

# Residential New Construction (RNC) Programs Impact Evaluation

Appendices to Volume I.

California Investor-Owned Utilities' Residential New  
Construction Program Evaluation for Program Years 2006-  
2008



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Final Evaluation Report - Prepared by:

KEMA, Inc.

The Cadmus Group, Inc.

Itron, Inc.

Nexus Market Research, Inc.

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## **A. Calculation of Adjusted Tracking Savings Estimates**

### **A.1 Orientation Adjustments**

Orientation adjustments were only necessary for homes recorded in the CalCERTS registry.

The orientation of a home can significantly affect its space cooling and heating energy requirements, chiefly due to solar gain through windows. However, when RNC participating homes are built and entered into the tracking registries (CHEERS and CalCERTS) their actual orientations are not recorded. Instead, production builders design homes which are built in all possible orientations, usually dependent upon the layout of the streets in a development. To accommodate this style of planning and to satisfy the RNC program requirements, builders model their homes in north, east, south, and west orientations to show that energy consumption meets minimum program requirements in all four “cardinal” orientations. The CHEERS registry contains the modeled energy consumption for all four orientations, and the average was used to calculate the gross energy savings for each home.

The CalCERTS registry only contains modeled energy for each plans’ worst orientation, but clearly not all homes are actually built in the worst possible orientation. To adjust for this, the CHEERS data were used to estimate “average” orientation energy as a function of worst orientation energy. Unique orientation adjustment b-ratios were estimated for the single family homes.

### **A.2 Ratio Estimation and B-Ratios**

Ratio estimation was used to adjust gross tracking energy savings through the use of b-ratios in six stratum: three end uses (heating, cooling, and water heating) in each of three climate regions (inland, coastal and high desert).<sup>1</sup> The target variable of analysis, denoted  $y$ , is the energy use of the project (home). The primary stratification variable, the estimated energy savings of the project, is denoted  $x$ , and is obtained from the tracking database. A ratio model

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<sup>1</sup> A home was classified as either coastal, desert or inland based on its CEC climate zone. Homes modeled (or built) in CEC climate zones 1-7 were classified as coastal, homes in CEC climate zone 15 was classified as desert, and homes modeled in CEC climate zones 8-14 and 16 were classified as inland.

was formulated to describe the relationship between  $y$  and  $x$  for all projects in the population, such that  $y = \beta x$ . In statistical jargon, the ratio model is a (usually) heteroscedastic regression model with zero intercept. Beta ( $\beta$ ) is referred to as a b-ratio. In the case of orientation adjustment,  $\beta$  is the sum of all homes' average orientation energy savings divided by the sum all homes' worst orientation energy savings within a stratum. A thorough description of ratio estimation can be found in the 2004 California Evaluation Framework.<sup>2</sup>

The orientation adjustments are based on a sample size of over 5,500 single family homes from the CHEERS registry.

### A.3 Summary of Results

Orientation adjustment results are presented in Table A-1.

**Table A-1: B-ratios for Orientation Adjustments**

Climate Region	Heating	Cooling
<b>Coastal</b>	1.11	1.28
<b>Desert</b>	1.16	1.06
<b>Inland</b>	1.14	1.29

B-ratios less than one indicate less energy savings than computed from the tracking data, while b-ratios greater than one yield increased savings. All of the B-ratios were greater than one implying that the worst orientation reports less savings than the average orientations used in the CHEERS registry.

### A.4 Interpretation and Conclusions

These findings, although not the focus of this report, are very significant. For example, the orientation results show that inland energy savings can be increased by 29% for space cooling, and 14% for space heating, by orienting a home from its worst energy orientation to its average

<sup>2</sup> TecMarket Works, 2004. *The California Evaluation Framework*. Prepared for the California Public Utilities Commission and the Project Advisory Group

energy orientation.<sup>3</sup> Even greater energy savings could be achieved by orienting homes to their best orientation or by selecting designs specific to the orientation of the site. This is not a “new” discovery, as the advantages of passive solar design and home orientation have been known for centuries, but the orientation adjustment b-ratios, based on analysis of thousands of homes, provide a quantitative estimate of the energy “cost” to builders of ignoring orientation. Conversely, water heating orientation b-ratios are 1.0, since the orientation of a home does not impact modeled energy water heating usage.

### A.5 Single Family Adjusted Gross Energy Savings

B-ratios were multiplied by gross savings from CalCERTS tracking data to arrive at the Orientation Adjusted Tracking Savings.

The overall impact of the orientation adjustment on gross tracking savings is presented in Table A-2. Gross tracking savings from the raw data (for which savings estimates could be obtained) increases by 6.42% as a result of the adjustment. We multiplied the CalCERTS portion of gross savings by the b-ratios for orientation adjustments to arrive at the orientation adjusted gross savings.

**Table A-2: Single Family Tracking Savings and Orientation Adjusted Savings**

Utility	Single Family Dwelling Units	Tracking before orientation adjustment (source kBtu)	Tracking after orientation adjustment (source kBtu)	% change
PG&E	5,244	87,816,143	93,393,552	6.35%
SCE	414	7,513,120	8,146,578	8.43%
SCG	67	1,455,735	1,455,735	0.00%
Total	5,725	96,784,998	102,995,866	6.42%

Note that the percent change was zero for SCG . This is because all of SCG participants were on the CHEERS database and no adjustments were needed.

<sup>3</sup> Although coastal space cooling savings increases by a dramatic 28% with orientation adjustment, the actual energy savings due to this adjustment are small since the coastal region has much smaller cooling loads and many fewer new homes.



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## **B. Residential New Construction Onsite Data Collection**

### **B.1 Building Characteristics**

Data collection for each site includes information on the building's characteristics, HVAC equipment serving the home, lighting, and major appliances per the IOU's prescriptive measures. This data will be used to inform Micropas input files. The details of these input parameters are described below.

For a given residential site, modeling parameters fall into the following hierarchy.

- 1) Site Overview Information
  - a) Overall floor area
  - b) Number of floors
  - c) Type of residence (single family, attached, etc)
  - d) Vintage of Residence
  - e) Number of bedrooms/bathrooms
  - f) City (CIMIS weather data)
  - g) Utility Meters and Accounts
  - h) Title 24 Documents if available
  - i) Builder/Development Information
  - j) Age and Number of Residents
  - k) Number of residents home during the day time
- 2) HVAC and Ventilation Systems
  - a) Primary Heating and Cooling Systems

- i) System type (central, room unit, hydronic, etc.)
- ii) Equipment type (split, packaged, heat pump, furnace, baseboard, etc.)
- iii) Manufacturer
- iv) Model number (Indoor and Outdoor for split systems)
- v) Cooling capacity
- vi) Cooling efficiency (SEER and EER)
- vii) TXV (thermostatic expansion valve) or non-TXV
- viii) Refrigerant Type (R-22, R-410a)
- ix) Heating capacity (kBtuh)
- x) Heating efficiency (AFUE, HSPF, or COP)
- xi) Evaporative cooling
- xii) Supply fan type (CV, two-speed, ECM, VSD)
- xiii) Presence of whole house fan, Smart Vent/Economizer, mechanical ventilation
- xiv) Indoor fan motor HP if available
- b) HVAC Schedules (for each system)
  - i) Thermostat Manufacturer/Type
  - ii) Thermostat Model Number
  - iii) Thermostat set points for heating and cooling during occupied and unoccupied periods
- c) Duct Systems
  - i) Location of Ducts
  - ii) Location of Registers

- iii) Duct Types
  - iv) Duct Sealant Types
  - v) Insulation R-Value
  - vi) Duct and Plenum Condition
  - vii) Total duct leakage (duct blaster test)
- 3) Envelope Characteristics
- a) Exterior Walls
    - i) Exterior wall construction Type
    - ii) Surface Type
    - iii) R-value
    - iv) Orientation (N, S, E, W)
    - v) Shading
    - vi) Number and Type of Doors
    - vii) Wall Area
  - b) Windows
    - i) Number of panes
    - ii) Glass type (clear, tinted, reflective, LowE (using EKT detector))
    - iii) Frame type (metal, vinyl, wood)
    - iv) Frame Style (fixed, slider, etc)
    - v) Height and width of each window
    - vi) Quantity of each type
    - vii) Internal/External Shading

- 
- viii) Orientation
  - c) Interior Walls
    - i) Height and width
  - d) Roofs
    - i) 1. Type
    - ii) 2. Surface area
    - iii) 3. Surface (Tile, Shingle, etc)
    - iv) 4. Color
    - v) 5. Ceiling insulation R-value or type
  - e) Floors
    - i) Number of Floors
    - ii) Total Conditioned Floor Area
      - (1) Ground Floor Area
    - iii) Construction Type (slab, crawl space, open)
    - iv) Area of Exposed Slab or perimeter
    - v) Area Over Unconditioned Garage
    - vi) Raised floor R-Value if available
  - 4) Lighting
    - a) Interior Lighting (to be catalogued in Title 24 spaces defined by usage)  
*The following parameters will be collected for all interior lights:*
      - i) Fixture type
      - ii) Fixture wattage

- 
- iii) Lamps per fixture
  - iv) Lamp wattage
  - v) Mounting type (recessed, direct, indirect, direct-indirect, track, plug in task, or furniture integrated task)
  - vi) Control strategy (switch, dimmer, occupancy sensor, etc.)
  - b) Exterior Lighting
    - The following parameters will be collected for all exterior lights:*
    - i) Fixture type
    - ii) Fixture wattage
    - iii) Control strategy
  - 5) Appliances and Other Equipment
    - a) Hot Water Heaters
      - i) Type (storage, instantaneous, heat pump)
      - ii) Manufacturer
      - iii) Model number
      - iv) Tank capacity
      - v) Input [kBtuh gas, kW electric]
      - vi) Fuel type
      - vii) Location
      - viii) Insulation Jacket
      - ix) Insulation on pipes
      - x) Presence of hot water reclaim
      - xi) Efficiency, %

- xii) Low flow fixtures
- xiii) Temperature settings (low, medium, high)
- xiv) Recirculation control type and pump HP
- b) Refrigerators and Freezers
  - i) Manufacturer
  - ii) Model Number
  - iii) Configuration (top mount freezer, side-by-side, etc)
  - iv) Location (conditioned, unconditioned space)
  - v) Volume
  - vi) Age
  - vii) Energy Star
  - viii) Presence of through-the-door water or ice
  - ix) Automatic ice maker
  - x) Energy Factor (ft<sup>3</sup>/kWh/day)
- c) Dishwasher
  - i) Manufacturer
  - ii) Model Number
  - iii) Energy Star
  - iv) Builder Installed, Purchased New, Installed Used
- d) Clothes Washer/Dryer
  - i) Manufacturer
  - ii) Model Number

- iii) Energy Star
- iv) Builder Installed, Purchased New, Installed Used
- v) Axis Type/Fuel Type
- e) Oven, Range, Pool/Spa Heater
  - i) Fuel Type
- f) Pool Pump
  - i) HP
  - ii) Speed
- g) Number of televisions and size, and number of computers
- h) Number of non-lamped ceiling fans and location

## **B.2 Performance Testing**

### **B.2.1 Whole House Infiltration**

To measure the infiltration of a home we used the Minneapolis blower door™. The Minneapolis blower door™ uses a fan and frame assembly that is temporarily sealed into an exterior doorway. The testing was performed at a pressure difference of 50 Pa (0.2 inches of water column) to create a slight pressure difference between the inside of the home and outside. Using a digital pressure gauge to measure the air flow that is required to maintain 50 Pa, the air tightness of the house can be gauged.

#### **B.2.1.1 Setup Procedure for Blower Door Test**

- 1) Close all windows and doors to the outside.
- 2) Open all interior doors and supply registers.
- 3) Close all dampers and doors on wood stoves and fireplaces. Seal fireplace or woodstove as necessary to prevent ash blowback into occupied spaces.
- 4) Make certain furnace and water heater cannot come on during test.

- 5) Put water heater and/or gas fireplace on “pilot” setting if they are within the conditioned space.
- 6) Make certain all exhaust fans and clothes dryer are off.
- 7) Make certain any other combustion appliances will not be backdrafted by the blower door.
- 8) Make certain doors to interior furnace cabinets are closed.
- 9) Also make certain crawlspace hatch is on, even if it is an outside access.
- 10) Check attic hatch position.
- 11) Put garage door in normal position.
- 12) If dryer is not installed seal off dryer vent.

### **Performing Blower Door Test Setup**

- 1) Setup and install Blower door frame in an exterior doorway- do not put fan in opening yet (see Figure B-1).

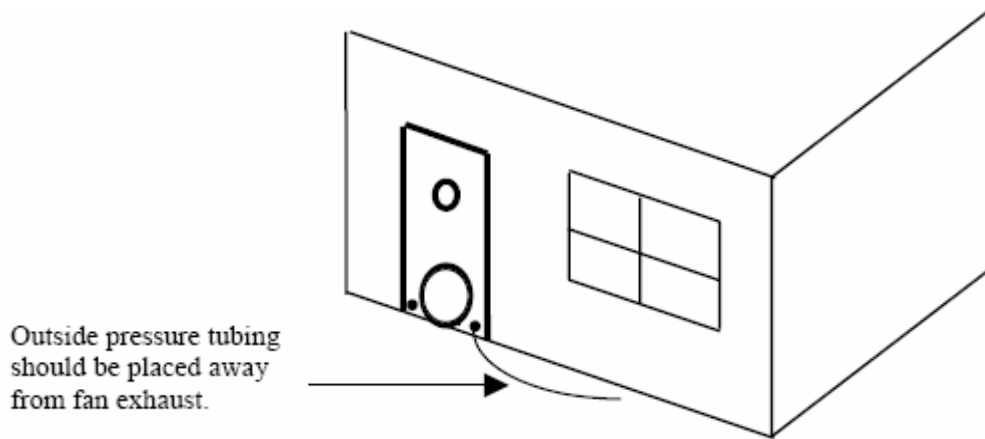
**Figure B-1: Installation of Blower Door Frame**





- 2) Put the **Green pressure tubing** through one of the opening in the door, run it approximately 3-5 feet away making sure that the end of the tubing is placed well away from the exhaust flow of the Blower Door fan (see Figure B-2).

**Figure B-2: Placement of Green Pressure Tubing**



- 3) Install the Blower door fan in the opening making certain the elastic band fits snugly around the fan with the collar resting in between the two sides of the electrical box (see Figure B-3).

**Figure B-3: Installation of Blower Door Fan**



- 4) Attach the fan to the cross bar with the Velcro strap- the fan should now be suspended in the door with the flow plate side facing towards you (see Figure B-4).

**Figure B-4: Attach the Fan to the Cross Bar**



- 5) Attach pressure gauge to mounting board and put on gauge hanger (see Figure B-5).

**Figure B-5: Attach Pressure Gauge**

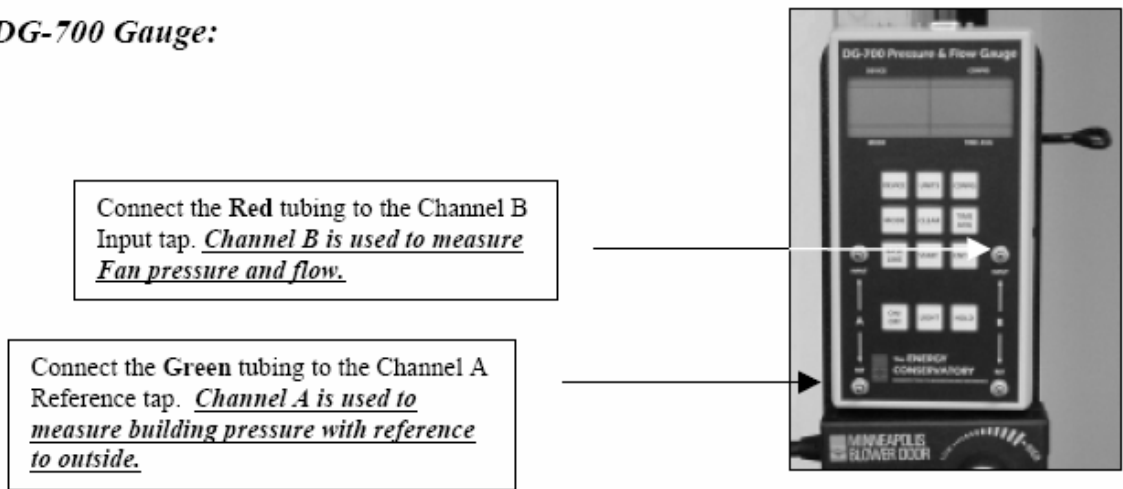


- 6) Connect the **Red** pressure tubing to the **Channel B Input Tap** and connect the other end to the pressure tap located on the blower door fan (see Figure B-6).

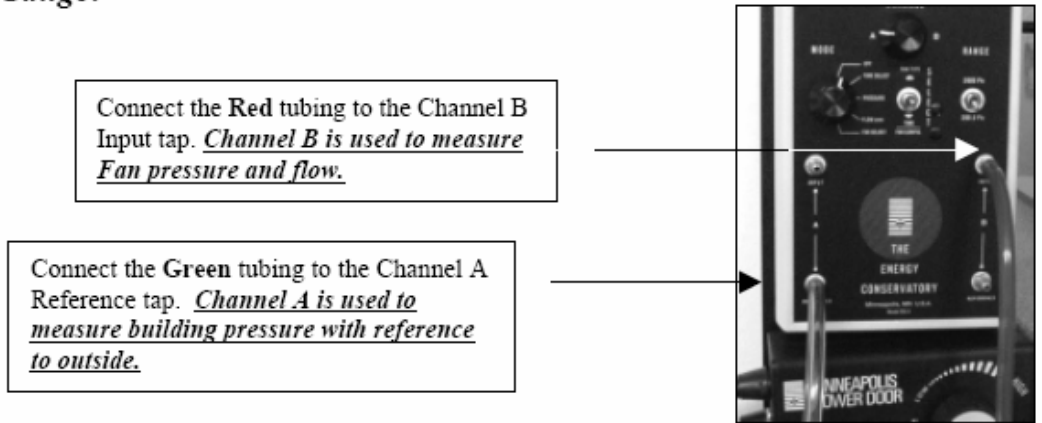
- 7) Connect the **Green** pressure tubing to the **Channel A Reference Tap** (see Figure B-6).

**Figure B-6: Attaching the Pressure Tubing to the Pressure Gauge**

**3.5.a DG-700 Gauge:**



**3.5.b DG-3 Gauge:**



- 8) Insert plug into blower door fan and connect to power supply-Make certain the fan speed controller is off when connecting to power (see Figure B-7).

**Figure B-7: Connecting Power to the Blower Door Fan**



- 9) Make certain fan direction switch is positioned towards the direction of airflow (see Figure B-8. Connecting power to the blower door fan)

**Figure B-8: Fan Direction Switch**



- 10) Perform Blower Door Test.

### **B.2.1.2 Blower Door Depressurization Test Procedures Using the DG-700**

- 1) Press the **Mode** button **twice** for **PR/FL@50**.
- 2) If **BD3** is not displayed on **Channel A** push **Device** until **BD3** is displayed.
- 3) Push **Configure** button to select a **flow ring** displayed on **Channel B**. **Typically you should start with ring B2** (Open= No Ring A1= ring A, B1= ring B) the rings on the blower door fan are labeled as such.

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

To check test, calculate the flow exponent,  $n$ . Use the following formula,  $n = \ln(Q_{50}/Q_{25})/\ln(P_{50}/P_{25})$ . Note  $Q_{50}$  and  $Q_{25}$  are the flows through the blower door at the testing pressures (which are denoted  $P_{50}$  and  $P_{25}$ ). Depending on the test, you may not get the house to exactly  $-50$  or  $-25$  Pa WRT outside. Use the exact  $\Delta P$  you measure when checking the flow exponent. For example, if the house gets to  $-48$  Pa for the high  $\Delta P$ , use this as the  $P_{50}$  in the equation. If the flow exponent is not between 0.50 and 0.75, repeat the test.

Note testing conditions (if windy, inaccessible room(s), garage door open or closed, etc).

