average Number of Stories	2.3	2.4	2.6	2.2	1.9	1.8
Windows						
Average % Glazing	9%	11%	7%	9%	8%	8%
Prescriptive % Glazing		16% & 20%	20%	20%	16%	16%
Average U-value	0.644	0.598	0.661	0.711	0.624	0.725
Air Conditioners						
Average SEER of Observed Data	10.07	10.00	10.04	10.05	10.15	10.01
> 10 SEER	26%	0%	13%	34%	36%	9%
% of sites w/No Air Conditioner	38%	77%	33%	8%	-	-
Gas Furnaces						
Average AFUE of Observed Data	79.99	80.00	80.00	79.87	80.13	81.00
> 80% AFUE	7%	0%	0%	0%	32%	100%
Gas Water Heaters						
Avg. % Above Std Energy Factor	13%	14%	14%	13%	11%	13%
% of sites w/Blankets	14%	8%	9%	21%	21%	13%
Ducts						
Average Leakage (cfm)	185	120	269	217	137	278
Average % Leakage	28%	14%	36%	35%	20%	40%
Radiant Barriers						
% of sites w/ a Radiant Barrier	-	-	-	-	-	-

Table 3-53: Comparison of Key Characteristics for Project Year #1 and Project Year #2[33] - by Building Type

	Single Family Homes		Attached Single Family and Multifamily Buildings	
	Project Year #1	Project Year #2	Project Year #1	Project Year #2
Building Shell				
Average Square Footage	2,232	2,329	15,463	21,536
Average Number of Stories	1.6	1.5	2.3	2.3
Windows				
Average % Glazing	17%	17%	9%	9%
Average U-value	0.586	0.595	0.644	0.645
Air Conditioners				
Average SEER of Observed Data	10.53	10.64	10.07	10.07
> 10 SEER	65%	55%	26%	19%
% of sites w/No Air Conditioner	20%	14%	38%	27%
Gas Furnaces				
Average AFUE of Observed Data	80.39	80.52	79.99	80.53
> 80% AFUE	8%	8%	7%	6%
Gas Water Heaters				
Avg. % Above Std Energy Factor	16%	16%	13%	13%
% of sites w/Blankets	32%	34%	14%	8%
Ducts				
Average Leakage (cfm)	218	210	185	229
Average % Leakage	14%	13%	28%	31%
Radiant Barriers				
% of sites w/ a Radiant Barrier	2.3%	3.5%	-	1.3%

[33] Note that the homes used in the analysis for Project Year #1 were built between July 1, 1998 and June 30, 1999, while the homes used in the analysis for Project Year #2 were built between July 1, 1999 and June 30, 2000.

4

Analysis of Title 24 Compliance for Low-Rise Residential Buildings

4.1 Introduction

This section discusses an assessment of the Title 24 compliance for low-rise residential buildings. The analysis is based on the MICROPAS simulation results using the on-site survey data. In particular, 719 sites were processed through the RNC Interface[1] and the % Compliance Margin was calculated for each site. The primary objective of the analysis is to establish key characteristics of buildings that are compliant (compliant) and those that are not compliant with Title 24 standards (non-compliant). This was accomplished by examining the MICROPAS 5.1 results. Specifically, the Compliance Margin Groups as defined in Section 4.3 were segmented and analyzed by RMST climate zones, building type (single family vs. multifamily), construction features, equipment types and efficiencies, and other building characteristics.

The remainder of this section presents a summary of the compliance data and an overview of the compliance groups used to characterize the results from the MICROPAS runs. Following this is a presentation of the compliance groups affected by RMST climate zone, building type, end-use energy budgets, building shell features, fenestration, HVAC equipment, and water heating equipment, as well as participation in residential new construction (RNC) programs and housing price.

4.2 Summary of Compliance Data

Compliance analysis was attempted for all 801 sites contained in the Residential Efficiency Market Share Tracking (RMST) Study on-site database. The status and disposition of the compliance runs for the 801 on-site surveys are presented in Table 4-1. As depicted in Table 4-1, 43 of the surveyed sites were excluded from the MICROPAS compliance runs because they are not subject to the Title 24 Low-Rise Residential Standards. In addition, 39 sites

[1] The RNC Interface, as explained in Section 2, uses on-site survey data to generate a MICROPAS 5.1 input file. MICROPAS 5.1 is a software tool used to determine compliance under the 1998 Low-Rise Residential Building Standards.

were removed from the analysis because there was a central water heater or boiler at the site,[2] leaving 725 usable sites. Table 4-1 also shows that six of the 725 valid MICROPAS sites have a MICROPAS run-time error and therefore do not have compliance results.

Table 4-1: Status of On-Site Surveyed Sites for MICROPAS Compliance Analysis

Site Disposition	# of Sites
Omitted Sites:	**76**
Mobile/ Manufactured Homes	21
Buildings > 3 Stories Tall	22
Sites w/ a Combo Water Heater or Boiler	33
Included Sites:	**725**
Running	719
Run-Time Errors	6
Total	**801**

A distribution of the usable sites by residence type and RMST climate zone[3] is presented in Table 4-2. The RMST climate zone with the largest number of sites (253) is RMST Climate Zone 4. RMST Climate Zone 4 roughly corresponds to the central valley (this includes such cities as Sacramento, Fresno, and Red Bluff), while the smallest number of sites is in the desert and mountain regions of the state (RMST Climate Zone 5).

[2] These sites were removed because details about the central water heating system were not obtainable. The recruitment protocol for the RMST on-site surveys was to survey the residential unit and not the complex. Therefore, the owner/renter of the unit, and not the maintenance manager, was contacted. Since central systems are maintained by the complex, they are typically in a locked maintenance room and not accessible without maintenance personnel. Since no equipment information was obtained, the project team decided to exclude them from the analysis. Note that these sites were not omitted during Project Year #1.

[3] A mapping of the CEC climate zones to the five RMST climate zones used in this analysis is provided in Section 3.2.

Table 4-2: Distribution of Usable Sites

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Overall	**719**	**121**	**127**	**169**	**253**	**49**
SF (detached single family)	**570**	**93**	**84**	**144**	**209**	**40**
1 story	257	30	11	50	132	34
2 story	306	62	72	92	74	6
3 story	7	1	1	2	3	0
SF-A (single family attached)	**52**	**14**	**12**	**14**	**5**	**7**
1 story	13	1	1	1	3	7
2 story	34	9	10	13	2	0
3 story	5	4	1	0	0	0
MF (multifamily)	**97**	**14**	**31**	**11**	**39**	**2**
1 story	0	0	0	0	0	0
2 story	63	10	10	8	33	2
3 story	34	4	21	3	6	0

4.3 Definition of Compliance Groups

Analysis of the MICROPAS results on a *non-compliant*/*compliant* criterion was not appropriate due to uncertainty with the MICROPAS results, characterized by the error band discussed in Section 2.4. As a result, a minimum of three "compliance groups" would have been needed to characterize the compliance runs. However, because of the interest in RNC programs, an additional group was formed. As shown below, this group, the overly compliant group, includes those sites that have a % Compliance Margin greater than 24%.[4] As such, four compliance groups were used as the basis for analysis of the MICROPAS results.

- ***Non-Compliant.*** This category includes sites that, based on the analysis, are not compliant with Title 24 code. In particular, these sites have a % Compliance Margin less than the lower end of the error band (i.e., <-5%).

[4] ENERGY STAR® requires that a home use approximately 20% less energy than the maximum allowed. The error band, discussed in Section 2.4, was then put around the 20%, which results in the 24% shown as the cut-off for this group.

- ***Indeterminate.*** This category includes sites that have a % Compliance Margin within the error band (-5% to 4%). As such, it is indeterminate as to whether these sites comply with the Title 24 codes.
- ***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., > 4% and < 24%).
- ***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 24%. This category was defined to assess the share of homes that would meet the existing ENERGY STAR® New Home Construction requirements, given the error band.

The distribution of sites within each compliance grouping is illustrated in Figure 4-1. As mentioned previously, these compliance groups form the basis against which construction features, equipment types and efficiencies, building characteristics, RMST climate zones, and energy budget results from the MICROPAS runs are characterized.

4.4 Compliance Analysis by RMST Climate Zone

This section studies the relationships between compliance groups and RMST climate zones by examining the distribution of sites by compliance groups and RMST climate zones and examining the average % Compliance Margin by RMST climate zone.

Distribution of Sites by Compliance Groups and RMST Climate Zones

A distribution of sites by compliance groups and RMST climate zones is presented in Table 4-3 and Figure 4-1 through Figure 4-6. Key findings are summarized below.

- Nearly 71% of the sites (411 + 96) are identified as compliant (i.e., they are in the compliant or overly compliant compliance groups). Note that 13% of the sites fall into the overly compliant group.
- Approximately 12% of the sites (86) are identified as non-compliant (i.e., they are in the non-compliant group).
- Nearly 18% of the sites (126) are in the indeterminate group, which means they are within the error band. Sites in the indeterminate group should be thought of as sites whose C-2Rs barely complied with Title 24—and since there is some error in the RNC interface, we can not determine whether these sites as-built have slightly positive or slightly negative compliance margins.

Table 4-3: Distribution of Sites by Compliance Group and RMST Climate Zone

Compliance Group	Totals	Percent	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Non-Compliant	86	12.0%	3	1	25	38	19
Indeterminate	126	17.5%	9	5	31	66	15
Compliant	411	57.2%	91	87	93	125	15
Overly Compliant	96	13.4%	18	34	20	24	0
# Sites in the Sample	719	100.0%	121	127	169	253	49
Overall Percentage	100.0%		16.8%	17.7%	23.5%	35.2%	6.8%

Figure 4-1: MICROPAS Results Summary—All Sites

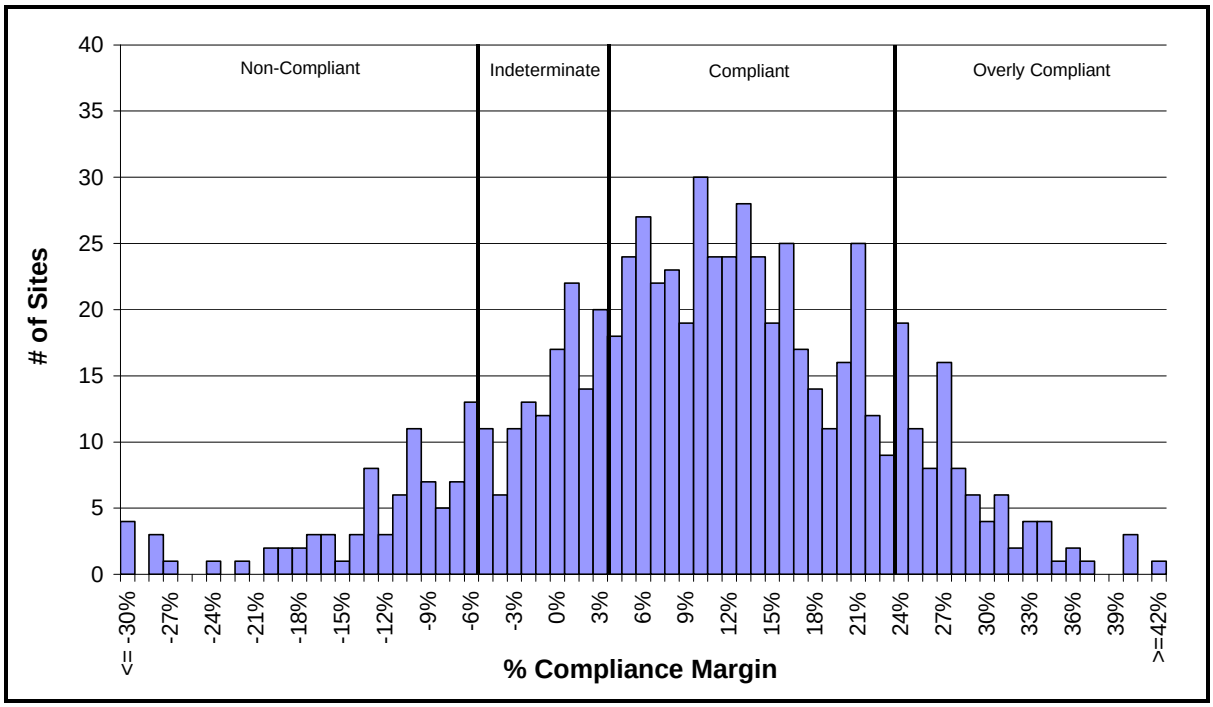


Figure 4-2: MICROPAS Results for RMST Climate Zone 1, All Sites

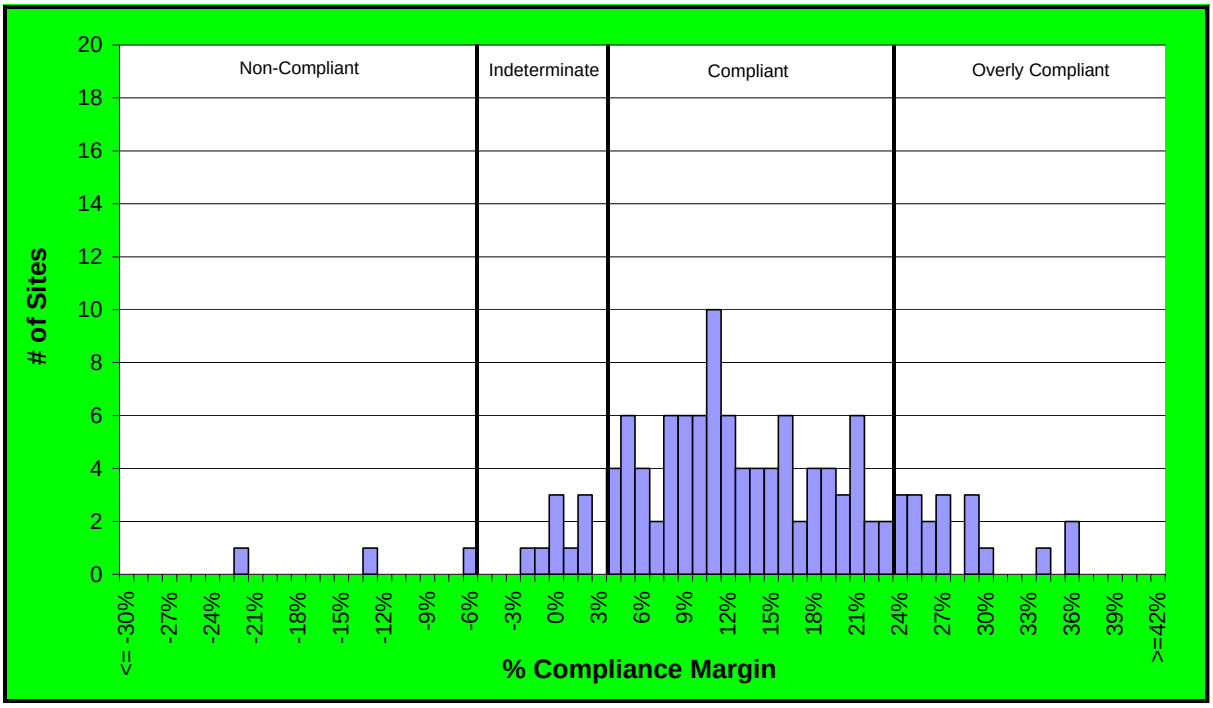


Figure 4-3: MICROPAS Results for RMST Climate Zone 2, All Sites

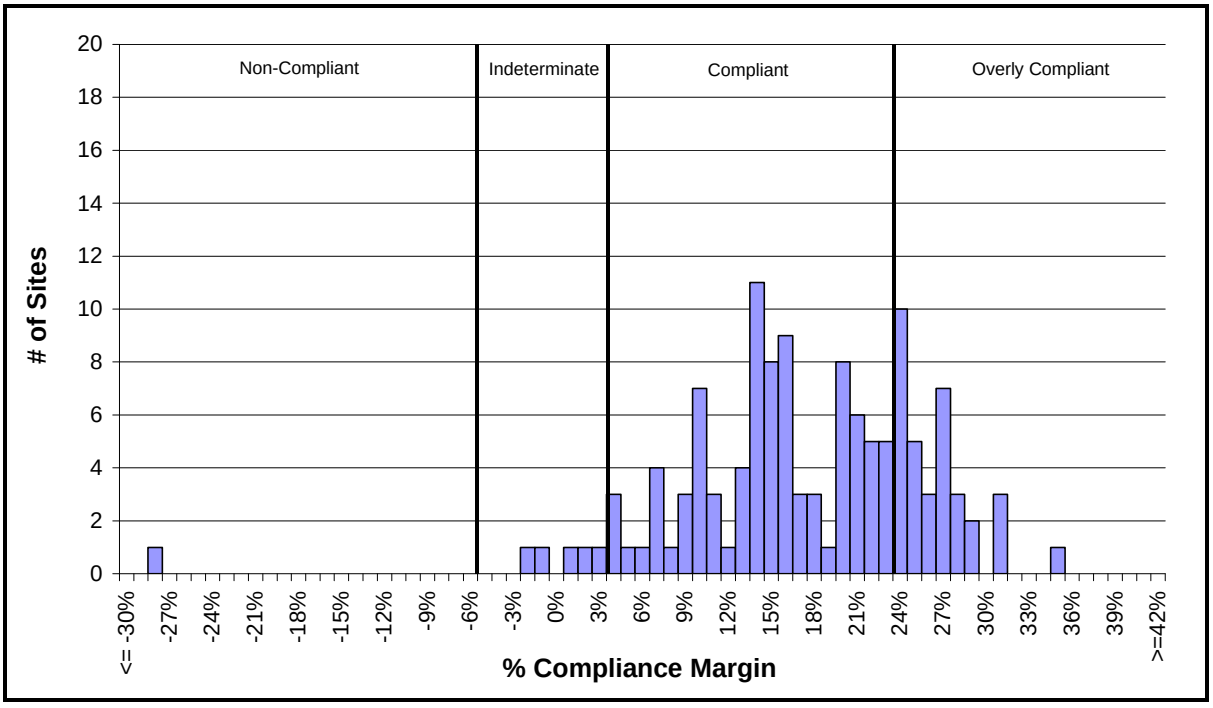


Figure 4-4: MICROPAS Results for RMST Climate Zone 3, All Sites

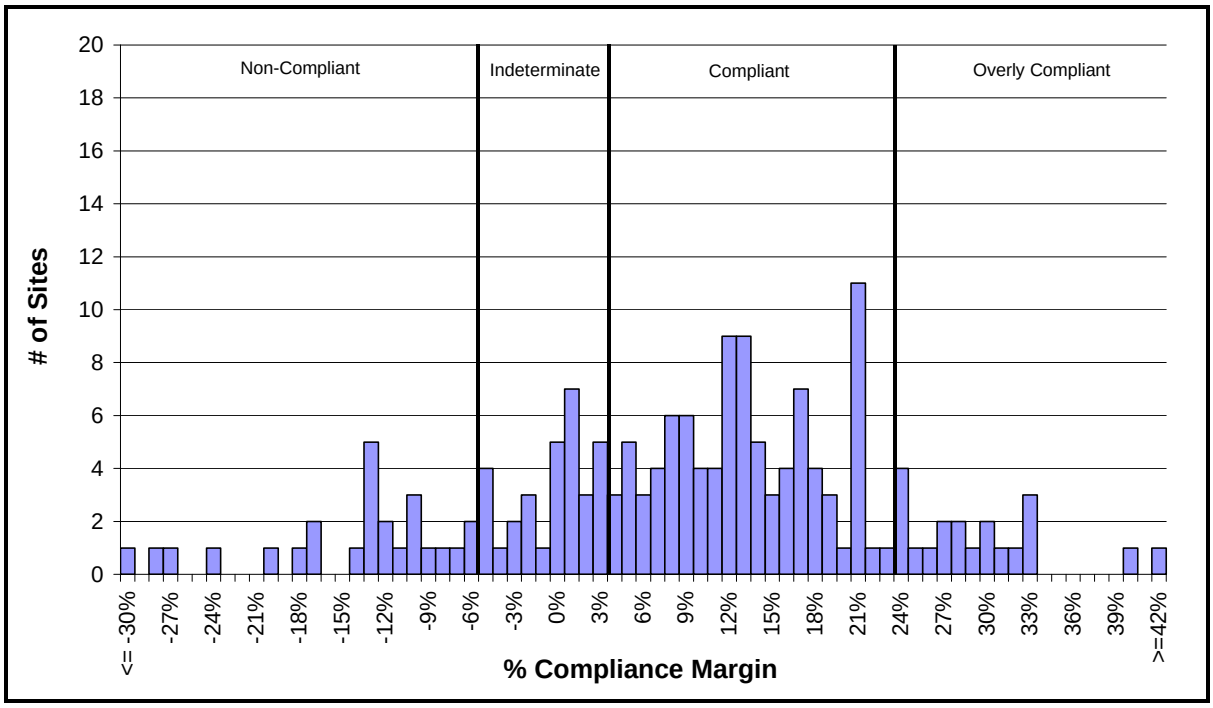


Figure 4-5: MICROPAS Results for RMST Climate Zone 4, All Sites

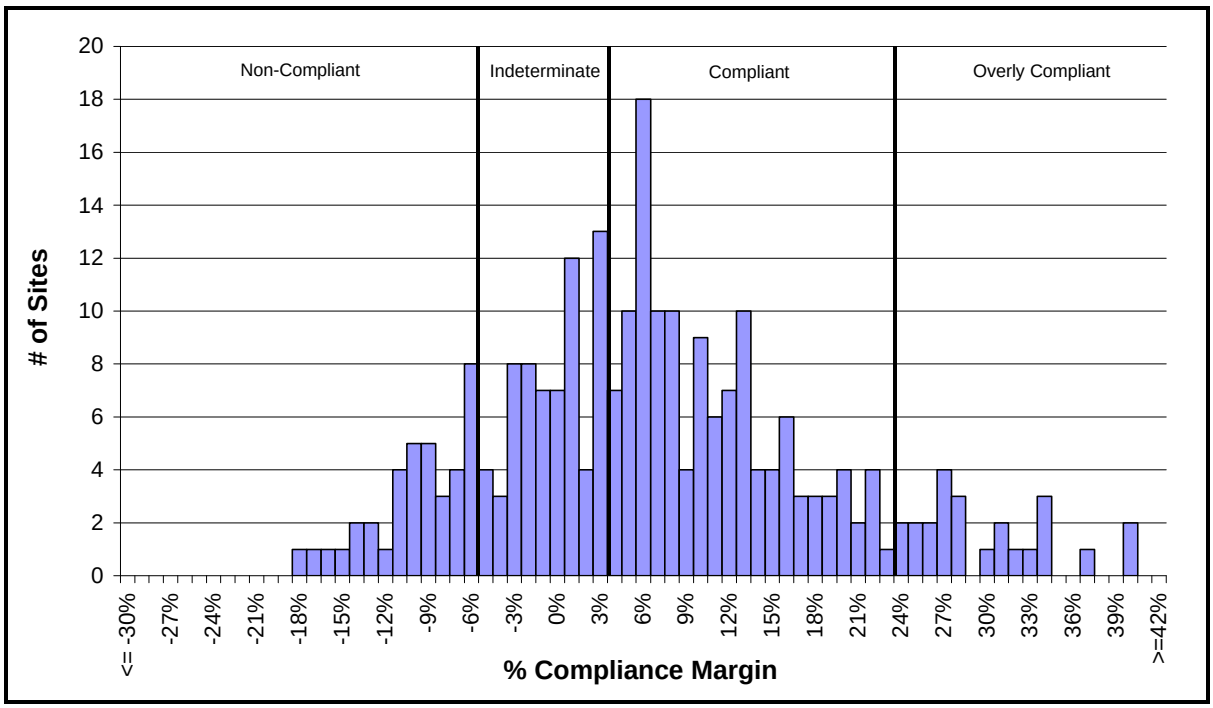
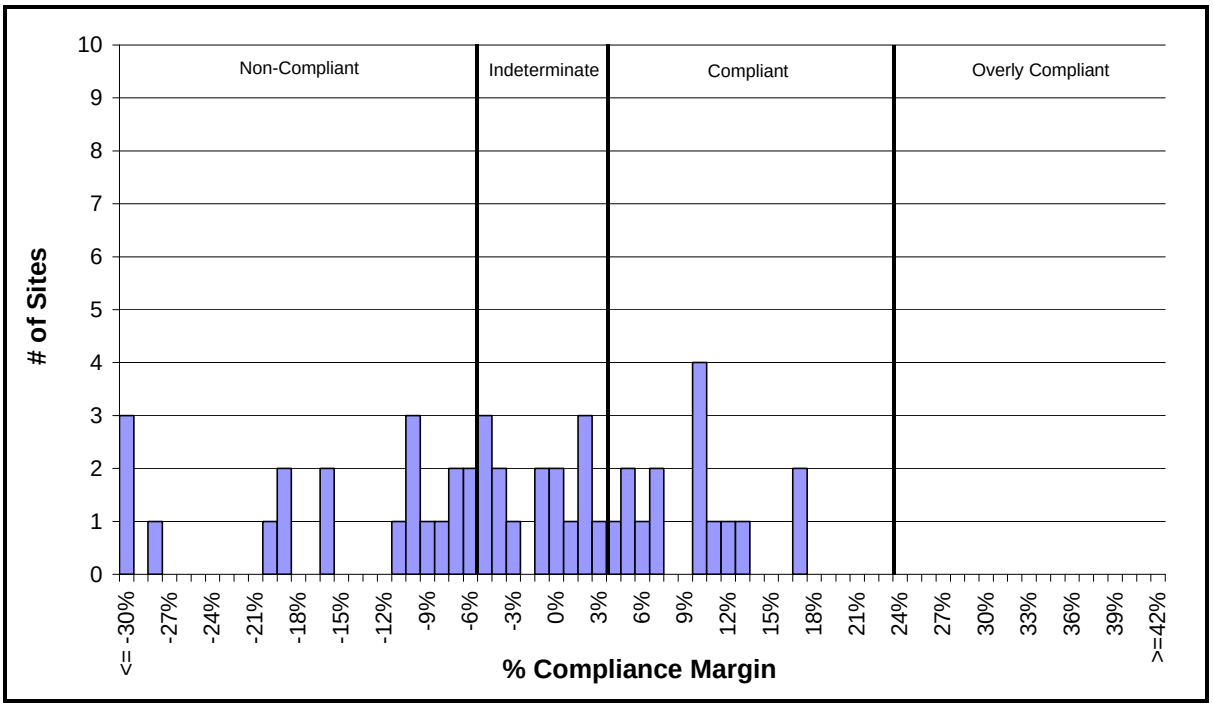


Figure 4-6: MICROPAS Results for RMST Climate Zone 5, All Sites



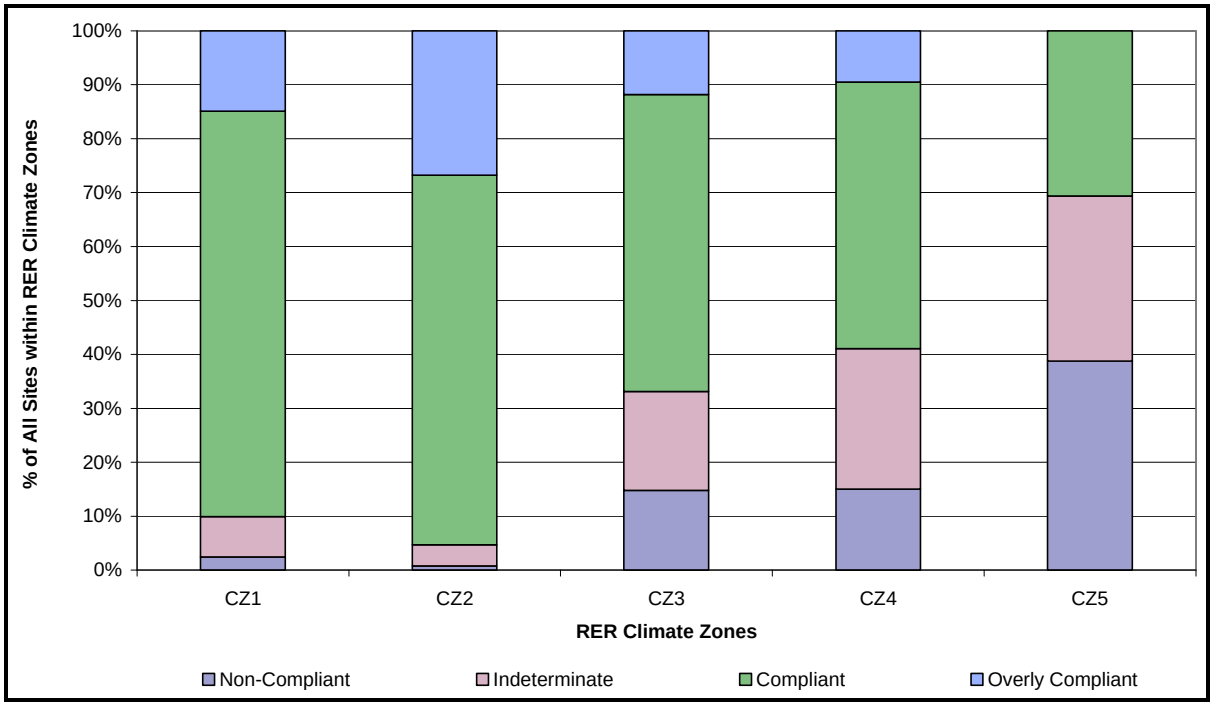
The percentage of sites in each compliance group is presented in Table 4-4 and Figure 4-7 for each RMST climate zone. Analysis on this basis was performed in order to make a qualitative assessment of the general compliance status of each RMST climate zone. Key findings are summarized below.

- Sites in RMST Climate Zone 5 appear to be the least compliant: most sites are either non-compliant or indeterminate (70%).
- Sites in RMST Climate Zone 2 appear to be the most compliant. Twenty-seven percent (27%) are overly compliant and only 5% are either non-compliant or indeterminate.

Table 4-4: Summary of Compliance Groups by RMST Climate Zone

Compliance Group	# Sites in Sample	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Non-Compliant	86	2%	1%	15%	15%	39%
Indeterminate	126	7%	4%	18%	26%	31%
Compliant	411	75%	69%	55%	49%	31%
Overly Compliant	96	15%	27%	12%	9%	0%
# Sites in Sample	719	121	127	169	253	49
Overall Percentage		16.8%	17.7%	23.5%	35.2%	6.8%

Figure 4-7: Distribution of Compliance Groups by RMST Climate Zone



Average % Compliance Margin *by RMST Climate Zone*

The relationship between average % Compliance Margin and RMST climate zones is summarized in Table 4-5. For a discussion on differences in compliance performance across climate zones, please see Section 4.12.

- RMST Climate Zone 2 has the highest overall average % Compliance Margin (17.5%).
- RMST Climate Zone 5 has the lowest overall average % Compliance Margin (-5.3%).

- Attached single family and multifamily buildings are, on average, more compliant than detached single family homes.

Table 4-5: Average % Compliance Margin and Number of Sites – by RMST Climate Zone

RMST CZ	CEC CZ	Overall	Detached Single Family Homes	Attached Single Family & Multifamily Buildings[5]
CZ1	**1, 2, 3, 4, 5**	14.1%	11.4%	22.3%
		121	93	28
CZ2	**6, 7**	17.5%	14.7%	22.1%
		127	84	43
CZ3	**8, 9, 10**	8.6%	6.1%	22.3%
		169	144	25
CZ4	**11, 12, 13**	7.0%	4.1%	22.0%
		253	209	44
CZ5	**14, 15, 16**	-5.3%	-6.2%	3.3%
		49	40	9

4.5 Compliance Analysis by Building Type

This section studies the relationship between compliance groups and building types by examining the distribution of sites by compliance groups and building types and examining other building characteristics such as number of floors and conditioned floor area by compliance group.

Distribution of Sites by Compliance Groups and Building Types

Results showing the relationship between compliance groups and building types are presented in Table 4-6 and illustrated in Figure 4-8 for detached single family homes and Figure 4-9 for multifamily buildings.

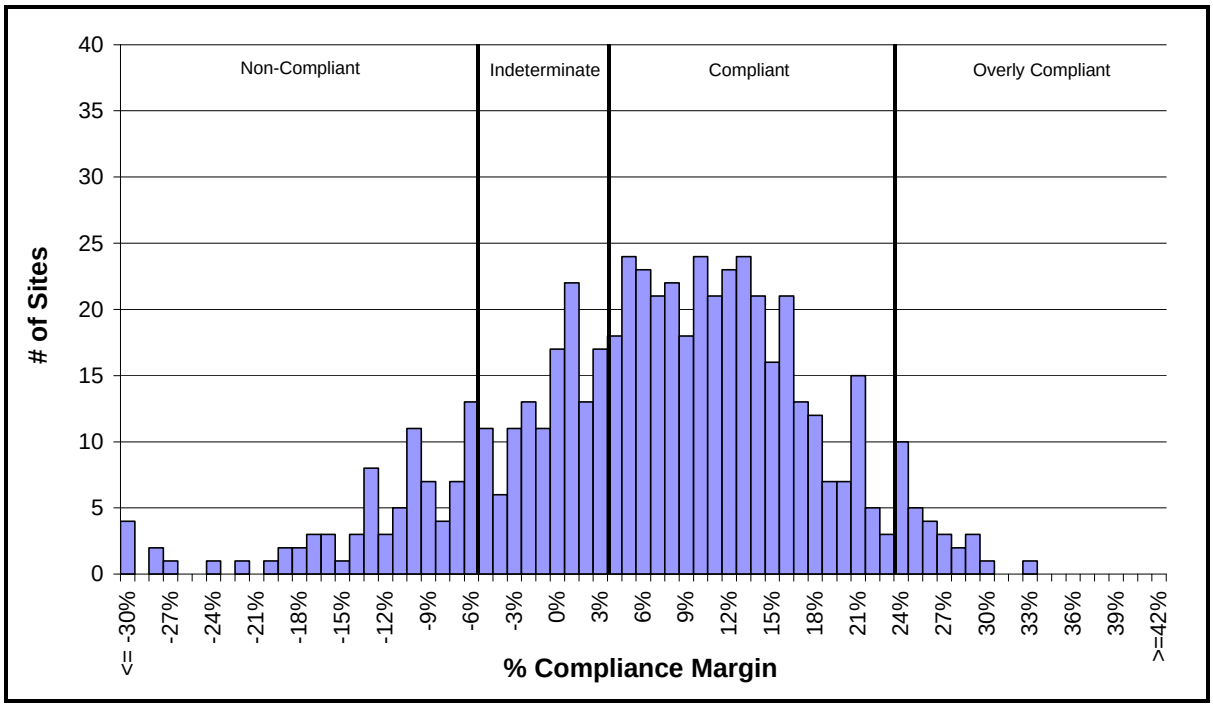
- Most multifamily buildings and detached single family homes are in the compliant group.
- There is a larger percentage of multifamily buildings in the overly compliant group than detached single family homes.

[5] Note that sites with a central water heater or boiler were removed from the analysis.

Table 4-6: Distribution of Sites by Compliance Group and Building Type

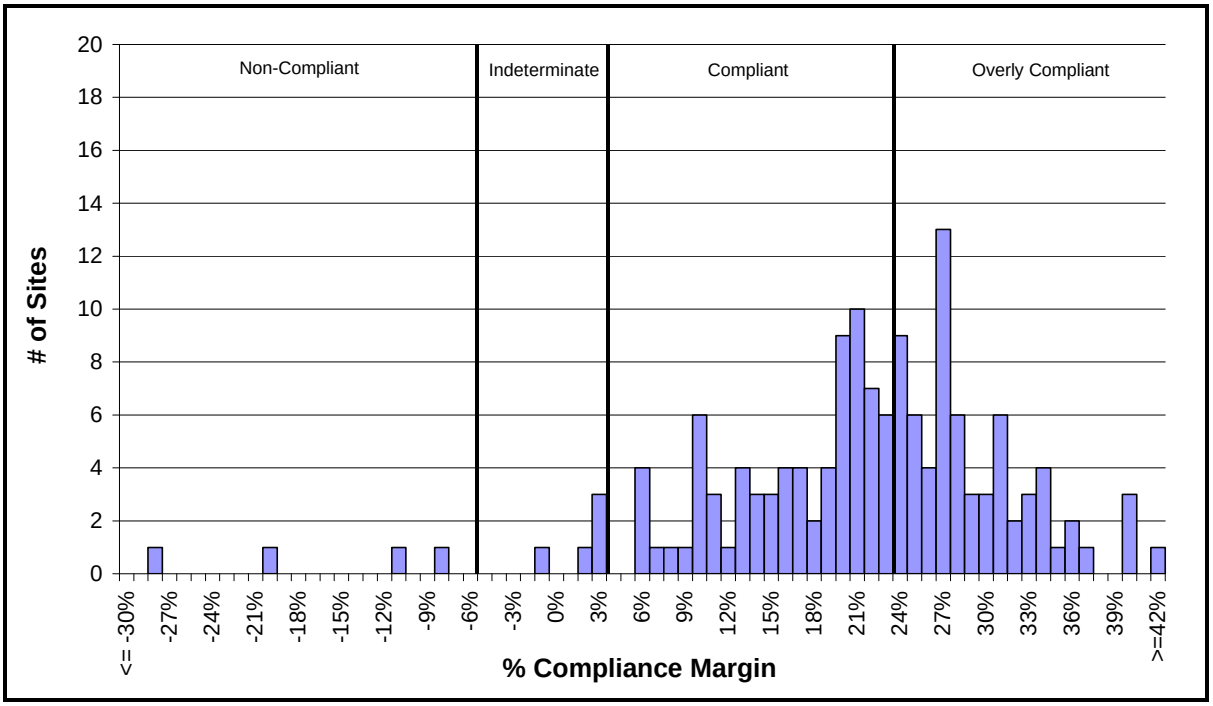
Compliance Group	# Sites in Sample	Detached Single Family Homes	Attached Single Family & Multifamily Buildings[6]
Non-Compliant	86	82	4
Indeterminate	126	121	5
Compliant	411	338	73
Overly Compliant	96	29	67
# Sites in Sample	719	570	149
Overall Percentage		79%	21%

Figure 4-8: MICROPAS Results Summary—Detached Single Family Homes



6 Note that sites with a central water heater or boiler were removed from the analysis.

Figure 4-9: MICROPAS Results Summary— Attached Single Family and Multifamily Buildings[7]



For each building type, the percentage of sites in each compliance group is presented in Table 4-7 and Figure 4-10. Analysis on this basis was performed in order to make a qualitative assessment of any differences in general compliance tendencies by building type. Key findings are summarized below.