### B.2.2 Total Duct Leakage Protocol

To measure the HVAC system duct leakage, a Minneapolis Duct Blaster<sup>®</sup> was used. The Minneapolis Duct Blaster<sup>®</sup> measures the amount of leakage in the duct system by pressurizing the ducts with a calibrated fan and simultaneously measuring the air flow through the fan. The duct blaster fan is connected directly to the duct system in a house, typically at a central return, or at the air handler cabinet. The remaining registers and grilles are taped off. The duct system is then pressurized to 25 Pa and duct system leakage is measured using a digital pressure

gauge. The test is done in order to measure total duct leakage, which includes leakage inside the thermal envelope of the home.

### **B.2.2.1 Setup Procedure for Total Duct Pressurization Test**

- 1) Make sure HVAC is turned off and blower compartment door is in place.
  - Remove all air filters.
  - Tape all registers. Use appropriate tape (Long Mask) for friable surfaces.

#### **Performing Total Duct Pressurization Test Setup**

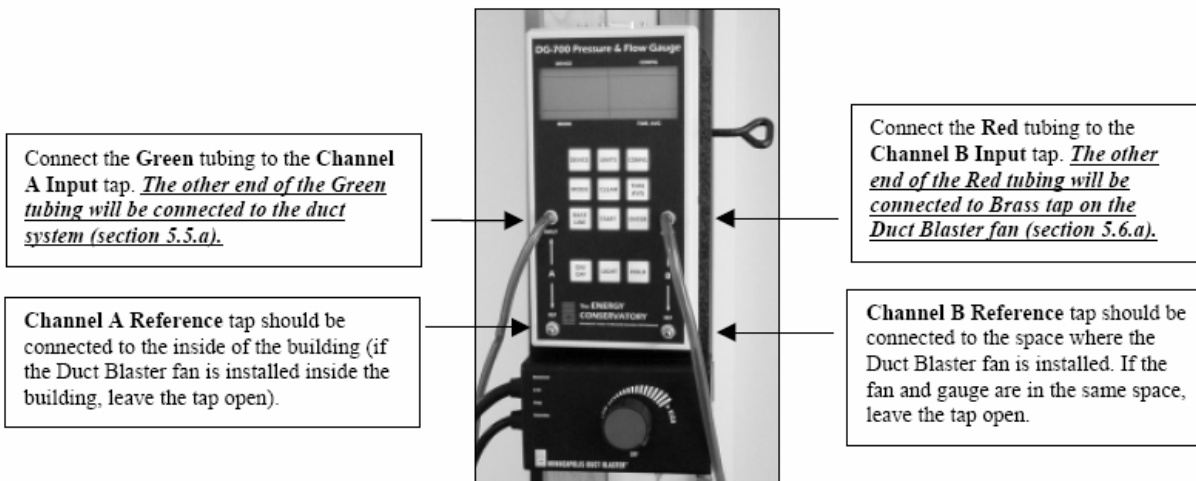
- 1) Install the duct blaster at the duct system at the central return or air handler cabinet (the return will be the most common installation; see Figure B-9). In the case of multiply returns seal off the smaller return and use the largest return for test.



**Figure B-9: Installing the Duct Blaster**

- 2) Connect the **Green** pressure tubing to the **Input** tap on **Channel A** and the **Red** pressure tubing to the **Input** tap on **Channel B** (see Figure B-10).

**Figure B-10: Connecting the Pressure Tubing to the Pressure Gauge**



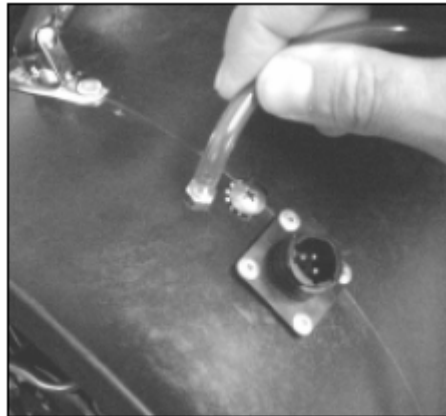
- 3) **Connect** the other end of the **Green** pressure tube to the static pressure probe and **insert probe into a supply register** and re-tape to secure probe in place (see Figure B-11).

**Figure B-11: Placing Static Pressure Probe in Supply Register**



- 4) **Connect** the other end of the **Red** pressure tube to the duct blaster fan (see Figure B-12).

**Figure B-12: Connect Red Pressure Tube to Duct Blaster Fan**



- 5) Next connect the controller to the duct blaster fan by the female power receptacle and plug into power supply (see Figure B-13). **Make certain fan controller is off when connecting to power.**

**Figure B-13: Connect Controller to Duct Blaster Fan**



- 6) Perform Duct Leakage Test.

### **B.2.2.2 Total Duct Pressurization Test Procedures Using the DG700**

- 1) Turn on Duct blaster Fan and Pressure Gauge
- 2) Push **Mode** button to **PR/FL**
- 3) Push the **Device** button until **DB B** is **displayed on the Channel A side**



- 4) Next push the **Config** button to select a flow ring (**Open= no ring,A1=ring 1, B2=ring 2,C3=ring 3**)
- 5) **Adjust** duct blaster fan speed control until **Channel A** reads **25 PA** or **as close as possible**
- 6) **Record values**
- 7) **Repeat steps 1-6 with duct blaster test pressure of 50 PA**
- 8) **Record** values and check flow exponent.
- 9) If flow exponent is within range test is complete.
- 10) Note any unusual testing conditions (wind, etc.):
- 11) If flow exponent is within range test is complete.
- 12) Note any unusual testing conditions (wind, etc.):

To check each test, calculate flow exponent as for the blower door test (previous page). The flow exponent,  $n$ , =  $\ln(Q^{50}/Q^{25})/\ln(P^{50}/P^{25})$ . If flow exponent not between 0.50 and 0.75, repeat test.

### **B.3 End Use Meter Data Collection**

This plan entails equipment monitoring at the primary residence(s) for the following equipment comprising the three Title 24 end-uses over the course of one year:

- 1) Central and wall air conditioning units
- 2) Domestic hot water heaters and boilers
- 3) Central and wall heating systems

#### **B.3.1 Cooling Equipment End Use Metering**

- 1) Data points to be metered
  - a) Time series current logging of the unit

- 2) Monitoring equipment to be used
  - a) Hobo U12-006 4-channel logger with appropriateOr
  - b) Owl 400 with appropriate CT for current monitoring
- 3) Sampling interval and Duration of metering
  - a) Loggers are typically set at 15 or 20 minute sampling interval
  - b) Duration of metering is for a full year
- 4) **Hobo U12-006 Logger and Associated Sensors** (see Figure B-14. Onset 0-50A CTV-B Current Transducer

**Figure B-14: Onset 0-50A CTV-B Current Transducer**



**Figure B-15: Hobo U12-006 4-Channel External Logger**



**Data Logger Properties**

- U12 4-External Channel Logger accepts a wide range of external sensors, including temperature, AC current, AC voltage, CO2, 4-20mA, and 0-2.5 VDC. 12-bit resolution provides great data accuracy.
- One channel will be used for real-time amp monitoring of the AC unit

**Installation Procedure**

- Connect the CT to channel 1 of the logger.
- Open up the CT, and slip in the CT in one leg of the HVAC unit. Select the leg that includes supply/condenser fan
- Logger will launch using delay launch settings set in the office before bringing to the field

**5) OWL 400 Data Logger****Data Logger Properties**

- These loggers combine with a 50A current transducer to measure AC current.
- To setup the Owl 400 data logger you must have ACR trend reader software installed and running on your computer.
- Used in conjunction with either Hobo Micro Station or Hobo Temperature loggers.



**Figure B-16: Owl 400 Data Logger**

**Installation Procedure**

- 1) First, make sure that the secondary end of the Sentran current transducer is plugged into the data port of OWL400.
- 2) Open up the split core CT, and slip in the CT in one leg of the HVAC unit. Select the leg that includes supply/condenser fan
- 3) Logger will launch using delay launch settings set in the office before bringing to the field

Additionally, one-time hand recorded field measurements will be collected for the following:

- 1) Air conditioner condenser unit amps
- 2) Air conditioner power factor
- 3) Premise voltage

Spot power reading and ambient air temperature (from weather station) measurements will be taken while on site. Two spot power measurements will be taken, and the average of the two will be used in the analysis.

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The amperage draw of each central air conditioning condenser unit will be logged at the electrical disconnect and will be representative of all power consumed for wall units and the split-system outdoor components including compressor, condenser fan, and controls.

For split systems, this amperage data in conjunction with the instantaneous readings of the unit's voltage and power factor along with nameplate fan power draw are used to calculate kilowatt and kilowatt hour energy use for cooling. If multiple air conditioning units are found at a site, all units will be summed together to produce the measure of total unit usage.

### **B.3.2 Domestic Hot Water End Use Metering**

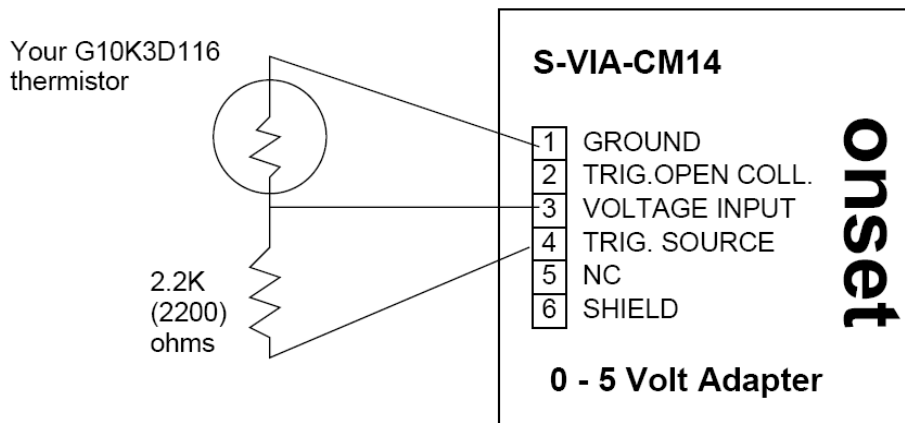
#### **B.3.2.1 Gas Storage DHW**

A storage tank heater maintains a set volume of hot water at a specified temperature at all times regardless of need. It operates by releasing hot water from the top of the tank when a hot water tap is turned on. To replace that hot water, cold water enters at the bottom of the tank, ensuring that the tank is always full. A thermostat monitors the water temperature and enables the burner to fire when the temperature drops below a pre-defined set point.

Installing an inline gas meter to precisely measure the annual gas consumption of water heaters would not have been cost effective. An economical and accurate way to measure the gas consumption is to record annual runtime of the burner. The temperature of the water heater flue is an indicator that the burner is firing; therefore, we logged the temperature of the exhaust flue to give the number of fires and duration of each firing of the hot water burner. We developed an approach to measure the temperature of the exhaust flue with help of a negative temperature coefficient (NTC) thermistor that provides a reliable and consistent indicator of burner run time.

Hobo Micro Station along with a 0 – 5 Volt adapter and a voltage divider was used to monitor the temperature of the exhaust flue of the water heater. The voltage divider (bridge circuit) was used to determine the resistance of the G type 10 K ohm @ 25°C NTC thermistor ( $R_t$ ). The balance resistor used with this bridge circuit is a fixed precision 2.2k ohm resistor ( $R_b$ ). One end of the thermistor was connected to the ground terminal of the Onset 0-5 Volt Adapter and the other end was connected to the voltage input terminal of the adapter. One end of the balance resistor was connected to the Trig. Source terminal of the volt adapter. Trig. Source provides voltage from the logger's battery to power the bridge circuit. The other end of the voltage adapter was connected to a Hobo Micro Station logger. The details of the circuit are shown in Figure B-17 below.

**Figure B-17: Circuit Details**



The HOBO Micro Station logger's excitation voltage ( $V_{exc}$ ) is the "switched DC output" coming from the logger.  $V_{exc}$  provides 1 mA current at 2.5 volt DC. The 1 mA current flows through the resistors to provide voltage across the bridge circuit. The voltage output from our bridge circuit as seen by the logger input is ( $V_{out}$ ). Thermistor to balance resistor ratio is  $R_t / R_b = V_{out} / (V_{exc} - V_{out})$ . Now multiply the value of our Balance resistor ( $R_b$ ) by this ratio to get the resistance of the thermistor ( $R_t$ ). To derive temperature from thermistor resistance plug values into the Steinhart-Hart equation. The Steinhart and Hart equation is an empirical expression that is used to determine the resistance temperature relationship of NTC thermistors. An Excel spreadsheet developed by the vendor named 'Thermistor-hotplate' can be used to convert voltage recorded by your Onset HOBO logger into temperature.

### Field Installation

- 1) Drill a 3/8" hole on the exhaust flue of the hot water and insert the 2" threaded end of the thermistor into the flue and cover it with metal tape to secure the thermistor for the duration of the study. Make sure the thermistor is in the exhaust air stream and not making contact with the sides of the flue.
- 2) Insert PC interface cable to the communication port of the Hobo Micro Station to configure the logger.
- 3) Follow the step-by-step process to setup the logger
  - a) Open the Hobo pro status window by double clicking the task bar or the logger icon

- b) Once status menu is displayed select launch logger option from device menu
  - c) Set the sample monitoring interval to 90 seconds
  - d) Then select launch options such as instant start, delayed start or push button
  - e) To start the logging session select the launch button
- 4) The HOBO Micro Station data loggers record an instantaneous flue temperature every ninety seconds. The ninety second logging configuration permits 350 days of monitored data. The loggers are configured to stop recording data when the memory reaches capacity to avoid overwriting previously collected data. Figure B-18 shows the typical logger installation implemented for storage domestic hot water heaters with a standard flue.
- 5) Record the name plate information of the hot water heater such as make, model number, serial number and nominal input (Btuh),

Note that the manifold (main burner) pressure will be measured on several units during the pilot sites to verify proper delivery pressure.

**Figure B-18: Domestic Hot Water Data Logger Installation**



### Data Processing

The recorded voltage data from the logger shall be downloaded to a PC. The voltage data is converted into temperature with the help of 'Thermistor-hotplate' Excel spreadsheet for further analysis.

#### B.3.2.2 Tankless Water Heaters

Instantaneous (tankless) water heaters operate without storage tanks. Cold water travels through a pipe into the unit, and either a gas burner or an electric element heats the water only when needed. As there are multiple controls to regulate the gas flow to the burner and the flow is variable, the most economical and accurate way to measure the annual gas consumption is to install an inline gas sub meter at the gas supply pipe of the water heater.

We used Elster Amco G4 gas meters to measure the annual gas consumption of the water heater. This meter's small size and lightweight design is ideally suited for sub metering applications. The G4 is a 200 cubic foot per hour, non-temperature compensated gas meter with a cyclometer register. Despite its small size, the G4 is accurate and reliable when measuring either natural or LP gas.

The design of the G4 consists of four measuring chambers separated by synthetic diaphragms. The chambers are filled and emptied periodically and the movement of the diaphragm is transferred via a gear to the crankshaft. This shaft moves valves that measure the volumetric gas flow. Rotations of the gear are transferred via a magnetic coupling to the index, thus assuring proper sealing of the meter's internal mechanisms. Figure B-19 shows the G4 gas meter.



**Figure B-19: G4 Gas Sub-Meter****Field Installation**

Authorized plumbers were hired to install the gas meter on the water heater. All gas safety codes and regulations will abide by all terms and conditions imposed by the utilities and governmental authorities.

- 1) Turn off the gas service to the house and cut the gas pipe before it enters the tankless water heater.
- 2) Blowout the gas service line before the meter is installed, so that no dirt, debris or liquids of any kind can be carried into the meter when gas is flowing through the pipe.
- 3) Place a new connection washer on each open end of the gas pipe
- 4) Support the meter so that both hubs are against the connection washers and run the connection nuts down hand tight.
- 5) In alternating fashion, tighten the nuts to an appropriate torque for the connection size.
- 6) Before turning the gas on in a new installation, check the system downstream of the meter to be sure that all connections are made up and tight or that the downstream valve, if there is one, is closed.
- 7) Now reset the gas meter's odometer and make sure that it reads zero.

- 8) Note down the date and time of installation
- 9) Record the nameplate information of the hot water heater such as make, model number, serial number and nominal input (Btuh).
- 10) At the end of the monitoring period, record the cubic feet on the meter and also the date and time of retrieval.

### **B.3.3 Heating Equipment End Use Metering**

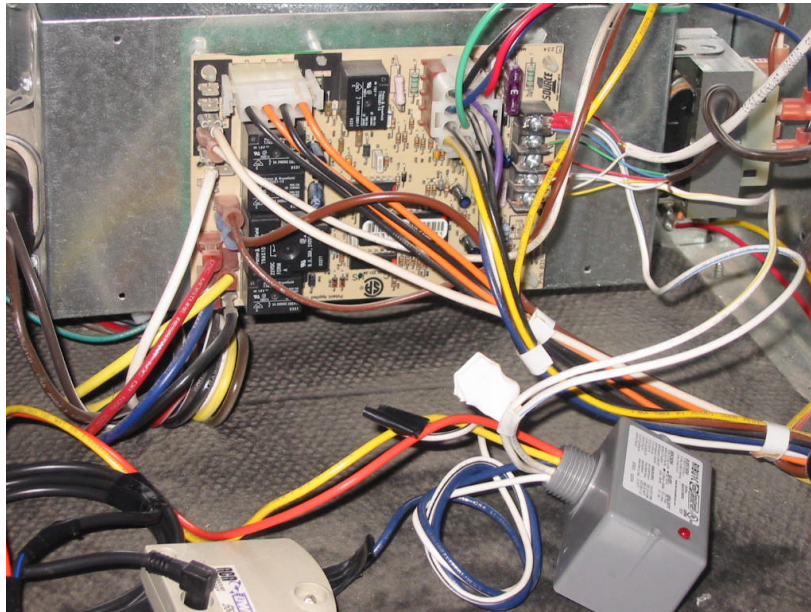
#### **B.3.3.1 Forced Air Furnace**

Heating systems monitored may include central forced air furnaces and central heat pumps. Owl 400 data loggers are used for heat pump heating mode, and Owl 200 data loggers are used for forced air furnaces. Considering the safety concerns and difficulty of measuring natural gas consumption, a unique approach is necessary to capture the forced air furnace run-time. Inside the air handler section of each furnace there is a low voltage (24 VAC) control board with a terminal block consisting of separate relay contacts for heating, cooling, and fan operation. Upon receiving a call for heat signal from the thermostat, the heating relay contact undergoes a change of state resulting in the operation of the furnace. KEMA determined that by “slaving” a small relay off of the call for heating circuit, and logging the change of state of the heating relay contact, we were able to precisely log the percentage run-time of the furnace on an hourly basis.

The furnace nominal input Btuh was obtained from the manufacturers’ specifications and utilized to inform the run-time data with actual gas input. During the pilot sites the main burner gas pressure was tested at each furnace unit to verify that the gas supply pressure was within the manufacturer’s specifications. By doing this, we demonstrated that the gas supply pressure is sufficient and RLW can confidently use the nameplate input Btuh rating for the fuel consumption calculations.

#### **Field Installation**

Figure B-20 below shows the typical logger installation implemented for forced air furnaces. For two stage heating units, we installed a second relay and OWL 200 to capture run-time for each stage.

**Figure B-20: Typical Logger Installation for Forced Air Furnaces****90+AFUE Forced Air Furnace****Method A- Additional Measurements**

Measurement of furnace inlet gas flow can be performed during both high and low burn stages. This could then be used to compute approximate gas usage.

Using the flue gas analysis kit, the combustion efficiency will be analyzed to ensure that the furnace is operating near its rated efficiency. This is not equivalent to an AFUE rating. The flue gas analysis kit determines O<sub>2</sub>, CO, probe temp., draft, and diff. pressure then calculates CO<sub>2</sub>, CO-Air Free and Combustion Efficiency. The Testo 327-1 Combustion Analyzer specifications are presented in Table B-1.

**Table B-1: Testo 327-1 Combustion Analyzer Specifications**

Parameter	Range	Resolution
O <sub>2</sub>	0 – 21%	0.1%
CO	0 – 4,000 ppm	1 ppm
Probe temp.	-40°F to +932°F	0.1°F
Draft	±16" H <sub>2</sub> O	0.001" H <sub>2</sub> O
Diff. pressure	±80" H <sub>2</sub> O	0.01" H <sub>2</sub> O
CO <sub>2</sub> (Calculated)	0 – CO <sub>2</sub> max	0.01%

In addition to the gas flow meter and flue gas analyzer, a relay and insulation piercing connector was attached to the gas fuel value to measure the gas flow time (Flame-on). The flame on-times was then compared with the times of the call-on events as recorded by the existing installed meter. The difference between these two times under various firing regimes (e.g. the CPU determined firing rate associated with prior short vs. long calls for heat) can be used to reduce the furnace operating time as recorded over the entire metering period.

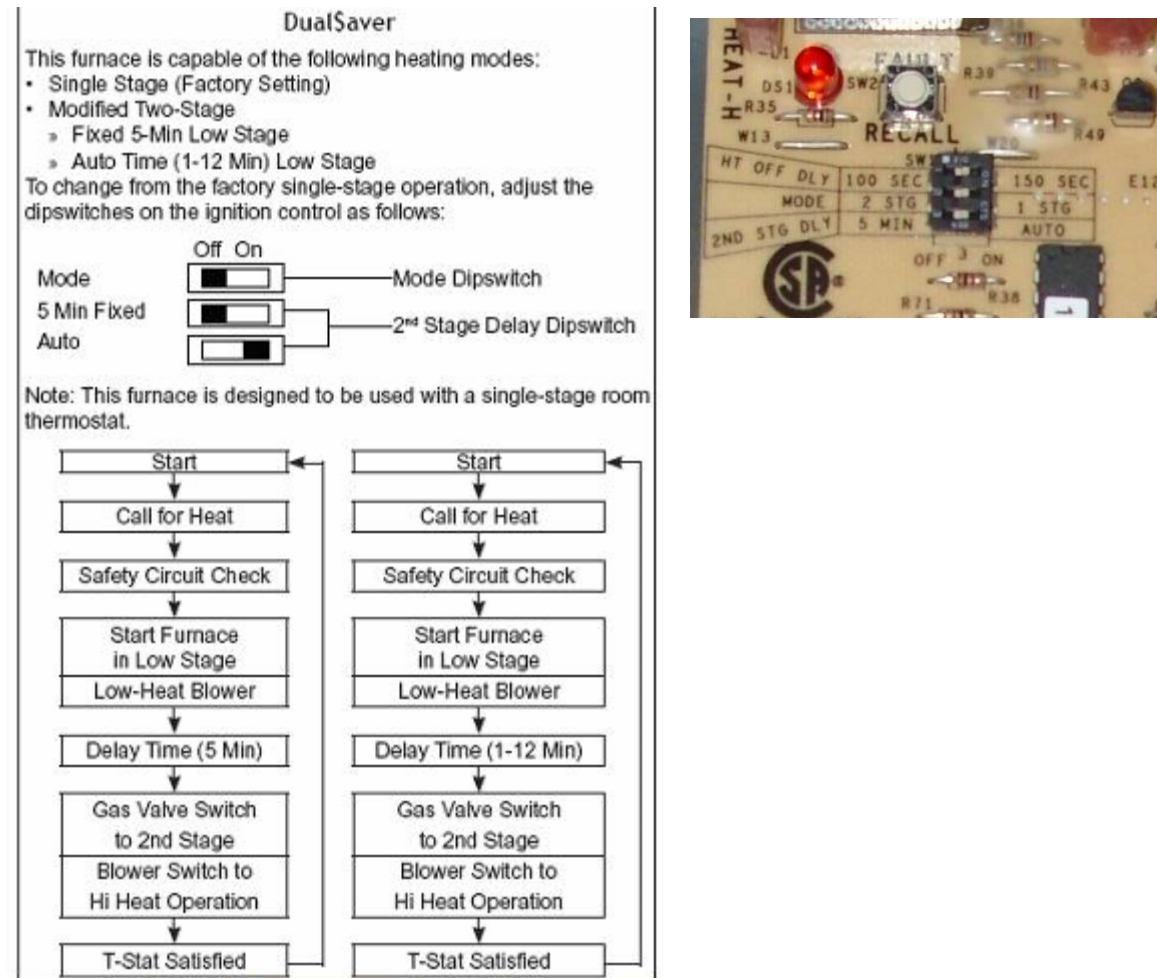
While the lag time for many furnaces has been published, our experience has shown that actual lag times can vary substantially from published values. On average, the lag times were 144% of published values, but they were as long as 183% for one furnace. The variation in lag time will make it difficult to convert runtimes to gas use rates. One work-around is to use the average observed value. This value varies from 9 second less to 23 seconds greater. For an average cycle time of about 7 minutes, the error induced would be up to 5%, but would be lower in most cases. While the improved observations of lag would improve the overall calculation, a greater source of uncertainty relates to the CPU-controlled firing of stages.

There is significant uncertainty around the duration and frequency of low fire and high fire events from two stage units. The determination of the cycle and the shift from low fire to high fire, in some cases, is controlled by proprietary algorithms programmed into the furnaces control circuitry. While the theory is relatively consistent – the programmed logic “learns” the demands of the space and will respond consistently to calls from the thermostat based on the past calls – a precise reproducible model appears to be unachievable, and despite numerous attempts, we have been unable to gain access to the proprietary algorithms from manufacturers.

One way in which it might be possible to check the operational delay of low versus high output modes is to modify the DIP switches in accordance with the furnace owners manual. See Figure B-21 below for a typical switch diagram. In two-stage mode, this particular furnace will

have a 1-12 minute delay which will vary based on previous usage. The other DIP option will produce a 5 minute delay between low and high firing modes regardless of previous usage. Unfortunately, this solution will not work for all makes and models. The lack of a clear resolution to this issue is why KEMA focused its efforts on a Method B as described below.

**Figure B-21: Typical Switch Diagram**



**Method B- DOE Calculations**

ASHRAE Standard 103 describes a methodology to determine a single stage equivalency for modulating and 2-stage furnaces which will allow different models to be analyzed together. For this method we first investigated if all the variables were available to determine estimated consumption and low/high stage runtimes. Such variables include; ratio of blower on-time to average burner on-time, fraction of heating load at reduced fuel input rate operating mode, annual household heating load, and blower motor electrical power consumption.

According to resources from EERE, DOE calculated the gas consumed by the burner and electricity consumed by the circulating air blower motor at the two firing rates. This calculation method is based on the procedure in the ASHRAE Standard 103.

Summaries of the methodology are available at the following sites.

Uniform Test Method for Measuring the Energy Consumption of Furnaces:

<http://www.fire.nist.gov/bfrlpubs/build02/PDF/b02022.pdf>

[http://www1.eere.energy.gov/buildings/appliance\\_standards/residential/pdfs/furnaces\\_boilers/furnace\\_boiler\\_app7\\_7.pdf](http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/furnaces_boilers/furnace_boiler_app7_7.pdf)

[http://www1.eere.energy.gov/buildings/appliance\\_standards/residential/pdfs/furnrbod.pdf](http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/furnrbod.pdf)

[http://edocket.access.gpo.gov/cfr\\_2009/janqtr/pdf/10cfr430BAppN.pdf](http://edocket.access.gpo.gov/cfr_2009/janqtr/pdf/10cfr430BAppN.pdf)

Using the equations and explanations available above and also through ASHRAE Standard 103, the AFUE of the furnace can be calculated. This procedure will also allow calculation of the estimated gas usage of the furnace on an annual basis, which can be found by dividing the annual household heating load by the AFUE and converting from BTUs to therms.

### C. End Use Meter Data Analysis

#### C.1 End Use Equipment Meter Data

##### C.1.1 Cooling Equipment

###### C.1.1.1 Split System Air Conditioner and Heat Pump

- AC monitoring relies on data loggers recording average amperage every 20 minutes using current transducers. The current draw data are combined with an instantaneous power measurement (spot-watt) taken at the time of the meter installation.
- It is then possible to translate these current readings into estimates of annual energy consumption (kWh) of the air conditioner or heat pump.
- Fan kWh is estimated by estimating the fraction of each period that the AC is running and multiplying it by the kW input of the fan. To inform the run-time data with actual power demand, a onetime spot power measurement of the condensing unit is taken using a Fluke 31 power meter.

The air conditioner monitoring approach is to record total condenser run-time utilizing the OWL 400 data logger with a 0-2.5 vdc output 50 amp split core current transducer (CT). This monitoring configuration operates by converting the analog signal of the 50 amp CT to a digital signal usable by the OWL 400.

Energy consumption of blower fans for central cooling systems will not be metered explicitly, but the fan is assumed to draw constant power during any condenser run period. The runtime for air conditioning and heat pump systems will then multiplied by the fan power draw to determine fan energy consumption. Cooling runtime for air conditioner and heat pump systems will calculate using the data and equipment performance curves.

Cooling Runtime was calculated as follows:

- 1) First translate the measured amperage information into an estimate of runtime.

**AMP** = Average Amp data, 20-minute interval (OWL Data)

**$\theta_{db}$**  = condenser inlet dry bulb temperature (°F) (Hourly Data)



$e_{wb}$  = evaporator inlet wet bulb temperature (°F) (Assumed constant at 67 F)

- 2) Use the DOE-2 Bi-Quadratic performance curves for split systems.

**Tonnage** = nominal system capacity in tons (Based on nameplate and matching)

$C_{ap}$  = (nominal cooling capacity)= 12000•**Tonnage** (Btuh)

**EER** = System efficiency at standard conditions (Based on nameplate and matching)

[The EER for each system was determined from the ARI Database of system efficiencies based on the particular condenser and coil match. If no match could be found the average EER for that SEER level across all manufacturers was used. The EER is the amount of cooling delivered in kBtu/h divided by the power input in kW at the standard condition of 95 F  $o_{db}$ , and 67 F  $e_{wb}$ .]

**EIRARI** = 3.412• (1/**EER**)

- 3) The bi-quadratic performance curves for cooling delivered and energy input ratio as functions of condenser entering dry-bulb temperature ( $o_{db}$ ) and evaporator entering wet bulb temperature ( $e_{wb}$ ) are presented below.

$$SysCool = C_{ap} \times \left[ \begin{array}{l} 1.191422708 - 0.01965 \cdot (e_{wb}) + 0.000315625 \cdot (e_{wb})^2 \\ + 0.0030587499 \cdot (o_{db}) - 0.0000093333 \cdot (o_{db})^2 - 0.0000782499 \cdot (e_{wb}) \cdot (o_{db}) \end{array} \right]$$

$$SysEIR = EIRARI \times \left[ \begin{array}{l} -0.06818927 + 0.022284379 \cdot (e_{wb}) - 0.0001171879 \cdot (e_{wb})^2 \\ + 0.00105933 \cdot (o_{db}) + 0.00014816 \cdot (o_{db})^2 - 0.000209999 \cdot (e_{wb}) \cdot (o_{db}) \end{array} \right]$$

- 4) The results were then translated into power draw by multiplying the energy input ratio by the amount of cooling delivered and converting the units back to Watts from Btu/h. The equation below incorporates the unit conversion in the determination power draw.

**POWER**=0.29308324•**SYSEIR**•**SYSCOOL** (Watts)

The power expected for a particular system with known efficiency and cooling capacity at any given hour for a particular location is now known.



- 5) By combining the spot measurements taken at the time of meter installation, we can then calculate the expected amperage draw given the local weather conditions.

**V** = Volts from Spot Watt Data

**PF** = Power Factor from Spot Watt Data

$$\mathbf{AMPA=POWER / (V * PF)}$$

- 6) If the unit was running for only a portion of the 20 minute interval the average amps divided by the expected amps will yield the percentage of the interval the unit was running at full power. Multiplying the percentage by one-third of an hour (20 minutes) [or ¼, if at 15-min intervals] allowed for runtimes to be calculated in units of hours. The equation below will be used for this analysis.

$$\mathbf{RUNTIME20 = (AMP/AMPA) * (1/3) \text{ (Hours)}}$$

- 7) The system's energy consumption can then be calculated as the measure energy consumption plus the fan energy consumption. The fan kW draw is assumed constant and will be taken from nameplate data. The equations below show how energy is computed using measured time series amperage data and instantaneous power factor and voltage data along with computed runtime and nameplate fan power.

**FANKW** = Fan Power for the system from nameplate data

$$\mathbf{ENERGY = (1/3) * AMP * PF * V + RUNTIME20 * FANKW}$$

### ***Heat Pump Separation Methodology***

There were only six heat pumps installed at the 454 homes that were visited. None of these homes were selected for metering, and therefore no Heat Pump methodology was used in this analysis.

### ***Filling in values for missing dates: Meter Data on Air Conditioners***

For the meters that were collected before a full year had passed between the time of installation, a method for filling in the missing data to create an annual usage profile was

needed. In light of this, weather normalization techniques were developed for the cooling end uses to fill in the missing data for loggers with less than a year of recorded usage.

To calculate a year of data, a regression analysis was done based on the average daily temperature and daily kWh. Cooling Degree Days (CDD) were calculated using the reference temperature of 65 degrees F, and were used in the regression against kWh. Daily total usage for the missing data was estimated using the equation below where  $\beta_0$  and  $\beta_1$  are constants based on the regression analysis:  $\beta_0$  is the average daily baseline usage and  $\beta_1$  is the temperature response of temperature-dependant cooling usage.

$$\text{Daily Total Usage}_{SITE} = \beta_0 + \beta_1 * CDD.$$

The predicted Average Daily Usages were combined with the actual Average Daily Usage to create a full year of daily usage for each site. For the meter adjustment factor estimation, these daily usages were aggregated into annual kWh.

### C.1.2 Water Heating Equipment

#### C.1.2.1 Storage Tank Domestic Hot Water (DHW) Heater

Temperature Cutoff Methodology (DHW heater). The voltage readings from the DHW loggers were converted into temperatures using the following equation:

$$\text{Temperature}(C) = (1/(0.001126733 + (\log(2200 * (VDC/(2.5 - VDC)))) * 0.000234594) + (0.0000000850781 * (\log(2200 * (VDC/(2.5 - VDC))))^3 + - 273.15))$$

The Temperature values were converted to Fahrenheit from Celsius and after a careful examination of the Temperature profiles converted from the logger data, a cut-point of 185 8F was established to differentiate between the on and off periods.

From the estimated on and off periods, an hourly percent runtime was calculated for each heater. For the adjustment factor analysis, these hourly usage totals will be summed for the 8760 hours following the meter installation date to yield an annual total usage for the study period. For sites that had less than a year of data, the usage was extrapolated to estimate the annual usage. It was determined that the seasonal

### C.1.2.2 Instantaneous Non Storage Domestic Hot Water (DHW) Heater

The G4 gas meter provided the total cubic feet gas consumed per year. We multiplied the total cubic feet of natural gas by 1,020 to obtain total gas consumption of the water heater during the installation period. This usage was then extrapolated based on the installation period and the removal date to get an annualized estimate of gas consumption

### C.1.3 Space Heating End Use Energy

#### C.1.3.1 Forced Air Furnace

The gas input and fan power draw was taken from nameplate data and applied to the unit runtime to determine energy consumption. By “slaving” a small relay off of the call for heating circuit we were able to precisely log the duration of a heating cycle. The relay contact change of state indicates runtimes.

The final stored data was percent time “on” during each 20 minute interval. The furnace nominal gas input rate (Btu/h) was obtained from the manufacturers’ specifications and utilized to inform the run-time data with actual gas input. The runtimes were multiplied by the input rating to estimate hourly gas consumption.

#### ***Filling in values for missing dates: Meter Data on Furnaces***

A handful of meters were collected before a full year had passed between the time of installation. For the purposes of the analysis, a full year of metered data was required in order to create an accurate comparison with the modeled usages. In light of this, weather normalization techniques were developed for the heating and cooling end uses to fill in the missing data for loggers with less than a year of recorded usage.

To calculate a year of data, a regression analysis was done based on the average daily temperature and daily kBtu. Heating Degree Days (HDD) were calculated using the reference temperature of 65 degrees F, and were used in the regression against kBtu. Daily total usage for the missing data was estimated using the equation below or similar form thereof where  $\beta_0$  and  $\beta_1$  are constants based on the regression analysis:  $\beta_0$  is the average daily baseline usage and  $\beta_1$  is the temperature response of temperature-dependant heating usage.

$$\text{Daily Total Usage}_{SITE} = \beta_0 + \beta_1 *HDD.$$

The predicted Average Daily Usages were combined with the actual Average Daily Usage to create a full year of daily usage for each site. For the meter adjustment factor estimation, these daily usages were aggregated into annual kBtu heating usages for the 365 days following the meter installation date.

### C.1.3.2 Heat Pump

There were no Heat Pumps in the meter data sample, so no methodology was developed or used.

### C.1.3.3 Hydronic Heating System

The data analysis developed a methodology to determine if hot water usage was attributed to the space heating or domestic hot water end uses.

#### ***Hydronic Separation Methodology:***

Note: Only one site was identified as having a hydronic heating system. Additionally, there was an issue with the site data that failed to pass the QC standards set for the analysis.

Subsequently, the site was dropped.

## C.2 Data Summary

The actual number of each type of system and the status and quality of the data obtained are described in the following tables. As mentioned previously, single family homes used the same metering approach for the three end uses at every site. Table C-1 below describes the number of installed loggers for each end use and the status of the data obtained.

**Table C-1: Single Family Metering Summary**

Unit Type	Installed/ Retrieved	Bad/ Missing	Used in Analysis
<b>AC</b>	142	20	122
<b>Furnace</b>	96	7	89
<b>DHW</b>	57	0	57

There were a few reasons that sites were removed from the end use analysis. A handful of loggers appeared to contain corrupt or incorrect data. A few appeared to be improperly installed or configured. Another QC measure was based on the system tracking data. If a site appeared to contain multiple units (AC or Furnace), but there were fewer loggers than systems, the entire

site had to be removed in order to ensure that the level of usage in the metered data was consistent with the estimated model usage. It should be noted that the necessity of removing a site from one of the end use analyses does not require that the site be removed from all the end uses analyses. Each end use was analyzed separately, so bad data from one end use did not affect the integrity of the other end use analyses.

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## D. Net Savings: Difference-of-Differences Calculation Methodology and Comparison Groupings

### D.1 Methodology and Equations for Computing Net Savings

The essence of the “difference-of-differences” analysis is to compare participant homes to non-participant homes’ standard construction practices. While gross savings is defined as the difference between standard (package D) and proposed modeled energy consumption, net savings is defined as the gross savings less naturally occurring savings (due to industry standard practice). If for one home,

$S_p^4$  = Participant CF-1R standard energy use (kBTU/sf-yr)

$P_p$  = Participant CF-1R proposed energy use (kBTU/sf-yr)

$S_{np}$  = Non-participant CF-1R standard energy use (kBTU/sf-yr)

$P_{np}$  = Non-participant CF-1R proposed energy use (kBTU/sf-yr)

SF = Conditioned floor area of the home

Then, the

Net Savings = (Gross savings) – (Natural savings) =  $(S_p - P_p) * SF - (S_{np} - P_{np}) * SF$ ,

And the equation can be seen to motivate the name, as the net savings is indeed a difference-of-differences.

$(S_{np} - P_{np}) * SF$  represents “the naturally occurring non-participant energy savings due to current standard building practice.” Unfortunately,  $S_{np}$  and  $P_{np}$  do not exist, since non-participant homes of the exact same size, location and other building characteristics were not constructed. To estimate them, a baseline sample of 422 residential new construction homes, inspected by KEMA, was utilized.

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<sup>4</sup> The subscript p is used to denote Participants, and np is used for Non-Participants.

The Net savings of the population of participant homes was calculated as follows:

- 1) Net savings = [savings of participant homes above standard] –  
[naturally occurring savings due to current practice]
- 2) Savings of participant homes above standard =  $[N_p * \overline{SF}_p * \overline{S}_p * \overline{CM}_p]$ , and
- 3) Estimated naturally occurring savings =  $[N_p * \overline{SF}_p * \overline{S}_p * \overline{CM}_{np}]$
- 4) So, Net Savings =  $[N_p * \overline{SF}_p * \overline{S}_p * \overline{CM}_p] - [N_p * \overline{SF}_p * \overline{S}_p * \overline{CM}_{np}]$
- 5) =  $N_p * \overline{SF}_p * \overline{S}_p * [\overline{CM}_p - \overline{CM}_{np}]$

Where:

$N_p$  = Number of participant homes

$\overline{SF}_p$  = Participant homes' average conditioned floor area =  $\frac{\sum_{i=1}^{N_p} SF_{p_i}}{N_p}$

$\overline{S}_p$  = Participant homes' weighted average Standard energy consumption =  $\frac{\sum_{i=1}^{N_p} S_{p_i} SF_{p_i}}{\sum_{i=1}^{N_p} SF_{p_i}}$

$\overline{CM}_p$ <sup>5</sup> = Participant homes' weighted average Compliance Margin =  $\frac{\sum_{i=1}^{N_p} (S_{p_i} - P_{p_i}) SF_{p_i}}{\sum_{i=1}^{N_p} S_{p_i} * SF_{p_i}}$

<sup>5</sup> Participant weighted average Compliance Margin is weighted by conditioned floor area of each home.

$$\overline{CM}_{np}{}^6 = \text{Non-participant weighted average Compliance Margin} = \frac{\sum_{i=1}^{N_{np}} (S_{np_i} - P_{np_i}) SF_{np_i}}{\sum_{i=1}^{N_{np}} S_{np_i} * SF_{np_i}} .$$

These compliance margins were computed and compared separately for each CEC climate zone. The savings from each climate zone were then aggregated for each end use.