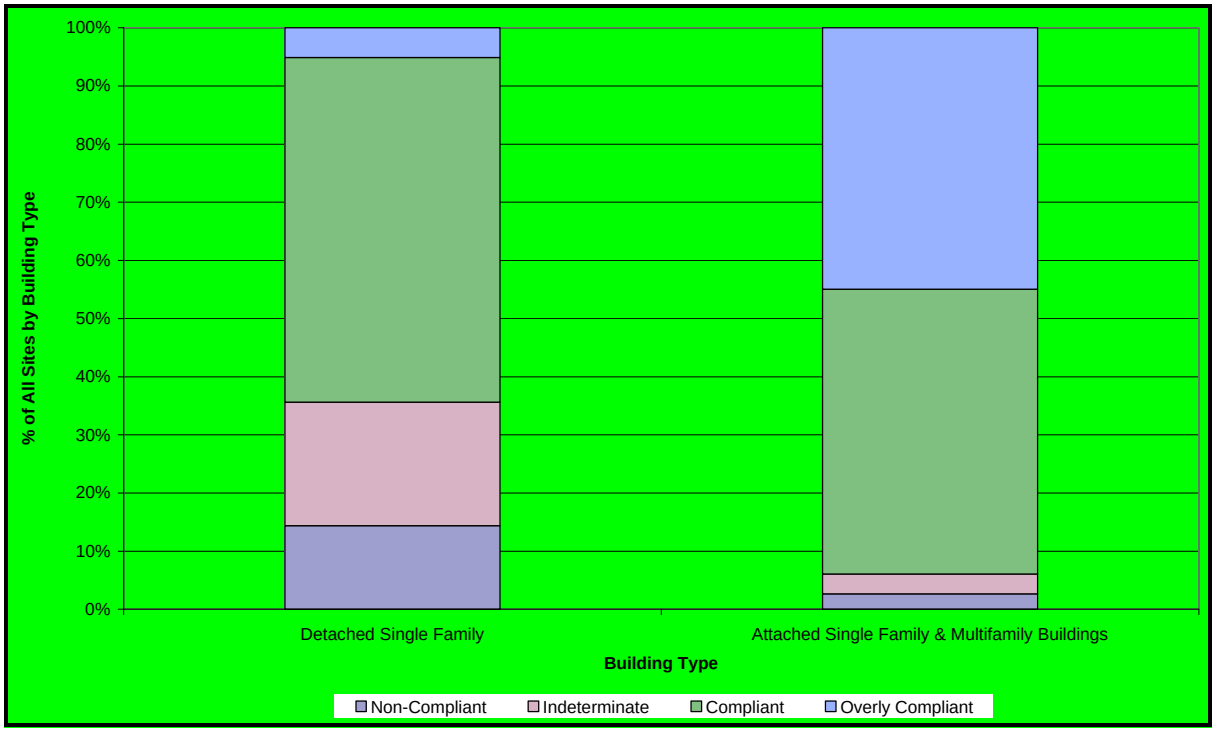
- Multifamily buildings are more compliant than detached single family homes based on percentages of overly compliant and compliant sites: 63% (4% overly compliant, 59% compliant) for detached single family homes versus 94% (44% overly compliant, 50% compliant) for multifamily buildings.

[7] Note that sites with a central water heater or boiler were removed from the analysis.

Table 4-7: Summary of Compliance Groups by Building Type

Compliance Group	# Sites in Sample	Detached Single Family Homes	Attached Single Family & Multifamily Buildings[8]
For Each Building Type, % of Sites in Each Compliance Group			
Non-Compliant	86	15%	3%
Indeterminate	126	22%	3%
Compliant	411	59%	50%
Overly Compliant	96	4%	44%
# Sites in Sample	719	570	149

Figure 4-10: Distribution of Compliance Groups by Building Type



8 Note that sites with a central water heater or boiler were removed from the analysis.

Distribution of Sites by Compliance Group, Building Type, and Number of Floors

The relationship between building types and compliance groups is summarized in Table 4-8. Key findings are summarized below.

- Examining the compliant and overly compliant site percentages, detached single family homes tend to be slightly less compliant than either attached single family homes or multifamily buildings (63% versus 100% and 91%, respectively).
- For detached single family homes, one-story homes tend to be less compliant than multi-story homes. Non-compliant percentages by number of floors decrease from 23% for one-story homes to 8% for two-story homes, and compliant/overly compliant percentages by number of floors increase from 55% for one-story homes to 70% for two-story homes.
- Most custom built, detached single family homes are compliant (60%). However, a large percentage of these homes are non-compliant (21%) or indeterminate (19%).

Table 4-8: Distribution of Compliance Groups by Building Type and Number of Floors

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
SF (detached single family)	570	15%	22%	59%	4%
1 story	257	23%	22%	53%	2%
2 story	306	8%	21%	65%	5%
3 story	7	-	56%	44%	-
SF-A (attached single family)	52	-	0%	68%	32%
1 story	13	-	2%	84%	13%
2 story	34	-	-	62%	38%
3 story	5	-	-	81%	19%
MF (multifamily)	97	5%	4%	41%	50%
1 story	-	-	-	-	-
2 story	63	6%	6%	47%	42%
3 story	34	2%	-	31%	67%
Custom detached single family homes		21%	19%	51%	9%

Distribution of Sites by Compliance Group and Conditioned Floor Area

The relationship for conditioned floor area by building type and compliance group is summarized in Table 4-9. Key findings are summarized below.

- The average floor area of detached single family homes is 2,323 square feet.
- The average floor area of attached single family homes is 9,869 square feet, while the average for multifamily homes is significantly greater (23,333 square feet).

Table 4-9: Summary of Comparison Groups by Average Conditioned Floor Area

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
SF (detached single family)	2,323	2,081	2,259	2,394	2,554
1 story	1,895	1,851	1,875	1,922	1,899
2 story	2,682	2,658	2,544	2,723	2,767
3 story	3,264	-	3,414	3,075	-
SF-A (single family attached)	9,869	-	7,560	9,498	10,694
1 story	3,888	-	7,560	3,870	3,360
2 story	11,008	-	-	10,834	11,291
3 story	11,529	-	-	11,704	10,800
MF (multifamily)	23,333	14,695	15,308	17,942	29,242
1 story	-	-	-	-	-
2 story	11,655	11,852	15,308	11,082	11,738
3 story	46,613	30,000	-	38,376	50,998

4.6 Compliance Analysis across HVAC and Water Heating Energy Budgets

Since compliance is determined by comparing the proposed energy used to the maximum energy usage allowed by specific end uses, it is important to consider how each end use affects the home's compliance. This section summarizes how the relative share of the HVAC and water heating energy budgets affects compliance.

HVAC and Water Heating Budgets

HVAC and water heating energy use, as determined from the MICROPAS budget results, was examined by compliance group in two ways. First, the end-use proportions of the total energy budget were examined (standard budget), followed by energy intensities in kBtuh/ft^2/yr.

Standard Energy Budget by HVAC and Water Heating

Table 4-10 shows how the standard energy budget changes across RMST climate zones. As shown, RMST Climate Zone 2 has the lowest average total standard energy budget. RMST Climate Zones 1 and 3 have the next lowest average total standard energy budget, while the budgets for RMST Climate Zones 4 and 5 are approximately triple that of RMST Climate Zone 2.

Table 4-10: Average Annual End Use Standard Budgets

Analysis Parameter Description	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Water Heating Intensity					
Average Standard Budget	13.98	12.61	12.48	14.26	13.29
% of Total Standard Budget	40.7%	63.6%	35.8%	23.0%	23.4%
Space Heating Intensity					
Average Standard Budget	14.77	3.84	9.18	25.52	17.77
% of Total Standard Budget	43.0%	19.4%	26.3%	41.2%	31.3%
Space Cooling Intensity					
Average Standard Budget	5.58	3.37	13.20	22.17	25.65
% of Total Standard Budget	16.2%	17.0%	37.9%	35.8%	45.2%
Total					
Average Standard Budget	34.32	19.82	34.87	61.95	56.71

For each compliance group, the average proportion of each end use (space heating, space cooling, and water heating), as developed from MICROPAS Standard budget results, is shown in Table 4-11 and Figure 4-11. Key findings are summarized below.

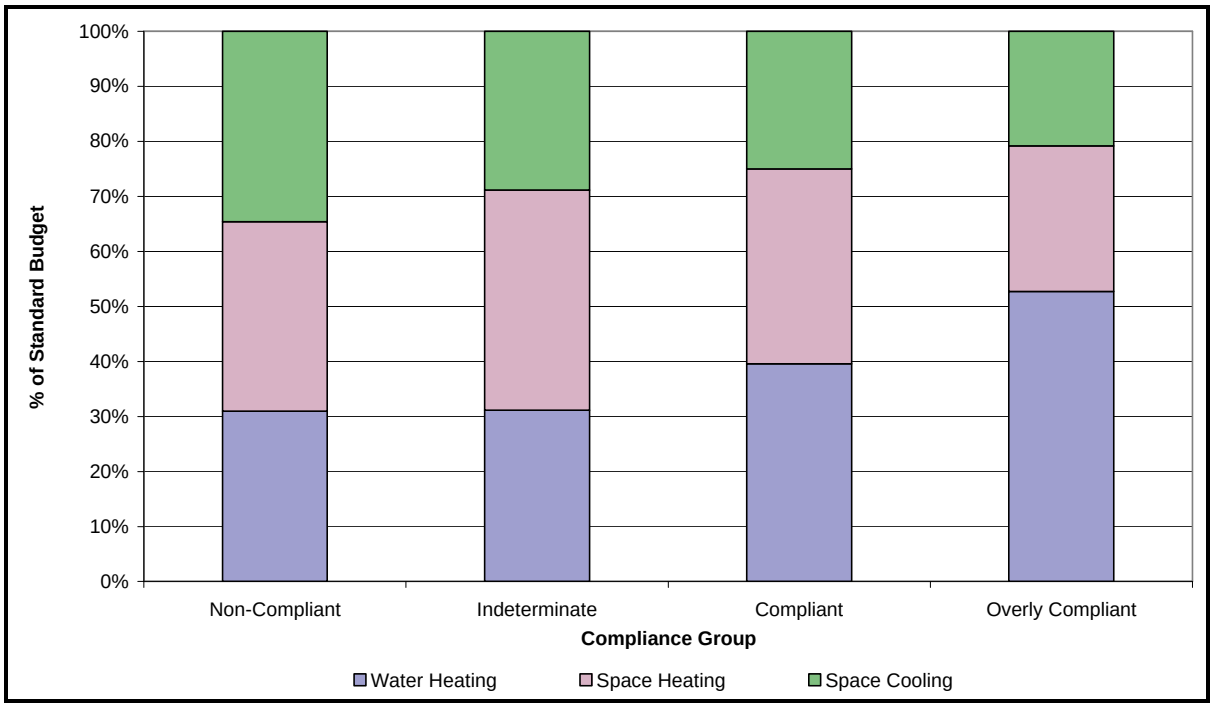
- Overall, water heating comprises approximately 38% of the total standard budget.
- Water heating has a slightly larger percentage of the energy budget for compliant and overly compliant sites (40% and 53%) than for indeterminate and non-compliant sites (31% and 31%).

- The opposite is true of space cooling. The space cooling budget as a percent of the total energy budget decreases across compliance groups 35% in the non-compliant group to 21% in the overly compliant group.

Table 4-11: Average Proportions of Standard Budget from Compliance Analysis

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
Water Heating	38%	31%	31%	40%	53%
Space Heating	35%	34%	40%	35%	26%
Space Cooling	26%	35%	29%	25%	21%

Figure 4-11: Average HVAC and Water Heating Percentages of Standard Budget by Comparison Group



Standard vs. Proposed Energy Budgets by HVAC and Water Heating

Table 4-12 shows the average standard and proposed energy budgets by RMST climate zone and end use. As mentioned earlier, RMST Climate Zone 2 has the lowest average standard budget, while RMST Climate Zones 4 and 5 have the largest. Also shown is that RMST Climate Zone 4 has the largest total margin.

Water Heating. Each RMST Climate Zone has positive water heating margins.[9] Note that while RMST Climate Zone 4 has the largest water heating margin, RMST Climate Zone 2 has the largest water heating margin as a percent of the total standard budget. Since RMST Climate Zone 2 has very small heating and cooling budgets, the positive water heating margin has a larger impact on overall compliance than the other RMST Climate Zones.[10]

HVAC. As shown in Table 4-12, RMST Climate Zones 3 and 5 have negative space cooling margins. In fact, the large negative space cooling margin for RMST Climate Zone 5 is the reason the average % Compliance Margin for these homes is -5.3%. On the other hand, the positive space cooling and space heating margins of RMST Climate Zones 1, 2, and 4 and the positive space heating margin of RMST Climate Zone 3 help these climate zones have positive average % Compliance Margins.

9 Please see Section 4.13 for a discussion on changes in the water heating budget between the 1995 standards and the 1998 standards.

10 The differences amongst the RMST Climate Zones are discussed in more detail in Section 4.12.

Table 4-12: Average Annual End Use Energy Intentsities (kBtuh/ft^2 per year) by RMST Climate Zone

Analysis Parameter Description	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Water Heating Intensity					
Average Standard Budget	13.98	12.61	12.48	14.26	13.29
Average Proposed Budget	12.36	11.30	11.00	12.32	11.63
Average Margin	1.61	1.31	1.49	1.94	1.65
Space Heating Intensity					
Average Standard Budget	14.77	3.84	9.18	25.52	17.77
Average Proposed Budget	13.01	3.08	6.92	23.08	17.07
Average Margin	1.76	0.76	2.26	2.44	0.70
Space Cooling Intensity					
Average Standard Budget	5.58	3.37	13.20	22.17	25.65
Average Proposed Budget	4.30	1.92	14.11	20.53	30.93
Average Margin	1.28	1.44	-0.91	1.64	-5.28
Total					
Average Standard Budget	34.32	19.82	34.87	61.95	56.71
Average Proposed Budget	29.67	16.30	32.03	55.92	59.63
Average Margin	4.66	3.51	2.84	6.03	-2.93

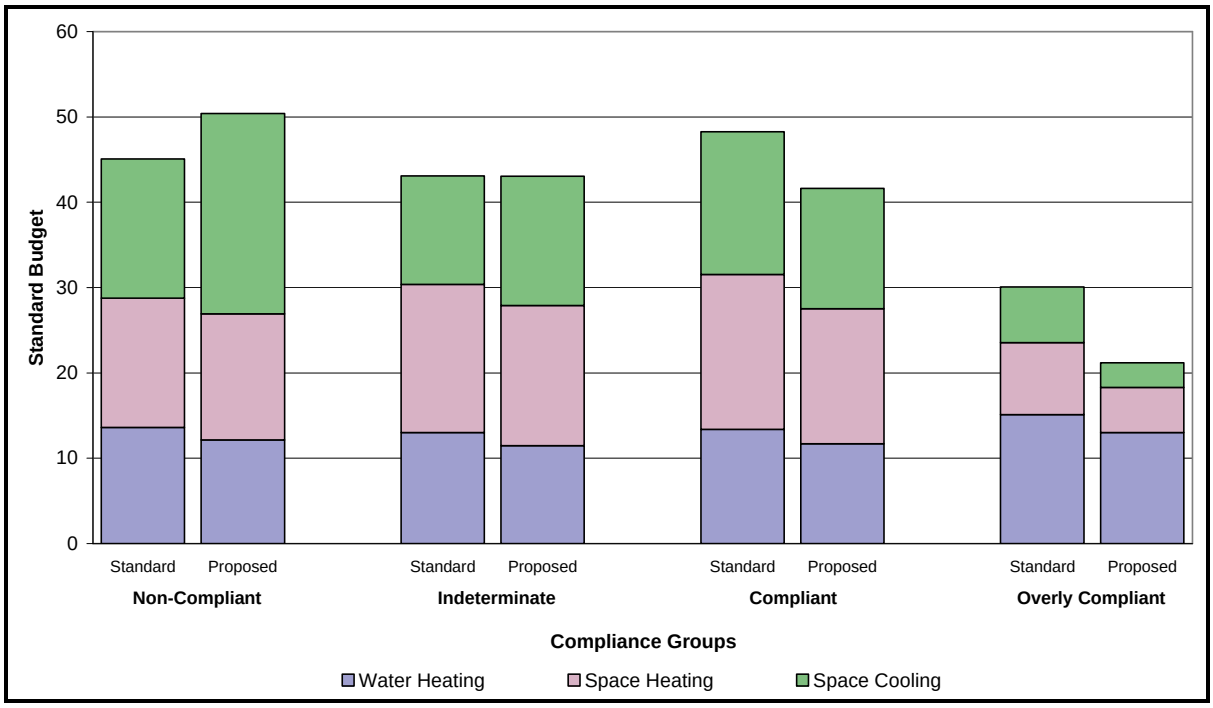
For each compliance group, the average end-use (space heating, space cooling and water heating) energy intensities, as developed from MICROPAS budget results, are presented Table 4-13 and illustrated in Figure 4-12 by compliance group. Key findings are summarized below.

- The average standard space heating budget decreases from the non-compliant group to the overly compliant group (15.15 to 8.43). Likewise, the average standard cooling budget also decreases from the non-compliant group to the overly compliant group (16.31 to 6.52).
- Non-compliant sites are typically non-compliant because of their large negative cooling margins, while overly compliant sites are typically overly compliant because of their large positive cooling and heating margins.

Table 4-13: Average Annual End-Use Energy Intensities (kBtuh/ft^2 per year) by Compliance Group

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
Water Heating Intensity					
Average Standard Budget	13.53	13.60	13.02	13.36	15.11
Average Proposed Budget	11.86	12.13	11.48	11.68	12.98
Average Margin	1.68	1.47	1.54	1.67	2.13
Space Heating Intensity					
Average Standard Budget	16.50	15.15	17.36	18.19	8.43
Average Proposed Budget	14.55	14.78	16.42	15.81	5.32
Average Margin	1.95	0.37	0.94	2.38	3.11
Space Cooling Intensity					
Average Standard Budget	14.73	16.31	12.70	16.72	6.52
Average Proposed Budget	14.17	23.49	15.14	14.14	2.86
Average Margin	0.56	-7.18	-2.44	2.58	3.66
Total					
Average Standard Budget	44.76	45.06	43.08	48.26	30.06
Average Proposed Budget	40.57	50.40	43.04	41.63	21.16
Average Margin	4.18	-5.34	0.04	6.63	8.90

Figure 4-12: Average Annual End-Use Energy Intensities (kBtuh/ft^2 per year)



As shown, water heating budgets remain relatively constant throughout the compliance groups. Also shown is that, on average, sites in every group have a small positive water heating margin (average margins range from 1.47 to 2.13). With the exception of sites with electric water heaters, water heating budgets do not seem to impact compliance much. Instead, HVAC budgets drive whether a site is non-compliant or overly compliant.

4.7 Building Shell Analysis

This section looks at the relationships between compliance groups and building shell features, including ceiling insulation, wall insulation, and roof/wall/floor construction types.

Ceiling and Wall Insulation

Table 4-14 presents the relationship between ceiling insulation and compliance. Included in the table are the percentages of sites with higher/equal/lower-than-prescriptive insulation installed, the average % below prescriptive values, and the percentages of sites with observed insulation levels—each by compliance group. The following observations can be made.

- Ceiling insulation R-values were gathered for approximately 22% of sites statewide.
- New homes have insulation that is, on average, 21% less efficient than prescriptive.

- For sites with observed data, examination of the *Average % of Presc. R-Value* shows a clear pattern of nearing prescriptive values across the compliance groups from non-compliant to compliant (-20%, -13%, -7%).

Table 4-14: Summary of Ceiling Insulation Levels by Compliance Group

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
Higher Performance (>Presc)	0%	-	-	0%	-
Equal to Prescriptive	26%	26%	22%	29%	23%
Lower Performance (<Presc)	73%	74%	78%	71%	77%
Average % of Presc. R-Value	-21%	-20%	-20%	-21%	-24%
% of sites w/observed data	22%	20%	22%	24%	14%
Average % of Presc. R-Value	-10%	-20%	-13%	-7%	-9%
% of sites w/default R-values	78%	80%	78%	76%	86%
Average % of Presc. R-Value	-24%	-20%	-22%	-25%	-26%

Table 4-15 presents the relationship between wall insulation and compliance. Included in the table are the percentages of sites with higher/equal/lower-than-prescriptive insulation installed, the average % below prescriptive value, and the percentage of sites with observed insulation levels—each by compliance group. The following observations can be made.

- Wall insulation R-values were gathered for very few sites (16% overall).
- There is a general pattern of wall insulation levels nearing and then exceeding the prescriptive values across compliance groups from non-compliant to overly compliant.
- For sites with observed data, the *Average % of Presc. R-value* increases across compliance groups (-25% for non-compliant to 49% for overly compliant).

Table 4-15: Summary of Wall Insulation Levels by Compliance Group

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
Higher Performance (>Presc)	5%	1%	1%	5%	12%
Equal to Prescriptive	87%	79%	81%	91%	86%
Lower Performance (<Presc)	9%	20%	18%	5%	1%
Average % of Presc. R-Value	0%	-5%	-5%	1%	7%
% of sites w/observed data	16%	21%	22%	13%	14%
Average % of Presc. R-Value	-2%	-25%	-23%	7%	49%
% of sites w/default R-values (set to prescriptive value)	84%	79%	78%	87%	86%

Roof, Wall, and Floor Construction

Table 4-16 shows the distribution of sites by Compliance Group and roof construction type. The following observations can be made regarding roof construction.

- Approximately 88% of homes have a framed-with-attic (FAT) roof type. Homes with this type of roof are fairly evenly spread across the non-compliant, indeterminate, and compliant groups.
- Nearly 46% of homes in the overly compliant group have a framed-without-attic roof type. (Note that 67 of the 96 sites in the overly compliant group are multifamily buildings, which explains the high percentage of sites that have a framed-without-attic roof type.)

Table 4-16: Summary of Roof Construction Type by Compliance Group

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
Framed w/Attic (FAT)	87.7%	92.9%	97.6%	92.0%	45.5%
Framed w/o Attic (FNO)	12.2%	7.1%	2.4%	8.0%	53.4%
Metal Decking (MET)	0.1%	-	-	-	1.1%

Table 4-17 shows the distribution of sites by compliance group and wall construction type. The following observations can be made.

- The percentage of metal-framed sites across compliance groups is extremely low—ranging from 0.0% to 0.8%.

Table 4-17: Summary of Wall Construction Type by Compliance Group

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
% Wood Framing	99.7%	99.2%	100.0%	99.7%	100.0%
% Metal Framing	0.3%	0.8%	-	0.3%	-

Table 4-18 shows the distribution of sites by compliance group and floor type. In addition, since 92% of homes are slab-on-grade, sites with this floor type are further broken out by building type. Regarding floor construction, the following observations can be made.

- Approximately 93% of the sites in the compliant group have slab-on-grade floors.
- A larger percentage (7.5%) of sites in the non-compliant group have raised floors (i.e., crawlspace) than those in the compliant group (4.3%), however, approximately 5.4% of the sites in the overly compliant group also have raised floors.

Table 4-18: Summary of Typical Floor Construction Type by Compliance Group

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
% Slab-On-Grade	92.2%	91.7%	94.9%	92.8%	85.4%
Detached Single Family	80.4%	95.5%	96.7%	82.3%	24.6%
Multifamily	13.8%	4.5%	3.1%	10.3%	61.1%
Attached Single Family	5.8%	-	0.2%	7.3%	14.3%
% Crawlspace	4.9%	7.5%	4.1%	4.5%	5.4%
% Other	2.9%	0.8%	0.9%	2.7%	9.3%

4.8 Fenestration Analysis

This section summarizes the relationship between compliance and percent glazing and between compliance and the types of windows installed.

Percent Glazing

Percent glazing is a major indicator of the tendency of a site to be compliant or non-compliant.

- The percentage of detached single family homes with higher-than-prescriptive percent glazing values decreases across compliance groups (non-compliant to overly compliant drops from 88.8% to 50.0%, then 27.3% to 26.8%).
- Detached single family homes in the non-compliant group have the largest average percent glazing (22%). The average percent glazing then decreases across compliance groups and is 15% for sites in the overly compliant group.
- Each of the attached single family residences surveyed has lower-than-prescriptive percent glazing values. Like detached single family homes, the average percent glazing decreases across compliance groups from the indeterminate group (14%) to the overly compliant group (8%). Note that no attached single family residences fall into the non-compliant group.
- The percentage of multifamily residences with lower -than-prescriptive percent glazing values increases across compliance groups from 43% in the non-compliant group to 100% in the compliant and overly compliant groups.

Table 4-19: Percent Glazing by Compliance Group – Detached Single Family Homes

Analysis Parameter Description	Overall (570 Sites)	Non-Compliant (82 Sites)	Indeter-minate (121 Sites)	Compliant (338 Sites)	Overly Compliant (29 Sites)
% of Sites in Compliance Group					
Higher than Prescriptive	41.6%	88.8%	50.0%	27.3%	26.8%
Equal to Prescriptive	0.8%	-	0.9%	1.0%	-
Less than Prescriptive	57.6%	11.2%	49.2%	71.7%	73.2%
Average % of Prescriptive	-2%	26%	4%	-10%	-19%
Average % Glazing	17%	22%	18%	16%	15%

Table 4-20: Percent Glazing by Compliance Group – Single Family Attached Homes

Analysis Parameter Description	Overall (52 Sites)	Non-Compliant (0 Sites)	Indeter-minate (1 Site)	Compliant (35 Sites)	Overly Compliant (16 Sites)
% of Sites in Compliance Group					
Higher than Prescriptive	-	-	-	-	-
Equal to Prescriptive	-	-	-	-	-
Less than Prescriptive	100.0%	-	100.0%	100.0%	100.0%
Average % of Prescriptive	-47%	-	-14%	-43%	-57%
Average % Glazing	10%	-	14%	11%	8%

Table 4-21: Percent Glazing by Compliance Group – Multifamily Buildings

Analysis Parameter Description	Overall (97 Sites)	Non-Compliant (4 Sites)	Indeter-minate (4 Sites)	Compliant (38 Sites)	Overly Compliant (51 Sites)
% of Sites in Compliance Group					
Higher than Prescriptive	3.8%	56.9%	30.4%	-	-
Equal to Prescriptive	-	-	-	-	-
Less than Prescriptive	96.2%	43.0%	69.6%	100.0%	100.0%
Average % of Prescriptive	-49%	-13%	-10%	-44%	-59%
Average % Glazing	9%	14%	16%	10%	7%

Window Types

Typical construction for window types (frame type, glass type, and number of panes) versus compliance group are presented in Table 4-22 for detached single family homes, Table 4-23 for attached single family residences, and Table 4-24 for multifamily residences on an average fenestration U-value basis. Table 4-25provides a summary of the types of windows installed by compliance group. Key findings are summarized below.

The trend for fenestration/windows across compliance groups is that non-compliant sites have lower performance fenestration/windows than overly compliant sites.

- The percentage of detached single family homes with lower performance fenestration decreases across compliance groups (non-compliant to overly compliant goes from 30% to 0%). The average U-value also decreases across compliance groups from 0.64 to 0.55.

- The same trends do not hold for attached single family and multifamily buildings. The average U-value for attached single family buildings ranges across compliance groups from 0.62 to 0.60 and from 0.77 to 0.65 for multifamily residences.

The use of metal-framed windows is more prevalent in non-compliant sites than overly compliant sites.

- Approximately 16% of the detached single family homes statewide have predominantly metal-framed windows, while 12% of attached single family buildings and 27% of multifamily buildings have metal-framed windows.
- For detached single family homes, the use of metal windows decreases across compliance groups from the non-compliant group (28%) to the overly compliant group (0%).

Regarding the use of dual-paned windows, these used in approximately 99% of homes.

- There is no trend in the use of dual-paned windows across compliance groups. Approximately 99.6% of detached single family homes are built with dual-paned windows, while 98.0% of attached single family buildings and 96.0% of multifamily buildings have dual-paned windows.

Regarding the use of low-E windows, these are more prevalent in compliant/overly compliant sites than non-compliant sites.

- The percentage of detached single family homes with low-E windows increases across compliance groups, from 2.6% in the non-compliant group to 14.1% in the compliant group to 20.9% in the overly compliant group.

Table 4-22: Summary of Average Fenestration U-Values by Compliance Group – Single Family Detached Homes

Analysis Parameter Description	Overall (570 Sites)	Non-Compliant (82 Sites)	Indeter-minate (121 Sites)	Compliant (338 Sites)	Overly Compliant (29 Sites)
Higher Performance (<Presc)	85.0%	67.2%	77.3%	91.5%	100.0%
Equal to Prescriptive	1.3%	2.7%	-	1.6%	-
Lower Performance (>Presc)	13.7%	30.2%	22.7%	6.9%	-
Average % of Prescriptive	-14%	-6%	-7%	-18%	-25%
Average U-value	0.597	0.638	0.623	0.579	0.551
Sites with metal-framed windows					
% of compliance group sites	16.2%	28.0%	22.4%	11.9%	0.0%
Sites with dual-paned windows					
% of compliance group sites	99.6%	98.7%	100.0%	99.6%	100.0%
Sites with Low-E glass					
% of compliance group sites	10.3%	2.6%	3.6%	14.1%	20.9%

Table 4-23: Summary of Average Fenestration U-Values by Compliance Group – Attached Single Family Buildings

Analysis Parameter Description	Overall (52 Sites)	Non-Compliant (0 Sites)	Indeter-minate (1 Site)	Compliant (35 Sites)	Overly Compliant (16 Sites)
Higher Performance (<Presc)	88.7%	-	100.0%	86.7%	92.8%
Equal to Prescriptive	7.5%	-	-	7.8%	7.2%
Lower Performance (>Presc)	3.8%	-	-	5.6%	-
Average % of Prescriptive	-15%	-	-8%	-15%	-14%
Average U-value	0.620	-	0.600	0.620	0.621
Sites with metal-framed windows					
% of compliance group sites	12.4%	100.0%	0.0%	9.6%	14.3%
Sites with dual-paned windows					
% of compliance group sites	98.0%	100.0%	100.0%	97.1%	100.0%
Sites with Low-E glass					
% of compliance group sites	6.4%	0.0%	0.0%	9.3%	0.0%

Table 4-24: Summary of Average Fenestration U-Values by Compliance Group – Multifamily Buildings

Analysis Parameter Description	Overall (97 Sites)	Non-Compliant (4 Sites)	Indeter-minate (4 Sites)	Compliant (38 Sites)	Overly Compliant (51 Sites)
Higher Performance (<Presc)	63.7%	45.7%	69.6%	58.0%	69.6%
Equal to Prescriptive	5.1%	-	-	7.4%	4.1%
Lower Performance (>Presc)	31.2%	54.3%	30.4%	34.6%	26.3%
Average % of Prescriptive	-3%	16%	-7%	-2%	-6%
Average U-value	0.668	0.769	0.645	0.681	0.650
Sites with metal-framed windows					
% of compliance group sites	27.3%	65.9%	11.7%	29.8%	23.9%
Sites with dual-paned windows					
% of compliance group sites	96.0%	79.7%	100.0%	93.9%	98.8%
Sites with Low-E glass					
% of compliance group sites	0.9%	0.0%	0.0%	2.1%	0.0%

Table 4-25: Summary of Window Types by Compliance Group

Analysis Parameter Description	Overall (752 Sites)	Non-Compliant (88 Sites)	Indeter-minate (132 Sites)	Compliant (427 Sites)	Overly Compliant (105 Sites)
2-paned Vinyl, Clear Glass	74.5%	66.5%	76.0%	75.1%	77.6%
2-paned Metal, Clear Glass	15.4%	27.4%	20.7%	10.7%	16.8%
2-paned Vinyl, Low-E	6.4%	1.3%	2.4%	9.2%	4.8%
2-paned Metal, Low-E	1.9%	1.1%	0.9%	2.9%	-
1-paned Vinyl, Clear Glass	0.8%	1.2%	-	1.0%	0.7%
1-paned Metal, Clear Glass	0.3%	1.3%	-	0.3%	-
2-paned Vinyl, Tinted/Reflective	0.4%	-	-	0.7%	-
2-paned Metal, Tinted/Reflective	0.2%	1.3%	-	-	-

4.9 Space Heating and Space Cooling Equipment Analysis

This section examines the relationship between various HVAC characteristics and compliance groups by showing average system efficiencies, system types, and duct locations by compliance group.

Space Heating Systems

A summary of space heating system characteristics, including average system efficiencies and the saturation of high efficiency gas furnaces, is presented in Table 4-26 by compliance groups. Regarding space heating efficiencies, the following observations can be made.

- The average efficiencies of gas furnaces installed in detached single family increases across compliance groups – from 80.2% AFUE in the non-compliant group to 80.6% AFUE in the overly compliant group.
- The average efficiencies of gas furnaces installed in multifamily buildings is also the highest in the overly compliant group (82.4%), while every attached single family building surveyed had an 80% AFUE furnace.
- Overall, as well as by compliance group, average AFUEs reflect a very low penetration of high efficiency systems. Approximately 3.4% of detached single family homes have a furnace with an AFUE greater than 90%, while 6.2% of multifamily buildings and no attached single family buildings do.

Table 4-26: Space Heating System Efficiencies by Compliance Group[11] – Single Family Detached Homes

Analysis Parameter Description	Overall (564 Sites)	Non-Compliant (82 Sites)	Indeter-minate (120 Sites)	Compliant (336 Sites)	Overly Compliant (26 Sites)
Average Efficiency (AFUE)	80.43	80.18	80.32	80.53	80.62
% of sites >= 90% AFUE	3.4%	1.4%	2.6%	4.1%	5.6%
% of sites w/observed data	82%	69%	81%	86%	98%
Average AFUE	80.52	80.25	80.39	80.62	80.63
% of sites w/default (set at 80% AFUE)	18%	31%	19%	14%	2%

[11] Only sites with natural gas or propane furnaces are included in this table.

Table 4-27: Space Heating System Efficiencies by Compliance Group[12] – Attached Single Family Buildings

Analysis Parameter Description	Overall (42 Sites)	Non-Compliant (0 Sites)	Indeter-minate (1 Site)	Compliant (27 Sites)	Overly Compliant (14 Sites)
Average Efficiency (AFUE)	80.00	-	80.00	80.00	80.00
% of sites >= 90% AFUE	-	-	-	-	-
% of sites w/observed data	83%	-	100%	74%	100%
Average AFUE	80.00	-	80.00	80.00	80.00
% of sites w/default (set at 80% AFUE)	17%	-	-	26%	-

Table 4-28: Space Heating System Efficiencies by Compliance Group[13] – Multifamily Buildings

Analysis Parameter Description	Overall (30 Sites)	Non-Compliant (3 Sites)	Indeter-minate (1 Site)	Compliant (14 Sites)	Overly Compliant (12 Sites)
Average Efficiency (AFUE)	80.92	80.00	80.00	80.00	82.36
% of sites >= 90% AFUE	6.2%	-	-	-	15.9%
% of sites w/observed data	65%	79%	100%	51%	77%
Average AFUE	81.42	80.00	80.00	80.00	83.06
% of sites w/default (set at 80% AFUE)	35%	21%	-	49%	23%

Table 4-29 shows the distribution of system types and duct locations by compliance group. The following observations can be made regarding space heating system types and duct locations.

- The predominant heating system type for all compliance groups is a central furnace (88% overall).
- While more than 90% of sites in the non-compliant, indeterminate, and compliant groups have central furnaces, only 49% of homes in the overly compliant group do. Instead, 41% of the sites have a hydronic heating system.[14]

[12] Only sites with natural gas or propane furnaces are included in this table.

[13] Only sites with natural gas or propane furnaces are included in this table.

[14] Of the 96 sites in the overly compliant group, 51 are multifamily buildings, which have a large percentage of hydronic systems.