What is the justification for equation (2)?

The Total Savings of the participant homes above standard must equal the sum of the savings of each individual home, or

$$\text{Savings of the participant homes above standard} = \sum_{i=1}^{N_p} (S_{p_i} - P_{p_i}) SF_{p_i}$$

Is this equal to equation (2)? Is,

$$N_p * \overline{SF}_p * \overline{S}_p * \overline{CM}_p = \sum_{i=1}^{N_p} (S_{p_i} - P_{p_i}) SF_{p_i} ?$$

By substitution into (2),

$$\text{Savings of participant homes above Standard} = N_p \frac{\sum_{i=1}^{N_p} SF_{p_i}}{N_p} * \frac{\sum_{i=1}^{N_p} S_{p_i} * SF_{p_i}}{\sum_{i=1}^{N_p} SF_{p_i}} * \frac{\sum_{i=1}^{N_p} (S_{p_i} - P_{p_i}) SF_{p_i}}{\sum_{i=1}^{N_p} S_{p_i} * SF_{p_i}} =$$

$$\sum_{i=1}^{N_p} (S_{p_i} - P_{p_i}) SF_{p_i} , \text{ so yes.}$$

Similarly equation (3) is derived, and the difference between the two sums in (4) is justified as the Net Savings.

<sup>6</sup> The non-participant weighted average Compliance Margin is also weighted by conditioned floor area of each home.



Comparisons for compliance margins were done CEC-to-CEC climate zone. For example, participants from CEC climate zone 2 were compared to non-participants from CEC climate zones 2. The difference in the compliance margins between the participant and the non-participant homes is the key factor driving estimated savings using the difference of differences methodology. This difference is positive for most comparison groups for heating, cooling and water heating, indicating positive savings in most climate zones.

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## **E. The RNC Interface**

### **E.1 Introduction**

This section briefly describes the development and testing of the RNC Interface. The RNC Interface was first developed in 2000, during the first year of the Statewide RNC Baseline Study. The primary purpose of the RNC Interface is to generate MICROPAS<sup>7</sup> compliance runs, which are then used to examine the compliance status for each residential building and to explore the energy conservation potential of some key energy saving technologies. Since the RNC Interface was initially developed, it has been updated and upgraded during the two subsequent RNC Baseline studies and for various other work relating to California's Title 24 Low-Rise Residential Energy Standards, the California ENERGY STAR New Homes Program, and the statewide energy savings potential in constructing more energy efficient residential buildings.

### **E.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 interpreting the on-site survey data then “writing” it to a file in the required MICROPAS input format. The RNC Interface then passes the input file to MICROPAS. Then it runs a MICROPAS simulation and stores the simulation results into a database table for further analysis. The interface stores the results in fields that correspond to the C-2R or the CF1R forms used for compliance documentation.

The interface was initially designed to batch process many sites at one time. During the first RNC Baseline Study (2000), 800 on-site surveys of low-rise residential buildings were conducted. Instead of using the MICROPAS interface to develop each input file by hand, one at a time, a decision was made to automate the process. The system that was developed became extremely useful during the last few months of the project when the focus changed to include analyzing the then upcoming 2001 Standards. Without the RNC Interface, it would have been necessary to manipulate each MICROPAS input file one at a time to run under the new version

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<sup>7</sup> MICROPAS was chosen as the compliance tool because it is the tool of choice among energy consultants for performing low-rise residential compliance analysis. Interviews with MICROPAS developers indicate that more than 75% of energy professionals use their product. Further, two subsequent studies by Itron indicate that more than 90% of energy compliance documentation was completed using MICROPAS.

of MICROPAS. Similarly, over the last four years requests have been made for new types of analysis that would have been either impossible or extremely costly to conduct without the many capabilities of the interface. Specifically, 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 (1995 Stds.), 5.1 (1998 Stds.), 6.0 & 6.5 (2001 Stds.) or 7.0 & 7.3 (2005 Stds.)
- Extract the MICROPAS compliance results, and
- Provide a platform for the technical potential analysis, and
- Conduct several other “what if” analyses.

### **E.2.1 MICROPAS Version 4.5, 5.1, 6.0, 6.5, 7.0, and 7.3**

It was recognized early on that the RNC Interface needed to be able to generate results for multiple versions of MICROPAS. At first it was designed to use 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.<sup>8</sup> Therefore, the capability to generate results for a third version of MICROPAS using the 2001 standards, MICROPAS6 (v6.0 & v6.5), was added to the interface. These standards were implemented in January 2002 for all low-rise residential homes and superseded the 1998 Standards. Then, in order to evaluate the 2005 Standards, adopted in November of 2005, the RNC Interface was again upgraded to generate results using MICROPAS6 (v6.58) and MICROPAS7 (v7.0 & v7.3). MICROPAS7, version 7.3 is the version used to generate the 2005 results for this study. The 2001 Standards results were generated using MICROPAS6, version 6.5.

### **E.2.2 Developing MICROPAS Inputs from the On-Site Survey Data**

The 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

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<sup>8</sup> 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.

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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 (2001) and Project Year #3 (2003) to collect additional information in order to limit the number of defaults required. 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 survey data to MICROPAS inputs can be characterized in the following three categories.

- **Direct Inputs.** These values, types, etc., are mapped directly from the 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 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.

*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.

### E.2.3 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, 6, 6.5, 7.0 or 7.3),

- Select whether to run a Cardinal,<sup>9</sup>
- Select the weather data set to use – FullYear or ReducedYear,<sup>10</sup> and
- Specify the source input database (this feature was used for the testing phase and during the Statewide Multifamily Study to read in building department C-2R data).

### E.3 Testing the RNC Interface

Considerable effort was made in 2000 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. A testing procedure was developed 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 2000 on-site database.<sup>11</sup> These data then were passed through the RNC Interface. The error band used in 2000 was calculated by comparing the compliance margins from these runs to the compliance margins from the C-2R forms.

As noted above, the Interface has been updated with each change to Title 24 and each new version of MICROPAS.

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<sup>9</sup> 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.

<sup>10</sup> “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*.

<sup>11</sup> For details on the testing procedure, please see the RNC 2003 Baseline Study (Itron, Inc. 2004. *Residential New Construction baseline Study of Building Characteristics Homes Built after 2001 Codes*, prepared for PG&E, available from [www.calmac.org](http://www.calmac.org)).

### F. Baseline Study Results

The results of the Baseline Study informed the Residential New Construction Evaluation, the Codes & Standards Evaluation and the Residential Market Effects Study (described in a separate report). No single, comprehensive document reporting all the baseline study results is planned. Instead, the analysis and results are described with the evaluation to which they were applied, located in the various volumes of this report. The Residential Market Effects Study report is a separate report

([http://www.energydataweb.com/cpucFiles/topics/7/RNCMarketEffectsPhaseI\\_FinalReportt\\_05212009.pdf](http://www.energydataweb.com/cpucFiles/topics/7/RNCMarketEffectsPhaseI_FinalReportt_05212009.pdf)). The following paragraphs describe the various applications of the baseline data and where the analyses and results can be found. This appendix goes on to report additional results not reported elsewhere.

**Residential Market Effects Study.** In January 2009, the Study Team conducted an initial analysis of the building characteristics found during the on-site surveys conducted during Phase I of the Baseline Study in preparation for the RNC Market Effects Report.<sup>12</sup> The report contains information on the 422 completed homes. The purpose of this analysis for the RNC Market Effects report was to summarize historic building characteristics over the last ten years using data from on-sites conducted under the three previous Residential New Construction Baseline Studies<sup>13</sup> and the current 2008 Residential New Construction Baseline Study.

Phase II of the Residential New Construction Market Effects Study will use the baseline of non-program homes to estimate the gross energy and demand savings associated with observed above-code practices (compared to code) and the savings associated with observed homes just meeting code (compared to the average noncompliant home) and apply the savings to the number of non-program homes. These will provide estimates of gross energy and demand savings for two of the three primary ways in which IOU programs can lead to the ultimate goal of reduced energy use, demand, and emissions, i.e., market effects: 1) by facilitating construction that is more efficient than required by the current code, and 2) by improving compliance with existing code (a third way is by contributing to code upgrades). Delphi panels of Title 24

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<sup>12</sup> KEMA, Nexus Market Research, Inc., Summit Blue Consulting, Itron, Inc., The Cadmus Group, Inc.. 2009. Phase I Report: Residential New Construction (Single Family Home) Market Effects Study. Available at <http://www.energydataweb.com/cpuc/default.aspx>

<sup>13</sup> Residential New Construction Study (RER 2001) for details of the sample design.

Consultants and building industry experts will be used to estimate the proportion of gross savings attributable to the IOU programs (i.e., net savings). Phase II is expected to be completed in Spring of 2010.

**Codes & Standards.** The RNC baseline study carried out onsite surveys of program participant and non participant homes. The site survey information of 194 non-participant samples was provided to C&S to be used in comparative energy software modeling to derive compliance rates. A subset of this population was used to compare Title 24 compliance as-permitted vs. as-built. The sample of 194 was also part of a lighting survey which was used to derive compliance rates for the residential hardwire lighting building standard.

Detailed information on how the baseline study results were used in the C&S evaluation is presented in the NCCS report Vol III, section 5.2.2.

**Residential New Construction Evaluation.** A subset of baseline study on-site homes, in addition to the standard on-site data collection, had one or more major end-use (air conditioning, heating or water heating) metered. The energy use for these homes was also modeled using software typically used to determine compliance with California's Title 24 building code. The RNC evaluation used this information to estimate the ratio between metered energy use and modeled energy use. These ratios (calculated by climate region) were used to adjust the modeled energy that was available for all participant homes to more accurately reflect actual usage patterns.

Detailed information on how the baseline study data were analyzed and used for the RNC evaluation is reported in the NCCS report, Vol I, sections 3.1 (methodology) and 3.4.3 (results).

This appendix presents additional information of interest that was not included in the other analyses. The information is similar to that included in the Phase 1 RNC Market Effects Report<sup>14</sup>, but has been updated to include all 422 on-sites completed as part of the Baseline Study.

- Glazing

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<sup>14</sup> Refer to the *Residential New Construction Market Effects Study - Phase I Draft Report* (March 2009) for background information on the detailed methodology and the building characteristics listed relate to the Residential Title 24 Standards.

- The average percent of glazing in new homes fell from 17% in homes built under the 1995 standards to 14% in homes built under the 2005 standards
  - The percentage of glass that was two-paned vinyl and low-e increased from 5% in homes built under the 1995 standards to 95% in homes built under the 2005 standards
- Space heating
  - The average furnace efficiency increased from 80% in homes built under the 1995 standards to 83% in homes built under the 2005 standards
  - The percentage of 90%+ AFUE furnaces increased from 2% in homes built under the 1995 standards to 19% in homes built under the 2005 standards
- Space cooling
  - The average central air conditioner SEER level increased from 10.5 SEER in homes built under the 1995 standards to 13.3 SEER in homes built under the 2005 standards; 13 SEER became the federal minimum standard in January of 2006
  - The percentage of central air conditioners with SEER levels greater than 13 increased from 0% in homes built under the 1995 standards to 34% in homes built under the 2005 standards
- Water heating
  - The percentage of water heaters that were instantaneous increased from 0% in homes built under the 1995 standards to 24% in homes built under the 2005 standards
- Ceiling insulation
  - The average R-value of ceiling insulation increased from 29.1 in homes built under the 1995 standards to 33.1 in homes built under the 2005 standards
- Radiant barriers
  - The percentage of homes with radiant barriers increased from 2% of homes built under the 1995 standards to 16% of homes built under the 2005 standards
- Duct leakage
  - The average duct leakage decreased from 13.5% in homes built under the 1995 standards to 11.4% of homes built under the 2005 standards



### F.1 Newly Built Single Family Homes over Time

Figure F-1 presents the total number of single family homes built in California by year since 1998.<sup>15</sup>

Table F-1 shows the number of homes built under the ENERGY STAR Homes program for the same time period.<sup>16</sup> Prior to 2004, the CA IOUs worked closely with the EPA to develop California ENERGY STAR Homes specifications. The CA IOU's 2004-2005 RNC Programs even incorporated ENERGY STAR in the name of the statewide program: ENERGY STAR New Homes Program (CESNHP). As can be seen in the table below, there is significant overlap between the ENERGY STAR New Homes and the IOU Program Participants.<sup>17</sup>

When reviewing the table, it is important to point out that there are inherent lag times in the data presented. The CIRB represents permit data, which for single family homes can have a lag of 6 months to 2 years before the home is completed; typically a 6 month lag is assumed. The Whole House Participants row has two different lags represented. Between 2002 and 2005, the numbers represent the number of participant homes that were committed under the Programs, not actually constructed during that time frame. However, for the 2006-2008 Program Cycle, the CPUC required the IOUs to only report units that were completed. Therefore, there is no lag for the 2006 and 2007 Whole House Participants.

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<sup>15</sup> Construction Industry Research Board (CIRB).

<sup>16</sup> Participant data was collected from the following sources:

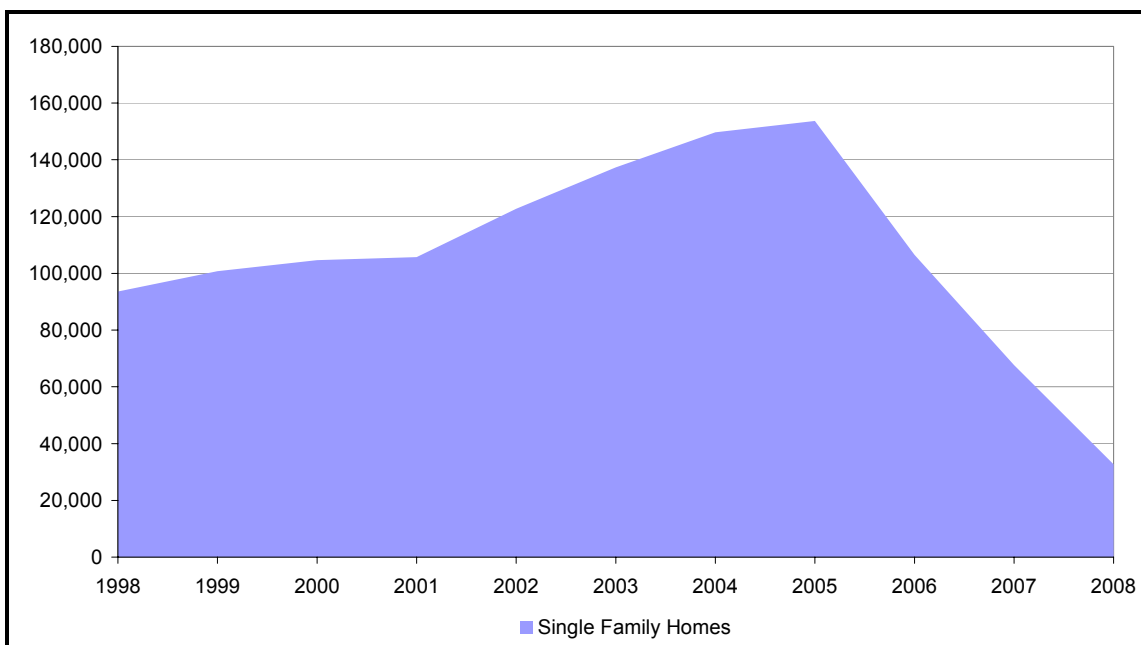
*EVALUATION, MEASUREMENT AND VERIFICATION OF THE 2002 & 2003 CALIFORNIA STATEWIDE ENERGY STAR® NEW HOMES PROGRAM.* June 2006. RLW Analytics.

*EVALUATION, MEASUREMENT, AND VERIFICATION OF THE 2004 & 2005 CALIFORNIA STATEWIDE ENERGY STAR® NEW HOMES PROGRAM.* July 2007. RLW Analytics.

California IOU program tracking data for 2006-2007.

<sup>17</sup> *RAISING THE BAR: THE EFFECT OF THE CALIFORNIA 2005 ENERGY EFFICIENCY STANDARDS ON RESIDENTIAL NEW CONSTRUCTION PROGRAM DESIGN – 2006 AESP.* Harcharik, Wolf, Blanke.

**Figure F-1: Single Family Homes Built in California since 1998**



**Table F-1: California Single Family Home Construction and Participation**

	<b>ENERGY STAR Homes</b>	<b>Whole House Participants</b>	<b>% of New Home Market</b>	<b>All New Homes IOU Territories</b>	<b>All SF New Homes</b>
1998	38			93,585	94,236
1999	612			100,800	101,615
2000	567			104,673	105,546
2001	1,563			105,727	106,498
2002	6,450	1,043	0.8%	122,741	123,815
2003	15,291	5,807	4.2%	137,407	138,706
2004	14,455	13,461	9.0%	149,676	151,332
2005	18,956	17,652	11.5%	153,667	155,222
2006**	18,534	419	0.4%	106,479	107,939
2007**	6,365	1,226	1.8%	67,645	68,348
2008**	5,381	3,947	12.1%	32,664	33,204

\* Data represents new permits (Construction Industry Research Board (CIRB)).

\*\* For 2006-2008 PY, only completed units are reported. In prior Program years it was the practice to include completed and "committed" units in the annual reports.

## F.2 Fenestration Baseline Results

### Percent Glazing

Percent glazing refers to the total glazing area of a home expressed as a percent of the total conditioned floor area. Average percent glazing values are presented in Table F-2 by region<sup>18</sup>. As can be seen, the average percentage of glazing has decreased in all regions, for homes built under the 2001 and again for homes built under the 2005 Standards. (A lower percentage glazing allows less solar heat gains and less heat loss and is therefore more compliant with the Standards.)

**Table F-2: Percent Glazing**

Analysis Parameter Description	Statewide	Region 1	Region 2	Region 3	Region 4	Region 5
<b>Percentage of Higher Performance Glazing</b>						
Homes Built under 1995 Standards	64%	62%	65%	96%	44%	39%
Homes Built under 1998 Standards	58%	63%	87%	73%	42%	34%
Homes Built under 2001 Standards	68%	50%	85%	84%	59%	68%
Homes Built under 2005 Standards	58%	63%	70%	64%	48%	69%
<b>Average % Glazing</b>						
Homes Built under 1995 Standards	17.0%	18.0%	19.0%	16.0%	17.0%	17.0%
Homes Built under 1998 Standards	17.4%	18.0%	16.5%	18.0%	16.8%	18.5%
Homes Built under 2001 Standards	15.7%	17.6%	16.3%	15.6%	15.4%	15.0%
Homes Built under 2005 Standards	14.3%	16.1%	15.7%	14.0%	13.6%	14.1%

<sup>18</sup> All of the housing characteristics are broken into 5 climate “regions” instead of 16 CEC climate zones. The climate zones were collapsed in to regions because they share similar requirements in Title 24 prescriptive path compliance, and because this allows us to keep the sample sizes large enough. Using this approach, climate zones were aggregated as follows:

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

### Window Types

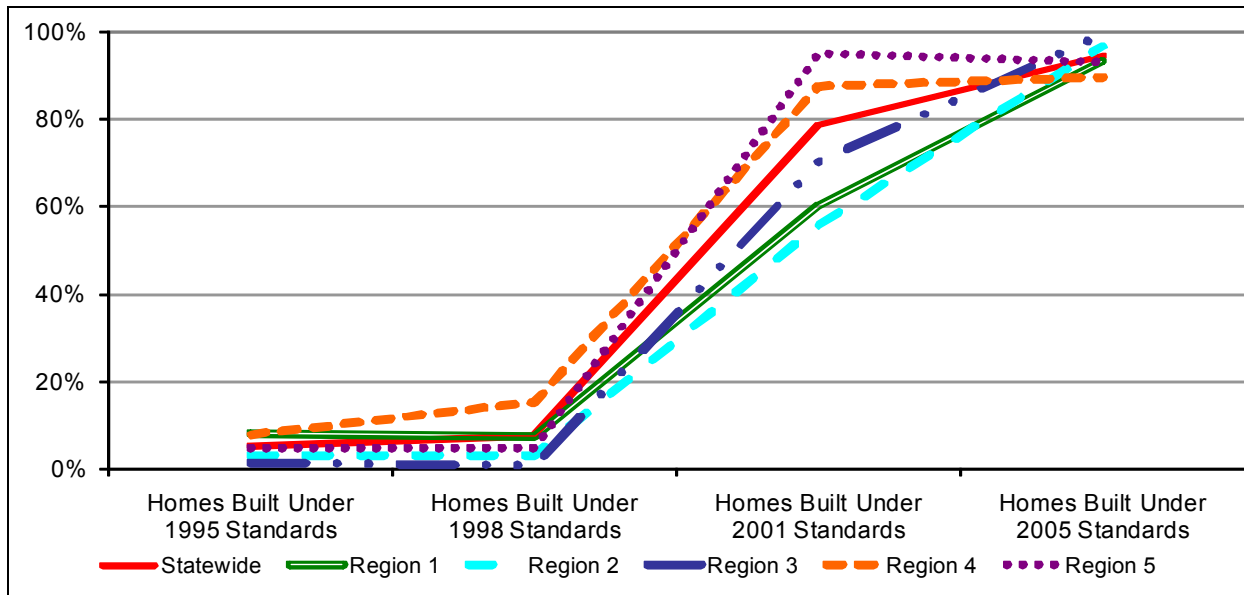
Table F-3 presents the prevalence of vinyl framed, dual-paned, clear and Low-E glass windows for single family homes built under the four sets of Standards. Although there are other types of windows, only these two types are presented because together they make up the vast majority of the windows installed in residential new constructions, and because they most clearly demonstrate the shift from less efficient to more efficient (Low-E) fenestration practices.

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

Window Types (# of panes, frame type, glass type)	State- wide	Region 1	Region 2	Region 3	Region 4	Region 5
<b>2-paned Vinyl, Clear Glass</b>						
Homes Built under 1995 Standards	88%	86%	91%	91%	86%	82%
Homes Built under 1998 Standards	75%	86%	99%	97%	48%	97%
Homes Built under 2001 Standards	14%	28%	28%	25%	6%	3%
Homes Built under 2005 Standards	5%	7%	2%	1%	10%	5%
<b>2-paned Vinyl, Low-E</b>						
Homes Built under 1995 Standards	5%	8%	3%	1%	8%	5%
Homes Built under 1998 Standards	8%	7%	-	1%	15%	-
Homes Built under 2001 Standards	79%	60%	56%	70%	87%	95%
Homes Built under 2005 Standards	95%	93%	98%	99%	90%	95%

The percentage of homes built with vinyl framed, dual-paned, clear glass windows decreased dramatically for home built under the 2001 Standards, and then fell again under the 2005 Standards, compared to homes built under the two previous Standards. Coinciding with the decrease in the vinyl framed, dual-paned, clear glass windows is an increase in the percentage of vinyl framed, dual-paned windows with Low-E glass. Only 5% of homes statewide built under the 2005 Standards have clear glass windows, whereas 95% of homes in California built under the 2005 Standards had these higher efficiency windows. The increase in Low-E windows is illustrated in Figure F-2.

**Figure F-2: Percentage of SF Homes with 2-paned Vinyl, Low-E Windows**



### F.3 Space Heating Systems Baseline Results

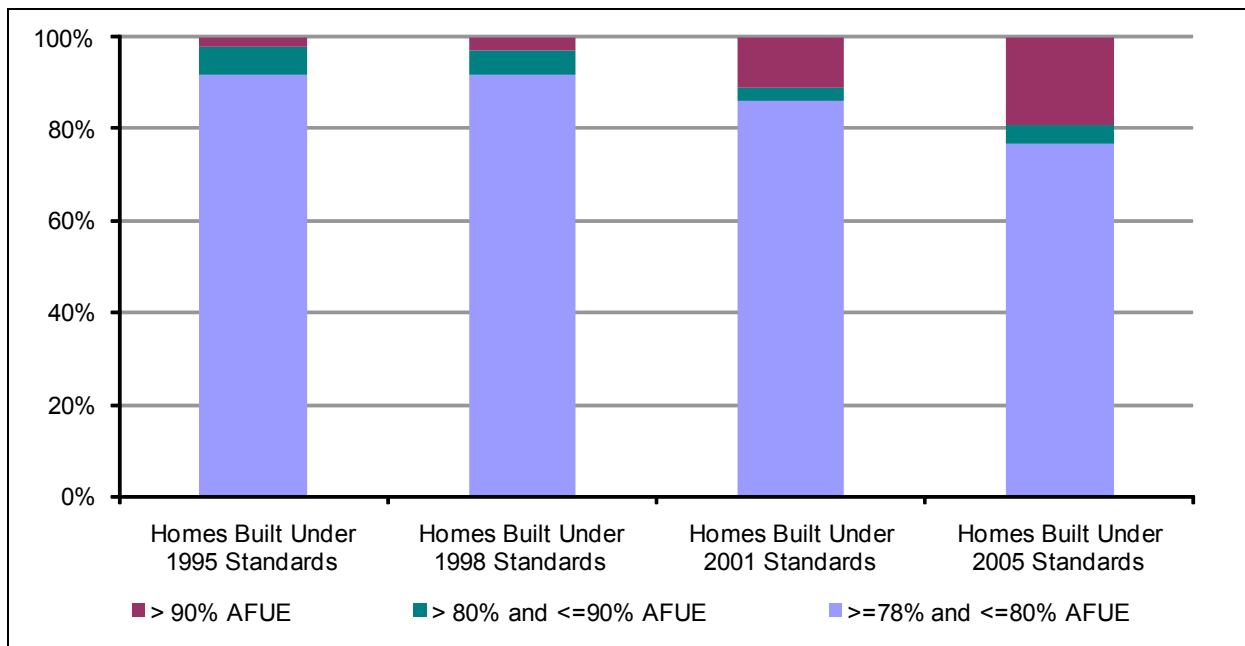
Table F-4 presents a summary of gas space heating system efficiencies for detached single family homes. The average AFUE has increased slightly for homes in every region.

**Table F-4: Central Gas Space Heating System Efficiency**

Analysis Parameter Description	Statewide	Region 1	Region 2	Region 3	Region 4	Region 5
<b>Average Efficiency (AFUE)</b>						
Homes Built under 1995 Standards	80%	80%	80%	80%	81%	80%
Homes Built under 1998 Standards	81%	81%	80%	80%	81%	80%
Homes Built under 2001 Standards	81%	85%	82%	80%	81%	81%
Homes Built under 2005 Standards	83%	85%	82%	82%	83%	83%

Figure F-3 presents the distribution of AFUEs under the four Standards for the entire state of California. The portion of space heating with the lowest level of efficiency has fallen, while the highest level of efficiency has increased.

**Figure F-3: AFUE Distribution – Average Statewide**



## F.4 Space Cooling System Baseline Results

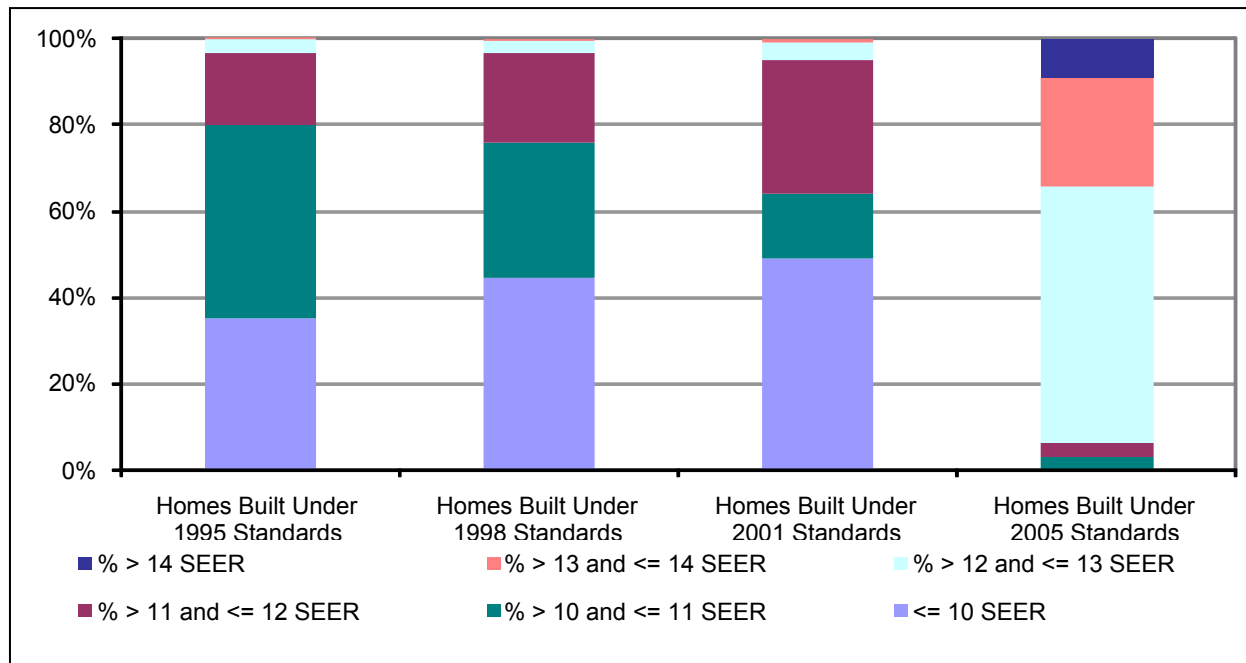
Results for cooling system efficiencies are presented in Table F-5 for detached single family homes. As can be seen, the average SEER increased significantly for homes built under the 2005 Standards, and all regional averages are now greater than 13 SEER. This is due to the Federal regulation stating that all air conditioning units manufactured after January 2006 must have a SEER of at least 13.

**Table F-5: Average SEER**

Analysis Parameter Description	Statewide	Region 1	Region 2	Region 3	Region 4	Region 5
<b>Average Efficiency (SEER)</b>						
Homes Built under 1995 Standards	10.5	10.4	10.2	10.2	11.0	10.9
Homes Built under 1998 Standards	10.6	10.5	10.2	10.2	11.0	10.5
Homes Built under 2001 Standards	10.9	10.5	10.3	10.5	10.9	11.5
Homes Built under 2005 Standards	13.3	13.5	13.3	13.1	13.4	13.2

Figure F-4 illustrates the distribution of efficiency levels for air conditioning units statewide. When comparing the distribution to the minimum SEER levels available at the time, approximately half of the homes built under any given Standard are installing the minimum allowable SEER level.

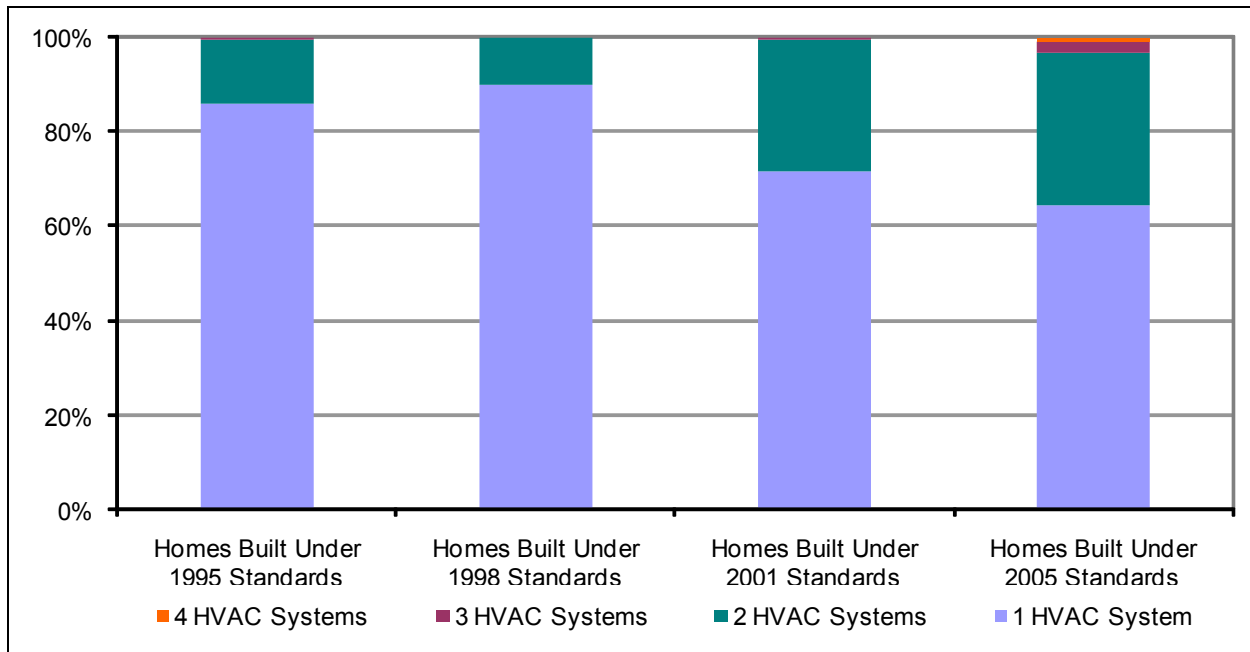
**Figure F-4: SEER Distribution – Average Statewide**



## F.5 Multiple HVAC Systems and Thermostat Types Baseline Results

A summary of the percent of homes with multiple units is presented in Figure F-5 for detached single family homes. The number of homes with multiple HVAC systems has increased between homes built under the 2001 Standards and the 2005 Standards.

**Figure F-5: Multiple HVAC System – Statewide Average**



## F.6 Water Heating Baseline Results

Figure F-6 presents the saturation of instantaneous water heaters (both gas and electric) in new homes built under the four sets of Standards. The percentage of homes with instantaneous water heaters increased greatly under the 2005 Standards. Many of the homes with instantaneous water heaters also had storage water heaters.



**Figure F-6: Percentage of Instantaneous Water Heaters (Gas and Electric)**

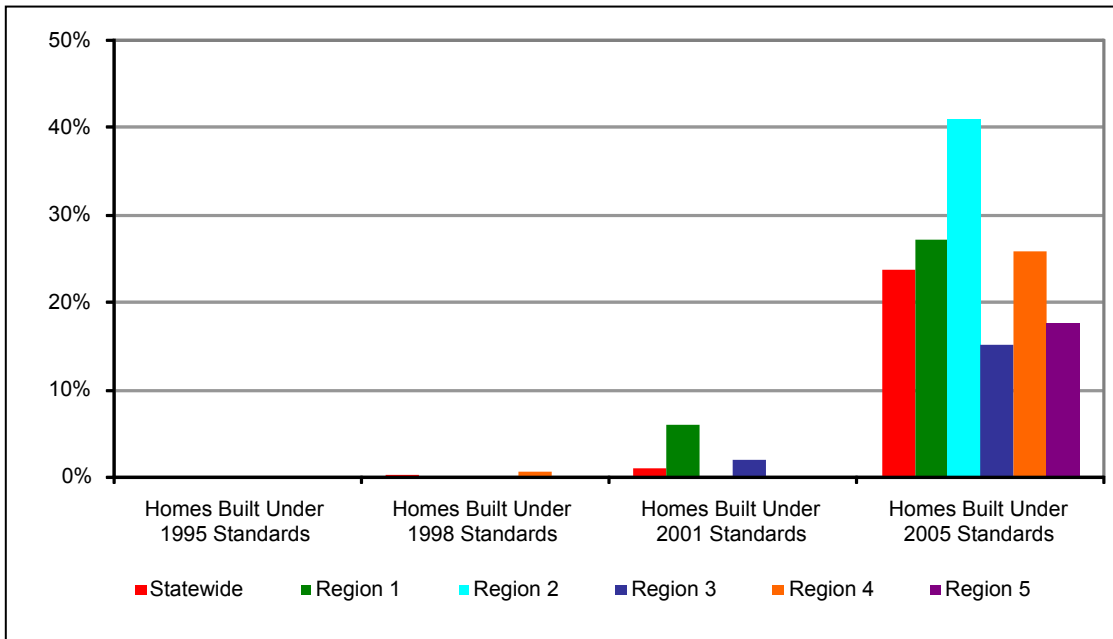
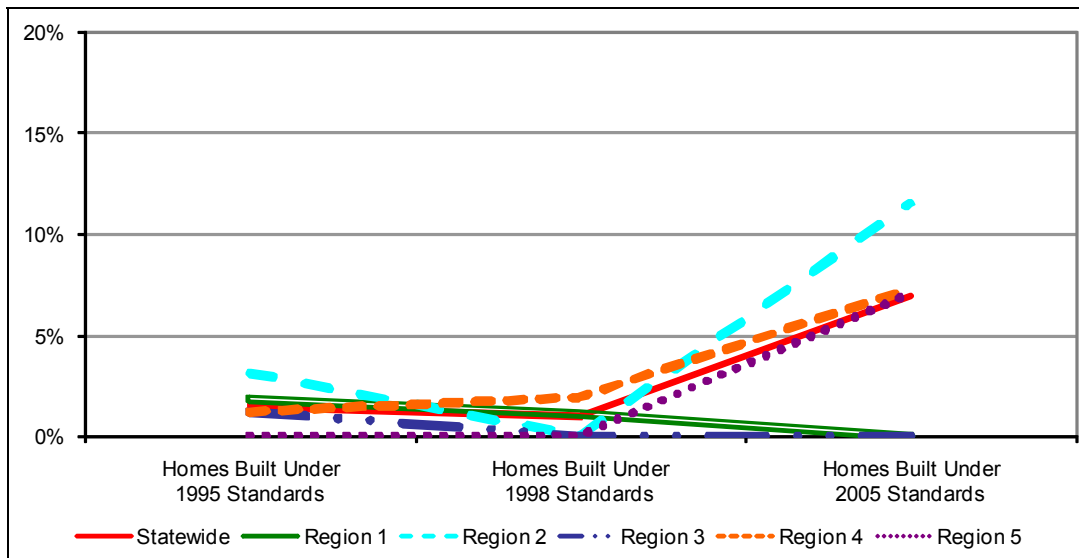


Figure F-7 presents the percentage of homes with multiple water heating units, which increased for homes built under the 2005 Standards. Approximately two-thirds of the homes with more than one water heater have instantaneous water heaters. Region 2 has the highest percentage of homes with multiple water heating units.

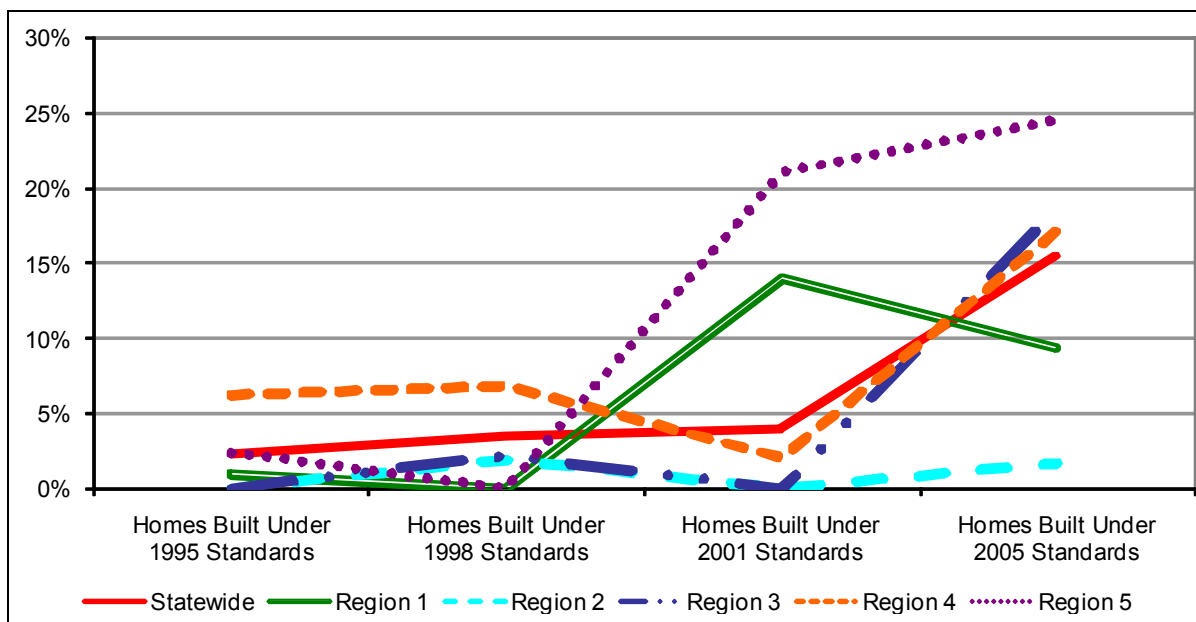
**Figure F-7: Homes with More than One Water-Heating Unit**



## Radiant Barriers

Figure F-8 presents the percentage of homes with radiant barriers for homes built under the four sets of Standards. For homes built under the 2005 Standards, Region 5 had the greatest percentage of homes with radiant barriers, with radiant barriers being present in one-fourth of the homes. Statewide, 16% of home built under the 2005 Standards has radiant barriers.