- The overly compliant group has the largest percentage of homes with non-ducted HVAC systems (11% compared to 1.7%, 2.3%, and 2% for the non-compliant, indeterminate, and compliant groups, respectively).

Table 4-29: Space Heating Equipment Types and Locations by Compliance Group

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
System Types					
Central Furnace	87.9%	98.7%	96.9%	90.8%	49.0%
Central Heat Pump	1.0%	-	0.8%	0.2%	6.5%
Electric Resistance	-	-	-	-	-
Hydronic	10.1%	1.3%	1.5%	8.5%	40.7%
Radiant Heat	0.1%	-	0.8%	-	-
Wall Furnace	0.6%	-	-	0.5%	2.3%
Window/Wall Heat Pump	0.2%	-	-	-	1.5%
HVAC Location					
Attic	67.6%	72.4%	78.2%	70.6%	31.4%
Garage	9.7%	10.9%	6.8%	10.3%	10.2%
None (non-ducted[15])	2.9%	-	1.7%	2.3%	10.9%
Other	19.7%	16.6%	13.3%	16.7%	47.5%

Space Cooling Systems

Table 4-30 shows the average efficiency of the space cooling systems installed, as well as the percentage of homes that have an observed efficiency for their space cooling system. Key findings are summarized below.

- The average SEER for the non-compliant and overly compliant detached single family homes are the lowest of all compliance groups (10.25).
- The average SEER values for both attached single family buildings and multifamily buildings are close to the minimum of 10.0 SEER, 10.08 and 10.03 respectively.

[15] Most of the sites with a non-ducted HVAC system were multifamily buildings.

Table 4-30: Space Cooling System Efficiencies by Compliance Groups – Detached Single Family Buildings

Analysis Parameter Description	Overall (570 Sites)	Non-Compliant (82 Sites)	Indeter-minate (121 Sites)	Compliant (338 Sites)	Overly Compliant (29 Sites)
Average Efficiency (SEER)	10.45	10.25	10.41	10.53	10.25
% of sites w/AC >= 12 SEER	16%	5%	13%	20%	12%
% of sites w/observed data	70%	77%	71%	69%	52%
Average SEER	10.64	10.33	10.58	10.77	10.49
% of sites w/default 10 SEER	30%	23%	29%	31%	48%

Table 4-31: Space Cooling System Efficiencies by Compliance Groups – Attached Single Family Buildings

Analysis Parameter Description	Overall (52 Sites)	Non-Compliant (0 Sites)	Indeter-minate (1 Site)	Compliant (35 Sites)	Overly Compliant (16 Sites)
Average Efficiency (SEER)	10.08	-	10.20	10.11	10.01
% of sites w/AC >= 12 SEER	0%	0%	0%	0%	0%
% of sites w/observed data	47%	-	100%	56%	28%
Average SEER	10.17	-	10.20	10.20	10.05
% of sites w/default 10 SEER	53%	-	0%	44%	72%

Table 4-32: Space Cooling System Efficiencies by Compliance Groups – Multifamily Buildings

Analysis Parameter Description	Overall (97 Sites)	Non-Compliant (4 Sites)	Indeter-minate (4 Sites)	Compliant (38 Sites)	Overly Compliant (51 Sites)
Average Efficiency (SEER)	10.03	10.03	10.00	10.00	10.06
% of sites w/AC >= 12 SEER	6%	0%	0%	0%	16%
% of sites w/observed data	70%	84%	72%	60%	77%
Average SEER	10.04	10.04	10.00	10.01	10.07
% of sites w/default 10 SEER	30%	16%	28%	40%	23%

Table 4-33 shows the distribution of cooling system types and duct locations by compliance group. The following observations can be made regarding space cooling system types and duct locations.

- The leading system type for sites with cooling is central air conditioning (CAC) at 76% overall.
- The overly compliant group has the highest percentage of hydronic systems (35%). Since this group is comprised mostly of multifamily buildings, which tend to be more compliant because of their small glazing areas, and hydronic systems, which are non-ducted and therefore more efficient, this is not surprising.

Table 4-33: Space Cooling Equipment Types and Locations by Compliance Groups

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
System Types					
Central Air Conditioner	75.9%	96.2%	92.7%	74.7%	34.1%
Central Heat Pump	1.0%	-	0.8%	0.2%	6.5%
Evaporative Cooler	-	-	-	-	-
No Air Conditioner	14.9%	2.5%	4.9%	19.2%	22.5%
Hydronic	8.0%	1.3%	1.5%	5.9%	35.4%
Water Loop Heat Pump	-	-	-	-	-
Window/Wall Air Conditioner	-	-	-	-	-
Window/Wall Heat Pump	0.2%	-	-	-	1.5%
HVAC Location					
Attic	62%	72%	76%	62%	25%
Garage	6%	11%	6%	6%	5%
None (non-ducted)	17%	2%	6%	20%	31%
Other	15%	14%	12%	12%	38%

4.10 Water Heating Equipment Analysis

A summary of water heating system characteristics including average system efficiencies and type of water heater by compliance group and residence type are presented in Table 4-34,

Table 4-35, Table 4-36. Table 4-37 presents the distribution of sites by water heater fuel types, blanket/efficiency[16] and compliance group.

Regarding water heating system efficiencies versus compliance groups, the following key findings are summarized.

- Water heaters installed in new detached single family homes are, on average, 15.6% above the minimum energy factor. The average % above the minimum energy factor for attached single family and multifamily buildings are 14.0% and 13.2% respectively.[17]
- The average % above the minimum energy factor for detached single family homes increases across compliance groups from 14.3% in the non-compliant group to 15.8% in the compliant and overly compliant groups.
- This same trend does not hold for attached single family or multifamily buildings. However, for both residence types, the overly compliant group has the highest average % above the minimum energy factor.

[16] The relationship between the efficiency of a unit and whether a blanket was installed is important because, under the 1995 Residential Standards, credit for an external water heater blanket was given regardless of efficiency. This credit was dropped from the 1998 Standards.

[17] The averages listed here are for those sites where the efficiencies were collected.

Table 4-34: Water Heating System Efficiencies by Compliance Group – Detached Single Family Buildings

Analysis Parameter Description	Overall (570 Sites)	Non-Compliant (82 Sites)	Indeter-minate (121 Sites)	Compliant (338 Sites)	Overly Compliant (29 Sites)
Higher Performance	99%	100%	96%	99%	100%
Equal to Prescriptive	1%	-	4%	1%	-
Lower Performance	0%	-	-	0%	-
Average Efficiency (% above Min. Energy Factor)	15.2%	14.3%	14.4%	15.8%	15.8%
% of sites w/actual data	80%	82%	81%	79%	91%
Average % above Standard	15.6%	14.2%	15.4%	16.1%	15.8%
% of sites w/RER default EFs[18]	18%	18%	16%	20%	9%
Average % above Standard	14.6%	14.5%	12.9%	15.1%	16.1%
% of sites w/CEC Standard water heater (=Min. Std EF)[19]	1%	-	4%	1%	-

[18] RER default efficiency values are higher than standard efficiency and were intended to represent typical construction practice. These values were developed from actual data that were available, and vary by tank size.

[19] The CEC standard water heater is assumed when tank size and/or equipment type is not available.

Table 4-35: Water Heating System Efficiencies by Compliance Group – Attached Single Family Buildings

Analysis Parameter Description	Overall (52 Sites)	Non-Compliant (0 Sites)	Indeter-minate (1 Site)	Compliant (35 Sites)	Overly Compliant (16 Sites)
Higher Performance	96%	-	100%	94%	100%
Equal to Prescriptive	4%	-	-	6%	-
Lower Performance	-	-	-	-	-
Average Efficiency (% above Min. Energy Factor)	13.7%	-	15.2%	12.6%	16.0%
% of sites w/actual data	72%	-	-	71%	76%
Average % above Standard	14.0%	-	-	13.1%	15.9%
% of sites w/RER default EFs[20]	23%	-	100%	22%	24%
Average % above Standard	15.2%	-	15.2%	14.7%	16.3%
% of sites w/CEC Standard water heater (=Min. Std EF)[21]	4%	-	-	6%	-

[20] RER default efficiency values are higher than standard efficiency and were intended to represent typical construction practice. These values were developed from actual data that were available and vary by tank size.

[21] The CEC standard water heater is assumed when tank size and/or equipment type is not available.

Table 4-36: Water Heating System Efficiencies by Compliance Group – Multifamily Buildings

Analysis Parameter Description	Overall (97 Sites)	Non-Compliant (4 Sites)	Indeter-minate (4 Sites)	Compliant (38 Sites)	Overly Compliant (51 Sites)
Higher Performance	93%	100%	100%	87%	98%
Equal to Prescriptive	7%	-	-	13%	2%
Lower Performance	-	-	-	-	-
Average Efficiency (% above Min. Energy Factor)	12.5%	7.5%	13.8%	10.0%	14.8%
% of sites w/actual data	82%	100%	100%	74%	85%
Average % above Standard	13.2%	7.5%	13.8%	11.3%	15.0%
% of sites w/RER default EFs[22]	12%	-	-	13%	13%
Average % above Standard	14.4%	-	-	12.6%	16.0%
% of sites w/CEC Standard water heater (=Min. Std EF)[23]	7%	-	-	13%	2%

Regarding water heater fuel types and blanket versus efficiency results by compliance groups, the following key findings are summarized.

- Of the two sites with electric water heaters, one is in the non-compliant group and the other site is in the compliant group.[24] Those sites with gas water heaters are non-compliant due to their HVAC margin, not their water heater margin.
- The indeterminate group has the largest percentage of water heaters with higher performance water heaters and external insulation blankets (41%), followed by the non-compliant group (33%). This could indicate that wrapping an insulation blanket around an already high efficiency water heater is one feature used as an attempt to achieve compliance for what would otherwise have been a non-compliant site.
- The predominant blanket efficiency configuration for all compliance groups is no blanket and efficiency greater than the standard minimum

[22] RER default efficiency values are higher than standard efficiency and were intended to represent typical construction practice. These values were developed from actual data that were available and vary by tank size.

[23] The CEC standard water heater is assumed when tank size and/or equipment type is not available.

[24] The site in the non-compliant group is a multifamily building with a -9.09 water heater margin because of the 12 electric water heaters installed at the site. The site in the compliant group, however, is a detached single family home with an instantaneous water heater that created a -3.97 water heater margin. This home is compliant, however, due to its large HVAC margin.

Table 4-37: Water Heater Fuel Type and Blanket/Efficiency Level by Compliance Group

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
Gas/Propane Water Heater	99.7%	99.2%	100.0%	99.7%	100.0%
Electric Water Heater	0.3%	0.8%	-	0.3%	-
EF > Std. w/Blanket	29%	33%	41%	28%	7%
EF > Std. w/out Blanket	69%	67%	56%	69%	91%
EF = Std. w/Blanket	1%	-	3%	1%	-
EF = Std. w/out Blanket	1%	-	1%	2%	1%

4.11 Analysis of Extraneous Non-MICROPAS Features

This section examines extraneous features not reflected in the MICROPAS runs that may have a bearing on how the residence is built. This includes issues such as participation of the residence in an existing RNC program and the cost of the home.

Participation in Utility-Sponsored Programs

Each customer was asked, as part of the RMST survey, if the home was built as part of an RNC program. RNC programs represented in these responses included the following:

- ENERGY STAR (two homes),
- PG&E Comfort Home (17 homes),
- SCE ComfortWise (one home), and
- SCG Program (one home).

Results for these homes are reported by compliance group in Table 4-38 and show the following.

- Overall, only 3% of the residences self-reported participation in RNC programs.
- Approximately 4% of the homes in the compliant, indeterminate, and non-compliant groups are participants, while none of the sites in the overly compliant group claims to be participants of a RNC program. This is exactly the opposite of the pattern that might be expected for such homes. However, participation in an RNC program and the use of features such as duct sealing were not accounted for in the MICROPAS runs.

Table 4-38: Participation in Utility Sponsered Programs by Compliance Group

Analysis Parameter Description	Overall (719 Sites)	Non-Compliant (86 Sites)	Indeter-minate (126 Sites)	Compliant (411 Sites)	Overly Compliant (96 Sites)
Nonparticipant	97%	96%	96%	96%	100%
RNC Program Participant	3%	4%	4%	4%	-
# of sites	21	3	5	13	0

Housing Purchase Price

Compliance groups versus housing purchase price are presented in Table 4-39. Key findings are summarized below.

- The non-compliant and indeterminate groups have the highest percentage of homes that cost under $300k (66% and 61% respectively), while only 18% of the homes in the overly compliant group cost under $300k.
- The overly compliant group has the largest percentage of high cost homes (over $400k) at 71%.
- The average price of the homes increases across compliance groups from an average of $289k for non-compliant sites to $423k for overly compliant sites.

Table 4-39: Housing Purchase Prices Versus Compliance Group

Analysis Parameter Description	Overall (621 Sites)	Non-Compliant (61 Sites)	Indeter-minate (100 Sites)	Compliant (366 Sites)	Overly Compliant (94 Sites)
Average Home Price Ranges					
Under $100,000	3%	3%	6%	2%	1%
$100,000 - $200,000	24%	42%	35%	22%	7%
$200,000 - $300,000	22%	21%	23%	24%	10%
$300,000 - $400,000	13%	5%	14%	14%	11%
Over $400,000	39%	29%	22%	38%	71%
Average Home Price	$344,650	$288,851	$289,679	$352,652	$423,423

4.12 Differences in Compliance Performance across RMST Climate Zones

As mentioned above, RMST Climate Zones 5 is the least compliant of the RMST climate zones, while RMST Climate Zone 2 is the most compliant. These differences in average compliance performance could be attributable to the following:

- Differences in the efficiency of the equipment installed across RMST climate zones,
- Differences in the prescriptive standards required across RMST climate zones, especially the prescriptive glazing percentages, and
- Differences in the mixtures of end-use budget compared to the total compliance budget for each home.

In an attempt to explain the differences in average % Compliance Margins across RMST climate zones, two steps were taken. First, key characteristics, such as equipment efficiencies and fenestration information, were gathered to compare the average efficiencies for various measures across RMST climate zones. Next, the end-use standard budgets as a percentage of the total standard budgets across RMST climate zones were analyzed.

Key Characteristics by RMST Climate Zone

To test whether homes in RMST Climate Zone 5 are being built with less efficient measures than homes in the other RMST climate zones, key housing characteristics were compared. However, as shown in Table 4-40, and discussed below, this is clearly not the case. Instead, homes in RMST Climate Zone 5 have the second highest average SEER value and the third highest average AFUE value.

Table 4-40 provides a summary of key characteristics by RMST climate zone, for detached single family homes and multifamily buildings combined, including average glazing percentages, average SEER value, average AFUE values, and average percent above standard for gas water heaters. Each measure is discussed below.

Table 4-40: Summary of Key Characteristics by RMST Climate Zone

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Building Shell						
Average Number of Stories	1.7	2.0	2.1	1.8	1.5	1.2
Windows						
Average % Glazing	15.4%	15.1%	13.4%	16.4%	15.3%	17.7%
Prescriptive % Glazing		20% & 16%	20%	20%	16%	16%
Average U-value	0.607	0.594	0.608	0.596	0.619	0.619
Air Conditioners						
Average SEER of Observed Data	10.53	10.38	10.17	10.20	10.80	10.42
% of sites w/No Air Conditioner	17.1%	56.9%	28.7%	3.4%	0.8%	-
Gas Furnaces						
Average AFUE of Observed Data	80.52	80.62	80.10	80.19	80.86	80.41
Gas Water Heaters						
Avg, % Above Std Energy Factor	15.2%	14.4%	13.9%	15.9%	15.6%	15.5%

Number of Stories

The average number of stories presented in Table 4-40 includes both detached single family homes and multifamily buildings. RMST Climate Zone 5 has the lowest average number of stories (1.2) and, therefore, the largest percent of homes with only one story. RMST Climate Zone 2 has the highest average number of stories (2.1), while RMST Climate Zones 1 and 3 are close behind (2.0 and 1.8, respectively). As mentioned earlier in this section, one-story homes are inherently less compliant.

Fenestration

RMST Climate Zone 2 has the average glazing percentage (13.4%). In addition, since the prescriptive glazing percentage is 20%, it also has the largest difference between the prescriptive glazing percentage and its average glazing percentage. The average glazing percentage (17.7%) for homes in RMST Climate Zone 5, on the other hand, is greater than the prescriptive glazing percentage (16%). Since the homes in RMST Climate Zone 5 have, on average, more fenestration than the prescriptive package allows, these homes need high efficiency measures to comply with the building standards.

Cooling

RMST Climate Zone 4 has the highest average SEER values (10.86), while RMST Climate Zones 1 and 5 are close behind at 10.38 and 10.42, respectively. The average SEER values of air conditioners installed in RMST Climate Zones 2 and 3, however, are closer to the 10 SEER standard. This is not surprising since these climate zones have milder weather.

Heating

The results are similar for space heating. RMST Climate Zone 4 has the highest average AFUE value at 80.86% AFUE, while the average AFUE for gas furnaces in RMST Climate Zone 2 is 80.10%.

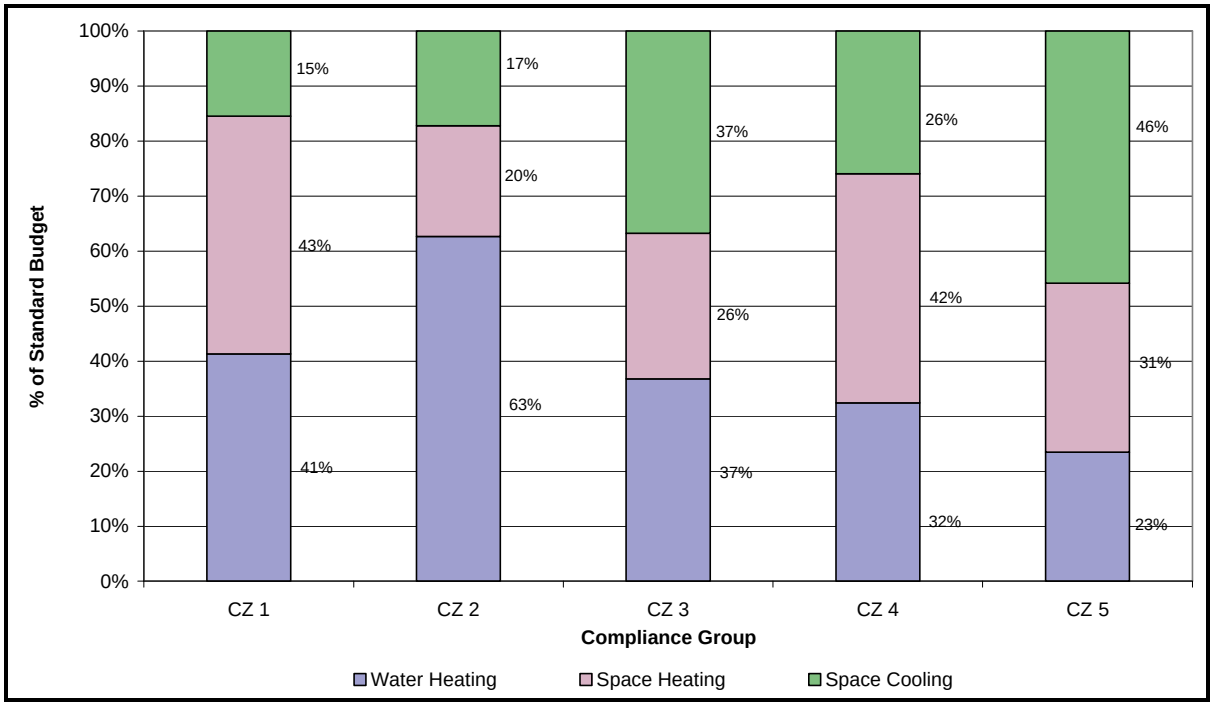
Water Heating

As shown in Table 4-40, the average percent above standard efficiency for gas water heaters ranges from 13.9% to 15.9% across RMST climate zones. The reason for this small range is a combination of the following: 1) the water heater budget is a large portion of the total budget in each RMST climate zone (this is discussed in more detail below) and 2) installing higher efficiency water heaters is seen as one of the most cost-effective ways to comply.

End-Use Budgets

To understand the differences in % Compliance Margins among RMST climate zones, it is important to first understand the differences in how the standard budgets are broken out by end use. As shown in Figure 4-13, RMST Climate Zone 5 has the largest space cooling budget as a percent of the total standard budget, while RMST Climate Zones 1 and 4 have the largest space heating budget as a percent of the total standard budget, as will be explained below. This information, along with the results of the compliance analysis by end use, helps to provide an explanation of why RMST Climate Zone 5 has the lowest average % Compliance Margin and why RMST Climate Zone 2 has the highest average % Compliance Margin.

Figure 4-13: Average End-Use Standard Budget as % of Total Standard Budget



Conclusion

The analysis of why homes in RMST Climate Zone 2 exhibit the highest compliance margins and homes built in RMST Climate Zone 5 exhibit the lowest compliance margins reveals the following. The baseline characteristics show that the average glazing percentage in RMST Climate Zone 2 is 6.4% lower than the prescriptive allowed in that climate zone compared to RMST Climate Zone 5, where the average glazing percentage is 1.7% higher than the prescriptive. This gives the homes in RMST Climate Zone 2 a significant advantage in trying to reach compliance. In addition, since high efficiency water heaters are standard practice and water heating is nearly two-thirds of the overall energy budget, homes in RMST Climate Zone 2 do not need high efficiency HVAC equipment to reach or greatly exceed compliance.

The homes in RMST Climate Zone 5, however, need high efficiency measures and sometimes even more to "just comply." Installing high efficiency HVAC equipment allows some of these homes to reach compliance, since a large portion of the standard budget in RMST Climate Zone 5 is HVAC (77%). As shown in the baseline characteristics, the average SEER value is 10.42 and the average AFUE is 80.4% in RMST Climate Zone 5, both of which are above standard. The compliance analysis shows that although some homes do have high efficiency equipment, the average compliance margin is -5.3%.

4.13 Summary of Compliance Results

The following summarizes the key findings of this chapter. Results are organized into the following groups:

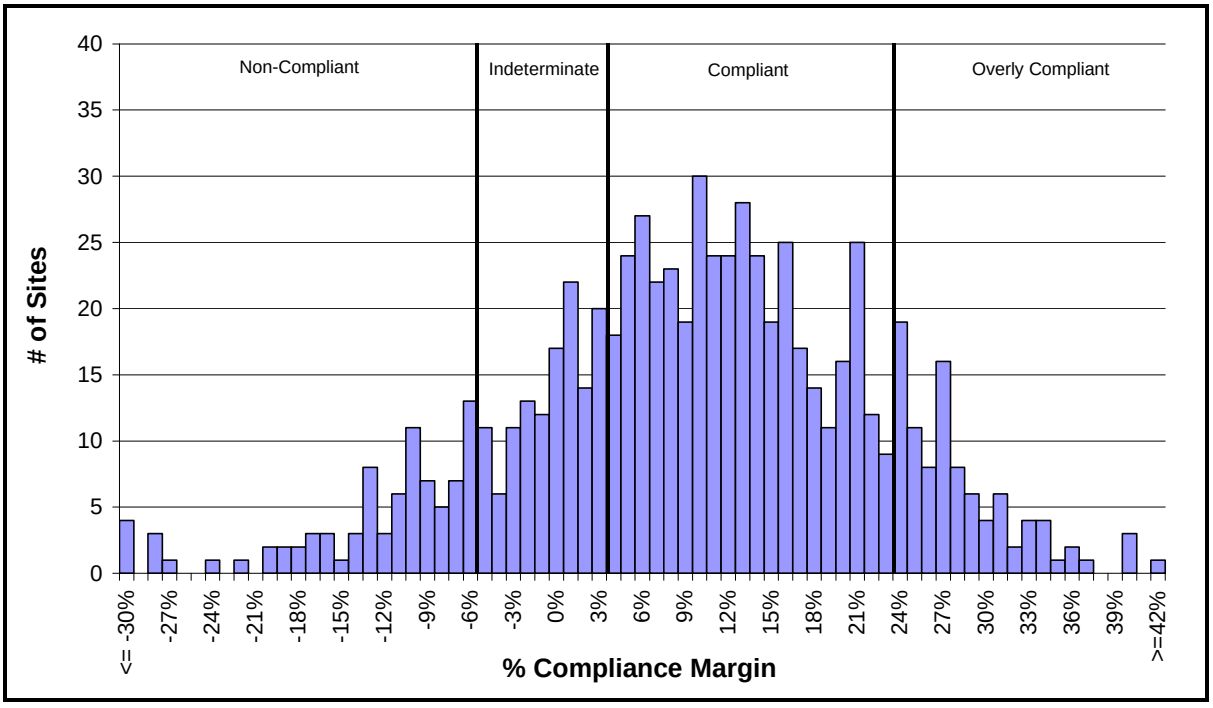
- Statewide/general,
- Regional (by RMST climate zone),
- Building type (single family vs. multifamily), and
- Compliance groups.

General Compliance Results

A brief summary of the statewide compliance results follows.

- **Approximately 12% of sites are in the non-compliant group.** Results from the RNC Interface show that most sites fall within the compliant group (57%) or within the indeterminate group (18%).[25]
- **Approximately 13% of sites are in the overly compliant group.**

Figure 4-14: MICROPAS Results Summary—All Sites



[25] See Section 2.4 for an explanation on the development of the error band.

Regional

The following summarizes the compliance results by RMST climate zone. In addition, Table 4-3 shows the average % Compliance Margin for each RMST climate zone.

- ***RMST Climate Zone 1*** (North Coast) tends to be compliant, as evidenced by an average % Compliance Margin of 14.1%. Of the sites in RMST Climate Zone 1, 75% fall in the compliant group, and only 9% are in either the indeterminate or non-compliant groups.
- ***RMST Climate Zone 2*** (South Coast) is the most compliant of the RMST climate zones with an average % Compliance Margin of 17.5%. Only 1% of sites in RMST Climate Zone 2 fall in the non-compliant group and only 4% fall in the indeterminate group.
- ***RMST Climate Zone 3*** (South Inland) tends to be compliant, as evidenced by an average % Compliance Margin of 9.0%. Approximately 12% of sites in RMST Climate Zone 3 fall in the overly compliant group, while 15% fall in the non-compliant group.
- ***RMST Climate Zone 4*** (Central Valley) also tends to be compliant, which is evidenced by an average % Compliance Margin of 7.0%. Of the sites in RMST Climate Zone 4, 15% fall in the non-compliant group and 26% are indeterminate.
- ***RMST Climate Zone 5*** (Desert/Mountain) is the most non-compliant of the RMST climate zones with an average % Compliance Margin of -5.3%. In fact, 39% of sites in RMST Climate Zone 5 fall in the non-compliant group and 31% are indeterminate.

Table 4-41: Average Compliance Margins by RMST Climate Zone

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average % Compliance Margin	9.4%	14.1%	17.5%	8.6%	7.0%	-5.3%

Building Type

As shown in Table 4-42, attached single family and multifamily buildings are more compliant than detached single family homes. One of the reasons for this is that the typical glazing percentage installed in these buildings is significantly less than the glazing percentage installed in detached single family homes.[26] As mentioned above, RMST Climate Zone 5 is the most non-compliant of the RMST climate zones. The table below shows that this is true for each building type.

[26] A significance test was conducted at the 95% confidence level.

Table 4-42: Average Compliance Margins by RMST Climate Zone and Building Type

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Detached Single Family Homes	6.2%	11.4%	14.7%	6.1%	4.1%	-6.2%
Attached Single Family Buildings	21.8%	22.7%	23.0%	21.5%	20.4%	10.8%
Multifamily Buildings	21.5%	21.9%	21.8%	23.5%	22.1%	-1.0%

Compliance Groups

The following is a summary of the compliance results by compliance groups.[27]

Non-Compliant

- **Large Glazing Percentages.** The average percent glazing for non-compliant sites is 21%, larger than for other compliance categories.
- **One-Story Homes are More Typical.** A higher percentage of one-story homes fall in the non-compliant group than two-story homes. This applies to both detached single family and attached single family homes.[28]
- **RMST Climate Zone 5** (Desert and Mountain) is the most non-compliant of the RMST climate zones based on the average % Compliance Margin of -5.3%. In fact, 39% of sites in RMST Climate Zone 5 fall in the non-compliant group, compared to only 1% of RMST Climate Zone 2 and 3% of RMST Climate Zone 1.[29]

Compliant and Overly Compliant

- **Smaller Glazing Percentages.** The average percent glazing for overly compliant sites is 9%, smaller than for other compliance categories.
- **Two-Story Homes are More Typical.** A higher percentage of two-story homes fall in the overly compliant group than one-story homes. This applies to both detached single family and attached single family homes.
- **RMST Climate Zone 2** (South Coastal) is the most compliant of the RMST climate zones based on the average % Compliance Margin of 17.5%. In fact, 27% of sites in RMST Climate Zone 2 fall in the overly compliant group, as opposed to only 9% of RMST Climate Zone 4 and 0% of RMST Climate Zone 5.[30]

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[27] See Section 4.1 for a detailed discussion of the compliance groups.

[28] This does not apply to multifamily buildings, since the definition of a multifamily building is that each unit share at least one floor or ceiling.

[29] See Section 3.5 for a summary of key characteristics by RMST climate zone.

[30] See Section 3.5 for a summary of key characteristics by RMST climate zone.

4.14 Caveats

This section includes caveats to keep in mind when reading the analysis that compares Project Year #1 homes and Project Year #2 homes.

Central Water Heating

Sites with a central water heating system were removed from the compliance analysis because details about the system were often not obtainable. The recruitment protocol for the RMST on-site surveys was to survey the residential unit and not the complex. Therefore, the owner/renter of the unit, and not the maintenance manager, was contacted. Since central systems are maintained by the complex, they are typically in a locked maintenance room and not accessible without maintenance personnel. Since no equipment information was obtained, it was decided to exclude them from the analysis. Note that these sites were not omitted during Project Year #1.

This primarily affects multifamily buildings. Recent research in new construction suggests that residential buildings, mainly multifamily buildings, with central water heaters have a higher % compliance margin than those with individual units. However, since efficiency information could not be collected during the on-site surveys, if these sites were left in the analysis, the default water heating would be zero. Outside sources claim that this low water heating margin would decrease the average % compliance margin of multifamily buildings. Therefore, the project team decided to remove these sites from the analysis.

Glazing Percentages

The protocols for collecting glazing information were changed for the second year of on-site surveys. These changes were implemented to improve the accuracy of the window area calculated during the on-site survey.

This affects detached single family homes, attached single family buildings, and multifamily buildings. The percent glazing area is one of the largest factors in determining compliance. Therefore, increasing the accuracy in how the glazing areas were collected improves the simulation estimates/compliance margins.

Ceiling and Wall Insulation

Ceiling and wall insulation R-values were collected for less than one-fourth of the sites surveyed. For the sites where the surveyor could not obtain this information, default R-values were used for the compliance analysis. The defaults were based on the standard construction practice in each RMST climate zone.

This affects detached single family homes, attached single family buildings, and multifamily buildings. Using default R-values for ceiling and wall insulation do not have much of an impact on the compliance results. When developing the RNC interface, time was spent testing the defaults and algorithms used in the interface. Changing the ceiling and/or wall insulation R-values only changes the % compliance margin slightly.

4.15 Differences in Compliance Performance between Project Year #1 and Project Year #2 by RMST Climate Zone – Single Family Homes

As shown in Table 4-43, the average % Compliance Margins for detached single family homes in each RMST climate zone change significantly between the first and second years of the project.[31] While the average % Compliance Margins in RMST Climate Zones 1, 2, and 4 increase significantly, those in RMST Climate Zones 3 and 5 decrease significantly. Overall, the average % Compliance Margin for detached single family homes increased significantly between those homes built from July 1998 to June 1999 (Project Year #1 homes) and those homes built from July 1999 to June 2000 (Project Year #2 homes)—from 4.8% to 6.2%. Is this change in average % Compliance Margin attributable to a change in building practices or to the change in the standards? Were the detached single family homes analyzed during Project Year #2 built with higher efficiency measures than the homes analyzed during Project Year #1, or is it due to the differences between the 1998 standards and the 1995 standards?[32]

Table 4-43: Average % Compliance Margin by Project Year and RMST Climate Zone – Single Family Homes

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #1 - 1995	4.8%	6.8%	6.7%	10.2%	-1.0%	-0.5%
Project Year #2 - 1998	6.2%	11.4%	14.7%	6.1%	4.1%	-6.2%
Difference	1.5%	4.5%	7.9%	-4.1%	5.1%	-5.7%

In studying the compliance results further, several other questions arise.

1) Why is RMST Climate Zone 2 the most compliant and why did its average % Compliance Margin increase significantly?

[31] A significance test was conducted at the 95% confidence level.

[32] Please note that in order to make a direct comparison of the average % compliance margins for the two project years, the sites with central water heaters were taken out of the Project Year #1 analysis and the average % compliance margins were recomputed. Please keep this in mind when comparing these results to the Project Year #1 report.

2) Why did the average % Compliance Margin RMST Climate Zone 1 significantly increase?
3) Why did RMST Climate Zone 4 also see a significant increase in its average % Compliance Margins?
4) Why did the average % Compliance Margin in RMST Climate Zone 3 significantly decrease?
5) Why did the average % Compliance Margins in RMST Climate Zone 5 significantly decrease and why is the average % Compliance Margin negative?

To answer these questions accurately, it is not enough to simply look at the differences in the % Compliance Margins from the two reports. Remember that the homes used in the first year of the project were analyzed using MICROPAS 4.5, which uses the 1995 low-rise residential building standards, whereas the homes used in the second year of the project were analyzed using MICROPAS 5.1, which uses the 1998 low-rise residential building standards.

Therefore, before attempting to compare the compliance results of the homes built between July 1, 1998 and June 30, 1999 (Project Year #1 homes) and those built between July 1, 1999 and June 30, 2000 (Project Year #2 homes), the compliance of the homes used for the second year of the project were analyzed using MICROPAS 4.5. These results were then used in two comparisons to help understand the differences in the results between Project Year #1 and Project Year #2, by RMST climate zone.

- **"Project Year #1—1995" results vs. "Project Year #2—1995" results.** Comparing the % Compliance Margins between these sets of results makes it possible to analyze how the differences in building practices between the two project years affected the average % Compliance Margin.
- **"Project Year #2—1995" results vs. "Project Year #2—1998" results.** Comparing the % Compliance Margins between these sets of results makes it possible to analyze how the changes in the standards affected the average % Compliance Margin.

The results of each of these comparisons are discussed below, followed by a conclusion section that answers the questions posed above.

Project Year #1—1995 Standards vs. Project Year #2—1995 Standards

Table 4-44 presents the average % Compliance Margin for both Project Year #1 and Project Year #2 homes, by RMST climate zone, under the 1995 low-rise residential building standards. As shown, the average % Compliance Margin for Project Year #2 homes is 3.6%, which is lower than the 4.8% average for Project Year #1 homes. The average % Compliance Margins in RMST Climate Zones 2 and 4 increased by 5.0% and 2.9%,

respectively, while the margins in RMST Climate Zones 3 and 5 decreased by 7.1% and 6.6%, respectively. These results imply that there have been some changes in the average building characteristics across and within certain RMST climate zones.[33]

Table 4-44: Average % Compliance Margin by Project Year and RMST Climate Zone – Single Family Homes – 1995 Standards

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #1 - 1995	4.8%	6.8%	6.7%	10.2%	-1.0%	-0.5%
Project Year #2 - 1995	3.6%	7.5%	11.8%	3.1%	1.9%	-7.1%

As mentioned earlier, glazing percentage plays a large role in determining the compliance of a home. A change in the average glazing percentage within a climate zone could result in a significant change in the average % Compliance Margin.[34] Table 4-45 shows that the average glazing percentage in RMST Climate Zone 5 for Project Year #1 homes was 16.7%, a little more than the prescriptive glazing percentage of 16%. However, the average for Project Year #2 homes is 18.5%, which is far greater than the prescriptive value. This increase in the glazing percentage is one reason for RMST Climate Zone 5 being, on average, non-compliant. Similarly, the average glazing percentage in RMST Climate Zone 3 increased from 16.2% to 18.0%. This increase is one of the reasons for the significant decrease in the average % compliance margin shown in Table 4-44.[35] Conversely, the glazing percentage in RMST Climate Zone 2 decreased from 18.6% to 16.5%, which is one, if not the major, reason why the average % Compliance Margin for RMST Climate Zone 2 increased significantly to 11.8%.[36,37]

Also shown in Table 4-45 are the average HVAC and water heating efficiencies by RMST climate zone. Depending on the breakout of the standard energy budget, the efficiencies of the space heating and space cooling equipment in a home can also have a large impact on compliance. As shown, the average SEER value in RMST Climate Zone 5 decreased from nearly 10.87 to 10.48, while the average AFUE in RMST Climate Zone 1 increased from 80.28 to 80.73. The efficiency of the water heater in a home can also affect compliance. As

[33] Note that a change in building characteristics that is not statistically significant could have a significant impact on compliance due to how compliance is calculated.

[34] Note that for this second year of the project, the on-site surveyors were given different protocols when gathering glazing information in order to improve the accuracy of their measurements.