**Figure F-8: Percentage of Homes with Radiant Barriers**



## F.7 Percent Duct Leakage Baseline Results

Duct blaster tests to determine duct leakage rates were conducted for a sub-sample of the sites surveyed for homes built under the 1995, 1998 and 2005 Standards. They were not performed on homes built under the 2001 Standards. 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. The percent of duct leakage decreased between homes built under the 1998 Standards and the 2005 Standards, in all regions except for region 5.

Test results are contained in Table F-6, which presents the average percent duct leakage by region. The percent duct leakage decreased statewide and in most regions between the homes built under the 1998 and 2005 Standards. Of the homes duct tested in the most recent round of on-sites, one-fifth had leakage of 6% or less.

**Table F-6: Average Percent Duct Leakage**

Analysis Parameter Description	State-wide	Region 1	Region 2	Region 3	Region 4	Region 5
<b>Homes Built under 1995 Standards</b>						
Number of Sites	72	16	10	19	20	7
Average % Duct Leakage (valid tests)	13.5%	19.9%	16.6%	11.7%	11.4%	19.3%
<b>Homes Built under 1998 Standards</b>						
Number of Sites	70	14	12	17	22	5
Average % Duct Leakage (valid tests)	13.3%	15.4%	12.4%	12.9%	13.7%	8.9%
<b>Homes Built under 2005 Standards</b>						
Number of Sites	132	8	24	47	32	21
Average % Duct Leakage (valid tests)	11.4%	9.6%	11.8%	12.5%	11.1%	10.5%

**Table F-7: Percent of Homes by Percent Duct Leakage**

Analysis Parameter Description	State-wide	Region 1	Region 2	Region 3	Region 4	Region 5
<b>Homes Built under 2005 Standards</b>						
6% Duct Leakage or Less	20%	25%	25%	21%	9%	29%
Greater than 6% to 12%	45%	38%	46%	36%	56%	52%
Greater than 12% Duct Leakage	34%	38%	29%	43%	34%	19%

## G. Verification-Guided Programs

### G.1 California Multifamily New Homes – Net to Gross Results

Table G-1 displays the question responses and calculated values that feed into the NTG estimate for each performance track project.

**Table G-1: Performance Track Net to Gross Values for Each Project**

(Performance Track projects)

Project	Question C5c—likelihood to have built to program requirements in absence of program	Initial Free-Rider Allocation	Question C16—level of agreement that program was critical to the decision to build to program requirements	Final Free-rider Allocation	Question C3—estimated percent above code of the original plans	Question C7—made changes due to HMG’s review	Question C8b—percent change due to HMG review	NTG
1	0	Non	10	Non	-5%	Yes	20%	1.33
2	0	Non	10	Non	-5%	Yes	20%	1.33
3	10	Pure	5	Partial	-12%	Yes	32%	2.13
4	4	Partial	8	Partial	12%	Yes	19%	1.27
5	3	Partial	7	Partial	10%	Yes	6%	0.82
6	9	Pure	5	Partial	20%	Yes	8%	0.65
7	5	Partial	7	Partial	17%	No		0.60
8	4	Partial	5	Partial	20%	No		0.55
9	4	Partial	4	Partial	36%	No		0.50
10	8	Pure	8	Partial	15%	DK		0.50
11	10	Pure	3	Partial	20%	Yes	5%	0.43
12	8	Pure	3	Partial	15%	Yes	0%	0.25
13	10	Pure	0	Pure	20%	No		0.00
14	8	Pure	0	Pure	18%	No		0.00
15	9	Pure	0	Pure	35%	No		0.00
16	10	Pure	2	Pure	15%	No		0.00
17	10	Pure	DK	Pure	23%	No		0.00

Table G-2 displays the question responses and calculated values that feed into the NTG estimate for each appliance-track project.

**Table G-2: Appliance Track Net-to-Gross Values for Each Project**

(Appliance Track projects)

Appliance	Question FR1 – Status of plans when learned of program	Question FR3 – Made changes to plans in order to meet program requirements	Question FR4 – likelihood of purchasing same efficiency level of appliances without program	Question FR5 - likelihood of purchasing same quantity of efficient appliances without program	Initial Free-Rider Allocation	Question FR6 – Agreement that the program was a critical factor in decision	Question FR7 – Agreement that would have paid full cost without program	Question FR8 – Agreement that the program was not necessary for purchase	Final Free-Rider Allocation	NTG
Dishwasher	4	No	0	0	Pure	5	0	0	Partial	0.90
Dishwasher	4	Yes	2	0	Non	3	3	3	Partial	0.78
Refrigerator	4	Yes	2	0	Non	3	3	3	Partial	0.78
Clothes Washer	3	Yes	6	10	Partial	3	4	5	Partial	0.44
Dishwasher	2	No	6	10	Partial	3	6	4	Partial	0.42
Refrigerator	2	No	6	10	Partial	3	6	4	Partial	0.42
Refrigerator	1	No	7	10	Partial	2	8	3	Partial	0.40
Dishwasher	3	No	10	2	Partial	7	8	4	Partial	0.38
Dishwasher	3	No	8	10	Pure	3	5	7	Partial	0.34
Refrigerator	3	Yes	8	8	Pure	0	8	9	Partial	0.34
Refrigerator	3	No	8	10	Pure	3	5	7	Partial	0.34
Refrigerator	2	No	10	10	Pure	5	5	5	Partial	0.30
Dishwasher	4	No	8	10	Pure	6	7	7	Partial	0.24
Dishwasher	4	No	8	8	Pure	5	10	7	Partial	0.24
Refrigerator	4	No	8	8	Pure	5	10	7	Partial	0.24
Refrigerator	4	No	8	10	Pure	6	7	7	Partial	0.24
Refrigerator	3	No	10	10	Pure	8	3	8	Partial	0.22
Dishwasher	3	No	10	10	Pure	5	8	8	Partial	0.18
Dishwasher	1	No	10	10	Pure	3	10	10	Partial	0.14
Clothes Washer	4	No	10	10	Pure	10	10	10	Pure	0.00
Dishwasher	4	No	10	10	Pure	10	10	10	Pure	0.00
Dishwasher	4	No	10	10	Pure	10	10	10	Pure	0.00
Lighting	4	No	10	10	Pure	10	10	10	Pure	0.00
Refrigerator	3	No	10	10	Pure	10	10	10	Pure	0.00
Refrigerator	4	No	10	10	Pure	10	10	10	Pure	0.00

(Appliance Track projects)

Appliance	Question FR1 – Status of plans when learned of program	Question FR3 – Made changes to plans in order to meet program requirements	Question FR4 – likelihood of purchasing same efficiency level of appliances without program	Question FR5 - likelihood of purchasing same quantity of efficient appliances without program	Initial Free-Rider Allocation	Question FR6 – Agreement that the program was a critical factor in decision	Question FR7 – Agreement that would have paid full cost without program	Question FR8 – Agreement that the program was not necessary for purchase	Final Free-Rider Allocation	NTG
Refrigerator	3	No	10	10	Pure	10	10	10	Pure	0.00
Refrigerator	3	No	10	10	Pure	5	9	10	Pure	0.00

**H. California Multifamily New Homes Net-to-Gross  
Interview Guide**



## Appendices

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### CMFNC Participant Interview Guide

Date \_\_\_\_\_

Interviewer \_\_\_\_\_

Name \_\_\_\_\_

Organization \_\_\_\_\_

Title \_\_\_\_\_

Phone \_\_\_\_\_

Email \_\_\_\_\_

**Program Track:** 1. Performance    2. Appliance    3. Performance + Appliance

My name is \_\_\_\_\_ calling from Nexus Market Research on behalf of the California Public Utilities Commission. I'm calling to discuss the \_\_\_\_\_ project, which was part of the California Multifamily New Construction program (CMFNC) operated by Heschong-Mahone Group (HMG).

You are listed as the primary contact person for this project—is that correct? [IF NO, ARRANGE TO INTERVIEW THE PROPER PERSON.]

Were you responsible for recommending that this project participate in the CMFNC program? [IF NO, GET CONTACT INFORMATION FOR THE CORRECT PERSON]

Were you responsible for developing the building plans? [IF NO, GET CONTACT INFORMATION FOR THE CORRECT PERSON]

Were you responsible for modeling the Title 24 calculations? [IF NO, GET CONTACT INFORMATION FOR THE CORRECT PERSON]

Did you work with HMG to ensure that the project met program requirements? [IF NO, GET CONTACT INFORMATION FOR THE CORRECT PERSON]

[Ideally, we would find the single person who is responsible for all the above areas. If not, then the person responsible for recommending participation should be able to answer all of the survey except the Code NTG section. The Code NTG section should be completed by the person who was responsible for the Title-24 modeling and worked with HMG; this person is likely the Title-24 consultant.]

I am part of the evaluation team, and our job is to determine how people involved in the program think it is operating, and to what extent the program influenced the efficiency of your project.





## Appendices

Please be aware that the information you provide will be held completely confidential. The interview will take about 20 minutes.

### PROJECT BACKGROUND

PB1. What were/are your roles and responsibilities with the \_\_\_\_\_ project?

PB2. Can you confirm some basic information about the \_\_\_\_\_ project?

1. Town or city:
2. Number of buildings:
3. Number of housing units:
4. Approximate size in square feet of all units:
5. Type of housing units – Apartments, condos, other:
6. Affordable/market rate/senior/special needs:
7. Anything unique about the buildings?

PB3. [IF APPLIANCE TRACK] According to program records, the \_\_\_\_\_ project received the following appliance and/or lighting incentives. Can you confirm that this information is correct?

Appliance Type	Number of Units	Total \$ Incentive

PB4. [IF PERFORMANCE TRACK] According to program records, the \_\_\_\_\_ project received the following performance incentives. Can you confirm that this information is correct?

# HSG UNITS \_\_\_\_\_; TOTAL \$ INCENTIVE \_\_\_\_\_

HERS RATER INCENTIVE, TOTAL \$ \_\_\_\_\_

ENERGY CONSULTANT INCENTIVE, TOTAL \$ \_\_\_\_\_

PB5. What stage of participation in the CMFNC Program has been completed to date? (i.e., installed measures, received incentive payments, etc.)

PB6. What stages in the design and construction process have been completed to date? (i.e., building is under construction, completed construction, occupied, etc)

PB7. How many multifamily new construction projects in California have you been involved in since the \_\_\_\_\_ project?

ENTER #:

-98. Don't Know

-99. Refused

PB8. Have any of these projects participated in the CMFNC program? Other energy efficiency programs? Which programs?

### **AWARENESS/PARTICIPATION**

AP1. When did you first learn about the CMFNC Program?

AP2. Did you learn about the program before or after you developed the building plans?

1. Before

2. After

-98. Don't Know

-99. Refused

AP3. How did you first learn about the CMFNC Program? Where else did you get information about the program?

AP4. What aspects of the program were most important in your decision to participate?

AP5. Were there any aspects of the program that caused you concern? What helped you overcome your concerns enough to participate?

AP6. What benefits did you receive from participating in the program?

### **SATISFACTION**

S1. [IF APPLIANCE TRACK] How satisfied were you with the types of energy-efficient appliances that were covered by the program?

- a. Extremely dissatisfied
- b. Dissatisfied
- c. Neither satisfied nor dissatisfied
- d. Satisfied
- e. Extremely satisfied

S2. [IF APPLIANCE TRACK] Why do you say that?

S3. [IF APPLIANCE TRACK] How satisfied were you with the amounts of the incentives for each of the following energy-efficient appliances and/or lighting? (READ ONLY APPLIANCE TYPES CONFIRMED IN PB3)

	DW	CW	RF	CD	Lighting
a. Extremely dissatisfied					
b. Dissatisfied					
c. Neither satisfied nor dissatisfied					
d. Satisfied					
e. Extremely satisfied					

S4. [IF APPLIANCE TRACK] Why do you say that? {IF LEVELS OF SATISFACTION ARE DIFFERENT FOR DIFFERENT APPLIANCES, ASK ABOUT INDIVIDUAL LEVELS}

S5. [IF PERFORMANCE TRACK] What type of design/technical assistance did the program provide to your project?

S6. [IF PERFORMANCE TRACK] How satisfied were you with the design/technical assistance provided through the program?

- a. Extremely dissatisfied
- b. Dissatisfied
- c. Neither satisfied nor dissatisfied
- d. Satisfied
- e. Extremely satisfied

S7. [IF PERFORMANCE TRACK] Why do you say that?

S8. Taking everything into consideration, how satisfied are you overall with the CMFNC Program?

- a. Extremely dissatisfied
- b. Dissatisfied
- c. Neither satisfied nor dissatisfied
- d. Satisfied
- e. Extremely satisfied

S9. Why do you say that?

### APPLIANCE FREERIDERSHIP – FOR PROJECTS WITH APPLIANCE INCENTIVES

[PRODUCT TYPE]	[MEASURE]	Program Criteria	Energy Efficiency Criteria	[ASSISTANCE]
Dishwasher (Fed Std EF=0.46)	ENERGY STAR dishwasher	CEE Tier 1 CEE Tier 2	EF>=0.65 EF>=0.68	\$30/unit \$50/unit
Clothes washer (Fed Std MEF=1.26)	ENERGY STAR clothes washer	CEE Tier 2 CEE Tier 3	MEF >= 2.0, WF<= 6.0 MEF >= 2.2, WF<= 4.5	\$35/unit \$75/unit
Refrigerator	ENERGY STAR refrigerator	ENERGY STAR	Exceed Fed Std by 20%	\$50/unit
Clothes dryer	Natural Gas clothes dryer	Include moisture sensor		\$50/unit
Hard-wired interior light fixture w/control	High efficacy hard-wired interior light fixture w/control	Exceed T24 requirements		\$10/fixture

[Randomly select up to two appliances for this section. We will monitor completed interviews to ensure that all appliances are reasonably represented]

I would like to ask you some questions about the **[APPLIANCE #1]** and **[APPLIANCE #2]** you installed through the program.

#### **APPLIANCE #1**

FR1. At the time that you first heard about the **[assistance]** from the program for **[measure]**, had you...? **{READ LIST}**

1. Not done any research on [product type]?
2. Already been thinking about purchasing [product type]?
3. Already begun collecting information about [product type]?
4. Already selected the [measure] you were going to get?
5. Already installed the energy efficient **[measure]**? **{SKIP TO FR21}**
6. **{DON'T READ}** Other: \_\_\_\_\_
  - 98. **{DON'T READ}** Don't Know
  - 99. **{DON'T READ}** Refused

FR3. Did you have to make any changes to your existing plans for **[product type]** in order to receive this **[assistance]** through the program?

1. Yes
2. No **{SKIP TO FR3C}**
  - 98. Don't Know **{SKIP TO FR3C}**
  - 99. Refused **{SKIP TO FR3C}**

FR3B. How did your plans change?

FR3C. **[IF FR3 = 2, 98, 99]** Did you intentionally develop your original plans for **[product type]** in order to meet program requirements?

1. Yes
2. No
  - 98. Don't Know
  - 99. Refused

**[IF FR1= 4 OR 5 AND FR3C=1: You said that you had already selected or installed the **[measures]** before learning of the program, yet you intentionally developed the original plans in order to meet program requirements. How so?]**

FR4. On a 0 to 10 scale, with 0 being not at all likely and 10 being very likely, how likely is it that you would have bought the same efficiency level of **[measures]** if you had not received any **[assistance]** from the program?

**{RECORD RESPONSE (0-10)}** \_\_\_\_\_

- 98. Don't Know
- 99. Refused

*[IF FR1= 4 OR 5 AND FR4 < 8: You said that you already selected or installed the **[measures]** before learning of the program, yet you were not likely to have bought the same efficiency of **[measure]** without the **[assistance]** from the program. How so?]*

*[IF FR3=2 AND FR3C=2 AND FR4 <8: You said that you did not develop your original plans to qualify for program and you made no changes to your original plans, yet you were not likely to have bought the same efficiency of **[measure]** without the **[assistance]** from the program. How so?]*

FR5. How likely is it that you would have bought the same quantity of **[measures]** if you had not received any **[assistance]** from the program? Please use the same scale.

{RECORD RESPONSE (0-10)} \_\_\_\_\_

- 98. Don't Know
- 99. Refused

Now I'm going to read several statements about how you came to choose your **[product type]**. On a scale of 0 to 10, where 0 is strongly disagree and 10 is strongly agree, how much do you agree with each statement?

FR6. The **[assistance]** from the program was a critical factor in my decision to purchase the high efficiency product.

{RECORD RESPONSE (0-10)} \_\_\_\_\_

- 98. Don't Know
- 99. Refused

*[IF FR6 CONTRADICTS FR4/FR5: Earlier you indicated that you were (un)likely to have bought the same quantity of **[measures]** without **[assistance]** from the program, but now you say the program was (not) a critical factor in your decision to purchase the **[measure]**. How so?]*

FR7. If I had not had any assistance from the program, I would have paid the additional **[amount of program incentive/subsidy]** to buy the **[measure]** on my own?

{RECORD RESPONSE (0-10)} \_\_\_\_\_

- 98. Don't Know

-99. Refused

*[IF FR7 CONTRADICTS FR4/FR5: Earlier you indicated that you were (un)likely to have bought the same quantity of [measures] without [assistance] from the program, but now you say you would (not) have paid the additional [incentive] to buy the [measure]. How so?]*

FR8. At the time I bought my new **[product type]**, the [assistance] from the program was not necessary to persuade me to purchase the higher efficiency product.

{RECORD RESPONSE (0-10)} \_\_\_\_\_

-98. Don't Know

-99. Refused

*[IF FR8 CONTRADICTS FR4/FR5: Earlier you indicated that you were (un)likely to have bought the same quantity of [measures] without [assistance] from the program, but now you say the program was (not) necessary to persuade you to buy the [measure]. How so?]*

### **APPLIANCE #2**

FR21. At the time that you first heard about the **[assistance]** from the program for **[measure]**, had you...? {READ LIST}

1. Not done any research on [product type]?
7. Already been thinking about purchasing [product type]?
8. Already begun collecting information about [product type]?
9. Already selected the [measure] you were going to get?
10. Already installed the energy efficient [measure]? {SKIP TO C1}
11. {DON'T READ} Other: \_\_\_\_\_

-98. {DON'T READ} Don't Know

-99. {DON'T READ} Refused

FR23. Did you have to make any changes to your existing plans for **[product type]** in order to receive this **[assistance]** through the program?

1. Yes
2. No {SKIP TO FR23C}
  - 98. Don't Know {SKIP TO FR23C}
  - 99. Refused {SKIP TO FR23C}

FR23B. How did your plans change?

FR23C. **[IF FR23 = 2, 98, 99]** Did you intentionally develop your original plans for **[product type]** in order to meet program requirements?

1. Yes
2. No
  - 98. Don't Know
  - 99. Refused

*[IF FR21= 4 OR 5 AND FR23C=1: You said that you had already selected or installed the **[measures]** before learning of the program, yet you intentionally developed the original plans in order to meet program requirements. How so?]*

FR24. On a 0 to 10 scale, with 0 being not at all likely and 10 being very likely, how likely is it that you would have bought the same efficiency level of **[measures]** if you had not received any **[assistance]** from the program?