[35] A significance test was conducted at the 95% confidence level.

[36] A significance test was conducted at the 95% confidence level.

[37] Please note that a change in building characteristics that is not statistically significant could have a significant impact on compliance due to how compliance is calculated.

shown below, RMST Climate Zone 4 is the only climate zone where the average % above standard increased from Project Year #1 to Project Year #2 (15.3% to 16.0%).

As discussed in "Distribution of Sites by Compliance Group, Building Type, and Number of Floors" on page 4-14, the number of floors also influences compliance. As shown in Table 4-45, the average number of floors remained the same between the two project years for every climate zone except for RMST Climate Zone 4, where the average number of floors increased. This increase in the number of two-story homes would increase the average % Compliance Margin for this climate zone.

Table 4-45: Average Building Characteristics by Project Year and RMST Climate Zone – Single Family Homes

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average Glazing %						
Project Year #1	17.1%	18.2%	18.6%	16.2%	16.6%	16.7%
Project Year #2	17.4%	18.0%	16.5%	18.0%	16.8%	18.5%
Average SEER						
Project Year #1	10.53	10.39	10.19	10.17	10.95	10.87
Project Year #2	10.64	10.48	10.24	10.22	10.95	10.48
Average AFUE						
Project Year #1	80.39	80.28	80.05	80.22	80.81	80.35
Project Year #2	80.52	80.73	80.12	80.11	80.81	80.45
Average Water Heating (% Above Std)						
Project Year #1	16.1%	15.7%	16.5%	16.7%	15.3%	16.6%
Project Year #2	15.6%	14.4%	15.5%	16.0%	16.0%	15.8%
Average # of Stories						
Project Year #1	1.6	1.7	1.9	1.7	1.3	1.2
Project Year #2	1.5	1.7	1.9	1.7	1.4	1.2

Project Year #2—1995 Standards vs. Project Year #2—1998 Standards

The differences in the average % Compliance Margins across the state can not entirely be explained by the changes in average building characteristics. There were a few changes made to code between the 1995 and 1998 low-rise residential standards. To investigate how the changes in the building code affects compliance, this section compares the compliance results of Project Year #2 homes using MICROPAS 4.5 (1995 Standards) and Project Year #2 homes using MICROPAS 5.0 (1998 Standards).

As shown in Table 4-46, Project Year #2 homes have a higher average % Compliance Margin using the 1998 standards than they do using the 1995 standards. What changes in the standards caused most RMST climate zones to have a higher average % Compliance Margin under the 1998 standards than the 1995 standards, while RMST Climate Zone 5 has only a 1% higher average % Compliance Margin? The following discussion is broken out by end-use—water heating, space cooling, and space heating—in an attempt to answer these questions.

Table 4-46 Average % Compliance Margin by RMST Climate Zone – Single Family Homes – Project Year #2

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #2 - 1995	3.6%	7.5%	11.8%	3.1%	1.9%	-7.1%
Project Year #2 - 1998	6.2%	11.4%	14.7%	6.1%	4.1%	-6.2%

Water Heating

The most straightforward change in the low-rise residential building standards between 1995 and 1998 involved 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."*[38] As shown in the baseline analysis in Section 3, nearly 98% of detached single family homes have water heaters that are above standard. Further analysis shows that, overall, 97.9% of detached single family homes have a gas water heater that has an energy factor of 0.58 or higher.[39] Therefore, over three-fourths of Project Year #2 homes received the water heater blanket credit. Compare this to Project Year #1 homes, which were analyzed using the 1995 standards where only 32% of detached single family homes had water heater blankets and received the credit in the compliance analysis.

Table 4-47 provides the average standard and proposed water heating budgets for Project Year #2 homes under both the 1995 and 1998 standards. As shown, the average standard water heating budgets in every RMST Climate Zone increased by approximately 1.0 to 1.3,

[38] http://www.energy.ca.gov/title24_1998_standards/summary_changes.html

[39] The percentage of homes with a 0.58 EF, or higher, water heater could be greater since 1.9% of homes were given the default standard water heater due to inaccessibility.

whereas the proposed increased by only 0.1 to 0.5 kBtuh/ft^2 per year. The proposed budget did not go up as much as the standard budget since most homes received the water heater blanket credit explained above. Because of this, the average water heater margin using the 1998 standards is between 0.7 kBtuh/ft2 per year to 1.1 kBtuh/ft2 per year larger (i.e., more compliant) than the water heater margin using the 1995 standards.

Table 4-47: Average Annual Water Heating Intensity (kBtuh/ft^2 per year) by RMST Climate Zone – Single Family Homes – Project Year #2

Analysis Parameter Description	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #2 - 1995					
Average Standard Budget	11.10	10.09	10.62	12.14	11.84
Average Proposed Budget	10.65	9.50	10.08	11.06	11.40
Average Margin	0.45	0.59	0.54	1.07	0.44
Project Year #2 - 1998					
Average Standard Budget	12.16	11.06	11.67	13.43	13.05
Average Proposed Budget	10.77	9.82	10.32	11.60	11.53
Average Margin	1.39	1.25	1.35	1.82	1.52
Differences					
Standard Budget	1.06	0.97	1.05	1.29	1.22
Proposed Budget	0.12	0.32	0.24	0.54	0.14
Margin	0.94	0.66	0.81	0.75	1.08

Space Heating and Space Cooling

A handful of other changes occurred in the low-rise residential building standards between 1995 and 1998 that involved the space heating and space cooling budgets. These changes, however, are not as straightforward as the water heater blanket credit. Changes include the following.

- Glazing—internal changes on how solar gain was calculated.
- Duct efficiency—a new duct efficiency scheme was established in order to accommodate a credit for duct sealing.
- Thermal mass—changes were made, but they did not cause a change in the compliance margin because the Standard budget and Proposed budget changed equally.

Since these changes are interrelated, it is difficult to ascertain the effect that each change has on compliance. Therefore, the following discussion only summarizes the results shown in the tables below.

The average standard and proposed space cooling budgets for Project Year #2 homes under both the 1995 and 1998 standards are provided in Table 4-48. As shown, RMST Climate Zone 4 is the only climate zone where the average space cooling margin increased from the 1995 standards to the 1998 standards (0.70 to 1.49). The average space cooling margin in RMST Climate Zone 5, on the other hand, decreased from -4.03 to -5.60. The average space cooling margins in RMST Climate Zones 1, 2, and 3 also decreased – though only slightly.

Table 4-48: Average Annual Space Cooling Intensity (kBtuh/ft^2 per year) by RMST Climate Zone – Single Family Homes – Project Year #2

Analysis Parameter Description	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #2 - 1995					
Average Standard Budget	5.34	4.02	12.72	20.75	19.18
Average Proposed Budget	4.46	2.87	13.77	20.05	23.21
Average Margin	0.88	1.15	-1.06	0.70	-4.03
Project Year #2 - 1998					
Average Standard Budget	5.69	3.68	14.35	25.45	25.13
Average Proposed Budget	4.95	2.55	15.62	23.96	30.73
Average Margin	0.74	1.12	-1.27	1.49	-5.60
Differences					
Standard Budget	0.35	-0.35	1.63	4.70	5.94
Proposed Budget	0.49	-0.32	1.85	3.91	7.52
Margin	-0.14	-0.03	-0.22	0.79	-1.57

Table 4-48 presents the average standard and proposed space cooling budgets for Project Year #2 homes under both the 1995 and 1998 standards. As shown, the average space heating margin increased each of the RMST climate zones.

Table 4-49: Average Annual Space Heating Intensity (kBtuh/ft^2 per year) by RMST Climate Zone – Single Family Homes – Project Year #2

Analysis Parameter Description	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #2 - 1995					
Average Standard Budget	13.61	3.68	8.61	23.61	15.10
Average Proposed Budget	12.79	3.14	6.92	22.13	14.74
Average Margin	0.82	0.55	1.70	1.48	0.37
Project Year #2 - 1998					
Average Standard Budget	16.57	4.42	10.06	28.57	19.14
Average Proposed Budget	15.04	3.79	7.76	26.22	18.45
Average Margin	1.54	0.63	2.30	2.35	0.69
Differences					
Standard Budget	2.96	0.74	1.44	4.96	4.03
Proposed Budget	2.25	0.65	0.84	4.09	3.71
Margin	0.72	0.08	0.60	0.87	0.32

Conclusion

As shown above, both building practices and changes to the standards were responsible for the significant changes in the average % Compliance Margins across RMST climate zones. In some of the RMST climate zones, the changes to the standards were the primary reason for the significant increase in the average % Compliance Margin. However, the increase in the average percent glazing in other RMST climate zones did result in a significant increase in average % Compliance Margin between Year 1 and Year 2. Below are possible answers to the RMST climate zone specific questions posed above.

1) Why is RMST Climate Zone 2 by far the most compliant and why did its average % Compliance Margin increase significantly?
   - Average glazing percentage decreased from 18.6% to 16.5%, while the average SEER and AFUE values increased slightly. In turn, the average % Compliance Margin increased from 6.7% to 11.8%.
   - The water heating standard budget is nearly two-thirds of the total standard budget, therefore, the water heating changes in the standards had a large impact on the average % Compliance Margin from RMST Climate Zone 2 (11.8% to 14.7%).
   - The decrease in % glazing area and the large water heating budget are the primary reasons for the significant increase in the average % Compliance

Margin (from 6.7% to 14.7%) and the reason that RMST Climate Zone 2 is the most compliant RMST climate zone.

2) Why did the average % Compliance Margin RMST Climate Zone 1 significantly increase?
   - The average glazing percentage for RMST Climate Zone 1 decreased slightly from 18.2% to 18.1%. The average SEER value increased slightly from 10.39 to 10.48. The average AFUE in RMST Climate Zone 1 also increased from 80.28% to 80.73%. These changes in building practices resulted in increases in the average % Compliance Margin from 6.8% to 7.5% in RMST Climate Zone 1.
   - In RMST Climate Zone 1, the water heating and space heating standard budgets each comprise nearly 40% of the total standard budget. Due to the changes in the standards, the average water heating and space heating margins in RMST Climate Zone 1 both increased, resulting in an increase in the average % Compliance Margin from 7.5% to 11.4%.
   - The decrease in % glazing area and the increase in both the water heating and space heating margins, due to the change in standards, are the primary reasons for the significant increase in the average % Compliance Margin (from 6.8% to 11.4%).

3) Why did RMST Climate Zone 4 also see a significant increase in its average % Compliance Margins?
   - The average water heating efficiency increased from 15.3% to 16.0% and the average number of floors increased from 1.3 to 1.4 in RMST Climate Zone 4. These changes in building practices resulted in an increase in the average % Compliance Margin from -1.0% to 1.9%.
   - RMST Climate Zone 4 is the only climate zone to see an increase in the average space cooling margin. In addition, the space heating and water heating margins increased. Therefore, the changes in the standards resulted in an increase in the average % Compliance Margin from 1.9% to 4.1%.[40]
   - The changes between the 1995 and 1998 standards, which increased each of the end-use margins, the increase in water heating efficiencies, and the increase in the number of two-story homes are the primary reasons for the significant increase in the average % Compliance Margin (from -1.0% to 4.1%).

4) Why did the average % Compliance Margins in RMST Climate Zone 3 significantly decrease?
   - The average glazing percentage for RMST Climate Zone 3 increased from 16.2% to 18.0%. Meanwhile, the average water heating efficiency and the

[40] Note that RMST Climate Zone 4 was the only RMST climate zone to have an increase in the average space cooling margin. Since the effects of the changes in the standards concerning heating and cooling are complex, it is difficult to determine a reason for this.

average AFUE decreased slightly. These changes in building practices caused the average % Compliance Margin to decrease from 10.2% to 3.1%.

- In RMST Climate Zone 3, the space cooling standard budget makes up approximately 39% of the total standard budget. Due to the changes in the standards, the average space cooling margin decreased slightly (nearly 2% of the space cooling standard budget). However, the average water heating and space heating margins both increased, which helped to increase in average % Compliance Margin from 3.1% to 6.1%.
- The increase in % glazing area is the primary reason for the significant decrease in the average % Compliance Margin (from 10.2% to 6.1%).

5) Why did the average % Compliance Margins in RMST Climate Zone 5 significantly decrease and why is the average % Compliance Margin negative?

- The average glazing percentage for RMST Climate Zone 5 increased from 16.7% to 18.5%, which is more than the prescriptive value for this RMST climate zone. The average SEER value decreased from 10.87 to 10.48 and the average AFUE value increased slightly. These changes in building practices resulted in the average % Compliance Margin decreasing from -0.5% to -7.1%.
- In RMST Climate Zone 5, the space cooling standard budget makes up nearly half of the total standard budget. Due to the changes in the standards, the average space cooling margin decreased approximately 8% (of the space cooling standard budget). However, since the average water heating and space heating margins both increased slightly, the overall effect of the change in the standards resulted in a small increase in average % Compliance Margin from -7.1% to -6.2%.
- The increase in % glazing area is the primary reason for the significant decrease in the average % Compliance Margin (from -0.5% to -6.2%).

4.16 Differences in Compliance Performance between Project Year #1 and Project Year #2 by RMST Climate Zone – Attached Single Family and Multifamily Buildings

As shown in Table 4-43, the average % Compliance Margins for attached single family and multifamily buildings in RMST Climate Zones 1, 2 and 4 increased significantly between the first and second years of the project.[41] Overall, the average % Compliance Margin increased significantly between those homes built from July 1998 to June 1999 (Project Year #1 homes) and those homes built from July 1999 to June 2000 (Project Year #2 homes)—from 14.9% to 21.6%. Is this change in average % Compliance Margin attributable to a change in building practices or to the change in the standards? Were the attached single family and multifamily buildings analyzed during Project Year #2 built with higher efficiency measures

[41] A significance test was conducted at the 95% confidence level.

than those analyzed during Project Year #1, or is this due to the differences between the 1998 standards and the 1995 standards? [42]

Table 4-50: Average % Compliance Margin by Project Year and RMST Climate Zone – Attached Single Family and Multifamily Buildings

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #1 - 1995	14.9%	11.0%	17.5%	21.7%	13.6%	9.6%
Project Year #2 - 1998	21.6%	22.3%	22.1%	22.3%	22.0%	3.3%
Difference	6.7%	11.3%	4.7%	0.6%	8.4%	-6.3%

In studying the compliance results further, a couple other questions arise.

1) Why did the average % Compliance Margin RMST Climate Zone 1 nearly double?
2) Why did the average % Compliance Margin RMST Climate Zone 2 significantly increase?
3) Why did the average % Compliance Margin RMST Climate Zone 4 significantly increase?

To answer these questions accurately, the same analysis performed above for detached single family homes was also performed for attached single family and multifamily buildings. The results are discussed below, followed by a section that answers the questions posed above.

Project Year #1—1995 Standards vs. Project Year #2—1995 Standards

Table 4-44 presents the average % Compliance Margin for both Project Year #1 and Project Year #2 buildings, by RMST climate zone, under the 1995 low-rise residential building standards. As shown, the average % Compliance Margin for Project Year #2 homes is 15.7%, which is greater than the 14.9% average for Project Year #1 homes. The average % Compliance Margins in RMST Climate Zones 1 and 4 increased by 5.8% and 0.5%, respectively, while the margins in RMST Climate Zones 2, 3, and 5 decreased by 0.4%, 4.1%, and 8.3%, respectively – though none of these changes are significant. These results imply that there have not been significant changes in the average building characteristics

[42] Please note that in order to make a direct comparison of the average % compliance margins for the two project years, the sites with central water heaters were taken out of the Project Year #1 analysis and the average % compliance margins were recomputed. Please keep this in mind when comparing these results to the Project Year #1 report.

across or within RMST climate zones, except in RMST Climate Zone 1.[43] While there have been some changes in the average efficiencies of some of the equipment have change, these small changes in averages in RMST Climate Zones 2, 3, 4, and 5 did not have a net impact on the compliance results.

Table 4-51: Average % Compliance Margin by Project Year and RMST Climate Zone – Attached Single Family and Multifamily Buildings – 1995 Standards

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #1 - 1995	14.9%	11.0%	17.5%	21.7%	13.6%	9.6%
Project Year #2 - 1995	15.7%	16.8%	17.1%	17.6%	14.1%	1.3%

As discussed earlier, glazing percentage plays a large role in determining the compliance of a home. A change in the average glazing percentage within a climate zone could result in a significant change in the average % Compliance Margin.[44] Table 4-45 shows that the average glazing percentage in RMST Climate Zone 2 increased from 7.4% during Project Year #1 to 8.8% during Project Year #2. Since the combined space heating and cooling budgets account for only 27% of the total standard budget in RMST Climate Zone 2, this increase does not have as much of an effect on compliance as it would in another climate zone.[45] On the other hand, the average glazing percentage in RMST Climate Zone 1 decreased from 11.0% during Project Year #1 to 9.7% during Project Year #2.[46]

Also shown in Table 4-45 are the average HVAC efficiencies by RMST climate zone. Depending on the breakout of the standard energy budget, the efficiencies of the equipment can also have a large impact on compliance. As shown, the average SEER value in RMST Climate Zone 5 decreased from 10.77 to 10.42, while the average AFUE in RMST Climate Zone 4 increased from 80.13 to 81.66. The average water heating efficiency in RMST Climate Zone 4 also increased from 10.8% to 13.6%.

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[43] A significance test, conducted at the 90% confidence level, reveals that the increase in the average % compliance margin from 11.0% in Project Year #1 to 16.8% in Project Year #2 was significant. (Note: When a significance test was conducted at the 95% confidence level, the difference was not significant.)

[44] Note that for this second year of the project, the on-site surveyors were given different protocols when gathering glazing information in order to improve the accuracy of their measurements.

[45] The increase in the average percent glazing in RMST Climate Zone 3 was approximately the same as it was for RMST Climate Zone 2. However, even with an increase in both the average AFUE and the average water heating efficiency, the average % compliance margin decreased 4.5% in RMST Climate Zone 3 and only 0.4% in RMST Climate Zone 2. The primary reason for this is that the space heating and cooling budget make up approximately 43% of the total budget as opposed to only 27% in RMST Climate Zone 2.

[46] Please note that a change in building characteristics that is not statistically significant could have a significant impact on compliance due to how compliance is calculated.

As discussed above, the number of floors also influences compliance. As shown Table 4-52, the average number of floors increased from 1.9 to 2.1 in RMST Climate Zone 4 and from 2.4 to 2.5 in RMST Climate Zone 1. This increase in the number of two- and three-story residences would increase the average % Compliance Margin for these climate zones.

Table 4-52: Average Building Characteristics by Project Year and RMST Climate Zone – Attached Single Family and Multifamily Buildings

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Average Glazing %						
Project Year #1	9.4%	11.0%	7.4%	8.7%	8.2%	8.5%
Project Year #2	9.3%	9.7%	8.8%	10.0%	8.6%	10.3%
Average SEER						
Project Year #1	10.07	10.00	10.04	10.05	10.15	10.01
Project Year #2	10.07	10.08	10.02	10.04	10.10	10.05
Average AFUE						
Project Year #1	79.99	80.00	80.00	79.87	80.13	81.00
Project Year #2	80.53	80.07	80.00	80.74	81.66	80.00
Average Water Heating (% Above Std)						
Project Year #1	13.3%	14.2%	14.5%	12.9%	10.8%	13.2%
Project Year #2	13.4%	14.2%	11.2%	14.9%	13.6%	13.1%
Average # of Stories						
Project Year #1	2.3	2.4	2.6	2.2	1.9	1.8
Project Year #2	2.3	2.5	2.5	2.2	2.1	1.6

Project Year #2—1995 Standards vs. Project Year #2—1998 Standards

As shown above, the differences in the average % Compliance Margins across the state can not be fully explained by the changes in average building characteristics. There were a few changes made to the building code between the 1995 and 1998 low-rise residential standards. To investigate how the changes in the building code affects compliance, this section compares the compliance results of Project Year #2 homes using MICROPAS 4.5 (1995 Standards) and Project Year #2 homes using MICROPAS 5.0 (1998 Standards).

As shown in Table 4-46, Project Year #2 homes have a higher average % Compliance Margin using the 1998 standards than they do using the 1995 standards. What changes in the standards caused each RMST climate zones to have a higher average % Compliance Margin

under the 1998 standards than the 1995 standards? The following discussion is broken out by end-use—water heating, space cooling, and space heating.

Table 4-53 Average % Compliance Margin by RMST Climate Zone – Attached Single Family and Multifamily Buildings – Project Year #2

	Overall	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #2 - 1995	15.7%	16.8%	17.1%	17.6%	14.1%	1.3%
Project Year #2 - 1998	21.6%	22.3%	22.1%	22.3%	22.0%	3.3%

Water Heating

Table 4-47 provides the average standard and proposed water heating budgets for Project Year #2 homes under both the 1995 and 1998 standards. As shown, the average standard water heating budgets in every RMST climate zone increased by approximately 1.6 to 2.0, whereas the proposed budget remained relatively constant. The proposed budget did not increase as much as the standard budget since most buildings received the water heater blanket credit explained above. Because of this, the average water heater margin using the 1998 standards is between 1.5 kBtuh/ft2 and 1.8 kBtuh/ft2 per year larger (i.e., more compliant) than the water heater margin using the 1995 standards in each of the RMST Climate Zones.

Table 4-54: Average Annual Water Heating Intensity (kBtuh/ft^2 per year) by RMST Climate Zone – Attached Single Family and Multifamily Buildings – Project Year #2

Analysis Parameter Description	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #2 - 1995					
Average Standard Budget	17.11	14.17	15.49	16.65	15.69
Average Proposed Budget	16.56	14.08	14.71	15.90	14.95
Average Margin	0.55	0.09	0.78	0.74	0.74
Project Year #2 - 1998					
Average Standard Budget	18.71	15.77	17.32	18.65	17.53
Average Proposed Budget	16.49	14.15	14.92	16.06	14.95
Average Margin	2.22	1.61	2.39	2.59	2.58
Differences					
Standard Budget	1.60	1.60	1.82	2.01	1.84
Proposed Budget	-0.07	0.08	0.21	0.16	0.00
Margin	1.67	1.52	1.61	1.84	1.84

Space Heating and Space Cooling

As explained above, a handful of other changes occurred in the low-rise residential building standards between 1995 and 1998 that involved the space heating and space cooling budgets. Since these changes are interrelated, it is difficult to ascertain the effect that each change has on compliance. Therefore, the following discussion only summarizes the results shown in the tables below.

The average standard and proposed space cooling budgets for Project Year #2 buildings under both the 1995 and 1998 standards are provided in Table 4-48. As shown, the average space cooling margin in RMST Climate Zone 4 increased from the 1995 standards to the 1998 standards from1.80 to 2.70. On the other hand, the average space cooling margin in RMST Climate Zones 2 and 5 decreased.

Table 4-55: Average Annual Space Cooling Intensity (kBtuh/ft^2 per year) by RMST Climate Zone – Attached Single Family and Multifamily Buildings – Project Year #2

Analysis Parameter Description	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #2 - 1995					
Average Standard Budget	5.10	3.55	8.02	7.46	20.77
Average Proposed Budget	2.46	1.12	5.74	5.66	20.16
Average Margin	2.64	2.43	2.28	1.80	0.61
Project Year #2 - 1998					
Average Standard Budget	5.17	3.11	8.53	8.53	27.63
Average Proposed Budget	2.39	1.01	6.24	5.82	27.39
Average Margin	2.79	2.10	2.29	2.70	0.25
Differences					
Standard Budget	0.07	-0.44	0.51	1.07	6.87
Proposed Budget	-0.07	-0.11	0.51	0.16	7.23
Margin	0.14	-0.33	0.01	0.90	-0.36

Table 4-48 presents the average standard and proposed space cooling budgets for Project Year #2 buildings under both the 1995 and 1998 standards. As shown, the average space heating margin increased each of the RMST climate zones.

Table 4-56: Average Annual Space Heating Intensity (kBtuh/ft^2 per year) by RMST Climate Zone – Attached Single Family and Multifamily Buildings – Project Year #2

Analysis Parameter Description	RMST CZ1	RMST CZ2	RMST CZ3	RMST CZ4	RMST CZ5
Project Year #2 - 1995					
Average Standard Budget	7.28	1.92	3.91	8.84	5.98
Average Proposed Budget	5.74	1.21	2.22	6.90	4.84
Average Margin	1.54	0.70	1.70	1.94	1.15
Project Year #2 - 1998					
Average Standard Budget	9.43	2.25	4.61	11.39	7.45
Average Proposed Budget	7.04	1.38	2.43	8.37	5.86
Average Margin	2.38	0.87	2.18	3.02	1.59
Differences					
Standard Budget	2.14	0.34	0.69	2.55	1.47
Proposed Budget	1.30	0.17	0.21	1.47	1.03
Margin	0.84	0.17	0.48	1.08	0.44

Conclusion

As shown above, the changes to the standards were primarily responsible for the significant increases in the average % Compliance Margins for attached single family and multifamily buildings in RMST Climate Zones 2 and 4. When comparing the buildings analyzed during Project Year #2 to those analyzed during Project Year #1, the average building practices in RMST Climate Zones 2, 3, 4, and 5 did not change much. However, the average % Compliance Margin was higher in each of the RMST climate zones under the 1998 standards than the average % Compliance Margin under the 1995 standards. On the other hand, the combination of the change in building characteristics and the changes in the standards resulted in the significant increase in the average % compliance margin in RMST Climate Zone1.

1) Why did the average % Compliance Margin in RMST Climate Zone 1 significantly increase?
   - The average percent glazing decreased from 11.0% to 9.7%. This decrease resulted in an increase in the average % Compliance Margin from 11.0% to 16.8%.

- The water heating and space heating budgets account for approximately 83% of the total standard budget. The changes in the standards caused both the water heating and space heating margins to increase which had a large and positive impact on the average % Compliance Margin, resulting in an increase from 16.8% to 22.3%.
- The combination of the changes in building characteristics and the changes in the standards are the primary reasons for the significant increase in the average % Compliance Margin (from 11.0% to 22.3%).

2) Why did the average % Compliance Margin in RMST Climate Zone 2 significantly increase?
   - The average percent glazing increased from 7.4% to 8.8% and the average water heater efficiency decreased from 14.5% to 11.2%. These changes in building practices resulted in a slight decrease in the average % Compliance Margin from 17.5% to 17.1%.
   - The water heating budget accounts for nearly three-fourths of the total standard budget. Therefore, the change in the water heating standard had a large and positive impact on the average % Compliance Margin, resulting in an increase from 17.1% to 22.1%.
   - The changes in the water heating portion of the standards are the primary reasons for the significant increase in the average % Compliance Margin (from 17.5% to 22.1%).

3) Why did the average % Compliance Margin RMST Climate Zone 4 significantly increase?
   - Even though the average percent glazing increased slightly from 8.2% to 8.6%, the average AFUE increased from 80.1 to 81.7 and the average water efficiency increased from 108% to 13.6%, which balanced out to cause a small increase in the average % Compliance Margin from 13.6% to 14.1%.
   - The changes in the low-rise building standards resulted in increases in each of the three end-use margins. The space heating margin increased by 1.04 kBtuh/ft2 per year, space cooling by 0.86 kBtuh/ft2 per year, and water heating by 1.73 kBtuh/ft2 per year. The combination of these changes resulted in an increase in average % Compliance Margin from 14.1% to 22.0%.
   - The primary reasons for the significant increase in the average % Compliance Margin in RMST Climate Zone 4 (from 13.6% to 22.0%) were the changes in the standards.

5

Summary of Results

5.1 Introduction

This section provides an overview of key findings discussed in the various sections of this report. It includes highlights from the baseline characterization, analysis of compliance, and a summary of the differences in the average % Compliance Margin, by RMST Climate Zone, between Project Year 1 and Project Year 2. This section also contains a brief discussion on residential standards issues.

5.2 Baseline Characterization

The following is a summary of current building practices in the low-rise residential sector. In particular, findings on efficiency levels and key differences in construction practice between detached single family homes and multifamily buildings, as well as differences among regions, and project years are summarized.

- ***Average HVAC equipment efficiencies in detached single family homes are slightly above the minimum equipment efficiency standards.*** The average efficiency of gas furnaces installed in detached single family homes is 80.5% AFUE, versus the 78% AFUE Standard value. The average efficiency of central air conditioners installed in detached single family homes is 10.6 SEER, versus the 10 SEER Standard value.
- ***Single family detached homes are more likely than multifamily buildings to have higher-than-standard efficiency air conditioners.*** Approximately 55% of detached single family homes have a higher-than-standard efficiency air conditioner (>10 SEER), compared to 19% of multifamily buildings.
- ***A large number of homes do not have cooling equipment.*** Approximately 54% of single family homes in RMST Climate Zone 1 and 34% of single family homes in RMST Climate Zone 2 do not have a cooling system, which is approximately 14% at the state level. Likewise, a significant number of multifamily buildings do not have cooling systems (27% statewide).

- ***The average duct leakage percentage for single family homes is significantly lower than for multifamily buildings.***[1] For detached single family homes, the average duct leakage percentage for those duct systems tested statewide was 13%, compared to 31% for multifamily buildings.
- ***Efficiency levels of water heating systems are generally above the Minimum Efficiency Standards for both single family homes and multifamily buildings.*** The average EF of water heating systems installed is 16% higher than required by the minimum efficiency standards for detached single family homes and 13% higher for multifamily buildings.
- ***Dual-paned vinyl-framed windows are typically installed in both detached single family homes and multifamily buildings.*** The predominant window type in for detached single family homes and multifamily buildings is a vinyl-framed, dual-paned, clear glass window.
- ***Use of metal-framed windows is more extensive in multifamily buildings than in single family detached homes.*** While vinyl-framed, dual-paned, clear glass windows are predominantly used in both detached single family homes and multifamily buildings, metal windows are used more often in multifamily buildings (23.0% compared to 16.2% in detached single family homes).
- ***Use of metal-framed windows varies significantly by climate zone.***[2] For multifamily buildings, the percent of metal-framed windows ranges from a low of 0% in RMST Climate Zone 2 to highs of 56% and 32% in RMST Climate Zones 4 and 5, respectively. For single family homes, the percent of metal-framed windows also ranges significantly from 0% in RMST Climate Zone 2 to 36% in RMST Climate Zone 4.
- ***Ceiling and wall insulation levels are usually below prescriptive values.***[3] For those residences where ceiling and wall insulation R-values were obtained, the observed insulation levels were typically lower than prescriptive values, but always greater than or equal to the minimum R-values specified by the Standards.

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1 A significance test at the 90% confidence level reveals that the estimates of the average percent duct leakage for single family and multifamily homes are significantly at the state level.

2 A significance test at the 90% confidence level reveals that there is a significantly higher percentage of metal-framed windows installed in multifamily buildings in RMST Climate Zones 3 and 5 than in multifamily buildings in the remaining RMST Climate Zones.

3 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.

Comparison of Homes Built in Project Year 1 and Project Year 2

Section 3 summarizes the comparisons between the results found in the first year[4] and the second year of the RNC project. While there were small changes in construction practices between Project Year #1 homes (built between July 1998 and June 1999) and the Project Year #2 homes (built between July 1999 and June 2000), there were no significant changes in the statewide average of any building characteristic. For detailed information on the differences between Project Year #1 homes and Project Year #2 homes by RMST Climate Zone, see Section 3.6.

5.3 Analysis of Compliance

Analysis of the MICROPAS results on a *non-compliant*/*compliant* criterion was not appropriate due to uncertainty with the MICROPAS results. Therefore, it was necessary to develop an error band.[5] Application of the error band resulted in the following four compliance groups, which were used as the basis for analysis of the MICROPAS results.

- ***Non-Compliant.*** This category includes sites that, based on the analysis, are not compliant with Title 24 code. In particular, these sites have a % Compliance Margin less than the lower end of the error band (i.e., <-5%).
- ***Indeterminate.*** This category includes sites that have a % Compliance Margin within the error band (-5% to 4%). As such, it is indeterminate as to whether these sites comply with the Title 24 codes.
- ***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., > 4% and < 24%).
- ***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 24%. This category was defined to assess the share of homes that would meet the existing ENERGY STAR® New Home Construction requirements, given the error band.

Below is a summary of the results from the compliance analysis.

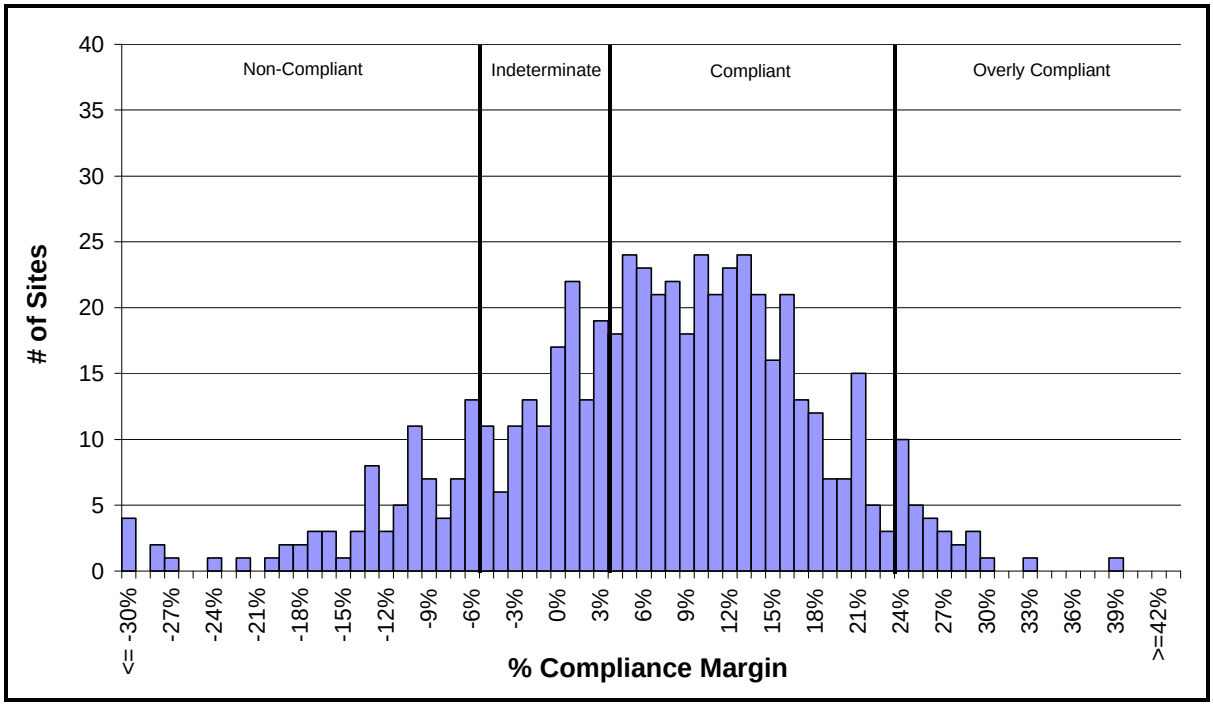
- ***Approximately 12% of Sites are identified as non-compliant.*** The results from the RNC Interface compliance analysis indicate that 12% of all homes built in the study period were non-compliant. The vast majority, however, fell within the compliant group (57%), while 13% fell in the overly compliant group. Figure 5-1 and Figure 5-2 provide a summary of the distribution of sites by %

[4] Regional Economic Research, Inc. *Residential New Construction Study*. Prepared for Pacific Gas & Electric. May 17, 2001.

[5] The error band was developed using a criteria of ±10% at a 90% confidence interval.

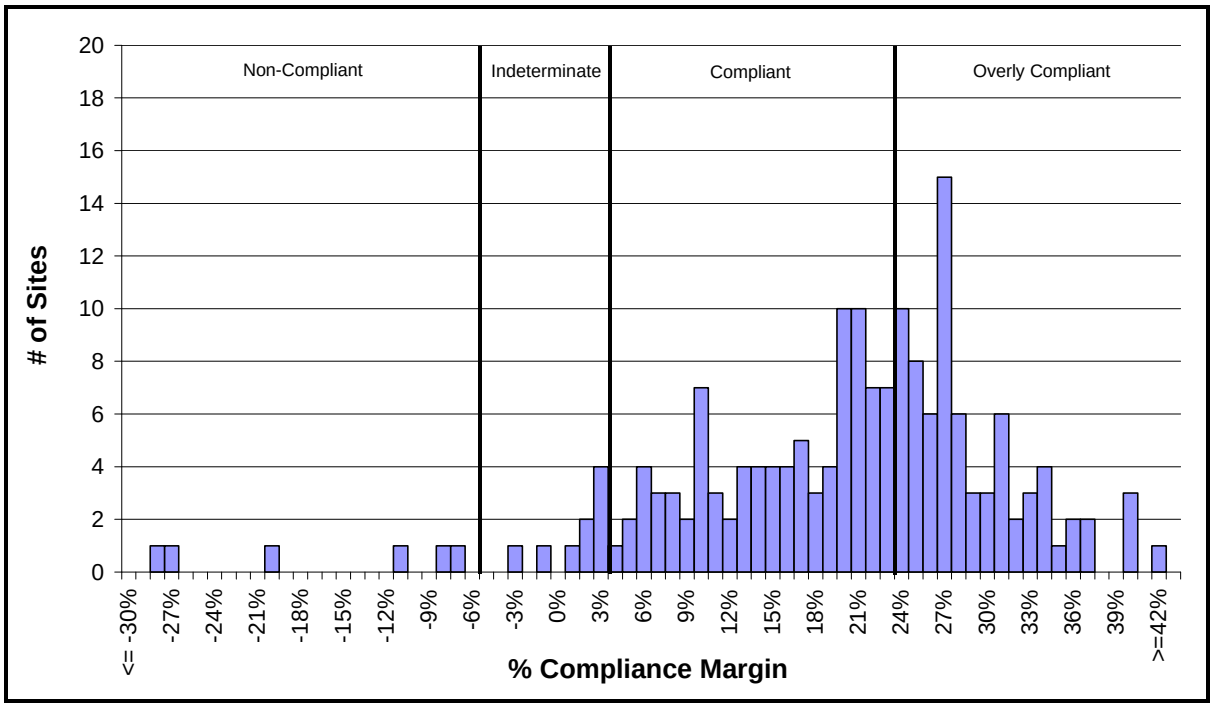
Compliance Margin and compliance group for single family homes and multifamily buildings respectively.[6]

Figure 5-1: MICROPAS Results Summary – Detached Single Family Homes



6 Please see Section 2.4 for a detailed discussion on the development of the error band and the compliance categories.

Figure 5-2: MICROPAS Results Summary – Multifamily Buildings



- ***Nearly 90% of homes have non-negative water heater margins.*** Approximately 93% of newly constructed homes with a gas water heaters have water heaters with energy factors above the minimum standard values. This translates into positive water heating (DHW) margins for these homes. In other words, a home with a high efficiency water heater will have an estimated energy use that is less than the maximum budget allowed—making the home more compliant. Builders and Title 24 consultants validated this result during the in-depth interviews. This is most likely due to the relatively low cost associated with increasing the water heater efficiency in an effort to meet compliance.
- ***The percent glazing area has a substantial impact on compliance.*** Homes with large glazing percentages tend to be non-compliant, while homes with small glazing percentages tend to be compliant or overly compliant.
- ***Ceiling and wall Insulation play a relatively minor role in compliance.*** The results of the analysis indicate that the impact of increases in wall and ceiling insulation levels on compliance is minimal. As such, when using performance-based methods to determine compliance, builders and Title 24 consultants do not typically use high efficiency insulation. This result is reflected in the fact that ceiling insulation installed in new homes is generally below prescriptive. In addition, wall insulation installed is typically R-13, which is at the prescriptive level in some climate zones but below in others.
- ***RMST Climate Zone 2 (South Coast) has the highest percentage of compliant homes.*** Approximately 95% of sites in RMST Climate Zone 2 fall in either the compliant or overly compliant groups. In fact, RMST Climate Zone 2

is the most compliant of the RMST climate zones with an average % Compliance Margin of 17.5%. Only 1% of sites in RMST Climate Zone 2 fall in the non-compliant group and only 4% fall in the indeterminate group.

- ***RMST Climate Zone 5 (desert and mountains) has the highest percentage of non-compliant homes.*** Approximately 39% of sites in RMST Climate Zone 5 fall in the non-compliant group and 31% are indeterminate. In fact, RMST Climate Zone 5 is the most non-compliant of the RMST climate zones with an average % Compliance Margin of -5.3%.

5.4 Compliance Variations among Climate Zones across Project Years

When comparing the compliance analysis results found in this report (for Project Year #2 homes – built between July 1999 and June 2000) and those in the first report (for Project Year #1 homes – built between July 1998 and June 1999), several questions arise. Are the compliance analysis results significantly different? If so, are the changes in average % Compliance Margin attributable to changes in building practices or to changes in the standards?

To answer these questions accurately, it is not enough to simply look at the differences in the % Compliance Margins from the two reports. Remember that the homes used in the first year of the project were analyzed using MICROPAS 4.5, which uses the 1995 low-rise residential building standards, whereas homes used in the second year of the project were analyzed using MICROPAS 5.1, which uses the 1998 low-rise residential building standards. Therefore, the compliance of the homes used for the second year of the project were analyzed using MICROPAS 4.5. These results were then used in two comparisons to help understand the differences in the results between Project Year #1 and Project Year #2, by RMST climate zone.

- ***"Project Year #1—1995" results vs. "Project Year #2—1995" results.*** Comparing the % Compliance Margins between these sets of results makes it possible to analyze how the differences in building practices between the two project years affected the average % Compliance Margin.
- ***"Project Year #2 – 1995" results vs. "Project Year #2 – 1998" results.*** Comparing the % Compliance Margins between these sets of results makes it possible to analyze how the changes in the standards affected the average % Compliance Margin.

The following subsections summarize the analysis reported in Sections 4.15 (detached single family homes) and 4.16 (attached single family and multifamily buildings).

Detached Single Family Homes

As shown in Table 5-1, the average % Compliance Margins for detached single family homes in each RMST climate zone change significantly between the first and second years of the project.[7] While the average % Compliance Margins in RMST Climate Zones 1, 2, and 4 increase significantly, those in RMST Climate Zones 3 and 5 decrease significantly. Overall, the average % Compliance Margin for detached single family homes increased significantly between those homes built from July 1998 to June 1999 (Project Year #1 homes) and those homes built from July 1999 to June 2000 (Project Year #2 homes)—from 4.8% to 6.2%.

The analysis in Section 4.15 concludes that both building practices and changes to the standards were responsible for the significant changes in the average % Compliance Margins across RMST climate zones.[8] Table 5-1 provides a summary of the conclusions of Section 4.15. As shown, the significant decrease in the average % Compliance Margin between Project Year #1 homes and Project Year #2 homes in RMST Climate Zones 3 and 5 was primarily due to the increase in the average percent glazing in these two RMST climate zones. Also shown is that the significant increase in the average % Compliance Margin in RMST Climate Zones 1 and 4 was due to the change in the standards from 1995 to 1998. The significant increase in the average % Compliance Margin in RMST Climate Zone 2 can be attributed to both the decrease in the average percent glazing and to the changes in the water heater portion of the standards.

[7] A significance test was conducted at the 95% confidence level.

[8] Note that a change in building characteristics that is not statistically significant could have a significant impact on compliance due to how compliance is calculated.

Table 5-1: Summary of Compliance Variations among Climate Zones across Project Years – Detached Single Family Homes

	Overall	CZ #1	CZ #2	CZ #3	CZ #4	CZ #5
Project Year #1 1995 Standards	4.8%	6.8%	6.7%	10.2%	-1.0%	-0.5%
Project Year #2 1998 Standards	6.2%	11.4%	14.7%	6.1%	4.1%	-6.2%
Difference	1.5%	4.5%	7.9%	-4.1%	5.1%	-5.7%
Significance*	Sig	Sig	Sig	Sig	Sig	Sig
Possible Reason(s)		? SpHt & WH Margin	? Glazing% & ? WH Margin	? Glazing%	? All Margins	? Glazing%
Project Year #1 1995 Standards	4.8%	6.8%	6.7%	10.2%	-1.0%	-0.5%
Project Year #2 1995 Standards	3.6%	7.5%	11.8%	3.1%	1.9%	-7.1%
Difference	-1.2%	0.6%	5.0%	-7.1%	2.9%	-6.6%
Significance *	Sig	Not Sig	Sig	Sig	Sig	Sig
Possible Reason(s)			? Glazing%	? Glazing%	? WH Eff & ? # Floors	? Glazing%
Project Year #2 1995 Standards	3.6%	7.5%	11.8%	3.1%	1.9%	-7.1%
Project Year #2 1998 Standards	6.2%	11.4%	14.7%	6.1%	4.1%	-6.2%
Difference	2.7%	3.9%	2.9%	3.0%	2.1%	0.9%
Significance *	Sig	Sig	Sig	Sig	Sig	Not Sig
Possible Reason(s)		? SpHt & WH Margin	? WH Margin	? SpHt & WH Margin	? All Margins	

* A significance test was conducted at the 90% confidence level.

Attached Single Family Homes and Multifamily Buildings

As shown in Table 5-2, the average % Compliance Margins for attached single family and multifamily buildings in RMST Climate Zones 1, 2, and 4 increase significantly. Overall, the average % Compliance Margin for attached single family and multifamily buildings increased significantly between those homes built from July 1998 to June 1999 (Project Year #1 homes) and those homes built from July 1999 to June 2000 (Project Year #2 homes)—from 14.9% to 21.6%.

The analysis in Section 4.16 concludes that both building practices and changes to the standards were responsible for the significant changes in the average % Compliance Margin in RMST Climate Zone 1,[9] while the change in the standards was the primary reason for the

[9] Note that a change in building characteristics that is not statistically significant could have a significant impact on compliance due to how compliance is calculated.

significant increase in RMST Climate Zones 2 and 4. Table 5-2 provides a summary of the conclusions of Section 4.16.

Table 5-2: Summary of Compliance Variations among Climate Zones across Project Years – Attached Single Family Homes and Multifamily Buildings

	Overall	CZ #1	CZ #2	CZ #3	CZ #4	CZ #5
Project Year #1 1995 Standards	14.9%	11.0%	17.5%	21.7%	13.6%	9.6%
Project Year #2 1998 Standards	21.6%	22.3%	22.1%	22.3%	22.0%	3.3%
Difference	6.7%	11.3%	4.7%	0.6%	8.4%	-6.3%
Significance*	Sig	Sig	Sig	Not Sig	Sig	Not Sig
Possible Reason(s)		? Glazing% & ? SpHt & WH Margin	? WH Margin		? All Margins	
Project Year #1 1995 Standards	14.9%	11.0%	17.5%	21.7%	13.6%	9.6%
Project Year #2 1995 Standards	15.7%	16.8%	17.1%	17.6%	14.1%	1.3%
Difference	0.8%	5.9%	-0.4%	-4.1%	0.6%	-8.3%
Significance *	Not Sig	Sig	Not Sig	Not Sig	Not Sig	Not Sig
Possible Reason(s)		? Glazing%				
Project Year #2 1995 Standards	15.7%	16.8%	17.1%	17.6%	14.1%	1.3%
Project Year #2 1998 Standards	21.6%	22.3%	22.1%	22.3%	22.0%	3.3%
Difference	5.9%	5.4%	5.1%	4.7%	7.8%	2.0%
Significance *	Sig	Sig	Sig	Not Sig	Sig	Not Sig
Possible Reason(s)		? SpHt & WH Margin	? WH Margin		? All Margins	

* A significance test was conducted at the 90% confidence level.

5.5 Residential Standards Issues

The following are some suggestions and observations designed to highlight issues that might be important to Title 24 consultants and agencies that design/revise the Standards.

- ***Window Performance Trade-Offs in Multifamily Buildings.*** From this and previous studies, percent glazing used in multifamily buildings is typically much less than the prescriptive values, which yields energy budget excess that can (and is) traded off against lower performance windows (i.e., metal-framed, clear

glass windows). The highest concentration of low-performance windows is in those regions subject to Prescriptive 20% glazing value.

- ***Separate Standards for Multifamily Buildings.*** Baseline values for water heating usage and internal loads between single family detached and multifamily buildings (single family attached and multifamily) already exist. A completely separate set of Standards for multifamily buildings has been considered and is currently/constantly being evaluated.[10]
- ***Unavailability of Insulation Certificate.*** Very few surveyors were able to locate an insulation certificate posted around the home or obtain this documentation from the homeowner.

[10] Separate standards for multifamily homes were considered as part of the AB 970 proceedings, but were not pursued.

Appendix A

Sample C-2R Form

Project Title..... PG&E RNC 2000 Date..... 12/08/00
Project Address..... 753 Whispering Trails *v4.50*
Documentation Author... RER, Inc.
Regional Economic Research
11236 El Camino Real
San Diego, CA 92130
858-481-0081
Climate Zone..... 07
Compliance Method..... MICROPAS4 v4.70 for 1995 Standards by Enercomp, Inc.

Building Permit # _____
Plan Check / Date _____
Field Check/ Date _____

MICROPAS4 v4.50 File-C2R02131 Wth-CTZ07S92 Program-FORM C-2R
User#-MP2206 User-Regional Economic Researc Run-Site.2131

MICROPAS4 ENERGY USE SUMMARY

Energy Use (kBtu/sf-yr)	Standard Design	Proposed Design	Compliance Margin
Space Heating.....	3.22	3.28	-0.06
Space Cooling.....	4.90	4.44	0.46
Water Heating.....	12.61	10.80	1.81
North Total	20.73	18.52	2.21
Space Heating.....	3.22	3.38	-0.16
Space Cooling.....	4.90	6.39	-1.49
Water Heating.....	12.61	10.80	1.81
East Total	20.73	20.57	0.16
Space Heating.....	3.22	3.66	-0.44
Space Cooling.....	4.90	4.60	0.30
Water Heating.....	12.61	10.80	1.81
South Total	20.73	19.06	1.67
Space Heating.....	3.22	3.51	-0.29
Space Cooling.....	4.90	3.49	1.41
Water Heating.....	12.61	10.80	1.81
West Total	20.73	17.80	2.93

*** Building complies with Computer Performance ***

GENERAL INFORMATION

Conditioned Floor Area..... 1804 sf
Building Type..... Single Family Detached
Construction Type ..... New
Building Front Orientation. Cardinal - N,E,S,W
Number of Dwelling Units... 1
Number of Building Stories. 2

Project Title..... PG&E RNC 2000 Date..... 12/08/00

| MICROPAS4 v4.50 File-C2R02131 Wth-CTZ07S92 Program-FORM C-2R |
| User#-MP2206 User-Regional Economic Researc Run-Site.2131 |

Weather Data Type..... ReducedYear
Floor Construction Type.... Slab On Grade
Number of Building Zones... 1
Conditioned Volume..... 18220 cf
Footprint Area..... 902 sf
Ground Floor Area..... 902 sf
Slab-On-Grade Area..... 902 sf
Glazing Percentage..... 25.8 % of floor area
Average Glazing U-value.... 0.7 Btu/hr-sf-F
Average Ceiling Height..... 10.1 ft

BUILDING ZONE INFORMATION

Zone Type	Floor Area (sf)	Volume (cf)	# of Dwell Units	Cond-itioned	Thermostat Type	Vent Height (ft)	Special Vent Area (sf)
HOUSE							
Residence	1804	18220	1.00	Yes	Setback	8.0	n/a

OPAQUE SURFACES

Surface	Area (sf)	U-value	Insul R-val	Act Azm	Tilt	Solar Gains	Form 3 Reference	Location/ Comments
HOUSE								
1 Wall	309	0.088	13	0	90	Yes	W.13.2X4.16	Default RVal
2 Wall	168	0.088	13	0	90	No	W.13.2X4.16	Default RVal
3 Wall	601	0.088	13	90	90	Yes	W.13.2X4.16	Default RVal
4 Wall	428	0.088	13	180	90	Yes	W.13.2X4.16	Default RVal
5 Wall	373	0.088	13	270	90	Yes	W.13.2X4.16	Default RVal
6 Wall	213	0.088	13	270	90	No	W.13.2X4.16	Default RVal
7 Door	40	0.330	0	0	90	Yes	None	Wooden Door
8 Roof	1209	0.031	30	n/a	0	Yes	R.30.2X4.24	Default RVal

PERIMETER LOSSES

Surface	Length (ft)	F2 Factor	Insul R-val	Solar Gains	Location/Comments
HOUSE					
9 SlabEdge	120	0.700	R-0	No	Slab

FENESTRATION SURFACES

Surface	Area (sf)	# of Pan-es	Frame Type	Vent Open Type	U-value	Act Azm	Tlt	SC Glass Only	SC Int Shade	Interior Shading/ Description
HOUSE										
1 Window	48.0	2	VinylDiv	Slider	0.600	0	90	0.88	0.78	VW.2.Clear.Wind
2 Window	12.0	2	VinylDiv	Slider	0.600	0	90	0.88	0.78	VW.2.Clear.Wind
3 Window	24.0	2	VinylDiv	Slider	0.600	0	90	0.88	0.78	VW.2.Clear.Wind

Project Title..... PG&E RNC 2000 Date..... 12/08/00

MICROPAS4 v4.50 File-C2R02131 Wth-CTZ07S92 Program-FORM C-2R
User#-MP2206 User-Regional Economic Researc Run-Site.2131

FENESTRATION SURFACES

Surface	Area (sf)	# of Pan-es	Frame Type	Vent Open Type	U-value	Act Azm	Tlt	SC Glass Only	SC Int Shade	Interior Shading/ Description
4 Window	30.0	2	Vinyl	Slider	0.600	0	90	0.88	0.78	VW.2.Clear.Wind
5 Window	24.0	2	VinylDiv	Slider	0.600	90	90	0.88	0.78	VW.2.Clear.Wind
6 Window	4.0	2	VinylDiv	Slider	0.600	90	90	0.88	0.78	VW.2.Clear.Wind
7 Window	48.0	2	Metal	Slider	0.750	90	90	0.88	0.78	Mtl.2.Clear.Win
8 Window	8.0	2	Metal	Slider	0.750	90	90	0.88	0.78	Mtl.2.Clear.Win
9 Window	36.0	2	Metal	Slider	0.750	90	90	0.88	0.78	Mtl.2.Clear.Win
10 Window	24.0	2	Metal	Slider	0.750	90	90	0.88	0.78	Mtl.2.Clear.Win
11 Window	11.0	2	Metal	Slider	0.750	180	90	0.88	0.78	Mtl.2.Clear.Win
12 Door	40.0	2	Metal	Slider	0.730	180	90	0.88	0.78	Mtl.2.Clear.Doo
13 Window	12.0	2	Metal	Slider	0.750	180	90	0.88	0.78	Mtl.2.Clear.Win
14 Window	36.0	2	Metal	Slider	0.750	180	90	0.88	0.78	Mtl.2.Clear.Win
15 Window	20.0	2	Metal	Slider	0.750	180	90	0.88	0.78	Mtl.2.Clear.Win
16 Window	18.0	2	Metal	Slider	0.750	180	90	0.88	0.78	Mtl.2.Clear.Win
17 Window	24.0	2	Metal	Slider	0.750	180	90	0.88	0.78	Mtl.2.Clear.Win
18 Window	24.0	2	Metal	Slider	0.750	180	90	0.88	0.78	Mtl.2.Clear.Win
19 Window	12.0	2	Metal	Slider	0.750	270	90	0.88	0.78	Mtl.2.Clear.Win
20 Window	10.0	2	Metal	Slider	0.750	270	90	0.88	0.78	Mtl.2.Clear.Win

OVERHANGS AND SIDE FINS

Surface	Area (sf)	---Window-- Hght	Wdth	------Overhang----- Dpth	Hght	Left Ext	Rght Ext	---Left Fin--- Ext	Dpth	Hght	---Right Fin-- Ext	Dpth	Hght
HOUSE													
1 Window	48.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2 Window	12.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3 Window	24.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4 Window	30.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5 Window	24.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6 Window	4.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7 Window	48.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8 Window	8.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9 Window	36.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
10 Window	24.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
11 Window	11.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
12 Door	40.0	7.5	n/a	3.0	1.75	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
13 Window	12.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
14 Window	36.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
15 Window	20.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
16 Window	18.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
17 Window	24.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
18 Window	24.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
19 Window	12.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
20 Window	10.0	4.5	n/a	2.0	2.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Project Title..... PG&E RNC 2000 Date..... 12/08/00

MICROPAS4 v4.50 File-C2R02131 Wth-CTZ07S92 Program-FORM C-2R
User#-MP2206 User-Regional Economic Researc Run-Site.2131

THERMAL MASS

Mass Type	Area (sf)	Thick (in)	Heat Cap	Conduct-ivity	Surface R-value	Location/Comments
HOUSE						
1 SlabOnGrade	180	3.5	28.0	0.98	R-0.0	20% Exposed Default
2 SlabOnGrade	722	3.5	28.0	0.98	R-2.0	80% Covered Default

HVAC SYSTEMS

System Type	Minimum Efficiency	Duct Location	Duct R-value	Duct Efficiency
HOUSE				
Furnace	0.800 AFUE	Attic	R-4.2	0.880
ACSplit	10.00 SEER	Attic	R-4.2	0.870

WATER HEATING SYSTEMS

Tank Type	Heater Type	Distribution Type	Number in System	Energy Factor	Tank Size (gal)	External Insulation R-value
1 Storage	Gas	Standard	1	0.615	40	R-12

SPECIAL FEATURES/REMARKS

This is a multiple orientation building with no orientation restrictions.
This printout is for the front facing North.

Appendix B

Gathering Building Department Compliance Forms

This section discusses the original methodology and final results of the effort to gather copies of C-2R and CF-1R compliance forms for a sample of surveyed sites, in order to use them to test the Interface.

B.1 Objectives

Identifying Building Departments to be Recruited

It does not make sense to contact a building department and only ask for the forms for a single site. As much as possible when contacting a building department, team members asked for forms for as many sites as possible. Other recruitment criteria included the following:

- Identifying building departments with the largest number of surveyed sites AND those that we have already contacted as part of the RMST CF-6R acquisition effort.
- Recruiting first from "friendly" building departments (those already providing CF-6Rs, especially those that provided forms for the overlap sites), and from those with "easy" driving distance from RER offices in San Diego.
- Attempting to recruit those building departments that were not providing CF-6Rs, but had been previously contacted for this effort.
- Identifying those building departments with the largest number of surveyed sites that had NOT been contacted as part of the RMST CF-6R acquisition effort. These were the most difficult and time-consuming to contact and were used as a last resort.

Key Features Used in Site Selection

The first step in selecting the test sites and building departments from which to recruit from is to identify key criteria. The following criteria were selected for examination:

- Building department and the total number of surveyed sites under the jurisdiction of each building department,

- Whether the building department was one previously contacted for the CF-6R effort, and whether they contributed to that effort,
- RER climate zone,
- Residence type,
- Predominant HVAC system type, and
- Existance of multiple HVAC systems.

A listing summarizing these features for every site was assembled. Also, in the process of identifying these features, some unique "special interest" sites were identified as follows:

- Sites with multiple HVAC system types
- Sites with multiple water heaters
- Sites that utilize hydronic heating systems

Criteria for Selecting Building Departments and Sites

Once the list of key features was assembled, the following criteria were used to ensure that selected sites provided enough variations to thoroughly test the process:

- Ensure all climate zones are represented in the sample.
- Obtain a mix of single family, single family attached, and multifamily types.
- Obtain as good a mix of HVAC system types as is possible.
- Attempt to obtain a few "special interest" sites, even if this means obtaining forms for only a single site from a building department that had never been contacted.

Selecting the Building Departments to be Contacted

RER reviewed the summary listing of key parameters and, for each climate zone, selected at least three building departments—a primary, a secondary, and a runner-up(s). Primary and secondary building departments were needed because some building departments only keep records for a limited time, and some may not keep the C-2R forms. Runner-ups were used as a last resort, some of which were building departments that had not contacted in the past. Initial selection of these building departments is given in the tables below.

Table B-1: Building Department Targets

RER CZ	BldgDept	SF-A[1]	SF	MF	BldgDept	SF-A	SF	MF
Primary and Secondary Targets								
1	Napa		5		Morgan Hill	2	3	
2	San Diego[2]	3	26	16	Chula Vista[2]	2	18	
3	Simi Valley		11	2	Murrieta		9	
4	Chico		4		Rocklin	1	8	2
5	Apple Valley		3		Palm Desert		6	
	Totals	**3**	**49**	**18**		**1**	**44**	**2**
Runner-Up Targets								
1	San Francisco		5		Oakland	2	1	2
2	None							
3	Temecula		3	1				
4	Bakersfield	1	20					
5	Hemet		3	2				
	Totals	**1**	**26**	**2**		**2**	**1**	**2**

Contacting Building Departments and Determine CF-1R/C-2R Status

The targeted building departments were contacted to determine if they had CF-1R and C-2R forms for the surveyed sites. Those previously contacted received a fax and a list of the sites for which forms were needed. This was then followed up with a telephone call to see if the building department was willing and able to contribute. Some forms were mailed to RER, while others were obtained by visiting the site to obtain copies.

B.2 Compliance Form Collection Results

RER contacted about 50 building departments, however only six were able to contribute CF-1R and C-2R forms. Forms for 40 on-site survey sites were collected. Of those, only 36 of matched 37 sites (one C-2R form matched two on-site survey sites). A final tabulation of the forms received from building departments is given in Table B-2. The locations of building departments contributing forms are shown in Figure B-1. The distribution is quite different from that given in the original plan. It was very difficult to entice building departments to

[1] SF=Single-family, unattached. SF-A=Single-family attached. MF=Multifamily.

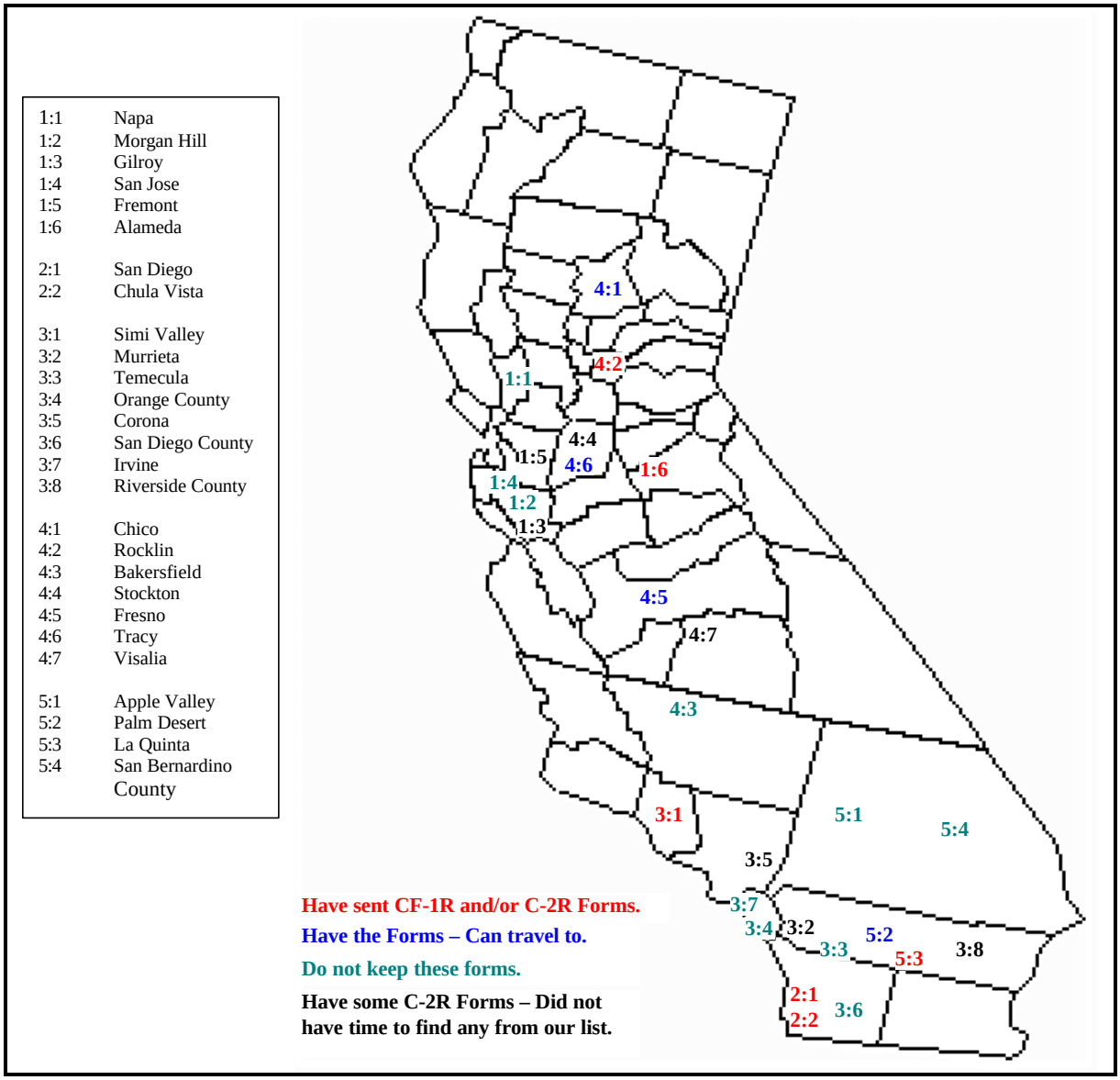
[2] RER will physically visit these building departments to obtain copies of the CF-1R and C-2R forms.

contribute to this effort due to their limited time and available manpower. However, all building types and RER climate zones are represented.

Table B-2: Final Building Department Sample

RER CZ	CEC CZ	BldgDept	SF-1Story	SF-2Story	SF-Attached	MF	Total C-2Rs
1	3, 12	Alameda	2	5	1		**8**
2	7, 10	San Diego		5		2	**7**
2	7	Chula Vista	2	13			**15**
3	9	Simi Valley		2		1	**3**
4	11	Rocklin	1	2		1	**4**
5	15	La Quinta	3				**3**
		Totals	**8**	**27**	**1**	**4**	**40**

Figure B-1: Location of Building Departments Contributing C-2Rs



Appendix C

On-Site Survey Instrument

This appendix contains the survey forms used for both the first and second year of on-site surveys, as well as an overview of the differences between the two forms.

C.1 Modifications of the RMST On-Site Survey Form for the Second Year

A number of modifications were made to the second year RMST on-site survey form. These changes were made to improve data availability and quality for the MICROPAS[1] analysis, and also to capture data requested by CEC personnel and other statewide RNC program managers. The changes are summarized below.

- Detailed information on kitchen lighting and diffuser types, bathroom lighting, and ceiling fan lighting systems were added.
- Ceiling fans that do not have lights are counted as miscellaneous equipment.
- Information on HVAC system location and an estimate of the distance between the HVAC system and water heating system was added. HVAC system equipment types were also expanded.
- Several changes were made to the water heating equipment page. A more direct way to specify a combination space/water heating type unit was added. Control types and features reflecting the various credits/debits available in MICROPAS were also added. Finally, additional fields needed to record performance and efficiency information for large water heaters and water heaters used in hydronic systems were added.
- Information on the location of supply and return ducts was added. Duct and duct-sealing types were expanded. A field for recording the duct sealing tape UL label information and brand name was also added (although, this data was gathered last year, there was no dedicated field to capture the data).
- Building shell data changes were made to enhance the MICROPAS runs. More detailed information on door shading, roof areas, roof insulation type, ground floor

[1] MICROPAS is a computer software tool used for performing Title 24 compliance analysis on low-rise residential buildings.

area, exposed/covered floor percentages and floor area above an unconditioned garage were added.

- For windows, interior and exterior shading details were separated and expanded to better reflect MICROPAS options. In addition, glass type options were revised to reflect the use of the ETEKT+ AE1600 Low-E Coating Detectors,[2] which were used to detect after-market window films as well as low-E coatings. In addition, surveyors measured the home's three largest windows and then used those measurements as the basis for estimating the areas of other windows (surveyors do not measure every window in the home due to time and budget constraints).

[2] ETETKT+ Low-E Coating Detectors were obtained from Electronic Design to Market, Inc. (www.edtm.com). These meters detect the presence of metal surface coatings on the outer or inner sides of single-paned or dual-paned glass windows.

1999 On-Site Survey Instrument

Site ID #

Residential New Construction
Market Share Tracking Project
On-Site Survey Form

Regional Economic Research, Inc. and Volt VIEWtech

Version: 11/17/1999

Contact Information:

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

Photo Information

Disposable Camera ID #		# of photos	

Survey Tracking Information:

	Date:	**Performed by, Initials**
Field Survey Performed:	__ / __ / __	__ __ __
Quality Control Check:	__ / __ / __	__ __ __
Data Entry Complete:	__ / __ / __	__ __ __
Duct Blaster test site?		
Survey and Data Received by RER:	__ / __ / __	__ __ __

Table of Contents

Energy Utility Meters & Accounts

Is customer responsible for the utility bills? ☐ Yes ☐ No

If Yes, is the customer aware of electric industry deregulation and the option to switch providers? ☐ Yes ☐ No

-- If Yes, has the customer changed energy providers? ☐ Yes ☐ No

Item #	Service Type*	Utility	Meter Number (Enter –7 if can't read it)	Account Number
1	**E G O**	**SDG&E SCE SCG PG&E OT**		
2	**E G O**	**SDG&E SCE SCG PG&E OT**		
3	**E G O**	**SDG&E SCE SCG PG&E OT**		
4	**E G O**	**SDG&E SCE SCG PG&E OT**		
5	**E G O**	**SDG&E SCE SCG PG&E OT**		
6	**E G O**	**SDG&E SCE SCG PG&E OT**		

*Description for Other (**O**) Service Type: _____

Comments

General Site Information

Type of residence: (CHECK ONLY ONE. If **MF** indicated, complete pages 18 and 19)

- **SF** ☐ Detached, tract-built single family house
- **SF** ☐ Detached, custom-built single family house
- **MF** ☐ Attached home, Townhome/Condo
- **MF** ☐ Apartment in small complex (fewer than 5 units)
- **MF** ☐ Apartment in large complex (5+ units)
- **SF** ☐ Manufactured housing
- **SF** ☐ Mobile home/trailer
- **MF** ☐ Other, describe _____

Does the occupant own or rent this residence? ☐ Own ☐ Rent

If owned, is the occupant a first-time homebuyer? ☐ Yes ☐ No

How many stories tall is the residence (including basement)? ___ ☐ Split foyer ☐ Split level

What is the total conditioned floor area of the residence (other than garage, basement, and porch)? _____

How many bedrooms/bathrooms does the residence have? _____ / _____

Are any of the following areas used as conditioned living space? (ENTER FLOOR AREA FOR ALL THAT APPLY)

_____ Garage (ft^2) _____ Porch (ft^2

_____ Basement (ft^2) _____ Other (ft^2)

HOMEOWNERS ONLY: Any Title 24 documents present in homeowner's information packet? ☐ Yes ☐ No
(If so, note below what forms were found)

What was the purchase price of the home?

Actual price $_____

OR ☐ Declined to state

OR ☐ Under $100,000
☐ $100,000 - $200,000
☐ $200,000 - $300,000
☐ $300,000 - $400,000
☐ over $400,000

Builder/Development Information

Builder's Name:	
Development/Complex Name:	
Month/Year the home was occupied by current resident:	
Month/Year the home was built:	

FOR HOME OWNERS ONLY: Was the residence built under any of the following utility or federal residential energy-efficiency programs? (NOTE: Check customers document package for this information.)

- ☐ Don't know
- ☐ Energy Star Home (look for a bronze plaque mounted somewhere on the home)
- ☐ Pacific Gas & Electric (PG&E) Comfort Home
- ☐ Southern California Edison (SCE) ComfortWise Home
- ☐ Southern California Gas (SCG) Energy Advantage Home
- ☐ San Diego Gas & Electric (SDG&E) ComfortWise Home

FOR HOME OWNERS ONLY: Were any energy-saving options offered by the builder?

- ☐ No high-efficiency options offered
- ☐ High-efficiency cooling or heating equipment
- ☐ Advanced heating/cooling control/thermostat
- ☐ Improved performance windows
- ☐ Pre-wired Home Automation System
- ☐ Other _____
- ☐ Don't know

Household Characteristics

Please have the respondent answer the following questions:

Number of people who live in this home at least 9 months of the year in the following age groups:

under 2 years _____
2-5 _____
6-21 _____
22-39 _____
40-64 _____
65 and over _____

Indicate the household's current annual income before taxes?

- ☐ Under $20,000 per year
- ☐ $20,000 - 39,999
- ☐ $40,000 - 59,999
- ☐ $60,000 - 79,999
- ☐ $80,000 - 120,000
- ☐ Over $120,000
- ☐ Refused

NOTE: If any significant devices that affect energy use or conservation (i.e photovoltaic systems, backup generator systems for Y2K, electric automobiles, etc.) are observed during the survey, ask the occupant about them and record relevant notes on the comments page at the end of the survey form.