- {RECORD RESPONSE (0-10)}** \_\_\_\_\_
- 98. Don't Know
  - 99. Refused

*[IF FR21= 4 OR 5 AND FR24 < 8: You said that you already selected or installed the **[measures]** before learning of the program, yet you were not likely to have bought the same efficiency of **[measure]** without the **[assistance]** from the program. How so?]*

*[IF FR23=2 AND FR23C=2 AND FR24 <8: You said that you did not develop your original plans to qualify for program and you made no changes to your original plans, yet you were not likely to have bought the same efficiency of **[measure]** without the **[assistance]** from the program. How so?]*

FR25. How likely is it that you would have bought the same quantity of **[measures]** if you had not received any **[assistance]** from the program? Please use the same scale.

- {RECORD RESPONSE (0-10)}** \_\_\_\_\_
- 98. Don't Know
  - 99. Refused



---

Now I'm going to read several statements about how you came to choose your **[product type]**. On a scale of 0 to 10, where 0 is strongly disagree and 10 is strongly agree, how much do you agree with each statement?

FR26. The **[assistance]** from the program was a critical factor in my decision to purchase the high efficiency product.

{RECORD RESPONSE (0-10)} \_\_\_\_\_

-98. Don't Know

-99. Refused

*[IF FR26 CONTRADICTS FR24/FR25: Earlier you indicated that you were (un)likely to have bought the same quantity of [measures] without [assistance] from the program, but now you say the program was (not) a critical factor in your decision to purchase the [measure]. How so?]*

FR27. If I had not had any assistance from the program, I would have paid the additional **[amount of program incentive/subsidy]** to buy the **[measure]** on my own?

{RECORD RESPONSE (0-10)} \_\_\_\_\_

-98. Don't Know

-99. Refused

*[IF FR27 CONTRADICTS FR24/FR25: Earlier you indicated that you were (un)likely to have bought the same quantity of [measures] without [assistance] from the program, but now you say you would (not) have paid the additional [incentive] to buy the [measure]. How so?]*

FR28. At the time I bought my new [product type], the [assistance] from the program was not necessary to persuade me to purchase the higher efficiency product.

{RECORD RESPONSE (0-10)} \_\_\_\_\_

-98. Don't Know

-99. Refused

*[IF FR28 CONTRADICTS FR24/FR25: Earlier you indicated that you were (un)likely to have bought the same quantity of [measures] without [assistance] from the program, but now you say the program was (not) necessary to persuade you to buy the [measure]. How so?]*

---

### CODE NTG – FOR PROJECTS WITH PERFORMANCE INCENTIVES

[REVIEW PLAN CHECK DOCUMENTS FROM HMG PRIOR TO INTERVIEW IN ORDER TO INFORM QUESTIONS AND PROBES]

- C1. Were the original building plans submitted to HMG for review above, below, or just meeting 2005 Title 24 code for the \_\_\_\_\_ project?
1. Above code
  2. Below code
  3. Just meeting code {SKIP TO C5}
    - 98. Don't Know {SKIP TO C5}
    - 99. Refused {SKIP TO C5}
- C2. What aspects of the plan contributed to the design being above/below code? [Probe issues identified in plan check documents, also percent glazing, water heater efficiency, occupancy assumptions]
- C3. What percent above/below code were these plans? **PROBE FOR BEST ESTIMATE**
- ENTER %:
- 98. Don't Know
  - 99. Refused
- C4. Why were the plans above/below code?
- C5. Was this original plan consistent with your standard practice for multifamily buildings prior to the HMG plan check?
1. Yes
  2. No
    - 98. Don't Know
    - 99. Refused
- C5\_1. [ASK IF C5 = 2] How and why was it different from your standard practice?
- C5a [ASK IF C1 = 1] Before the HMG review, did your original plan meet the CMFNC program requirements to exceed code by 15%?
1. Yes

- 2. No
- 98. Don't Know
- 99. Refused

*[IF C5a= 1 AND C3<15%: You said that your original plans met program requirements, which are 15% above code, but earlier you said that the plans exceeded code by less than 15%. Which is correct?]*

C5b *[IF C5a=1]* Did you intentionally try to develop your original plans in order to meet program requirements?

- 1. Yes
- 2. No
- 98. Don't Know
- 99. Refused

C5c On a scale of 0-10, how likely would you have been to build this project at or above the program standard (15% above Title 24 code) had there been no review and assistance from the CMFNC program?

*{RECORD RESPONSE (0-10)}* \_\_\_\_\_

- 98. Don't Know
- 99. Refused

*[PROBE FOR EXPLANATION IF AP2= 2 AND C5A=1 AND C5C<=4: You said earlier that you became aware of the program after developing your building plans, and that your original plans met program requirements but you were unlikely to have built to program requirements in the absence of the program. How so?]*

*[PROBE FOR EXPLANATION IF C1= 2 OR 3 AND C5C>5: You said that your original plans were at or below T24 code, but you were likely to have built to program requirements in the absence of the program. How so?]*

*[IF C5B=1 AND C5C>5: You said that you intentionally developed your plans to meet program requirements, but you were likely to have built to program requirements in the absence of the program. How so?]*

C6. What type of feedback did HMG provide from their review of your original plans?

C7. Did their feedback cause you to revise your original plans?

1. Yes
2. No {SKIP TO C11}
  - 98. Don't Know {SKIP TO C11}
  - 99. Refused {SKIP TO C11}

[PROBE FOR EXPLANATION IF C5A= 1 AND C7=1]

C8A. What were the three most significant design changes that you made as a result of HMG's feedback? [Probe the type of equipment or designs involved]

[CATEGORIZE INTO DESIGN CHANGES #1, #2, #3]

Design Change #1 \_\_\_\_\_

Design Change #2 \_\_\_\_\_

Design Change #3 \_\_\_\_\_

C8B. Relative to code, by what percentage did all of the revisions alter your original plans? For example, if the revisions altered the plans from 5% below code to 15% above code, the total percentage change equals 20%. **PROBE FOR BEST ESTIMATE**

ENTER %:

98. Don't Know
- 99. Refused

C11. Were there any other factors that influenced changes to your design after it was submitted to HMG for review?

1. Yes
2. No {SKIP TO C16}
  - 98. Don't Know {SKIP TO C16}
  - 99. Refused {SKIP TO C16}

C12. What other factors influenced the design changes?

C13. What were the three most significant design changes that you made as a result of these factors? [Probe the type of equipment or designs involved]

Design Change #1 \_\_\_\_\_

Design Change #2 \_\_\_\_\_

Design Change #3 \_\_\_\_\_

C14. Relative to code, by what percentage did all of these revisions alter your original plans? For example, if the revisions altered the plans from 5% below code to 15% above code, the total percentage change equals 20%. **PROBE FOR BEST ESTIMATE**

ENTER %:

C16. On a scale of 0 to 10, where 0 is strongly disagree and 10 is strongly agree, how much do you agree with the following statement? The review and [assistance] from the program was a critical factor in your decision to build to program requirements (15% above Title 24 code).

**{RECORD RESPONSE (0-10)}** \_\_\_\_\_

-98. Don't Know

-99. Refused

**[IF C16 CONTRADICTS C5C: Earlier you said were (un)likely to have built to program requirements in the absence of the program, but now you say the program was (not) a critical factor in your decision to build to program requirements. How so?]**

C17. Subsequent to your participation in the CMFNC program, has what you learned about multifamily energy code from the HMG plan review affected your design of any non-program multifamily buildings?

1. Yes

2. No **{SKIP TO W1}**

-98. Don't Know **{SKIP TO W1}**

-99. Refused **{SKIP TO W1}**

C19. How has (have) the design(s) been affected?

C18. How many multifamily building designs have been affected? How many housing units are in each of these buildings?

### WRAP-UP

I have just a few more questions then we are done with the interview.

W1. Overall, what aspects of the CMFNC Program do you think work best?

W2. What about the program needs the most improvement?

W3. Is there anything else you would like to tell me about the program?

THANK YOU VERY MUCH!

**I. Designed for Comfort Onsite Inspection Forms**



**CPUC/DFC Onsite Verification Survey Form  
MiraVista/Pepperwood**

1.11 Case:	1.12 Project:	1.13 Bldg #:
------------	---------------	--------------

1.14 Housing Unit #:	1.15# of Bdrms	1.16Lg/Small (MiraVista)
----------------------	----------------	--------------------------

1.17 Field Staff Name:

1.18 Date: (mm/dd/yy)	1.19 Time:	1.20 Occupied:
-----------------------	------------	----------------

1.21 Bldg mgr have any problems with installed units? Yes/No

1.22 Comments if 1.21 is yes:



CPUC/DFC Onsite Verification Survey Form  
Heating and Cooling System Data

2.11 Enter type unit (Packaged at Pepperwood; ASHP at MiraVista)

2.12 Matches Manufacturer's data (Y/N)

2.13 Indication of Recent Service (Y/N)

2.14 If Yes, Date of recent service (mm/dd/yyyy)

2.15 % of visible duct work not sealed:

2.16 Programmable Thermostat (Y/N):

2.17 Occupant controlled thermostat (Y/N):

2.18 Thermostat setting heat (F):

2.19 Thermostat setting cool (F):

2.20 Hot air output (Y/N)

2.21 Cool air output (Y/N)

2.22 Unusual Sounds (Y/N)

2.23 % of wall grille area obstructed (MiraVista only)

2.24 % of inadequate wall seal around packaged unit (Pepperwood):

2.25 Thermostat location (Describe)

Comments:

CPUC/DFC Onsite Verification Survey Form  
Unit Water Heating Data

3.11 % inadequate visible pipe insulation:

3.12 Temperature setting (Describe scale and set point)

3.13 Water temperature (F)

3.14 Matches manufacturer's data (Y/N)

3.15 Indication of recent service (Y/N)

3.16 If 3.15 yes, Date of recent service (mm/dd/yyyy)

3.17 Unusual Sounds (Y/N)

3.18 Comments:

---

<p>CPUC/DFC Onsite Verification Survey Form Windows</p>
---

<p>4.11 Model information if visually available:</p>
--

<p>4.12 # of windows that are not different from old windows:</p>
---

<p>4.13 # of windows that are not double-paned:</p>
---

<p>4.14 # of windows that do not open properly:</p>
---

<p>4.15 # of windows that do not have adequate interior seal:</p>
---

<p>4.16 # of windows that do not have adequate exterior seal:</p>
---

<p>4.17 # of windows not securely installed to building frame:</p>
--

<p>4.18 # of total windows in unit:</p>
---

<p>4.19 Comments:</p>
-----------------------

CPUC/DFC Onsite Verification Survey Form  
Building Data

5.11 Project:

5.12 Bldg #:

5.13 Field Staff Name:

5.14 Date: (mm/dd/yy)

5.15 Time:

5.16 Comments:

**CPUC/DFC Onsite Verification Survey Form  
MiraVista/Pepperwood: Attic Insulation**

6.11 Enter material  
[fiberglass/foam/  
cellulose]

6.12 Enter material  
[fiberglass/foam/cellulose]

6.13 Enter material  
[fiberglass/foam/cellulose]

6.14 Enter average depth of insu-  
lated attic space [Enter number of  
inches]

6.15 % of space with inadequate insula-  
tion depth [Enter percent]

6.16 % of inadequate corner/eave/roofline coverage [Enter percent]

6.17 Enter approximate R-Value of in-  
sulated attic space [Enter number]

6.18 % of ventilation systems obscured  
[Enter percent]

6.19 Comments

**CPUC/DFC Onsite Verification Survey Form  
MiraVista Only: Central Water Heating Data**

7.11 Percent of inadequate visible pipe insulation [Enter Percent]

7.12 Temperature setting [Describe scale and set point]

7.14 Indication of recent service? [Yes/No]

7.15 [IF YES] Date of recent service [mm/dd/yyyy]

7.13 Matches manufacturer's data? [Yes/No]

7.16 Comments

## J. California Multifamily New Homes Detail Tables

Table J-1: Performance Track Net to Gross Values for Each Project

(Performance Track Projects)

Project	Question C5c—likelihood to have built to program requirements in absence of program	Initial Free-Rider Allocation	Question C16—level of agreement that program was critical to the decision to build to program requirements	Final Free-rider Allocation	Question C3—estimated percent above code of the original plans	Question C7—made changes due to HMG’s review	Question C8b—percent change due to HMG review	NTG
1	0	Non	10	Non	-5%	Yes	20%	1.33
2	0	Non	10	Non	-5%	Yes	20%	1.33
3	10	Pure	5	Partial	-12%	Yes	32%	2.13
4	4	Partial	8	Partial	12%	Yes	19%	1.27
5	3	Partial	7	Partial	10%	Yes	6%	0.82
6	9	Pure	5	Partial	20%	Yes	8%	0.65
7	5	Partial	7	Partial	17%	No		0.60
8	4	Partial	5	Partial	20%	No		0.55
9	4	Partial	4	Partial	36%	No		0.50
10	8	Pure	8	Partial	15%	DK		0.50
11	10	Pure	3	Partial	20%	Yes	5%	0.43
12	8	Pure	3	Partial	15%	Yes	0%	0.25
13	10	Pure	0	Pure	20%	No		0.00
14	8	Pure	0	Pure	18%	No		0.00
15	9	Pure	0	Pure	35%	No		0.00
16	10	Pure	2	Pure	15%	No		0.00
17	10	Pure	DK	Pure	23%	No		0.00

**Table J-2: Performance Track Net to Gross Values for Each Project**

(Performance Track Projects)

Project	Question C5c—likelihood to have built to program requirements in absence of program	Initial Free-Rider Allocation	Question C16—level of agreement that program was critical to the decision to build to program requirements	Final Free-rider Allocation	Question C3—estimated percent above code of the original plans	Question C7—made changes due to HMG’s review	Question C8b—percent change due to HMG review	NTG
1	0	Non	10	Non	-5%	Yes	20%	1.33
2	0	Non	10	Non	-5%	Yes	20%	1.33
3	10	Pure	5	Partial	-12%	Yes	32%	2.13
4	4	Partial	8	Partial	12%	Yes	19%	1.27
5	3	Partial	7	Partial	10%	Yes	6%	0.82
6	9	Pure	5	Partial	20%	Yes	8%	0.65
7	5	Partial	7	Partial	17%	No		0.60
8	4	Partial	5	Partial	20%	No		0.55
9	4	Partial	4	Partial	36%	No		0.50
10	8	Pure	8	Partial	15%	DK		0.50
11	10	Pure	3	Partial	20%	Yes	5%	0.43
12	8	Pure	3	Partial	15%	Yes	0%	0.25
13	10	Pure	0	Pure	20%	No		0.00
14	8	Pure	0	Pure	18%	No		0.00
15	9	Pure	0	Pure	35%	No		0.00
16	10	Pure	2	Pure	15%	No		0.00
17	10	Pure	DK	Pure	23%	No		0.00



**Table J-3: Appliance Track Net-to-Gross Values for Each Project**

(Appliance Track projects)

Appliance	Question FR1 – Status of plans when learned of program	Question FR3 – Made changes to plans in order to meet program requirements	Question FR4 – likelihood of purchasing same efficiency level of appliances without program	Question FR5 - likelihood of purchasing same quantity of efficient appliances without program	Initial Free-Rider Allocation	Question FR6 – Agreement that the program was a critical factor in decision	Question FR7 – Agreement that would have paid full cost without program	Question FR8 – Agreement that the program was not necessary for purchase	Final Free-Rider Allocation	NTG
Dishwasher	4	No	0	0	Pure	5	0	0	Partial	0.90
Dishwasher	4	Yes	2	0	Non	3	3	3	Partial	0.78
Refrigerator	4	Yes	2	0	Non	3	3	3	Partial	0.78
Clothes Washer	3	Yes	6	10	Partial	3	4	5	Partial	0.44
Dishwasher	2	No	6	10	Partial	3	6	4	Partial	0.42
Refrigerator	2	No	6	10	Partial	3	6	4	Partial	0.42
Refrigerator	1	No	7	10	Partial	2	8	3	Partial	0.40
Dishwasher	3	No	10	2	Partial	7	8	4	Partial	0.38
Dishwasher	3	No	8	10	Pure	3	5	7	Partial	0.34
Refrigerator	3	Yes	8	8	Pure	0	8	9	Partial	0.34
Refrigerator	3	No	8	10	Pure	3	5	7	Partial	0.34
Refrigerator	2	No	10	10	Pure	5	5	5	Partial	0.30
Dishwasher	4	No	8	10	Pure	6	7	7	Partial	0.24
Dishwasher	4	No	8	8	Pure	5	10	7	Partial	0.24
Refrigerator	4	No	8	8	Pure	5	10	7	Partial	0.24
Refrigerator	4	No	8	10	Pure	6	7	7	Partial	0.24
Refrigerator	3	No	10	10	Pure	8	3	8	Partial	0.22
Dishwasher	3	No	10	10	Pure	5	8	8	Partial	0.18
Dishwasher	1	No	10	10	Pure	3	10	10	Partial	0.14

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(Appliance Track projects)

Appliance	Question FR1 – Status of plans when learned of program	Question FR3 – Made changes to plans in order to meet program requirements	Question FR4 – likelihood of purchasing same efficiency level of appliances without program	Question FR5 - likelihood of purchasing same quantity of efficient appliances without program	Initial Free-Rider Allocation	Question FR6 – Agreement that the program was a critical factor in decision	Question FR7 – Agreement that would have paid full cost without program	Question FR8 – Agreement that the program was not necessary for purchase	Final Free-Rider Allocation	NTG
Clothes Washer	4	No	10	10	Pure	10	10	10	Pure	0.00
Dishwasher	4	No	10	10	Pure	10	10	10	Pure	0.00
Dishwasher	4	No	10	10	Pure	10	10	10	Pure	0.00
Lighting	4	No	10	10	Pure	10	10	10	Pure	0.00
Refrigerator	3	No	10	10	Pure	10	10	10	Pure	0.00
Refrigerator	4	No	10	10	Pure	10	10	10	Pure	0.00
Refrigerator	3	No	10	10	Pure	10	10	10	Pure	0.00
Refrigerator	3	No	10	10	Pure	5	9	10	Pure	0.00

## **K. Baseline Study and RNC Evaluation Recruitment Details**

We took a number of measures to minimize the potential for systematic biases in who had the opportunity/willingness to be metered/visited for on-site surveys. Recruitment efforts were conducted using a Computer Aided Telephone Interview (CATI) system. We attempted to contact a household multiple times over different times of the day (up until 8 pm), different days of the week, including weekends, and different weeks of the recruiting periods. In addition, we offered incentives of \$50 and \$10 to the occupants in order to overcome any lack of interest on their part, thus making it less likely we would only attract a biased subset of respondents. Detailed disposition codes were updated after each attempted contact. The final disposition of the sample is shown in Table K-1.