Indoor & Outdoor Lighting

Item #	1	2	3	4	5	6	7	8
Location: **X** = Outside Lighting **K** = Kitchen **L**=Living Room **D** = Dining Room **F** = Family Room **H** = Halls/Entry **B** = Bathroom **MB** = Master Bed. **OB** = Other Bedroom **G** = Garage **OT** = Other (describe)								
Control Type: **S** = Switch (on/off) **M** = Motion sensor **D** = Dimmer **P** = Photocell **T** = Timer **H** = Home Automation System **OT** = Other (describe) _____								
Fixture Type: **C** = Ceiling, surface-mounted **L** = Floor/table lamp **D** = Downlights (cans) **T** = Torchiere **W** = Wall –mounted **H** = Other hard-wired **R** = Recessed **P** = Other plug-in **S** = Suspended								
Total Number of Fixtures								
Number of lamps per fixture								
Watts per Lamp (enter 2 or 3-way as 50/100/150)								
Lamp Type & Lamp-Specific Details								
I = Incandescent Standard, medium base	I	I	I	I	I	I	I	I
IS = Incandescent Standard, small base	IS	IS	IS	IS	IS	IS	IS	IS
IP = Incandescent PAR	IP	IP	IP	IP	IP	IP	IP	IP
IR = Incandescent Reflector	IR	IR	IR	IR	IR	IR	IR	IR
For Incand. lamps: CFs Applicable (medium base)?	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
F = Fluorescent Tube	F	F	F	F	F	F	F	F
UT = Fluorescent U-tube	UT	UT	UT	UT	UT	UT	UT	UT
OF = Other Fluorescent (describe in comment block)	OF	OF	OF	OF	OF	OF	OF	OF
For Fluor. tubes: Length in ft. (e.g., 2 4 6 8)								
Diameter (e.g. T8 T10 T12)								
CFG = CF w/Globe-Shaped diffuser	CFG	CFG	CFG	CFG	CFG	CFG	CFG	CFG
CFC = CF, w/Capsule-Shaped diffuser	CFC	CFC	CFC	CFC	CFC	CFC	CFC	CFC
CFR = CF w/reflector	CFR	CFR	CFR	CFR	CFR	CFR	CFR	CFR
CF = Compact Fluorescent, Other	CF	CF	CF	CF	CF	CF	CF	CF
CIR = Circline	CIR	CIR	CIR	CIR	CIR	CIR	CIR	CIR
For CF and CIR,lamps, indicate base type: I=Integrated M=Modular D=Dedicated	I M D	I M D	I M D	I M D	I M D	I M D	I M D	I M D
HA= Halogen "A"	HA	HA	HA	HA	HA	HA	HA	HA
HT = Halogen Tubular	HT	HT	HT	HT	HT	HT	HT	HT
HL = Halogen low voltage	HL	HL	HL	HL	HL	HL	HL	HL
HP = Halogen reflector/PAR	HP	HP	HP	HP	HP	HP	HP	HP
MV = Mercury Vapor	MV	MV	MV	MV	MV	MV	MV	MV
MH = Metal Halide	MH	MH	MH	MH	MH	MH	MH	MH
HPS = High Pressure Sodium Vapor	HPS	HPS	HPS	HPS	HPS	HPS	HPS	HPS
LPS = Low Pressure Sodium Vapor	LPS	LPS	LPS	LPS	LPS	LPS	LPS	LPS
Field Notes: (Counts)								

Indoor & Outdoor Lighting

Item #	9	10	11	12	13	14	15	16
Location: **X** = Outside Lighting **K** = Kitchen **L**=Living Room **D** = Dining Room **F** = Family Room **H** = Halls/Entry **B** = Bathroom **MB** = Master Bed. **OB** = Other Bedroom **G** = Garage **OT** = Other (describe)								
Control Type: **S** = Switch (on/off) **M** = Motion sensor **D** = Dimmer **P** = Photocell **T** = Timer **H** = Home Automation System **OT** = Other (describe) _____								
Fixture Type: **C** = Ceiling, surface-mounted **L** = Floor/table lamp **D** = Downlights (cans) **T** = Torchiere **W** = Wall –mounted **H** = Other hard-wired **R** = Recessed **P** = Other plug-in **S** = Suspended								
Total Number of Fixtures								
Number of lamps per fixture								
Watts per Lamp (enter 2 or 3-way as 50/100/150)								
Lamp Type & Lamp-Specific Details								
I = Incandescent Standard, medium base	I	I	I	I	I	I	I	I
IS = Incandescent Standard, small base	IS	IS	IS	IS	IS	IS	IS	IS
IP = Incandescent PAR	IP	IP	IP	IP	IP	IP	IP	IP
IR = Incandescent Reflector	IR	IR	IR	IR	IR	IR	IR	IR
For Incand. lamps: CFs Applicable (medium base)?	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
F = Fluorescent Tube	F	F	F	F	F	F	F	F
UT = Fluorescent U-tube	UT	UT	UT	UT	UT	UT	UT	UT
OF = Other Fluorescent (describe in comment block)	OF	OF	OF	OF	OF	OF	OF	OF
For Fluor. tubes: Length in ft. (e.g., 2 4 6 8)								
Diameter (e.g. T8 T10 T12)								
CFG = CF w/Globe-Shaped diffuser	CFG	CFG	CFG	CFG	CFG	CFG	CFG	CFG
CFC = CF, w/Capsule-Shaped diffuser	CFC	CFC	CFC	CFC	CFC	CFC	CFC	CFC
CFR = CF w/reflector	CFR	CFR	CFR	CFR	CFR	CFR	CFR	CFR
CF = Compact Fluorescent, Other	CF	CF	CF	CF	CF	CF	CF	CF
CIR = Circline	CIR	CIR	CIR	CIR	CIR	CIR	CIR	CIR
For CF and CIR,lamps, indicate base type: I=Integrated M=Modular D=Dedicated	I M D	I M D	I M D	I M D	I M D	I M D	I M D	I M D
HA= Halogen "A"	HA	HA	HA	HA	HA	HA	HA	HA
HT = Halogen Tubular	HT	HT	HT	HT	HT	HT	HT	HT
HL = Halogen low voltage	HL	HL	HL	HL	HL	HL	HL	HL
HP = Halogen reflector/PAR	HP	HP	HP	HP	HP	HP	HP	HP
MV = Mercury Vapor	MV	MV	MV	MV	MV	MV	MV	MV
MH = Metal Halide	MH	MH	MH	MH	MH	MH	MH	MH
HPS = High Pressure Sodium Vapor	HPS	HPS	HPS	HPS	HPS	HPS	HPS	HPS
LPS = Low Pressure Sodium Vapor	LPS	LPS	LPS	LPS	LPS	LPS	LPS	LPS
Field Notes: (Counts)								

Indoor & Outdoor Lighting

Item #	__	__	__	__	__	__	__	__
Location: **X** = Outside Lighting **K** = Kitchen **L**=Living Room **D** = Dining Room **F** = Family Room **H** = Halls/Entry **B** = Bathroom **MB** = Master Bed. **OB** = Other Bedroom **G** = Garage **OT** = Other (describe)								
Control Type: **S** = Switch (on/off) **M** = Motion sensor **D** = Dimmer **P** = Photocell **T** = Timer **H** = Home Automation System **OT** = Other (describe) _____								
Fixture Type: **C** = Ceiling, surface-mounted **L** = Floor/table lamp **D** = Downlights (cans) **T** = Torchiere **W** = Wall –mounted **H** = Other hard-wired **R** = Recessed **P** = Other plug-in **S** = Suspended								
Total Number of Fixtures								
Number of lamps per fixture								
Watts per Lamp (enter 2 or 3-way as 50/100/150)								
Lamp Type & Lamp-Specific Details								
I = Incandescent Standard, medium base	I	I	I	I	I	I	I	I
IS = Incandescent Standard, small base	IS	IS	IS	IS	IS	IS	IS	IS
IP = Incandescent PAR	IP	IP	IP	IP	IP	IP	IP	IP
IR = Incandescent Reflector	IR	IR	IR	IR	IR	IR	IR	IR
For Incand. lamps: CFs Applicable (medium base)?	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
F = Fluorescent Tube	F	F	F	F	F	F	F	F
UT = Fluorescent U-tube	UT	UT	UT	UT	UT	UT	UT	UT
OF = Other Fluorescent (describe in comment block)	OF	OF	OF	OF	OF	OF	OF	OF
For Fluor. tubes: Length in ft. (e.g., 2 4 6 8)								
Diameter (e.g. T8 T10 T12)								
CFG = CF w/Globe-Shaped diffuser	CFG	CFG	CFG	CFG	CFG	CFG	CFG	CFG
CFC = CF, w/Capsule-Shaped diffuser	CFC	CFC	CFC	CFC	CFC	CFC	CFC	CFC
CFR = CF w/reflector	CFR	CFR	CFR	CFR	CFR	CFR	CFR	CFR
CF = Compact Fluorescent, Other	CF	CF	CF	CF	CF	CF	CF	CF
CIR = Circline	CIR	CIR	CIR	CIR	CIR	CIR	CIR	CIR
For CF and CIR,lamps, indicate base type: I=Integrated M=Modular D=Dedicated	I M D	I M D	I M D	I M D	I M D	I M D	I M D	I M D
HA= Halogen "A"	HA	HA	HA	HA	HA	HA	HA	HA
HT = Halogen Tubular	HT	HT	HT	HT	HT	HT	HT	HT
HL = Halogen low voltage	HL	HL	HL	HL	HL	HL	HL	HL
HP = Halogen reflector/PAR	HP	HP	HP	HP	HP	HP	HP	HP
MV = Mercury Vapor	MV	MV	MV	MV	MV	MV	MV	MV
MH = Metal Halide	MH	MH	MH	MH	MH	MH	MH	MH
HPS = High Pressure Sodium Vapor	HPS	HPS	HPS	HPS	HPS	HPS	HPS	HPS
LPS = Low Pressure Sodium Vapor	LPS	LPS	LPS	LPS	LPS	LPS	LPS	LPS
Field Notes: (Counts)								

Appliances & Other Equipment

Refrigerators & Freezers *- Manufacturer/Model Data*

Item #1 -- Manufacturer	
-- Model Number	
Item #2 -- Manufacturer	
-- Model Number	
Item #3 -- Manufacturer	
-- Model Number	

Refrigerators & Freezers *- Type/Configuration Data*

Item #	**1**	**2**	**3**
Equipment type: **R** = Refrigerator/Freezer **F** = Freezer **OT=** Other	**R F OT**	**R F OT**	**R F OT**
Defrost type: **F** = Frost-free **M** = Manual	**F M**	**F M**	**F M**
Configuration: ***Ref/Frz:*** **T**=Top mount **B**=Bottom mount **S**=Side-by-side **D**=1-door ***Freezer:*** **C** = Chest **U** = Upright **OT** = Other	**T B S D** **C U** **OT**	**T B S D** **C U** **OT**	**T B S D** **C U** **OT**
Space/Location: **C** = Conditioned **U** = Unconditioned	**C U**	**C U**	**C U**
Volume/size, ft^3			
Age in years (enter 1 if less than 1 year old)			
EF (Energy Factor, ft^3/kWh/day)			

Dishwasher

Manufacturer	**Model Number**

Clothes Washer

Axis Type	**Manufacturer**	**Model Number**	**Age**
Vert **H**oriz			

Clothes Dryer

Fuel Type	**Manufacturer**	**Model Number**	**Age**
E G P O			

Miscellaneous Equipment

Appliance	**Quantity**	**Fuel Type**
Oven		E G P O
Range		E G P O
Pool Heater		E G P O
Spa Heater		E G P O
Pool Pump		
Color Televisions		
Personal Computers		
Other _____		
Other _____		
Other _____		

Water Heating Equipment *(complete multiple sheets if multiple water heaters)*

Manufacturer	Model Number	EF (Energy Factor)

Equipment type: **S** = Standard 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**
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**
Solar Backup Type (if relevant): **E** = Electricity **G** = Natural Gas **P** = Propane (LPG) **OT**=Other _____	**E G P OT**
Heat trap? Y=yes, N=no	**Y N**
Low-flow fixtures (showerheads, faucets, etc.)? **Y**=yes, **N**=no	**Y N**
Input Capacity (Check units, either kBtuh or kW)	❑ kBtuh ❑ kW
Tank Capacity (Gallons)	
Does the hot water tank have an external insulation jacket? **Y**=yes, **N**=no	**Y N**
Are hot water pipes insulated? **Y**=yes, **N**=no	**Y N**
Hot water recirculation system present? **Y**=yes, **N**=no	**Y N**
Recirculation pump power (hp) (Enter zero for no pump.)	_____ hp
Hot water temperature (°F) If unknown: **H**=High **M**=Medium **L**=Low	**H M L**
Where is the water heater located? **C**=Conditioned or **U**=Unconditioned space	**C U**
Does the water heater serving this dwelling also serve others? Y=yes, N=no	**Y N**

Heating, Cooling, Fans, and Ducts

Heating and Cooling Systems

System ID	# ___	#___
System Information		
System Type: **C** = Central Unit **P** = Portable Unit **WW** = Window/Wall Unit **S** = Shared central system **EV** = Evaporative Cooler **OT** = Other* _____ **H** = Hydronic **BB** = Baseboard/Radiant Heater	C P WW S EV OT H BB	C P WW S EV OT H BB
% of Residence Served by this System		
Location: **G**=Garage **A**=Attic **S**=Cond. Space **M**= Mech. Room **OT**=Other _____	**G A S M OT**	**G A S M OT**
Heating Equipment		
Manufacturer		
Model Number (include dash numbers)		
Number of units:		
Equipment Type: **F** = Furnace, **HP** = Heat Pump, **RH** = Radiant Heater, **ER** = Elec. Resist, **HW** = Boiler, **BB** = Baseboard Heater, **N** = None, **OT** = Other*	**F HP RH ER HW BB N OT**	**F HP RH ER HW BB N OT**
Fuel Type: **E** = Electricity, **G** = Natural Gas, **P** = Propane (LPG), **F** = Fuel Oil, **W** = Wood, **OT** = Other* _____	**E G P F W 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), **HP** = Heat Pump, **EV** = Direct Evap, **ID**= Indirect/Direct Evap, **N** = None, **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**

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**
Special Features: **SV**= SmartVent ™ **WH***=Whole-house fan **OT***=Other	**SV WH OT**	**SV WH OT**
Thermostat/Controls		
Manufacturer		
Model Number		
Thermostat Type (only if applicable): **EM** = Electromechanical **D** = Digital **H** = Hybrid **HAS** = Home Automation System **OT** = Other _____	 **EM** **D** **H** **HAS** **OT**	 **EM** **D** **H** **HAS** **OT**

Duct Systems

☐ N/A

Does this residence have an accessible attic or ceiling crawl space? ☐ Yes ☐ No

Does this residence have an accessible floor crawl space? ☐ Yes ☐ No

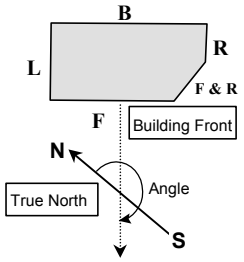
	Supply	Return
Location of Ducts (indicate all that apply): **A**=Attic **CR** =Crawl Space **CS**=Cond. Space **W**=Wall Cavity **B**=Basement **OT**=Other*	**A CR CS W B OT**	**A CR CS W B OT**
Duct Types (indicate all that apply): **F**=Flexduct **M**=Metal **P**=Panned Joist **U**=Unfinished wall cavity **OT**=Other*	**F M P U OT**	**F M P U OT**
Duct Sealant Types (indicate all that apply): **M**=Mastic **BT**=Butyl Tape **MT**=Metal Tape **C**=Mech. clamps **OT**=Other*	**M BT MT C OT**	**M BT MT C OT**
--- Aerosol sealing used (check for certificate)**?**	**Y N**	**Y N**
Duct Insulation R-Value (–7 if insulation not labeled, 0 if not insulated)		
Duct Condition (note tape brand name if present)		
Plenum Condition		

* Describe Other types in comments block.

Additional Comments:

Building Orientation and Construction

Front Wall Orientation



Front orientation angle: (0-360°) _____

External Walls and Doors

Wall orientation (reference: facing the Front wall)	**Front**	**Left**	**Back**	**Right**
Shading: N= None L=Light M=Medium H=Heavy				
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				

Roof/Ceilings

Roof/Ceiling Type	FAT=Framed w/Attic-Crawl Space MET=Metal Decking ADB= Conditioned space above FNO=Framed w/o Attic-Crawl Space CON=Concrete Decking	
-- 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**
Non-Vaulted Ceiling Height	Feet	
=> Vaulted Ceilings, Estimated % of Total Floor Area with Vaulted Ceilings?		%
Ceiling Insulation R-value	Indicate R-value OR	
	Indicate inches of insulation in roof cavity	

* Note "Other" construction types in comments block.

Building Orientation and Construction (cont.)

Floor

Number of floors	
Total conditioned floor area, ft^2	
Floor construction type	**S** =Slab **C** =Crawl **U** =Unheated Basement **O** =Open (Garage) **ADB** =Cond. space below
Insulation R-value	

Windows, Glass Doors, and Skylights

Item # (use multiple sheets if necessary)		1	2	3	4	5	6
Unit Type	**W** = Window **D** = Door **S** = Skylight						
Shading	**I** = Interior (blinds/drapes) **N** = None **E** = Exterior (overhangs/awnings) **B** = Both						
Style	**S**=Slider **F**=Fixed **A**=Art glass **D**=Double-hung **B**=Bay/Bow **C**=Casement **W**=Awning **OT**=Other						
Layers of glazing	**S**=Single **D**=Double **T**=Triple						
Muntins/grids?	**I**=Internal/between panes **E**=External **B**=Both						
Frame type	**M**=Metal **W**=Wood **V**=Vinyl **OT**=Other*						
Glass Type	**C**=Clear **T**=Tinted **R**=Reflective **L**=LowE						
-- Was this an after-market film/treatment?		**Y N**	**Y N**	**Y N**	**Y N**	**Y N**	**Y N**
Area per unit	Square feet						
Number of units installed:	=> **Front** wall (or **Roof** if skylight)						
	=> **Left** wall						
	=> **Back** wall						
	=> **Right** wall						
Fill Type	**N**=None **A**=Air **G**=Gas-filled						
Mfr. Or MFR. CODE	Enter **SB** if it looks like it was site-built						
SERIES	Enter window series/style						
SHGC	Solar Heat Gain Coefficient						
U-Value	Overall heat transfer coefficient						

* Describe Other frame type in comments block

Comments:

Building Orientation and Construction (cont.)

Windows, Glass Doors, and Skylights (cont.)

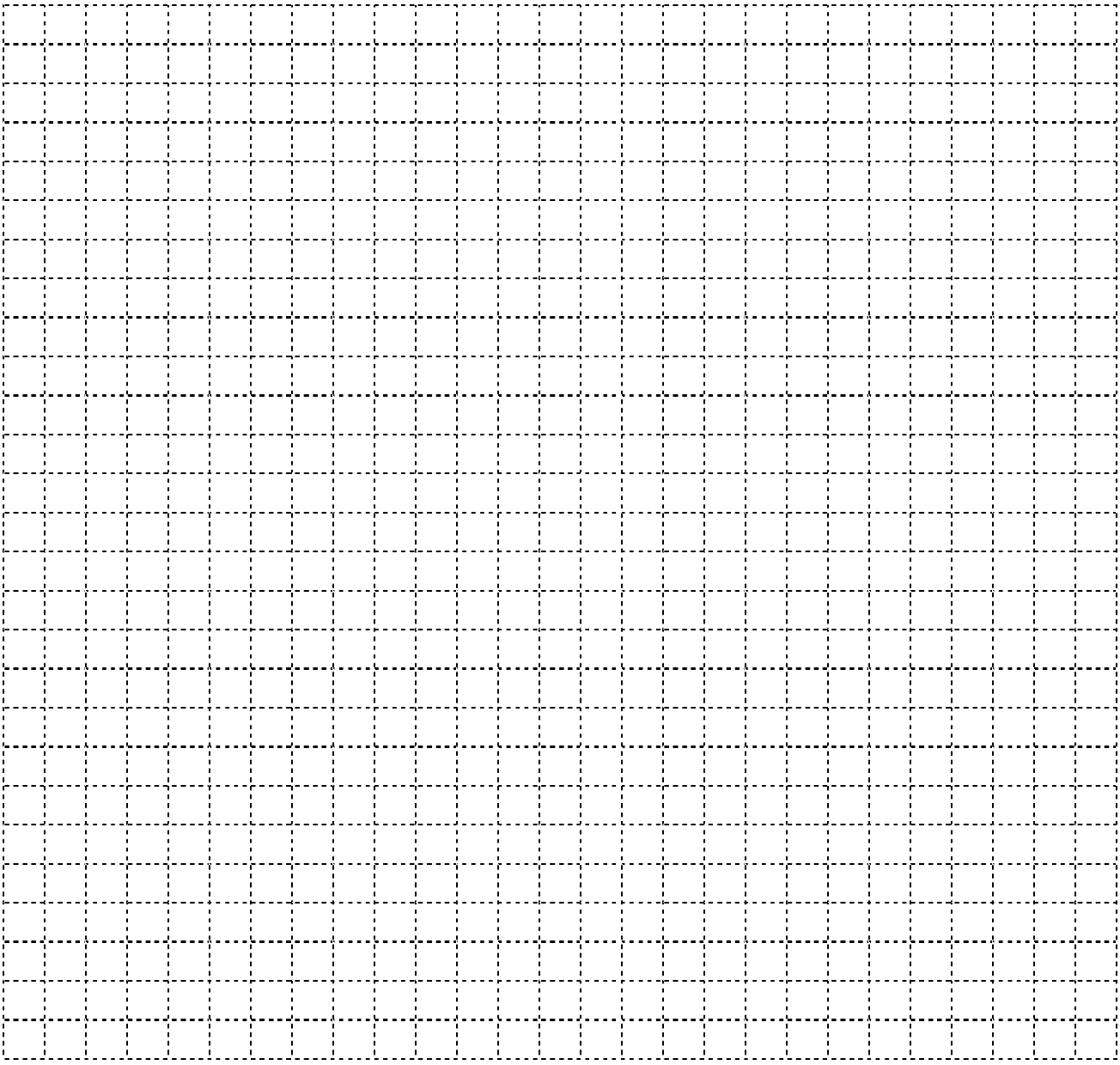
Item # (use multiple sheets if necessary)		__	__	__	__	__	__
Unit Type	**W** = Window **D** = Door **S** = Skylight						
Shading	**I** = Interior (blinds/drapes) **N** = None **E** = Exterior (overhangs/awnings) **B** = Both						
Style	**S**=Slider **F**=Fixed **A**=Art glass **D**=Double-hung **B**=Bay/Bow **C**=Casement **W**=Awning **OT**=Other						
Layers of glazing	**S**=Single **D**=Double **T**=Triple						
Muntins/grids?	**I**=Internal/between panes **E**=External **B**=Both						
Frame type	**M**=Metal **W**=Wood **V**=Vinyl **OT**=Other*						
Glass Type	**C**=Clear **T**=Tinted **R**=Reflective **L**=LowE						
-- Was this an after-market film/treatment?		**Y N**	**Y N**	**Y N**	**Y N**	**Y N**	**Y N**
Area per unit	Square feet						
Number of units installed:	=> **Front** wall (or **Roof** if skylight)						
	=> **Left** wall						
	=> **Back** wall						
	=> **Right** wall						
Fill Type	**N**=None **A**=Air **G**=Gas-filled						
Mfr. Or MFR. CODE	(Enter **SB** if it looks like it was site-built)						
SERIES	Enter window series/style						
SHGC	Solar Heat Gain Coefficient						
U-Value	Overall heat transfer coefficient						

* Describe Other frame type in comments block

Comments:

Site Sketch

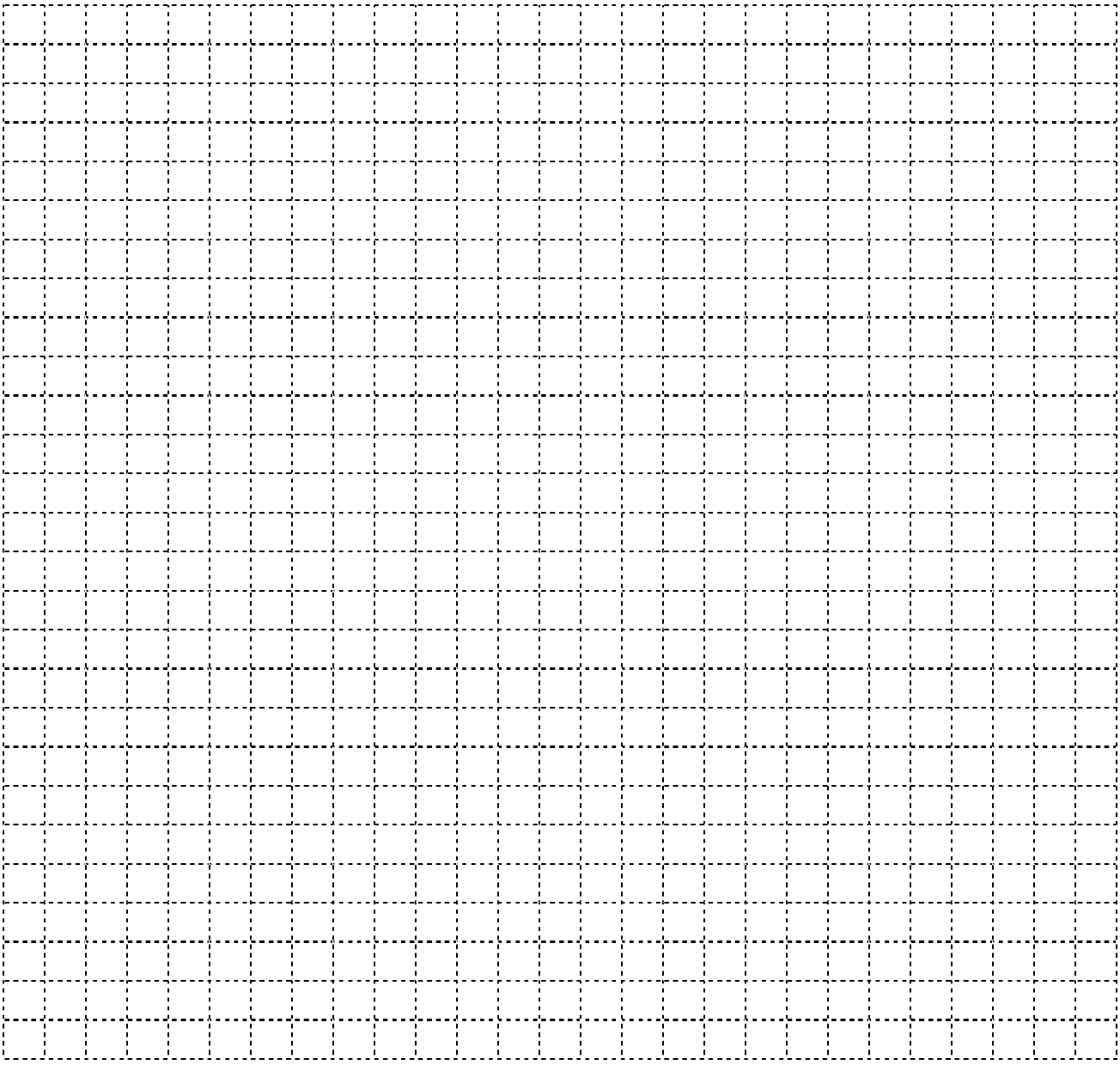
Sketch an outline (i.e. external walls) of the site. Include dimensions and note location of the garage. Draw an arrow to indicate North and show the Front Orientation angle. Note other external walls as Left, Right, and Back (see page 8). Indicate areas with vaulted ceilings. Indicate glazing locations. Show any trees or structures that provide significant shading. Use multiple sheets if needed and number accordingly.



Comments

Site Sketch, Additional Sheet

Sketch an outline (i.e. external walls) of the site. Include dimensions and note location of the garage. Draw an arrow to indicate North and show the Front Orientation angle. Note other external walls as Left, Right, and Back (see page 8). Indicate areas with vaulted ceilings. Indicate glazing locations. Show any trees or structures that provide significant shading. Use multiple sheets if needed and number accordingly.



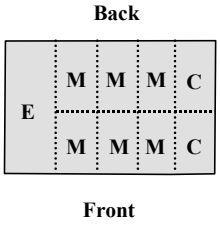
Comments

Multi-Family Building and Complex Information

Surveyed Residential Unit Characteristics

Residential unit configuration type	B=Back-to-back S=Straight-through H= Hallway (interior) P= Perimeter units (arranged around a central area) O=Other	**B S H P O**
Horizontal/Floorplan Location (figure below)	E=End Unit C=Corner unit M=Middle unit O=Other	**E C M O**
Vertical/Floor Location	Indicate floor/story number or **M** if Multi-floor unit	_____ or **M**
Are all residential units in this building the same size/ft^2?		**Y N**

Horizontal/Floorplan Location within Building



Building Characteristics

Number of floors	
Total number of residential units in this bldg?	
Approx. % of this building that is non-residence type space/activity (i.e. laundry facilities, rec. rooms, etc.)	
Approx **Front/Back** Length of building (Front same as for residential unit)	
Approx **Left/Right** Width of building	
Approx %Glass on => **Front** wall	
=> **Left** wall	
=> **Back** wall	
=> **Right** wall	

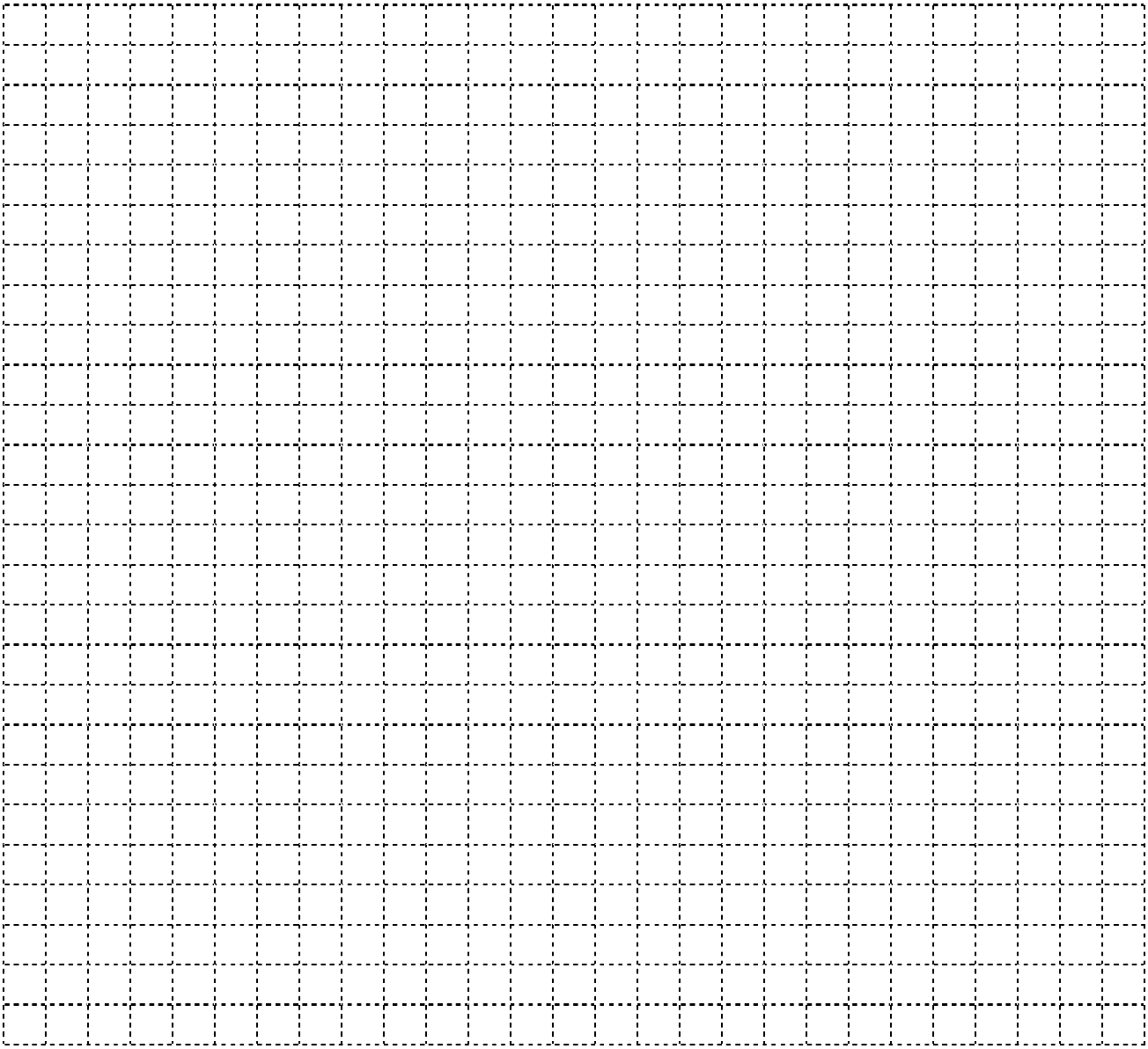
Housing Complex Characteristics

Total number of *residential units* in the complex?	
Total # of residential-unit *buildings* in the complex?	
-- # of buildings with this same floor plan?	
-- Typical orientation of other buildings	**S** = Same as surveyed bldg **V** = Varies

Comments:

Multi-Family Residence Building Sketch

Sketch an outline (i.e. external walls) of the building in which the surveyed residential unit was located. Indicate if there are areas other than residential units located within the building. Note overall dimensions and the *location of the surveyed unit within the building*. Draw an arrow to indicate North and show the Front Orientation angle. Note other external walls as Left, Right, and Back (see page 8). Indicate glazing locations. Show any trees or structures that provide significant shading. Use multiple sheets if needed and number accordingly.



Comments

Comments and Observations

Page #	Item	Comments

2000 On-Site Survey Instrument

Site ID #

Residential New Construction
Market Share Tracking Project
On-Site Survey Form

Regional Economic Research, Inc. and Volt VIEWtech

Version: 11/06/2000

Contact Information:

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

* Only needed if different from Street Address

Photo Information

Disposable Camera ID #		# of photos	

Survey Tracking Information:

	Date:	**Performed by, Initials**
Field Survey Performed:	__ / __ / __	__ __ __
Quality Control Check:	__ / __ / __	__ __ __
Data Entry Complete:	__ / __ / __	__ __ __
Duct Blaster test site?		
Survey and Data Received by RER:	__ / __ / __	__ __ __

Table of Contents

Energy Utility Meters & Accounts

Is customer responsible for the utility bills? ☐ Yes ☐ No

If Yes, is the customer aware of electric industry deregulation and the option to switch providers? ☐ Yes ☐ No

-- If Yes, has the customer changed energy providers? ☐ Yes ☐ No

Item #	Service Type*	Utility	Meter Number (Enter –7 if can't read it)	Account Number
1	**E G O**	**SDG&E SCE SCG PG&E OT**		
2	**E G O**	**SDG&E SCE SCG PG&E OT**		
3	**E G O**	**SDG&E SCE SCG PG&E OT**		
4	**E G O**	**SDG&E SCE SCG PG&E OT**		
5	**E G O**	**SDG&E SCE SCG PG&E OT**		
6	**E G O**	**SDG&E SCE SCG PG&E OT**		

*Description for Other (**O**) Service Type: _____

Comments

General Site Information

Type of residence: (CHECK ONLY ONE. If **MF** indicated, complete pages 18 and 19)

- **SF** ☐ Detached, tract-built single family house
- **SF** ☐ Detached, custom-built single family house
- **MF** ☐ Attached home, Townhome/Condo
- **MF** ☐ Apartment in small complex (fewer than 5 units)
- **MF** ☐ Apartment in large complex (5+ units)
- **SF** ☐ Manufactured housing
- **SF** ☐ Mobile home/trailer
- **MF** ☐ Other, describe _____

Does the occupant own or rent this residence? ☐ Own ☐ Rent

If owned, is the occupant a first-time homebuyer? ☐ Yes ☐ No

How many stories tall is the residence (including basement)? ___ ☐ Split foyer ☐ Split level

What is the total conditioned floor area of the residence other than garage, basement, and porch? _____

How many bedrooms/bathrooms does the residence have? _____ / _____

Are any of the following areas used as conditioned living space? (ENTER FLOOR AREA FOR ALL THAT APPLY)

_____ Garage (ft^2) _____ Porch (ft^2

_____ Basement (ft^2) _____ Other (ft^2)

HOMEOWNERS ONLY: Any Title 24 documents present in homeowner's information packet? ☐ Yes ☐ No
(If so, note below what forms were found)

What was the purchase price of the home?

Actual price $_____

OR ☐ Declined to state

OR ☐ Under $100,000
☐ $100,000 - $200,000
☐ $200,000 - $300,000
☐ $300,000 - $400,000
☐ over $400,000

Builder/Development Information

Builder's Name:	
Development/Complex Name:	
Month/Year the home was occupied by current resident:	
Month/Year the home was built:	

FOR HOME OWNERS ONLY: Was the residence built under any of the following utility or federal residential energy-efficiency programs? (NOTE: Check customers document package for this information.)

- ☐ Don't know
- ☐ Energy Star Home (look for a bronze plaque mounted somewhere on the home)
- ☐ Pacific Gas & Electric (PG&E) Comfort Home
- ☐ Southern California Edison (SCE) ComfortWise Home
- ☐ Southern California Gas (SCG) Energy Advantage Home
- ☐ San Diego Gas & Electric (SDG&E) ComfortWise Home

FOR HOME OWNERS ONLY: Were any energy-saving options offered by the builder?

- ☐ No high-efficiency options offered
- ☐ High-efficiency cooling or heating equipment
- ☐ Advanced heating/cooling control/thermostat
- ☐ Improved performance windows (e.g. LowE, spectral LowE, or LowE^2)
- ☐ Pre-wired Home Automation System
- ☐ Other _____
- ☐ Don't know

Household Characteristics

Please have the respondent answer the following questions:

Number of people who live in this home at least 9 months of the year in the following age groups:

under 2 years _____
2-5 _____
6-21 _____
22-39 _____
40-64 _____
65 and over _____

Indicate the household's current annual income before taxes?

- ☐ Under $20,000 per year
- ☐ $20,000 - 39,999
- ☐ $40,000 - 59,999
- ☐ $60,000 - 79,999
- ☐ $80,000 - 120,000
- ☐ Over $120,000
- ☐ Refused

NOTE: If any significant devices that affect energy use or conservation (i.e photovoltaic systems, backup generator systems for Y2K, electric automobiles, etc.) are observed during the survey, ask the occupant about them and record relevant notes on the comments page at the end of the survey form.

Indoor & Outdoor Lighting

Item #	1	2	3	4	5	6	7	8
Location: **X** = OutsideLtg **G** = Garage **L**=LivingRoom **D** = DiningRoom **F** = FamilyRoom **BT** = BathRm w/Toilet **BN** = BathRm NoToilet **MB** = MstrBdRm **OB** = OthrBedRm **H** = Halls/Entry **K** = Kitchen* **N** = BrkfstNook **OT** = Other (describe)								
***Kitchen Diffuser Color / Mat'l:** **G**=Glass **CP**=ClearPlastic **WP**=WhitePlastic **OT**=Other								
Control Type: **S** = Switch (on/off) **M** = Motion sensor **D** = Dimmer **P** = Photocell **T** = Timer **H** = Home Automation System **OT** = Other (describe) _____								
Fixture Type: **C** = Ceiling, surface-mounted **L** = Floor/table lamp **D** = Downlights (cans) **T** = Torchiere **W** = Wall –mounted **H** = Other hard-wired **R** = Recessed **P** = Other plug-in **S** = Suspended **F** = Ceiling fan**								
****Ceiling Fan: Is it the only light source in the room?**	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
Total Number of Fixtures								
Number of Lamps per Fixture								
Watts per Lamp (enter 2 or 3-way as 50/100/150)								
Lamp Type & Lamp-Specific Details								
I = Incandescent Standard, medium base	I	I	I	I	I	I	I	I
IS = Incandescent Standard, small base	IS	IS	IS	IS	IS	IS	IS	IS
IP = Incandescent PAR	IP	IP	IP	IP	IP	IP	IP	IP
IR = Incandescent Reflector	IR	IR	IR	IR	IR	IR	IR	IR
For Incand. lamps: CFs Applicable (medium base)?	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
F = Fluorescent Tube	F	F	F	F	F	F	F	F
UT = Fluorescent U-tube	UT	UT	UT	UT	UT	UT	UT	UT
OF = Other Fluorescent (describe in comment block)	OF	OF	OF	OF	OF	OF	OF	OF
For Fluor. Tubes: Length in ft. (e.g., 2 4 6 8)								
Diameter (e.g. T8 T10 T12)								
CFG = CF w/Globe-Shaped diffuser	CFG	CFG	CFG	CFG	CFG	CFG	CFG	CFG
CFC = CF, w/Capsule-Shaped diffuser	CFC	CFC	CFC	CFC	CFC	CFC	CFC	CFC
CFR = CF w/reflector	CFR	CFR	CFR	CFR	CFR	CFR	CFR	CFR
CF = Compact Fluorescent, Other	CF	CF	CF	CF	CF	CF	CF	CF
CIR = Circline	CIR	CIR	CIR	CIR	CIR	CIR	CIR	CIR
For CF and CIR,lamps, indicate base type: S = Screw-based P = Pin-based	S P	S P	S P	S P	S P	S P	S P	S P
I=Integrated M=Modular D=Dedicated	I M D	I M D	I M D	I M D	I M D	I M D	I M D	I M D
HA= Halogen "A"	HA	HA	HA	HA	HA	HA	HA	HA
HT = Halogen Tubular	HT	HT	HT	HT	HT	HT	HT	HT
HL = Halogen low voltage	HL	HL	HL	HL	HL	HL	HL	HL
HP = Halogen reflector/PAR	HP	HP	HP	HP	HP	HP	HP	HP
MV = Mercury Vapor	MV	MV	MV	MV	MV	MV	MV	MV
MH = Metal Halide	MH	MH	MH	MH	MH	MH	MH	MH
HPS = High Pressure Sodium Vapor	HPS	HPS	HPS	HPS	HPS	HPS	HPS	HPS
LPS = Low Pressure Sodium Vapor	LPS	LPS	LPS	LPS	LPS	LPS	LPS	LPS
Field Notes: (Counts)								

Indoor & Outdoor Lighting

Item #	9	10	11	12	13	14	15	16
Location: **X** = OutsideLtg **G** = Garage **L**=LivingRoom **D** = DiningRoom **F** = FamilyRoom **BT** = BathRm w/Toilet **BN** = BathRm NoToilet **MB** = MstrBdRm **OB** = OthrBedRm **H** = Halls/Entry **K** = Kitchen* **N** = BrkfstNook **OT** = Other (describe)								
***Kitchen Diffuser Color / Mat'l:** **G**=Glass **CP**=ClearPlastic **WP**=WhitePlastic **OT**=Other								
Control Type: **S** = Switch (on/off) **M** = Motion sensor **D** = Dimmer **P** = Photocell **T** = Timer **H** = Home Automation System **OT** = Other (describe) _____								
Fixture Type: **C** = Ceiling, surface-mounted **L** = Floor/table lamp **D** = Downlights (cans) **T** = Torchiere **W** = Wall –mounted **H** = Other hard-wired **R** = Recessed **P** = Other plug-in **S** = Suspended **F** = Ceiling fan**								
****Ceiling Fan: Is it the only light source in the room?**	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
Total Number of Fixtures								
Number of Lamps per Fixture								
Watts per Lamp (enter 2 or 3-way as 50/100/150)								
Lamp Type & Lamp-Specific Details								
I = Incandescent Standard, medium base	I	I	I	I	I	I	I	I
IS = Incandescent Standard, small base	IS	IS	IS	IS	IS	IS	IS	IS
IP = Incandescent PAR	IP	IP	IP	IP	IP	IP	IP	IP
IR = Incandescent Reflector	IR	IR	IR	IR	IR	IR	IR	IR
For Incand. lamps: CFs Applicable (medium base)?	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
F = Fluorescent Tube	F	F	F	F	F	F	F	F
UT = Fluorescent U-tube	UT	UT	UT	UT	UT	UT	UT	UT
OF = Other Fluorescent (describe in comment block)	OF	OF	OF	OF	OF	OF	OF	OF
For Fluor. Tubes: Length in ft. (e.g., 2 4 6 8)								
Diameter (e.g. T8 T10 T12)								
CFG = CF w/Globe-Shaped diffuser	CFG	CFG	CFG	CFG	CFG	CFG	CFG	CFG
CFC = CF, w/Capsule-Shaped diffuser	CFC	CFC	CFC	CFC	CFC	CFC	CFC	CFC
CFR = CF w/reflector	CFR	CFR	CFR	CFR	CFR	CFR	CFR	CFR
CF = Compact Fluorescent, Other	CF	CF	CF	CF	CF	CF	CF	CF
CIR = Circline	CIR	CIR	CIR	CIR	CIR	CIR	CIR	CIR
For CF and CIR,lamps, indicate base type: S = Screw-based P = Pin-based	S P	S P	S P	S P	S P	S P	S P	S P
I=Integrated M=Modular D=Dedicated	I M D	I M D	I M D	I M D	I M D	I M D	I M D	I M D
HA= Halogen "A"	HA	HA	HA	HA	HA	HA	HA	HA
HT = Halogen Tubular	HT	HT	HT	HT	HT	HT	HT	HT
HL = Halogen low voltage	HL	HL	HL	HL	HL	HL	HL	HL
HP = Halogen reflector/PAR	HP	HP	HP	HP	HP	HP	HP	HP
MV = Mercury Vapor	MV	MV	MV	MV	MV	MV	MV	MV
MH = Metal Halide	MH	MH	MH	MH	MH	MH	MH	MH
HPS = High Pressure Sodium Vapor	HPS	HPS	HPS	HPS	HPS	HPS	HPS	HPS
LPS = Low Pressure Sodium Vapor	LPS	LPS	LPS	LPS	LPS	LPS	LPS	LPS
Field Notes: (Counts)								

Indoor & Outdoor Lighting

Item #	__	__	__	__	__	__	__	__
Location: **X** = OutsideLtg **G** = Garage **L**=LivingRoom **D** = DiningRoom **F** = FamilyRoom **BT** = BathRm w/Toilet **BN** = BathRm NoToilet **MB** = MstrBdRm **OB** = OthrBedRm **H** = Halls/Entry **K** = Kitchen* **N** = BrkfstNook **OT** = Other (describe)								
***Kitchen Diffuser Color / Mat'l:** **G**=Glass **CP**=ClearPlastic **WP**=WhitePlastic **OT**=Other								
Control Type: **S** = Switch (on/off) **M** = Motion sensor **D** = Dimmer **P** = Photocell **T** = Timer **H** = Home Automation System **OT** = Other (describe) _____								
Fixture Type: **C** = Ceiling, surface-mounted **L** = Floor/table lamp **D** = Downlights (cans) **T** = Torchiere **W** = Wall –mounted **H** = Other hard-wired **R** = Recessed **P** = Other plug-in **S** = Suspended **F** = Ceiling fan**								
****Ceiling Fan: Is it the only light source in the room?**	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
Total Number of Fixtures								
Number of Lamps per Fixture								
Watts per Lamp (enter 2 or 3-way as 50/100/150)								
Lamp Type & Lamp-Specific Details								
I = Incandescent Standard, medium base	I	I	I	I	I	I	I	I
IS = Incandescent Standard, small base	IS	IS	IS	IS	IS	IS	IS	IS
IP = Incandescent PAR	IP	IP	IP	IP	IP	IP	IP	IP
IR = Incandescent Reflector	IR	IR	IR	IR	IR	IR	IR	IR
For Incand. lamps: CFs Applicable (medium base)?	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
F = Fluorescent Tube	F	F	F	F	F	F	F	F
UT = Fluorescent U-tube	UT	UT	UT	UT	UT	UT	UT	UT
OF = Other Fluorescent (describe in comment block)	OF	OF	OF	OF	OF	OF	OF	OF
For Fluor. Tubes: Length in ft. (e.g., 2 4 6 8)								
Diameter (e.g. T8 T10 T12)								
CFG = CF w/Globe-Shaped diffuser	CFG	CFG	CFG	CFG	CFG	CFG	CFG	CFG
CFC = CF, w/Capsule-Shaped diffuser	CFC	CFC	CFC	CFC	CFC	CFC	CFC	CFC
CFR = CF w/reflector	CFR	CFR	CFR	CFR	CFR	CFR	CFR	CFR
CF = Compact Fluorescent, Other	CF	CF	CF	CF	CF	CF	CF	CF
CIR = Circline	CIR	CIR	CIR	CIR	CIR	CIR	CIR	CIR
For CF and CIR,lamps, indicate base type: S = Screw-based P = Pin-based	S P	S P	S P	S P	S P	S P	S P	S P
I=Integrated M=Modular D=Dedicated	I M D	I M D	I M D	I M D	I M D	I M D	I M D	I M D
HA= Halogen "A"	HA	HA	HA	HA	HA	HA	HA	HA
HT = Halogen Tubular	HT	HT	HT	HT	HT	HT	HT	HT
HL = Halogen low voltage	HL	HL	HL	HL	HL	HL	HL	HL
HP = Halogen reflector/PAR	HP	HP	HP	HP	HP	HP	HP	HP
MV = Mercury Vapor	MV	MV	MV	MV	MV	MV	MV	MV
MH = Metal Halide	MH	MH	MH	MH	MH	MH	MH	MH
HPS = High Pressure Sodium Vapor	HPS	HPS	HPS	HPS	HPS	HPS	HPS	HPS
LPS = Low Pressure Sodium Vapor	LPS	LPS	LPS	LPS	LPS	LPS	LPS	LPS
Field Notes: (Counts)								

Appliances & Other Equipment

Refrigerators & Freezers *- Manufacturer/Model Data*

Item #1 -- Manufacturer	
-- Model Number	
Item #2 -- Manufacturer	
-- Model Number	
Item #3 -- Manufacturer	
-- Model Number	

Refrigerators & Freezers *- Type/Configuration Data*

Item #	**1**	**2**	**3**
Equipment type: **R** = Refrigerator/Freezer **F** = Freezer **OT=** Other	**R F OT**	**R F OT**	**R F OT**
Defrost type: **F** = Frost-free **M** = Manual	**F M**	**F M**	**F M**
Configuration: ***Ref/Frz:*** **T**=Top-mount freezer **B**=Bottom-mount freezer **S**=Side-by-side **D**=1-door ***Freezer:*** **C** = Chest **U** = Upright **OT** = Other _____	**T B S D** **C U** **OT**	**T B S D** **C U** **OT**	**T B S D** **C U** **OT**
Space/Location: **C** = Conditioned **U** = Unconditioned	**C U**	**C U**	**C U**
Volume/size, ft^3			
Age in years (enter 1 if less than 1 year old)			
EF (Energy Factor, ft^3/kWh/day)			

Dishwasher

Manufacturer	**Model Number**

Clothes Washer

Axis Type	**Manufacturer**	**Model Number**	**Age**
Vert **H**oriz			

Clothes Dryer

Fuel Type	**Manufacturer**	**Model Number**	**Age**
E G P O			

Miscellaneous Equipment

Appliance	**Quantity**	**Fuel Type**
Oven		E G P O
Range		E G P O
Pool Heater		E G P O
Spa Heater		E G P O
Pool Pump		
Color Televisions		
Personal Computers		
Ceiling Fans (non-lamped)		Location from page 7 (circle all): **L D F BT BN MB OB H K N OT**
Other _____		
Other _____		

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**
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**
Recovery Efficiency/AFUE(fraction)		
Standby Loss (fraction)		
Does the hot water tank have an external insulation jacket? **Y**=Yes **N**=No	**Y N**	**Y N**
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**
Hot water temperature (°F) If unknown: **H**=High **M**=Medium **L**=Low	**H M L**	**H M L**

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 EV RT RW FR FL WF WG HF HR BB S P OT	C EV RT RW FR FL WF WG HF HR BB S P OT
% of Residence Served by this System		
Location: **G**=Garage **A**=Attic **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 ID** **HP N** **EV OT**	**AC ID** **HP N** **EV 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**

* 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**
Special Features: **SV**= SmartVent ™ **WH***=Whole-house fan **OT***=Other	**SV WH OT**	**SV WH OT**
Thermostat/Controls		
Manufacturer		
Model Number		
Thermostat Type (only if applicable): **EM** = Electromechanical **D** = Digital **H** = Hybrid **HAS** = Home Automation System **OT** = Other _____	 **EM** **D** **H** **HAS** **OT**	 **EM** **D** **H** **HAS** **OT**

* Describe Other types in comments block.

Duct Systems

☐ N/A

Does this residence have an accessible attic or ceiling crawl space? ☐ Yes ☐ No

Does this residence have an accessible floor crawl space? ☐ Yes ☐ No

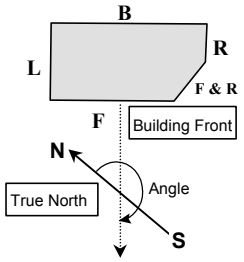
	Supply	Return
Predominant Location of Registers: **F**=Floor **C** =Ceiling **I**=Interior Walls **P**=Perimeter **OT**=Other*	**F C I P OT**	**F C I X OT**
Location of Ducts (indicate all that apply): **A**=Attic **CR** =Crawlspace **CS**=Conditioned Space **W**=Wall Cavity **B**=Basement **OT**=Other*	**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 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**
Duct Condition		
Plenum Condition		

* Describe Other types in comments block.

COMMENTS:

Building Orientation and Construction

Front Wall Orientation



Front orientation angle: (0-360°) _____

External Walls and Doors

Wall orientation (reference: facing the Front wall)	**Front**	**Left**	**Back**	**Right**
Wall Shading: N= None L=Light M=Medium H=Heavy				
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/Ceilings

Ceiling (under Roof) Footprint Area, ft^2	_____ ft^2	
Roof/Ceiling Type	FAT=Framed w/Attic-Crawl Space MET=Metal Decking ADB= Conditioned space above FNO=Framed w/o Attic-Crawl Space CON=Concrete Decking	
-- 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**
Non-Vaulted Ceiling Height, ft		
=> Vaulted Ceilings, Estimated % of Total Floor Area with Vaulted Ceilings?		%
Ceiling Insulation R-value	Indicate R-value OR	
	Insulation type: **B** = Batt/Blanket **L** = Loose-fill **OT** = Other _____	
	Indicate inches of insulation in roof cavity	

* Note "Other" construction types in comments block.

Building Orientation and Construction (cont.)

Floor(s)

Number of floors		_____
Total Conditioned Floor Area, ft^2		_____ ft^2
Ground Floor Area, ft^2 (=same as above for 1-story home)		_____ ft^2
-- Ground Floor Construction Type	**S** = Slab **C** = Crawl/Raised **U** = Unheated Basement **O** = Open (Garage) **ADB** = Cond. Space below	
-- Ground Floor Insulation R-Value		R-_____
-- For Slab Floors: Exposed Slab (e.g. tiled, wood flooring) Area, ft2		_____ ft^2
2nd Floor, Floor area over an unconditioned garage, ft^2		_____ ft^2
-- Raised Floor Insulation R-Value		R-_____

Windows, Glass Doors, and Skylights

Item # (use multiple sheets if necessary)		1	2	3	4	5	6
Unit Type	**W** = Window **D** = Door **S** = Skylight						
Interior Shading Device Type	**D** = Drapes **B** = Blinds (Venetian / vertical/ mini) RollerShades: **RO** = Opaque **RT** = Translucent **N** = None **OT** = Other (describe in comments)						
-- IntShadeColor	**L** = Light **M** = Medium **D** = Dark						
Exterior Shading Device Type	**S** = BugScreens **W** = WovenShadeScreens Louvered: **A** = LowSunAngle(LSA) **L** = Not LSA **R** = Roll-down (blinds/awnings/slats) **N** = None						
Exterior Shading	**O** = Architectural Overhang **A** = Awning **C** = PatioCover/RecessedEntry **OT** = Other						
Style	**S**=Slider **F**=Fixed **A**=Art glass **D**=Double-hung **B**=Bay/Bow **C**=Casement **W**=Awning **OT**=Other						
Layers of glazing	**S**=Single **D**=Double **T**=Triple						
Muntins/grids?	**I**=Internal/between panes **E**=External **B**=Both						
Frame type	**M**=Metal **W**=Wood **V**=Vinyl **OT**=Other*						
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**
Area per unit	Square feet						
Number of units installed:	=> **Front** wall (or **Roof** if skylight)						
	=> **Left** wall						
	=> **Back** wall						
	=> **Right** wall						
Fill Type	**A**=Air **G**=Gas-filled (e.g. argon)						

NOTE: If AAMA Permanent Label is found on any windows, please record the Mfr. Or MFR. CODE, SERIES, SHGC, and U-value in theComments block.

* Describe Other frame type in comments block

Building Orientation and Construction (cont.)

Windows, Glass Doors, and Skylights (cont.)

Item # (use multiple sheets if necessary)		__	__	__	__	__	__
Unit Type	**W** = Window **D** = Door **S** = Skylight						
Interior Shading Device Type	**D** = Drapes **B** = Blinds (Venetian / vertical/ mini) RollerShades**: RO** = Opaque **RT** = Translucent **N** = None **OT** = Other (describe in comments)						
-- IntShadeColor	**L** = Light **M** = Medium **D** = Dark						
Exterior Shading Device Type	**S** = BugScreens **W** = WovenShadeScreens Louvered: **A** = LowSunAngle(LSA) **L** = Not LSA **R** = Roll-down (blinds/awnings/slats) **N** = None						
Exterior Shading	**O** = Architectural Overhang **A** = Awning **C** = PatioCover/RecessedEntry **OT** = Other						
Style	**S**=Slider **F**=Fixed **A**=Art glass **D**=Double-hung **B**=Bay/Bow **C**=Casement **W**=Awning **OT**=Other						
Layers of glazing	**S**=Single **D**=Double **T**=Triple						
Muntins/grids?	**I**=Internal/between panes **E**=External **B**=Both						
Frame type	**M**=Metal **W**=Wood **V**=Vinyl **OT**=Other*						
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**
Area per unit	Square feet						
Number of units installed:	=> **Front** wall (or **Roof** if skylight)						
	=> **Left** wall						
	=> **Back** wall						
	=> **Right** wall						
Fill Type	**A**=Air **G**=Gas-filled (e.g. argon)						

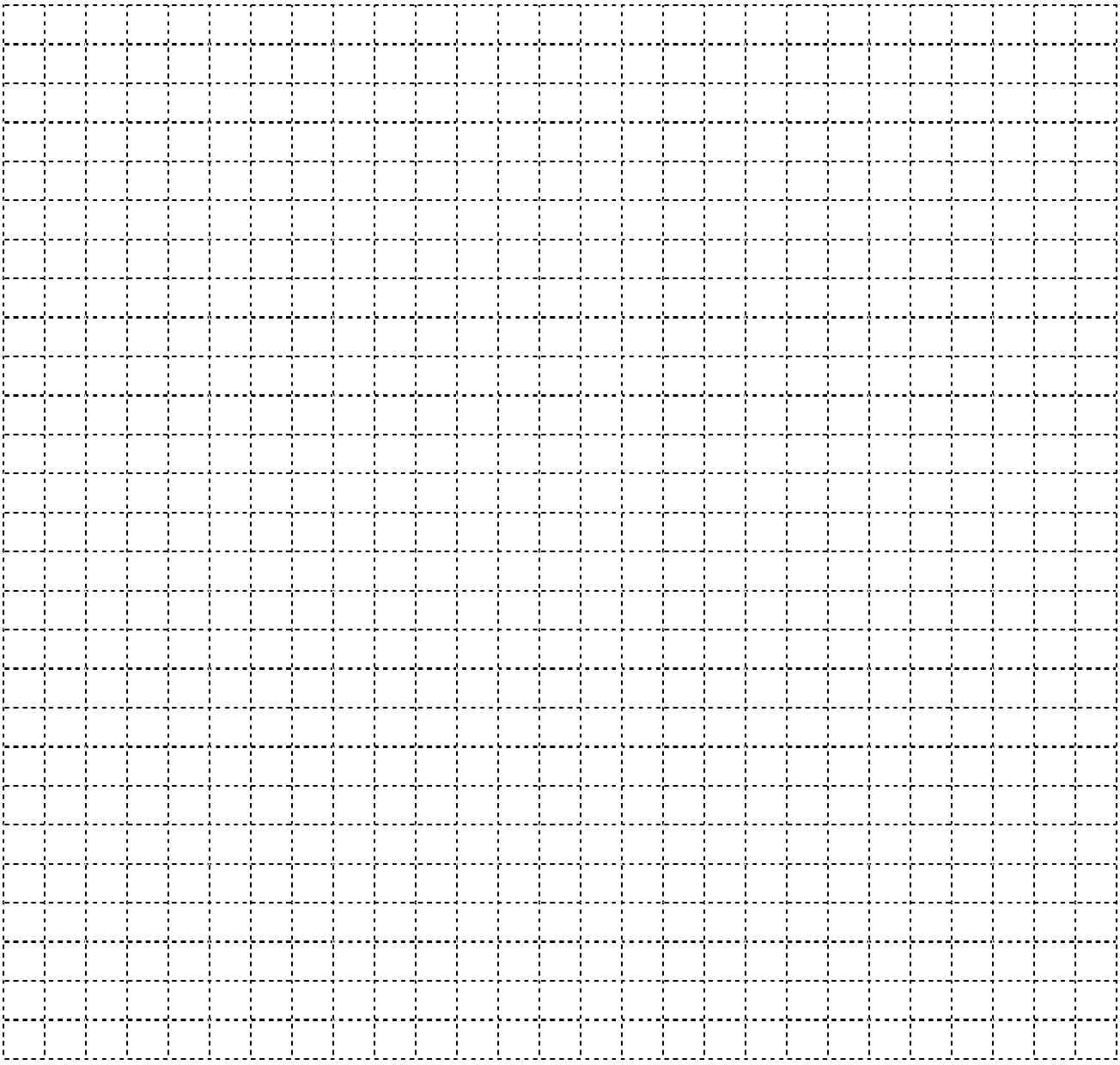
NOTE: If AAMA Permanent Label is found on any windows, please record the Mfr. Or MFR. CODE, SERIES, SHGC, and U-value in theComments block.

* Describe Other frame type in comments block

Comments:

Site Sketch

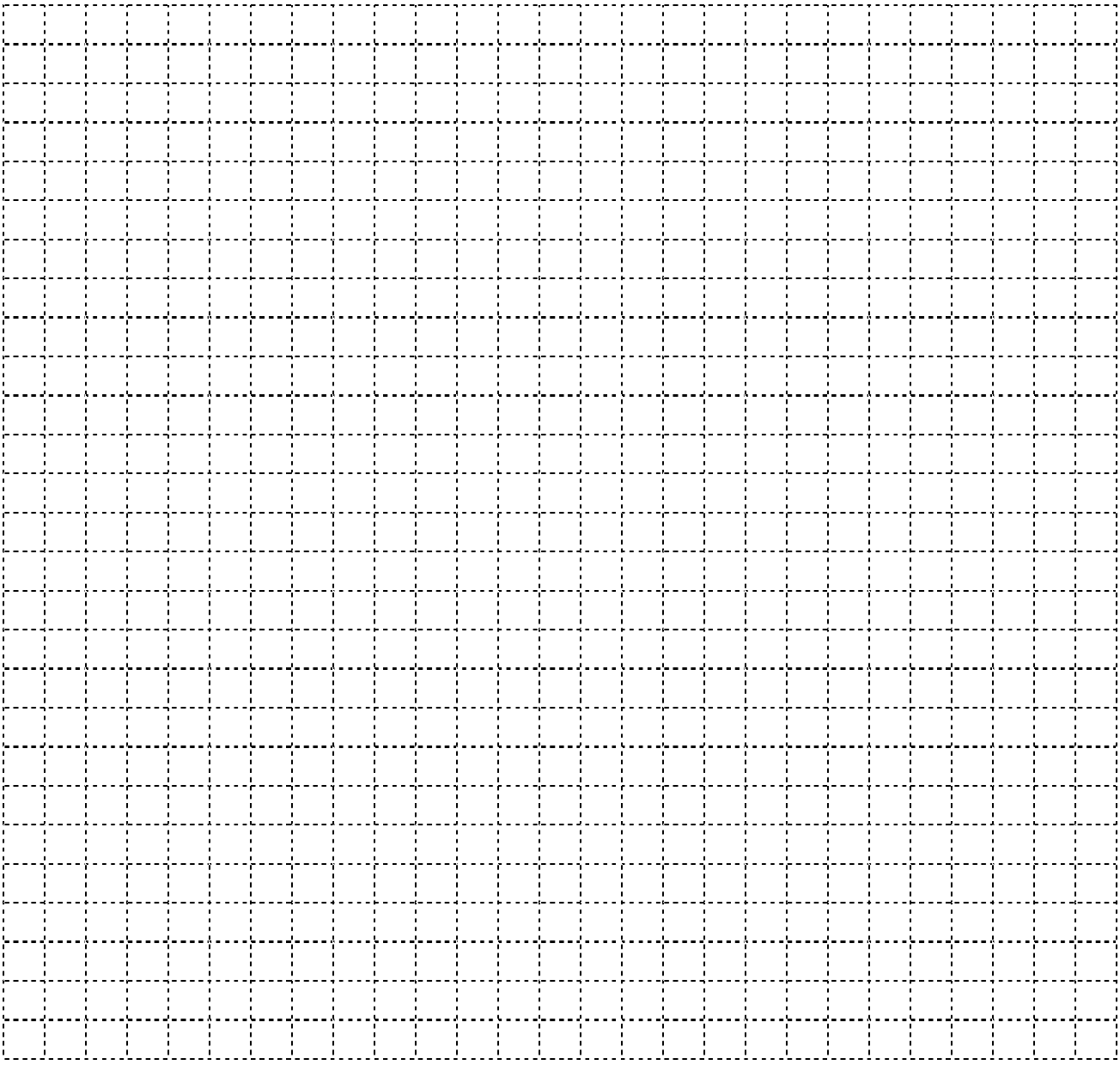
Sketch an outline (i.e. external walls) of the site. Include dimensions and note location of the garage. Draw an arrow to indicate North and show the Front Orientation angle. Note other external walls as Left, Right, and Back (see page 8). Indicate areas with vaulted ceilings. Indicate glazing locations. Show any trees or structures that provide significant shading. Use multiple sheets if needed and number accordingly.



Comments

Site Sketch, Additional Sheet

Sketch an outline (i.e. external walls) of the site. Include dimensions and note location of the garage. Draw an arrow to indicate North and show the Front Orientation angle. Note other external walls as Left, Right, and Back (see page 8). Indicate areas with vaulted ceilings. Indicate glazing locations. Show any trees or structures that provide significant shading. Use multiple sheets if needed and number accordingly.



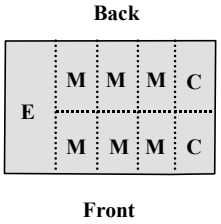
Comments

Multi-Family Building and Complex Information

Surveyed Residential Unit Characteristics

Residential unit configuration type	B=Back-to-back S=Straight-through H= Hallway (interior) P= Perimeter units (arranged around a central area) O=Other	**B S H P O**
Horizontal/Floorplan Location (figure below)	E=End Unit C=Corner unit M=Middle unit O=Other	**E C M O**
Vertical/Floor Location	Indicate floor/story number or **M** if Multi-floor unit	_____ or **M**
Are all residential units in this building the same size/ft^2?		**Y N**

Horizontal/Floorplan Location within Building



Building Characteristics

Number of floors	
Total number of residential units in this bldg?	
Approx. % of this building that is non-residence type space/activity (i.e. laundry facilities, rec. rooms, etc.)	
Approx **Front/Back** Length of building (Front same as for residential unit)	
Approx **Left/Right** Width of building	
Approx %Glass on => **Front** wall	
=> **Left** wall	
=> **Back** wall	
=> **Right** wall	

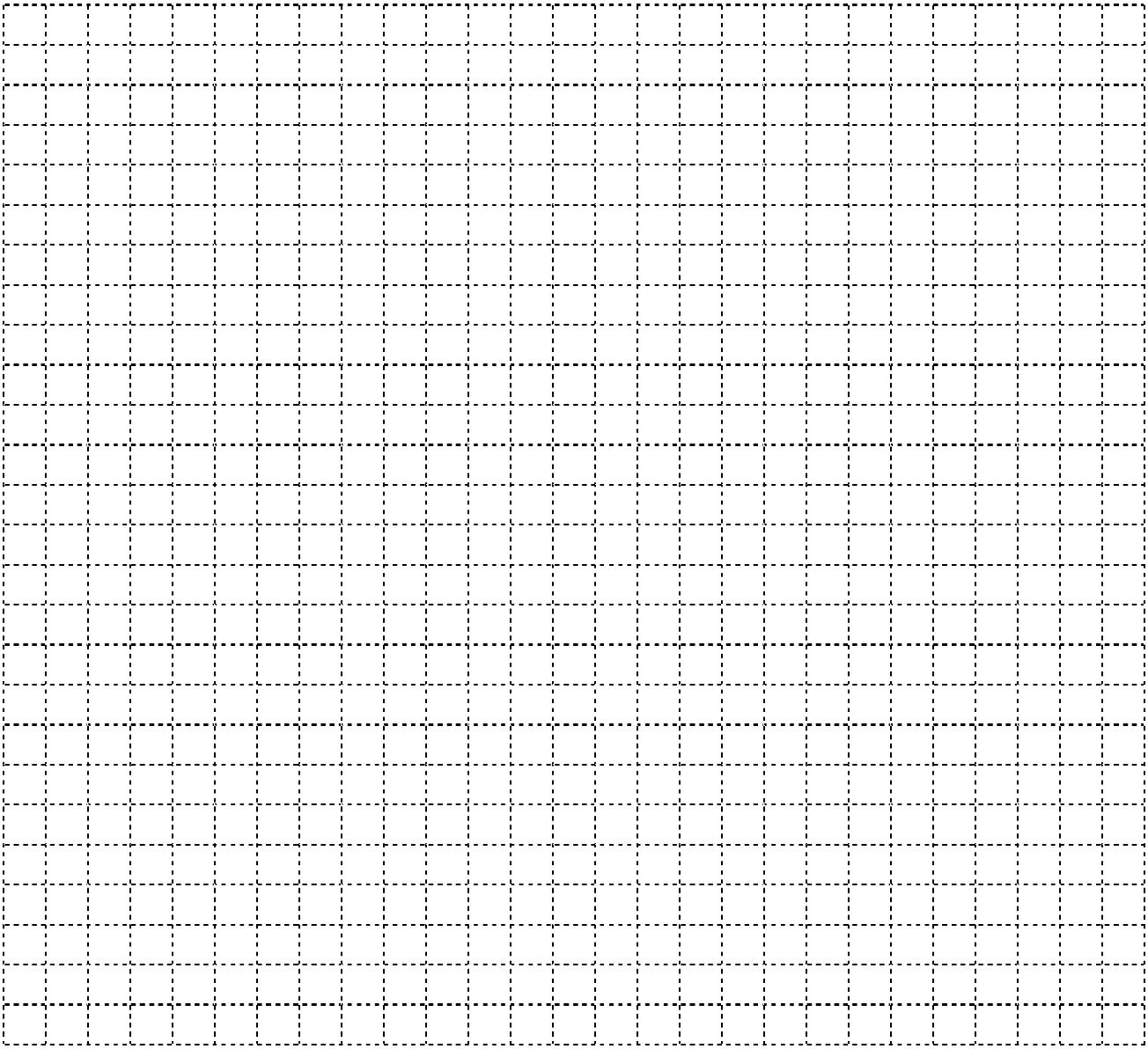
Housing Complex Characteristics

Total number of *residential units* in the complex?	
Total # of residential-unit *buildings* in the complex?	
-- # of buildings with this same floor plan?	
-- Typical orientation of other buildings	**S** = Same as surveyed bldg **V** = Varies

Comments:

Multi-Family Residence Building Sketch

Sketch an outline (i.e. external walls) of the building in which the surveyed residential unit was located. Indicate if there are areas other than residential units located within the building. Note overall dimensions and the *location of the surveyed unit within the building*. Draw an arrow to indicate North and show the Front Orientation angle. Note other external walls as Left, Right, and Back (see page 8). Indicate glazing locations. Show any trees or structures that provide significant shading. Use multiple sheets if needed and number accordingly.



Comments

Comments and Observations

Page #	Item	Comments

Appendix D

Duct Blaster Survey Instruments

1999 Duct Blaster Data Collection Form

Duct Blaster Data Collection Form

Site ID:	**Customer Name:**
Address:	**City:**
Date test performed:	**Test Performed by:**
Company Name:	**Duct Blaster Equipment/Model Type:**

HVAC System Type (check one):

- ❑ FAU with Platform Return or Return Air Chase
- ❑ FAU without Platform Return
- ❑ Attic FAU with Return Air Chase
- ❑ FAU with Sealed Blower compartment

TEST RESULTS	COMMENTS/DIAGRAM
Single point @ 25 Pascals: _____ Fan Pressure 1 2 3 Flow Ring (circle one) _____ Fan Flowrate (CFM)	

2000 Duct Blaster Data Collection Form

Duct Blaster Data Collection Form

Site ID:	**Customer Name:**
Address:	**City:**
Date test performed:	**Test Performed by:**
Company Name:	**Duct Blaster Equipment/Model Type:**

TEST FOR EACH SYSTEM: Single point @25 Pa for each system

HVAC SYSTEM #	# 1	# 2	# 3
HVAC System Type (circle one): **PR** = FAU with Platform Return or Return Air Chase **NPR** = FAU without Platform Return **AT** = Attic FAU with Return Air Chase **SB** = FAU with Sealed Blower compartment **OT** = Other (describe in Comments)	**PR** **NPR** **AT** **SB** **OT**	**PR** **NPR** **AT** **SB** **OT**	**PR** **NPR** **AT** **SB** **OT**
Description/Location			
Fan Pressure (Pa)			
Flow Ring used (circle one)	**None 1 2 3**	**None 1 2 3**	**None 1 2 3**
Fan Flowrate (CFM)			

COMMENTS/DIAGRAM
_____ _____ _____ _____ _____ _____ _____ _____

Appendix E

Creating the RNC Interface

E.1 Introduction

This appendix provides details on the development and testing of the RNC Interface that were not included in Section 2. The RNC Interface created to generate MICROPAS Title 24 standard compliance analyses (compliance runs) was based on survey data collected for the California Residential Efficiency Market Share Tracking (RMST) Study.[1] The primary purpose of the RNC Interface is to generate MICROPAS compliance runs from the RMST survey data of newly constructed residences. These runs are used to examine the compliance status for each residential building and to explore the energy conservation potential of some key energy saving technologies. MICROPAS was chosen as the compliance tool because it is the tool of choice among energy consultants for performing low-rise residential compliance analysis.[2] The interface was designed to do the following:

- Translate the on-site survey data into MICROPAS input files,
- Run MICROPAS in a batch mode,
- Facilitate the use of either MICROPAS 4.5 or 5.1,
- Extract the MICROPAS compliance results, and
- Provide a platform for the technical potential analysis.

[1] *California Residential Efficiency Market Share Tracking. First-Year Interim Report.* Prepared for Southern California Edison by Regional Economic Research, Inc. October 2000.

[2] Interviews with MICROPAS developers indicate that more than 75% of energy professionals use their product. Further, two recent studies by RER indicate that more than 90% of energy compliance documentation was completed using MICROPAS.

E.2 Overview of the RNC Interface

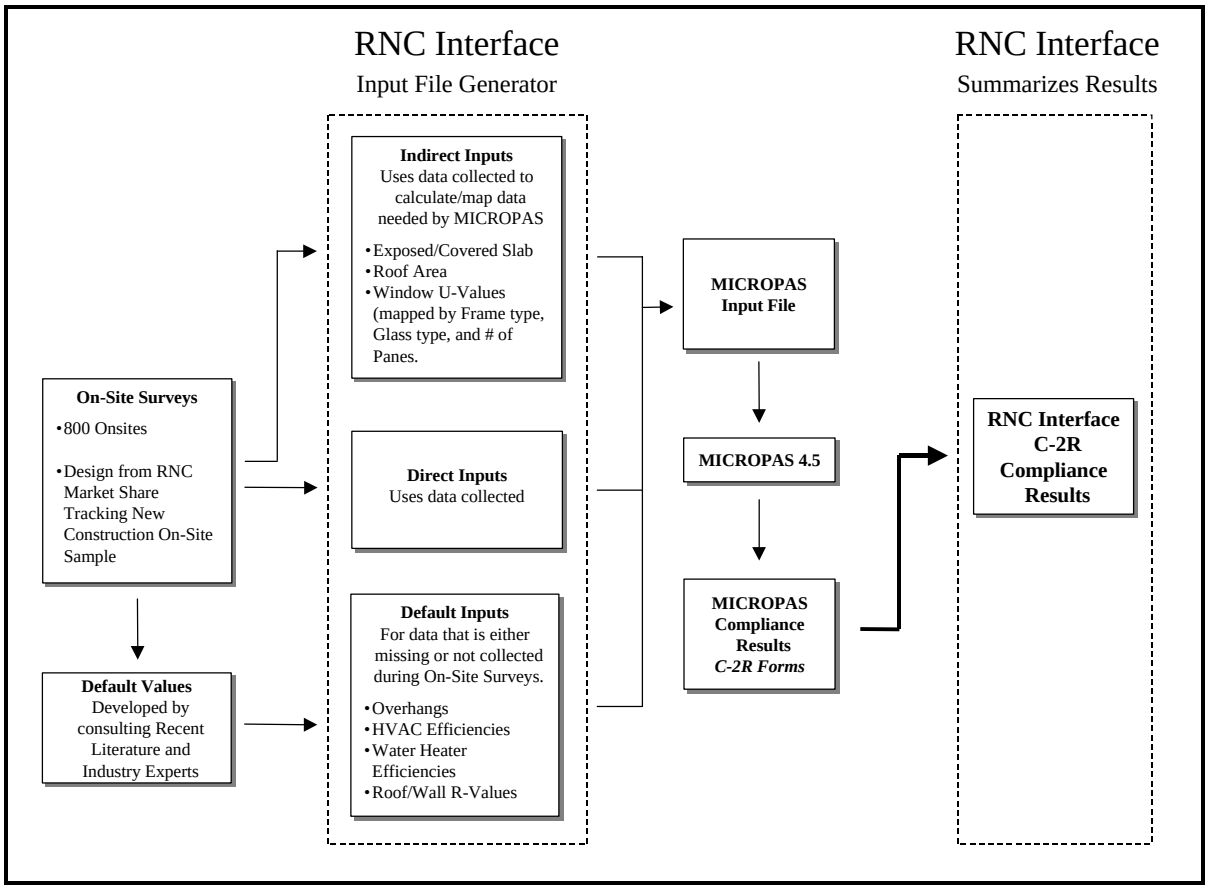
Figure E-1 presents an overview of the RNC Interface. As shown, the RNC Interface uses the data collected from 800 on-site surveys to create a MICROPAS input file. This is accomplished by first manipulating the data,[3] then "writing" it to a file in the required MICROPAS input format. The RNC Interface then passes the input file through MICROPAS 4.5. Results from the MICROPAS compliance runs utilized for this project are as follows:

- ***C-2R Forms.*** The interface produces results in the same format as the C-2R forms used for compliance documentation. The C-2R form contains the following information:
  - **General Information:** floor area, building type, and number of stories.
  - **Opaque Surfaces:** wall area and the insulation R-value.
  - **Perimeter Losses:** slab edge length, F2 factor, and the insulation R-value.
  - **Fenestration Surfaces:** window area, # of panes, frame type, glass type, U-value, and overhang dimensions.
  - **Thermal Mass:** slab area, slab thickness, and R-value.
  - **HVAC Systems:** duct efficiency, heating equipment efficiency, and cooling equipment efficiency.
  - **Water Heating Systems:** tank size and energy factor.

  A copy of a C-2R form is contained in Appendix A.
- ***Summary of Compliance Energy Simulations.*** In addition, the RNC Interface is capable of outputting the compliance energy use results and producing summary tables of energy use by end use and by site.

[3] For information on how the RNC Interface manipulates the data, please see the subsection below entitled "Developing MICROPAS Inputs from the RMST On-Site Survey Data".

Figure E-1: Overview of the RNC Interface Framework



MICROPAS Version 4.5 and 5.1

It was recognized early on that the RNC Interface needed to be able to generate results for two versions of MICROPAS: MICROPAS4 (v4.5) for the 1995 Standards and MICROPAS5 (v5.1) for the 1998 Standards. The Residential Standards are normally revised on a three-year cycle. The current standards are the 1998 Standards, which were implemented in July 1999 and superceded the 1995 Standards.

Because of the long lead time usually involved with production-type housing—one to two years from plan approval to actual construction—it was known that most residences surveyed in the first year of the RMST study (residences occupied July 1998 through June 1999) would likely have been built under the 1995 Standards. Furthermore, it was expected that most of the sites surveyed for the second year of the RMST study would have been built under the 1998 Standards. In addition, being able to utilize the new features incorporated into MICROPAS5 for the technical potential portion of the RNC study was highly desirable. This situation required that the RNC Interface be able to run both versions of MICROPAS.

The major differences between MICROPAS versions 4.5 and 5.1 include the revision of window performance parameters, the use of water heater insulation blankets, the addition of new compliance credits, and a revision to the use of thermal mass, as summarized below.[4]

- ***Window Shading Performance*** is now based on the Solar Heat Gain Coefficient (SHGC) instead of the Shading Coefficient (SC). The National Fenestration Rating Council (NFRC) ratings from the window manufacturer are the preferred rating source.
- ***Water Heater Insulation Blanket*** installation is no longer a credit, but an R-12 blanket is mandatory if the Energy Factor (EF) is below 0.58.
- ***New Compliance Credits*** for housewrap, radiant barriers, diagnostic duct testing, reduced infiltration, duct design per ACCA Manual D,[5] and combinations of these credits are included in the latest Standards.
- ***Thermal Mass.*** Slab exposed/covered areas are defaulted to 20/80%, respectively, except for exceptionally high mass (>30% exposed area) residences.

Developing MICROPAS Inputs from the RMST On-Site Survey Data

The RMST on-site survey database contains detailed information on HVAC and water heating equipment and building envelope characteristics. Some of these data were taken directly out of the database and written to the MICROPAS input file. However, the on-site survey did not collect all of the information needed to create a valid MICROPAS input file. In particular, some of the information needed to create the input file was simply not collected or had to be manipulated in order to be utilized in the MICROPAS run. As such, the transformation of RMST survey data to MICROPAS inputs can be characterized in the following four categories.

- ***Direct Inputs.*** These values, types, etc., are mapped directly from the RMST survey database into the MICROPAS input file. Examples of direct inputs include square footage, heating and cooling equipment efficiencies, and roof and wall insulation values.
- ***Indirect Inputs.*** These values, types, etc., from the RMST survey database are used to indirectly populate specific fields in the MICROPAS input file, whether by a mathematical calculation or by a query used to map the information obtained to one of MICROPAS' keywords. One example of an indirect input is roof area. Since roof area is not directly collected during the on-site survey, it is calculated from the data that are collected, which includes Total Conditioned Floor Area,

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4 A detailed discussion of the differences can be found in the MICROPAS5 User Manual. *MICROPAS5 User Manual.* Enercomp, Inc. June 10, 1999 memo to MICROPAS Users

5 Air Conditioning Contractors of America (ACCA). 1995. *Residential Duct Systems: Manual D. 2nd Ed.* Washington, DC.

Number of Floors, and the Estimated % of Total Floor Area with Vaulted Ceiling. Another is window performance characteristics.

- ***Default Inputs.*** These values, types, etc., are required MICROPAS inputs, including MICROPAS run parameters, for which no equivalent direct or indirect survey data value exists. Examples of default inputs include the dimensions and positioning of overhangs over windows and doors and slab thickness and thermal performance characteristics.
- ***Direct/Indirect Defaults.*** These are defaults for direct or indirect values that are required MICROPAS inputs, but for which no value was entered on the survey form (missing data). Examples of direct/indirect defaults include roof insulation, wall insulation, and HVAC and water heating equipment efficiencies.

Direct inputs are inserted directly into the MICROPAS input files. The methods and sources used to develop *indirect inputs*, *default inputs*, and *direct/indirect defaults* include the use of algorithms and mapping tables, the MICROPAS User's Guide, consultation with industry experts, building department C-2R forms, and on-site survey data. Each input type is used by the RNC Interface to generate the MICROPAS input files.

Features of the RNC Interface

It was recognized early on that the need to do batch compliance runs for a large number of sites from outside MICROPAS, and to be able to easily extract the results for these runs, was critical to performing the runs efficiently. This task was accomplished using MICROPAS's "command line" run option. This feature allows outside control of MICROPAS execution and outputs results and errors into a comma-delimited text file. The RNC Interface utilizes the MICROPAS command line run option to control the execution of each MICROPAS run, then imports the run results into an Access database table automatically as each run is completed. The command line version of MICROPAS, along with the other controls implemented within the RNC Interface, make it relatively easy to perform batch runs and review the run results for any version of MICROPAS.

In addition to performing batch runs, the RNC Interface has several other useful capabilities:

- Select individual or multiple sites,
- Select the version of MICROPAS (4.5, 5, or 6),
- Select whether to run a Cardinal,[6]
- Select the weather data set to use – FullYear or ReducedYear,[7] and

[6] A Cardinal run is actually four runs—a run is done for the home facing each of the four cardinal directions (North/East/South/West) and compliance is determined by the run with the smallest margin.

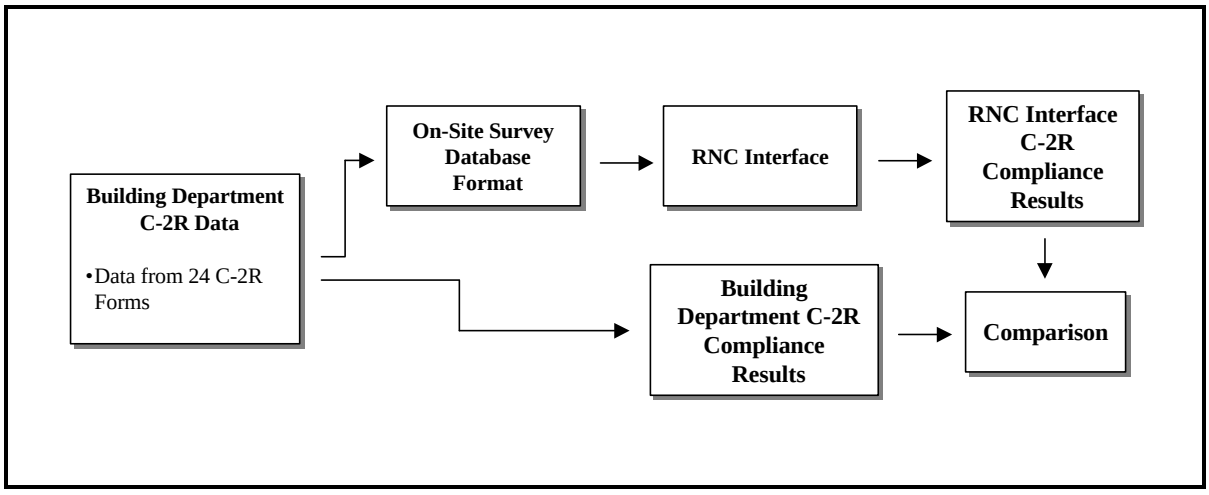
[7] "MICROPAS can be run using full-year weather data (365 days) or reduced-year data (42 days). The reduced-year run performs only one-eighth of the calculations of the full-year run. Because of the reduced

- Specify the source input database (this feature was used for the testing phase to read in building department C-2R data).

E.3 Testing the RNC Interface

A considerable effort was made to ensure that the RNC Interface produced accurate MICROPAS simulation results given the limitations of the available data and the design of the RNC Interface. To accomplish this task, a testing procedure to evaluate the default parameters and underlying algorithms and structure of the RNC Interface was developed. An overview of the RNC Interface testing procedure is depicted in Figure E-2. As shown, Title 24 compliance forms (C-2R forms) for a subsample of RMST surveyed sites were gathered from building departments. For each subsampled site, data from the C-2R compliance documentation were used to populate an RMST survey form. These forms were then processed through the RNC Interface. The results were then compared to the compliance data on the original C-2R forms. Based on the analysis of the differences in the compliance results, additional changes were made to the RNC Interface. This procedure was repeated until an acceptable margin of error was reached. Once reached, a final error band was developed for use in analyzing the remaining RMST surveyed sites.

Figure E-2: Overview of RNC Interface Testing Procedure



The testing procedure has three major elements:

- Collecting building department compliance documentation,
- Transforming the building department compliance documentation (C-2R forms) into the RMST format, and

calculation time, the reduced-year weather data is used for most compliance work … Very small differences in results may occur between reduced and full year calculations." *MICROPAS4 User's Manual.*

- Comparing the RNC Interface compliance results to the building department C-2R compliance results.

Each element is discussed below.

Collecting Building Department Compliance Documentation

The original sampling plan for collecting C-2R forms was a stratified random sample of RMST surveyed sites. The sample was stratified by residence type (i.e., single family, single family detached, multifamily) and climate zone. Primary and secondary lists of sites were randomly selected from the RMST surveyed sites for each stratum. However, after contacting a majority of the sites from both the primary and secondary lists,[8] it was discovered that nearly half of the original sample of building departments did not keep C-2R forms. Further, some of those that did were unable to retrieve the forms due to limited manpower. Therefore, a simplified approach was taken. In particular, RER identified building departments with the largest number of surveyed sites and building departments that had already been contacted as part of the RMST study effort. From this list, an attempt was made to recruit participants from those building departments that have already been providing compliance documentation as part of the RMST study. Also recruited were those building departments on the list in San Diego County. The latter group was added out of convenience so that RER staff could visit the building department in person and facilitate the collection of the compliance documentation. To increase the sample size, RER also tried to recruit those building departments with relatively large numbers of surveyed sites that had not been contacted as part of the RMST study effort. These were the most difficult and time consuming to contact and were used as a last resort.

RER contacted over 50 building departments, but only six were willing and able to contribute C-2R forms. The locations of participating building departments are shown in Figure E-3. Forms for 40 on-site survey sites were collected, but only 36 of those matched 37 sites (one of the C-2R forms matched two on-site survey sites). A summary of the completed sample of building departments providing C-2R forms is presented in Table E-1. The distribution is quite different from that given in the original plan, because it was very difficult to convince building departments to contribute to this effort due to their limited time and available manpower. However, all building types and RMST climate zones are represented.

[8] The primary and secondary building departments to contact are detailed in the work plan. For further information, please see Appendix B.

Figure E-3: Location of Building Departments Contributing C-2R forms

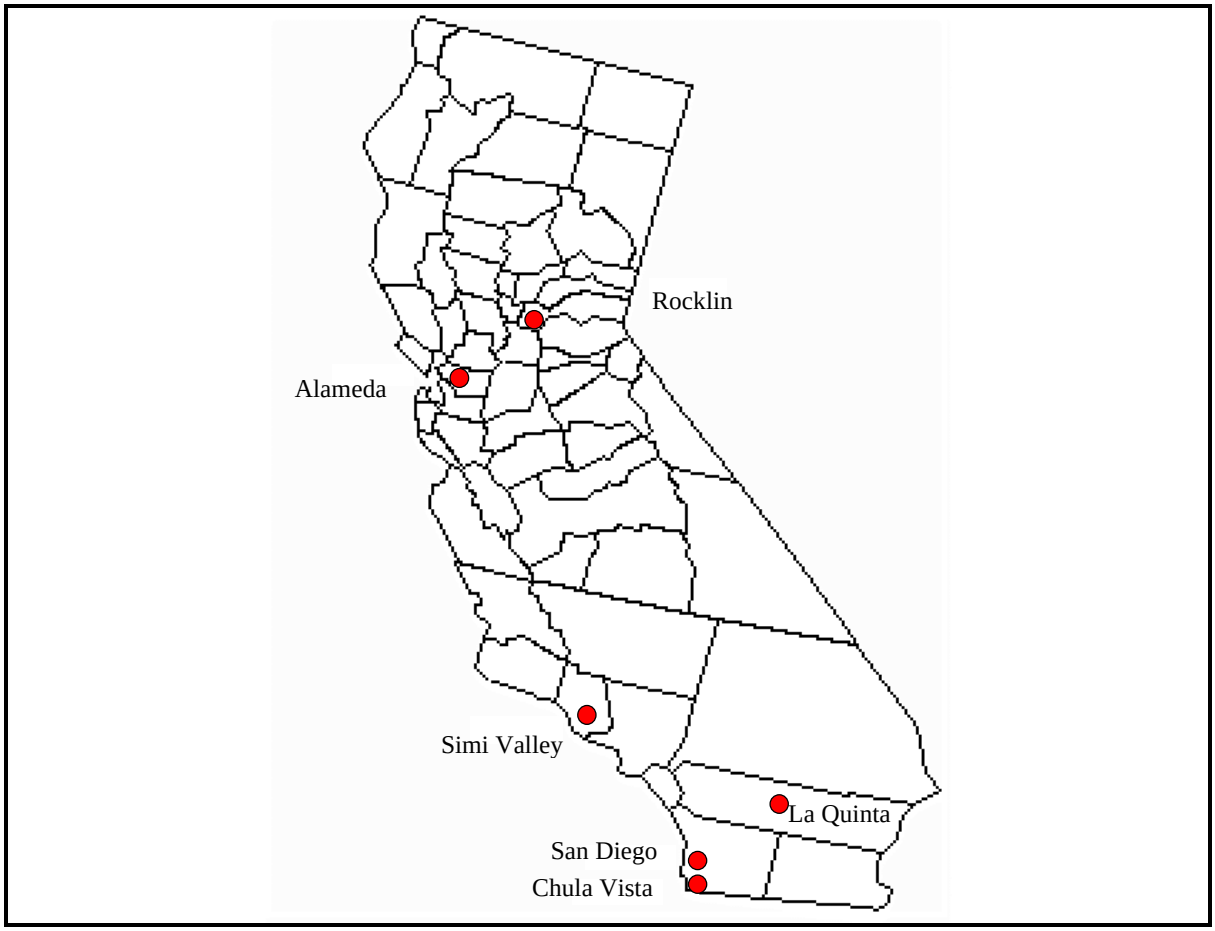


Table E-1: Final Building Department Sample

RER CZ	CEC CZ	Bldg Dept	SF 1-Story	SF 2-Story	SF Attached	MF	Total C-2R Forms
1	3, 12	Alameda	2	5	1		**8**
2	7, 10	San Diego		5		2	**7**
	7	Chula Vista	2	13			**15**
3	9	Simi Valley		2		1	**3**
4	11	Rocklin	1	2		1	**4**
5	15	La Quinta	3				**3**
		Totals	**8**	**27**	**1**	**4**	**40**

Table E-2 presents a summary listing of key information contained in the C-2R compliance documentation and from the RMST surveys for the test sample. Although C-2R documentation for 40 sites was collected, further review of the documentation revealed that three of the sites were in fact not matched for the RMST surveyed sites. These three sites were dropped from the analysis. Notable findings from these data include the following:

- Total conditioned floor area on the building department C-2R forms (*C2Rft2*) is typically within 10% of the square footage information gathered during the RMST survey (*ONSft2*).
- Thirty-one (31) of the matched C-2R forms were run using MICROPAS v4.5 (*MP Version*). There are also three C-2R forms run using MICROPAS v5.1 and two using Comply 24.
- Almost 90% of the matched C-2R forms were run with the "Cardinal" (*CardRun?*)[9] run option. Custom single family homes using a single front orientation angle comprised the remainder.
- As indicated in the column labeled *C2Rweather* in Table E-2, 31 of the matched C-2R forms were run with the *ReducedYear*[10] weather run option. The remaining six used the *FullYear* weather run option.
- As indicated in the column labeled *DBTest?* in Table E-2, duct blaster tests were performed as part of the on-site surveys for four sites.

A key parameter used in the testing of the RNC Interface is the *% Compliance Margin*. The % Compliance Margin is the compliance margin (standard energy budget—proposed energy budget) expressed as a percent of the standard energy budget.[11] A summary of the % Compliance Margin by residence type for the building department C-2R forms is presented in Table E-3.

[9] If "Cardinal" is specified for the front orientation angle in MICROPAS, four runs are performed, one for each of the four cardinal directions—North, East, South, West—and compliance is determined from the run with the smallest margin (Standard Budget minus Proposed Budget).

[10] The MICROPAS *ReducedYear* run-option is a CEC-approved method that allows users to drastically reduce the calculation time associated with a *FullYear* (8760 hourly) run.

[11] For further discussion on the "Margin % of Standard," please see Section 2.3 Testing the RNC Interface.

Table E-2: Key Site and C-2R Compliance Run Characteristics

SiteID	CEC CZ	Bldg Type	# of Units	# Floors	C-2R sq. ft.	On-Site sq. ft.	MP Version	Cardinal Run?	C2R Weather	Duct Blaster Test?
346	3	SF	1	2	1,413	1,400	4.50	Y	ReducedYear	No
405	12	SF	1	1	2,586	2,587	4.50	Y	ReducedYear	No
478	3	SF	1	2	1,819	1,870	4.51	Y	ReducedYear	No
743	11	SF	1	2	4,744	4,778	4.50	**N**	**FullYear**	No
1297	9	**MF**	16	2	9,732	9,200	4.51	Y	ReducedYear	No
2131	7	SF	1	2	1,804	1,800	4.50	Y	ReducedYear	No
2134	7	SF	1	2	2,042	2,200	4.50	Y	ReducedYear	No
2152	7	SF	1	2	2,272	2,145	4.50	Y	ReducedYear	No
2159	7	SF	1	2	1,923	1,923	**5.00**	Y	ReducedYear	No
2161	10	SF	1	2	2,652	2,451	4.50	Y	ReducedYear	Yes
2195	7	SF	1	2	2,181	2,200	4.50	Y	ReducedYear	No
2300	7	SF	1	2	1,798	1,800	**5.00**	Y	ReducedYear	No
2334	7	SF	1	2	1,793	1,793	4.51	Y	ReducedYear	No
2403	7	**MF**	6	2	6,852	10,560	4.50	Y	ReducedYear	No
3452	11	SF	1	2	2,261	2,538	4.50	Y	ReducedYear	No
4563	15	SF	1	1	2,610	2,688	4.51	**N**	ReducedYear	Yes
4571	15	SF	1	1	2,349	2,500	4.51	**N**	ReducedYear	No
4591	7	**MF**	6	2	6,672	7,200	4.50	Y	ReducedYear	Yes
4668	7	SF	1	2	2,025	1,800	4.50	Y	ReducedYear	No
4700	7	SF	1	2	1,698	1,700	4.50	Y	ReducedYear	No
4731	7	SF	1	1	1,856	1,859	4.50	Y	ReducedYear	Yes
4748	7	SF	1	2	1,627	1,600	4.50	Y	ReducedYear	No
4753	7	SF	1	2	2,314	2,300	**5.00**	Y	ReducedYear	No
4764	7	SF	1	2	2,221	2,000	4.50	Y	ReducedYear	No
5014	3	SF	1	2	2,331	2,350	4.50	Y	ReducedYear	No
5300	3	SF	1	1	1,575	1,650	4.50	Y	ReducedYear	No
5350	3	SF	1	2	2,822	3,100	4.50	Y	ReducedYear	No
5841	11	**MF**	8	2	7,793	8,000	4.50	Y	ReducedYear	No
6080	11	SF	1	1	1,674	1,260	4.50	Y	**FullYear**	No
6575	9	SF	1	2	1,183	1,205	4.50	Y	**FullYear**	No
7068	15	SF	1	1	2,025	2,094	**Comply24**	Y	**FullYear**	No
7154	7	SF	1	2	2,017	2,100	4.50	Y	ReducedYear	No
7185	7	SF	1	2	2,952	3,000	4.50	Y	ReducedYear	No
7197	7	SF	1	2	1,860	1,860	4.50	Y	ReducedYear	No
7508	3	SF-A	1	2	2,490	2,000	4.50	Y	ReducedYear	No
7905	3	SF	1	2	2,584	3,300	4.51	Y	**FullYear**	No
14556	15	SF	1	1	2,025	2,000	**Comply24**	Y	**FullYear**	No

Table E-3: Summary of % Compliance Margin from Building Department C-2R Forms

Building Type	# of Sites	Average % Margin	Minimum % Margin	Maximum % Margin
SF Two Story	24	2.5%	0.0%	11.8%
SF One Story	8	2.2%	0.2%	5.9%
SF Attached	1	4.3%	4.3%	4.3%
MF	4	6.1%	3.5%	8.4%
Total	**37**	**2.9%**	**0.0%**	**11.8%**

As stated above, usable compliance documents for 37 sites were collected. Of these 37 sites, 13 sites were omitted from the analysis of the RNC Interface. In particular, six sites were dropped because the C-2R forms for those sites were run using either MICROPAS v5.1 or Comply 24. The other seven sites were omitted for site-specific reasons.

Transforming Building Department C-2R Information into the On-Site Survey Data Format

The first step in the RNC Interface testing procedure was to transform the data from the building department C-2R forms into the RMST on-site survey data format. This involved first entering the C-2R data into an Access database. These data were then translated into the RMST survey data format by a variety of methods that are characterized as *direct*, *mapped*, and *constructed input*, as explained below.

- ***Direct Input.*** Direct translation values were those building department C-2R values that could be inserted into the RMST on-site survey data format either directly or with a simple mapping of MICROPAS keywords to RMST values. Examples of these values include total conditioned square footage, heating and cooling efficiencies, and water heating efficiency.
- ***Mapped Input.*** This approach involved mapping a set of values from the building department C-2R forms to a corresponding set of RMST survey data values. A good example of this method is the mapping of window performance parameters. For the RNC Interface, window thermal performance parameters (U-values and shading coefficients) are generated from multiple fenestration characteristics collected on the survey form, such as fenestration type (window/door/skylight), glass type, frame type, and number of panes. However, the building department C-2R forms contain only the U-value, shading coefficient, and frame type. As such, the C-2R data were then mapped to the corresponding RMST window type. For example, a window on the building department C-2R form with a U-value=0.60, SC=0.88 and a frame type of *VinylDiv* was mapped in the RMST survey data format to a vinyl-framed, two-paned, clear glass window with dividers.

- ***Constructed Input.*** This approach involved constructing an RMST value using one or more values from the building department C-2R form. A good example of a constructed input is wall area. The wall area printed on the C-2R form is the net wall area (i.e., gross wall area minus the window and door areas), but gross wall area is collected on the RMST survey form. As such, the C-2R wall, window, and door areas for each orientation had to be summed in order to obtain a value for the gross wall area that could be used in the RMST data format.

These data translation methods were typically implemented via Access queries to convert data from the Building Department C-2R database into an RMST-formatted database that could be used by the RNC Interface.

Comparing the RNC Interface Run to the Building Department C-2R Compliance Results and Refining the RNC Interface

The RNC Interface was refined based on the comparison of the results from the RNC Interface and the original C-2R compliance results. The goal of comparing the results generated by the RNC Interface to the results taken off the building department C-2R was to test the defaults and algorithms used in the RNC Interface.

The % Compliance Margin was used to compare the two sets of results. This value represents the compliance margin expressed as a percentage of 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 30% better than Title 24 (i.e., % Compliance Margin=30%) to qualify as an ENERGY STAR home.

A multi-step approach was used to refine the RNC Interface based on the comparison of the results.

- ***Step 1: Identify Problem Sites.*** The first step in comparing the two sets of results was to identify sites where the % Compliance Margin generated by the RNC Interface was negative, meaning noncompliance. Also identified were those sites where the % Compliance Margin generated by the RNC Interface was at least ±10% different from the % Compliance Margin taken from the building department C-2R form.
- ***Step 2: Identify Potential Problem Inputs for the Problem Sites.*** For each of these sites, the input parameters generated by the RNC Interface and the original building department C-2R data were examined. Parameters with

significant discrepancies were identified and labeled as potential problem input parameters.

- ***Step 3: Conduct a Sensitivity Analysis for each of the Problem Input Parameters.*** In this step, a sensitivity analysis of the % Compliance Margin for each of the problem input parameters and problem sites was conducted. This was done to determine which of the problem input parameters had the largest effect on the % Compliance Margin. It was determined that some of the problem input parameters identified in the previous step did not have much of an impact on the % Compliance Margin, while others clearly did. For those that did, a further review and refinement was carried out in the next step.
- ***Step 4: Refine the RNC Interface Input Parameters and Algorithms.*** The parameters that had a significant impact were then reviewed and refined based on information from the building department compliance data and industry experts.

Results of the Evaluation of the RNC Interface

The results of the initial RNC Interface compliance runs are presented in Figure E-4. Based on the multi-step approach presented above, the following refinements were made to the initial RNC Interface.

MICROPAS Run Options. MICROPAS run options are high-level parameters affecting the overall compliance analysis. The run options affected by the interface testing procedure are discussed below.

- ***ReducedYear versus FullYear.*** The interface was originally set up to use the *FullYear* weather data MICROPAS run option. However, as most of the building department C-2R forms were run with the *ReducedYear* option (83% of sites), the interface default was to set to *ReducedYear*.[12]
- ***Cardinal Run versus Actual Front Orientation Angle.*** The interface was originally set up to use the actual front orientation angle associated with each site. However, most of the building department C-2R forms showed that the *Cardinal* run option was used instead of a specific front orientation angle, so the interface default was set to the *Cardinal* option.[13] For a *Cardinal* run, MICROPAS

[12] The FullYear run option uses a full year (365 days) of weather data, whereas the ReducedYear run option uses only 42 days of weather data. The ReducedYear run performs only one-eighth of the calculations of the FullYear run and as such, reduces the required calculation time. Note that a small difference in results may occur between ReducedYear and FullYear calculations; however, both methods are acceptable for compliance.

[13] The only exception to this was custom-built, single family homes that, as might be expected, used the actual orientation angle option instead of the *Cardinal* run option. However, since most of the homes are production/tract type homes and the surveyed residences are supposed to be sample representatives, not just individual sites, the *Cardinal* run option was used for all sites.

performs four runs in all the cardinal directions—North, East, South, West—and compliance is determined from the run with the smallest compliance margin.

Construction Features not Captured by the RMST Survey Form. Due to the focus, cost, and time constraints of the RMST survey, the data gathered lack detailed information for certain features used to generate a MICROPAS compliance run. As such, default values and algorithms were developed for these features. In some cases, these assumptions were refined during the RNC Interface evaluation process. Examples of these changes are discussed below.

- ***Roof Area for Two-Story Residences.*** The algorithm originally used by the RNC Interface to calculate roof areas was consistently yielding values that were significantly lower than the roof areas indicated on the building department C-2R forms. In particular, the roof area from the building department C-2R data are on average 34% larger than the roof area calculated from our algorithm for two-story homes. Therefore, the RNC Interface multiplies the calculated roof area by 1.34.
- ***Window/Door Overhangs.*** The original RNC Interface baseline assumption was to impose an overhang with some assumed dimensions for window height and overhang height/width on windows in all directions. A close examination of the building department C-2R forms confirmed that most of the building department C-2R forms took a similar approach. However, these sites have overhangs on only a few windows. There was also significant variation in the dimensions used for window height and overhang height/width. To account for these variations, an average value from the C2-R data was developed for use in the RNC Interface.

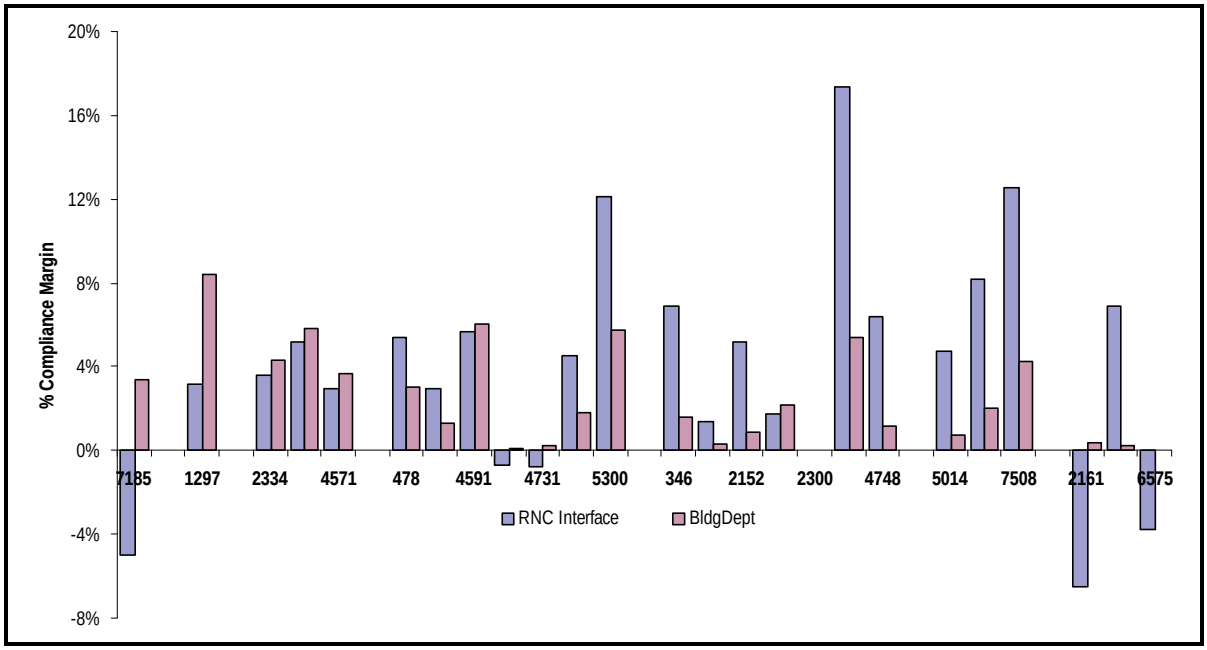
Thermal Performance Characteristics. Two thermal performance characteristics were refined during the RNC Interface evaluation.

- ***Slab Edge F2 Value.*** Early on in the examination of the C-2R forms, it was determined that the slab edge heat loss factor, or the F2 value, was a key parameter affecting compliance. The algorithm originally used assumed an F2 value of 0.76. However, it was determined that relatively small changes in the value had a significant impact on compliance. Again, information from the building department C-2R data was used to redefine the F2 value as 0.70.[14]
- ***Window U-Values and Glass Shading Coefficients (SC).*** The initial attempt to map the windows reported on the building department C-2R forms to the default set of "standard practice" window U-values and SCs made it difficult to validate the effectiveness of the interface. First, the building department window U-values and SCs from the C-2R forms had to be mapped to the window types listed on the on-site surveys. These window types were then mapped to RER's default window U-values and SCs. RER's window U-value defaults were then

[14] The F2 value/factor defines the slab edge heat loss per linear foot of slab edge. The redefined F2 value of 0.70 will result in less heat loss than an F2 value of 0.76.

changed as a result of comparing the runs using the C-2R data to results on the building department C-2R forms.

Figure E-4: Summary of Initial RNC Interface Compliance Runs



Once the refinements described above were completed, the RNC Interface was finalized for the present round of analyses. Table E-4 compares the results of the compliance runs using the initial and final RNC Interface. Two factors were compared.

- ***Number of Non-Compliant Sites.*** This is the total number of non-compliant sites.
- ***Difference in % Compliance Margin.*** The difference in the % Compliance Margin is defined as the difference in the % Compliance Margin generated by the RNC Interface and the % Compliance Margin generated by using data from the matching original building department C-2R compliance data.

The refinements to the RNC Interface decreased the number of non-compliant sites and, even more importantly, decreased the average difference in the % Compliance Margin. In particular, the number of non-compliant sites dropped by one and the average difference in % Compliance Margin more than halved from 1.6% to 0.7%. The results of the compliance runs using the final RNC Interface are presented in Figure E-5.

Table E-4: Comparison of the Initial and Final RNC Interface Compliance Runs

	Initial RNC Interface	Final RNC Interface
Number of Non-Compliant Sites	5	4
Avg. difference in % Compliance Margin	1.6%	0.7%
Max difference in % Compliance Margin	12.0%	5.2%
Min difference in % Compliance Margin	-8.4%	-6.0%

Figure E-5: Summary of the Final RNC Interface Compliance Runs