**Table K-1: RNC Site Recruitment Sample Disposition**

	Total Sample		PG&E		SDG&E		SCE and SCG	
	Number of Households	% of Sample	Number of Households	% of Sample	Number of Households	% of Sample	Number of Households	% of Sample
<b>Total Sample Sent</b>	<b>11,287</b>		<b>3,971</b>		<b>1,898</b>		<b>5,418</b>	
Max Attempts	3,103	27%	1,059	27%	611	32%	1,433	26%
Refuse	1,633	14%	546	14%	317	17%	770	14%
Unobtainable	1,285	11%	412	10%	143	8%	730	13%
Designated Respondent Not Available	1,372	12%	670	17%	51	3%	651	12%
Language	490	4%	170	4%	58	3%	262	5%
Wrong Bldg Type	300	3%	53	1%	157	8%	90	2%
Wrong Address	324	3%	99	2%	57	3%	168	3%
Not a Residence	384	3%	178	4%	14	1%	192	4%
Quota Full	253	2%	89	2%	47	2%	117	2%
Other	949	8%	257	6%	243	13%	449	8%
Completed Phone Survey	1,194	11%	438	11%	200	11%	556	10%
<i>Recruited for Visit</i>	588	49%**	200	46%**	117	59%**	271	49%**
<i>Recruited for Metering</i>	353*	30%**	121	28%**	65	33%**	167	30%**
<i>Metering completed (participants and nonparticipants)</i>	162	14%**	56	13%**	42	21%**	64	12%**

\*Subset of recruited for visit

\*\*Percent of completed phone survey

## L. Public Comments on the Draft Evaluation Report with Responses

Table L-1: Comments on the Draft Report with Responses

	SOURCE	Subject:	Section / Page:	Type	Comment or Question
1	PGE	Appliance savings		Question 1	Please explain how the gross savings estimates were adjusted because of difference with DEER numbers.
				Response 1	The evaluation team was directed by ED to make sure that savings numbers, where applicable, conformed to the latest DEER numbers. The team searched the DEER database (version 2008.2.05, posted December 16, 2008) for products with a similar size, features, and efficiency level to the products eligible for the CMFNH program. If a similar DEER model was available, we compared the annual electricity and gas usage per unit between DEER and program assumptions. The team found similar DEER models only for clothes washers and refrigerators, where DEER savings values were higher and lower, respectively. The team believes these discrepancies are due to the fact that HMG developed program assumptions using an earlier version of the DEER database. Next, the team multiplied the difference in energy savings per unit by the number of incentivized units. There was a net decrease in gross program savings because the program incentivized many more refrigerators than clothes washers.
2	PGE	Explanation of results	Table 1-7	Question 2	Ex post kWh realization rates are shown (Table 1-7) to range from 1.5 to 4.67. Given that the kWh metered-to-modeled ratios (Table 3-9) only range from 1.06 to 1.4, can the evaluators explain why the realization rates are so high? We expect that this ties into the baseline study. However, the baseline study is so briefly documented that we are unable to confirm or deny this assumption.
				Response 2	While the metered to modeled ratios influence the final realization rates, they are not directly associated with each other. So the fact that the ranges of values between the realization rates and the metered to modeled ratios are fairly different is not an issue.  There are a number of possible explanations for the high realization rates. The metered to modeled ratios for kWh are greater than 1. This indicates that the Micropas models are

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	SOURCE	Subject:	Section / Page:	Type	Comment or Question
					underestimating the cooling based usage and therefore understating the savings associated with the cooling end use. Additionally, the Net-to-Gross ratios (for PG&E) were greater than 1 for kWh. This implies that there was a lower level of compliance among the non-participant homes, and therefore, a higher level of savings over baseline. Finally, the ex-ante savings estimates for the program may have been understated. These three factors all contribute to the high realization rates: increased savings due to underestimated usage in the models, increased savings due to low levels of compliance among baseline homes, and low ex-ante savings estimates.
3	PGE	MF - Micropas results	3.4.1	Question 3	The residential new construction metering results showed large kWh and kW realization rates, purportedly due to inaccuracies in Title 24 simulations. Shouldn't those same realization rate findings be applicable to the multifamily gross savings estimates, for MF projects using Micropas (primarily low-rise)?
				Response 3	Multifamily buildings, even low-rise buildings, have significantly different energy characteristics than single-family homes, typically having less glazing, shared walls, etc. We do not believe that it is appropriate to apply single-family results to multifamily buildings.
4	PGE	MF - Self-report analysis		Question 4	Were any secondary sources used to confirm participant responses? It appears that all results are solely based on participant interviews/surveys.
				Response 4	The evaluation team also reviewed program documents regarding the HMG review of the projects' Title 24 energy modeling analyses in order to guide the decision-maker survey. Most useful were the files that included the HMG reviewer's comments regarding the discrepancies, questions, or other feedback provided to the T24 consultant. However, these comments were not available for every project. In most cases, the respondents provided a reasonably accurate description of the level of feedback – whether it was major or minor, but without the details listed in the HMG review documents.

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	SOURCE	Subject:	Section / Page:	Type	Comment or Question
5	PGE	MF - Self-report analysis	4.5.2	Question 5	Program managers' experience working with participants strongly differs from the self-reported experiences. Given the weaknesses in a self-report method administered several years after the fact, shouldn't the managers' experience be given some credence, especially as it was backed with records of program interactions with customers? Doesn't the self-report method as applied tend to bias the findings in a consistently downward direction?
				Response 5	<p>We recognize that the impressions of program staff in working with participants may differ from the experience reported by the participants themselves. However, the evaluation team believes that the participants know their own motivations better than program staff does, even if the interview occurred a year or more after project completion. Note that some respondents clearly reported that the program strongly influenced their project design, though likely not as many participants as the program staff may believe. The evaluation team believes that self-report interviews were the appropriate methodological choice for assessing NTG for this program, and did not find information to support the contention that the self-report method yields reduced estimates of program influence.</p> <p>The methods we developed were consistent with the Evaluator Protocols adopted by the Commission, and build upon methods employed in prior evaluations. The methods also include checks for internal consistency and reliability both in the course of conducting the interviews and the analysis and calculation of the results. We believe that the reliability of these methods are an improvement upon past studies and the consistency in approaches makes the reliability across the portfolio greater.</p>
6	PGE	Net savings	1.1.6	Question 6	Can you provide more detail on the H-factor analysis? We were not given enough information to review the analysis. Do the evaluators have enough confidence in the H-factors used for the CPUC to rely upon the results?
				Response 6	Under the original sample plan, the size of the metered participant sample would have been large enough to conduct an independent verification of kW savings. Unfortunately, with the reduction in the sample size of metered participants' homes for reasons detailed in the report, this was not possible. Instead, KEMA used a simplified approach, called the H-factor approach. This approach has been used in previous studies where kW verification was not a goal of the study. The H-factor approach is quite simple. KEMA used utility

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	SOURCE	Subject:	Section / Page:	Type	Comment or Question
					<p>tracking data for gross per-unit kWh and gross per-unit kW to calculate the ratio of kW to kWh that was assumed by the utilities for their program planning. These ratios are called H-factors. KEMA then estimated ex-post net kW savings by applying these H-factors to the ex-post net energy savings value.</p> <p>This method does not provide any independent verification of actual kW savings. It is only as accurate as the IOU ex ante calculations were, and only adheres to the definition of demand reduction definition in DEER to the extent that the IOU claimed savings did. For example, the gross coincident peak demand reduction per unit for coastal PG&amp;E homes from program tracking data was 0.61 kW. The gross annual energy savings per unit from tracking data was 259.81. The H-factor was calculated as 0.61/258.81, or 0.00233. So to get ex-post kW for PG&amp;E coastal homes, we multiplied the ex-post kWh by 0.00233.</p>
7	PGE	Sample/P	1.1.4, Table 1-3, p1-7	Question 7	Why so few PG&E participants in the study, if there were 4500 in the program?
				Response 7	<p>KEMA used all of the participant compliance information from the tracking database in our study, so in that sense all PG&amp;E participants were included in the analysis.</p> <p>Based on our original sample plan, we were going to meter 170 participant sites and 170 nonparticipant sites.</p> <p>KEMA proposed, and ED agreed, to modify the methodology so that metered-to-modeled ratios from nonparticipants would be applied to both participants and non-participants, negating the need for the participant sample. Data collection for participants was halted and the sample plan for non-participants was revised. In the end, results for the 31 participant sites that were metered were combined with 131 non-participant metered sites.</p>
8	PGE	Time for review	General	Comment 8	We would like to thank the ED and its evaluators for their obvious hard work and diligence, for their rapid responses to our data requests following the webinar, and for their open and thoughtful approach to this study. Despite ED's commendable efforts, the very abbreviated two week review period was wholly inadequate to complete a meaningful review of the evaluation. The time was only adequate to read the reports and ask questions. It became



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	SOURCE	Subject:	Section / Page:	Type	Comment or Question
					<p>apparent the report left out much of the important explanation and data that would be needed for that purpose. The abbreviated review time forces hurried data requests and though the ED responded with admirable swiftness, there was hardly time to digest and sift through the numbers provided before these comments were due to be filed. In addition, we are left with the distinct impression that the evaluators are still scrambling to complete their findings. An e-mail from Ms. Osman on Dec 15th indicated that the NRNC whole building analysis had been found to have errors requiring that the models be re-run. This occurred during the final review period, mere days before the comment period was set to close. As of COB Dec 18th, the results of this re-analysis were still unpublished. Meanwhile, additional appendix material was only first made available by that date. Comments were due a mere two working days later and, given our own requirements for the review of those comments, there was virtually no opportunity to review these late-posted materials. PG&amp;E requested a time extension to 12/31, but only two additional business days were granted (12/18 to 12/22). We are greatly concerned that the ED's own deadlines are being only partially met in the rush to complete. If the final results are to be relied on, an adequate review period must be provided following the publication of a thorough report which includes all necessary appendices and supporting data to support the findings.</p>
				Response 8	<p>We appreciate the utilities' time and effort spent in reviewing and commenting on the draft evaluation reports. However, ED is working under strict deadlines as set by the Commission, and that transferred into the scheduled review period.</p>
9	PGE	RNC Baseline Study	Appendix F	Question 9	<p>The Baseline study consumed hundreds of thousands of evaluation dollars and its results affect the RNC, C&amp;S and other evaluation findings. It will be invaluable in planning future RNC efforts and in steering toward the statewide strategic goals. Appendix F provides a mere 16 pages of summary information on this important study. When will a complete and detailed report on the Baseline be prepared and published?</p>

	SOURCE	Subject:	Section / Page:	Type	Comment or Question
				Response 9	<p>In addition to the RNC report appendix, baseline results are included in the body of the RNC volume, in the Codes and Standards volume, and in the Market Effects report. All of these publications are available on <a href="http://www.energydataweb.com/cpuc/default.aspx">http://www.energydataweb.com/cpuc/default.aspx</a> <a href="http://www.energydataweb.com/cpucFiles/topics/7/RNCMarketEffectsPhaseI_FinalReport_05212009.pdf">http://www.energydataweb.com/cpucFiles/topics/7/RNCMarketEffectsPhaseI_FinalReport_05212009.pdf</a></p> <p>It was not a part of the scope of this project to produce a complete stand-alone baseline report.</p> <p>We amended Appendix F to refer readers to the various reports that detail different aspects of the baseline results and to include additional data..</p> <p>The complete data from the baseline study are available for further analysis for those who wish to pursue it.</p>
10	SCE	Clarification of Baseline results		Question 10	Please provide more detailed information from Baseline study on std. practice in RNC, including but not limited to, how it relates to code compliance, how is it applied to C&S and how is it applied to RNC. What are the implications for how the IOUs allocate savings between programs?
				Response 10	The usage of the baseline results in the RNC analysis and in the Codes and Standards analysis are detailed in those volumes. We added text to Appendix F that provides an overview to these results and how they were used, and refers the reader to the appropriate reports.
11	PGE, SCE	Gross savings	1.1.5	Question 11	Can you provide more detail on how error bound was calculated?
				Response 11	<p>The methodology for the calculating the relative precision and error bounds were taken from 'The California Evaluation Framework'. A basic breakdown of the calculation is presented below.</p> <p>&gt; ratio = sum(xi)/sum(yi)</p> <p>&gt; se = sqrt(sum((xi - ratio*yi)^2))/sum(xi)</p> <p>&gt; rp = (se*1.645)/ratio</p> <p>Where,</p>

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	SOURCE	Subject:	Section / Page:	Type	Comment or Question
					<p><math>x_i</math> is the metered data,  <math>y_i</math> is the modeled data,  ratio is the meter to modeled ratio,  se is the standard error, and rp is the relative precision.</p>
12	PGE, SCE	metered to modeled ratios	3.4.3	Question 12	<p>The metered-to-modeled rates for RNC are not explained very well, except to assert that Micropas does a very poor job of estimating actual energy use. On average, this is shown to be true. However, in the detailed scatter plots of metered to modeled results, a huge variability is evident in the actual energy use, compared to Micropas. Although the averages end up being substantially different from reality, there are significant numbers of houses where Micropas overestimates electricity use (or under estimates gas use). Can you provide more explanation of why this is the case? How can these results be used to improve future program efforts and ex ante estimates? Are they reliable enough for the program managers to change the way they estimate their savings? Please provide your recommendations.</p>
				Response 12	<p>There is variability. The compliance models (Micropas) take building characteristics as inputs, but underlying the model are behavioral assumptions (occupancy and set-points) that are fixed. Of course, in reality, behavior can vary widely from household to household. We believe that the gap between metered and modeled usage has its origins primarily in the way orientation is treated and the gap between actual behavior and modeled behavior.</p> <p>The compliance models are designed to determine whether a building complies with the building code and are not designed to accurately predict energy use.</p> <p>For future program efforts: There are alternatives to using Micropas for modeling building energy use. The Department of Energy's DOE2 and EnergyPlus simulation tools are two such options. Since the data collected in this study were based on field work, they can be used in the future to test alternative simulation tools in order to find one that aligns more closely with metered usage over the range of California climates.</p>

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	SOURCE	Subject:	Section / Page:	Type	Comment or Question
13	PGE, SCE	program participation	table 3.5	Question 13	What was the market penetration of the program for each IOU?
				Response 13	We feel that the utilities are in the best position to answer this question.
14	PGE	RNC Realization Rates	Table 3-15	Question 14	One key finding of the study is that there are very high kWh and kW realization rates, and low therm realization rates. This indicates that ex ante estimates are far off, both low and high. Please discuss your recommendations based on this result. How can the research be applied to support the development of new ex-ante estimates? Should program managers increase and decrease their ex ante estimates appropriately? Would you recommend applying the 06-08 realization rates as-is?
				Response 14	There are alternatives to using Micropas for modeling building energy use. The Department of Energy's DOE2 and EnergyPlus simulation tools are two such options. The IOUs could use the data from this study to test alternative simulation tools in order to find one that aligns more closely with metered usage over the range of California climates, and thus to provide more reliable ex ante expectations.
15	SCE	Sample design	1.1.2 / p. 1-3	Question 15	Section 1.1.2 describes the development sample designs, but never makes clear how the designs were actually executed. It is conventional to report on the plan(s), the number of attempts to recruit, the number of refusals, the numbers of final surveys, and the numbers used in the final analysis, with explanations for how and why reality deviated from the ideal. In this case, these would be broken out by surveyed, on-sites, metered, by utility. This is typically related to the population, with the sample weights indicated. In this case, it would also be useful to show how these varied by utility, and by whole building/systems analysis/industrial participants. Can this information be included and clearly explained in the report?
				Response 15	We added an Appendix (K) to the final version of the report that provides these statistics. The second to last sentence of the comment seems to be written for non-residential; while we can break out these statistics by utility, all the residential participants were whole-house participants.

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	SOURCE	Subject:	Section / Page:	Type	Comment or Question
16	PGE, SCE	self-selection bias	3.3	Question 16	How was self-selection bias addressed?
				Response 16	We took a number of measures to minimize the potential for systematic biases in who had the opportunity/willingness to be metered/visited for on-site surveys. First, we offered \$50-\$100 in incentives to overcome resistance from less interested occupants. Further, recruitment efforts were conducted using a Computer Aided Telephone Interview (CATI) system. We attempted to contact a household multiple times over different times of the day (up until 8 pm), different days of the week, including weekends, and different weeks of the recruiting periods. Detailed disposition codes were updated after each attempted contact.
17	SCE	H Factor Inputs	Page 3-41	Question 17	There needs to be an analysis in the report or in an appendix that includes the calculations used to derive H factors for each of the IOUs.
				Response 17	The following text has been added to the report: "The H-factor approach is quite simple. KEMA used utility tracking data for gross per-unit kWh and gross per-unit kW to calculate the ratio of kW to kWh that was assumed by the utilities for their program planning. These ratios are called H-factors. KEMA then estimated ex-post net kW savings by applying these H-factors to the ex-post net energy savings value. This method does not provide any independent verification of actual kW savings. It is only as accurate as the IOU ex ante calculations were, and only adheres to the definition of demand reduction definition in DEER to the extent that the IOU claimed savings did."
18	SCE	Sample	Pg.3-16	Question 18	Table 3-4 does not include the original sample size for non-metered. Please include that information in the final report.
				Response 18	All participant on-sites called for metering. That is, the number of planned non-metered participant sites was zero. We have amended the table to reflect this.  The two unmetered participant sites were unplanned, i.e., when a homeowner backed out of the agreement to allow metering when staff was already on site.

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	SOURCE	Subject:	Section / Page:	Type	Comment or Question
19	SCE	Sample size	Pg.1-11	Question 19	The report states that “the reduced savings did not justify the level of rigor that had originally been planned for the evaluation and the CPUC ED approved calling a halt to participant on-sites after only 33 on-sites out of the original 170 planned participants.” This seems like an arbitrary approach to arriving at a final sample size, particularly given that the participant samples for SCE were either a 1 or 0 (with an original sample target of 45). We would have expected that the evaluation team would have developed a new sampling plan with a "reasonable" sample size for each IOU, rather than accepting a sample size arrived at based on an arbitrary date in time. How is this defensible based on the M&E protocols and standards of good judgment and best practice in the program evaluation field? At the very least, we feel that there should be notations in the report that explain how the sample you arrived at impacts the reliability and validity of the findings.
				Response 19	The only planned purpose for the participant metered data in the analysis was to calculate participant metered-to-modeled ratios. All participant modeled information was available from program records. Once the decision was made to use the non-participant ratios for both participants and non-participants, the sample design for the metered participant sample became moot. It is not necessary to have a statistically representative sample for data that you do not intend to use.  In the end, the participant and non-participant data were combined to calculate the meter ratios in order to maximize the pool of available data.
20	SCE	Savings Estimates	Page 3-6	Question 20	In the report it states that "SCE's per unit savings were not broken down by region, and therefore the weighted average of estimates was applied across the Inland and Coastal regions." In our 4th Quarter report, we provided per unit ex ante estimates that were climate zone dependent and therefore did vary by region. If you can't find that information, can you please submit a data request to SCE so we can provide that to you again to have it addressed in the final report?

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	SOURCE	Subject:	Section / Page:	Type	Comment or Question
				Response 20	Our copy of the SCE 4th Quarter report, downloaded from the EEGA website, does not show measures by region for SCE 2505 whole building measures. We did see inland, coastal, and desert measures for some measures for SCE 2510 and SCE 2517, but not for SCE 2505. We have double checked the report posted on the website, and found nothing to contradict our findings in any of our tracking data sources.
21	SDGE/SCG	Compliance Models	p 1-20	Question 21	<p>The result from the compliance models, relative to the metered data, suggests that the models are highly inaccurate and subject to relatively wide variation, much of which is unexplained. The authors of the study note this directly on page 1-20. Specifically, they state:</p> <p>“The metered data indicate that the MICROPAS compliance software, on average, overestimates the amount of heating energy consumed at a site and underestimates the amount of cooling energy consumed. Because the baseline for the utilities’ ex ante estimates of energy savings is a home that meets the minimum of California’s building code, and the compliance software that is used to estimate baseline energy use for this purpose does not accurately predict energy use, ex ante energy savings from the utility tracking databases may not reflect actual savings.”</p> <p>This raises serious questions concerning the reliability of the study. Can this be corrected? If not, should this study continue to be used in the VRT process?</p>

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	SOURCE	Subject:	Section / Page:	Type	Comment or Question
				Response 21	<p>To clear up some confusion in regards to the quote of the report used in the comment.</p> <p>The last sentence in the quote states: "... ex ante energy savings from the utility tracking databases may not reflect actual savings." This should be revised in the report to say: "... ex ante energy savings from the utility tracking DO not accurately reflect actual savings."</p> <p>The ex ante estimates, which are created by the program managers and utilities to estimate site level savings during implementation, are used to estimate program savings. These are un-verified, inaccurate estimates. The entire point of doing the evaluation was to verify the program savings and provide a method to adjust the ex ante estimates to better reflect real world savings. If anything, the finding that the ex ante estimates do not accurately reflect actual savings demonstrates the need for the study.</p>
22	SDGE/S CG	Participant /Non-Part Behaviors		Question 22	<p>(1) Samples sizes are extremely small, which raises the question of whether any real inference can be drawn about the population. This issue is heightened when small state-level sample sizes are used to make inferences about specific utility service territories and/or specific climate zones. Moreover, because the study was forced to reduce the sample size due to the economic downturn, the target precision for the meter-to-model ratios were significantly reduced. Specifically, the original plan (prior to the reduction in sample size) called for target precision for the calculation of meter-to model ratios of 25% at the 90% level of confidence (90/25). However, due to the small actual sample sizes the achieved level of precision for the meter-to model ratio was only 70% to 18% at the 90% confidence level. Thus, the small sample sizes added a significant amount of uncertainty to the meter-to-model ratios and cast doubt on the validity of the results. Do the authors agree with this interpretation? If so, should the study continue to be used in the VRT process?</p> <p>(2) The application of the non-participant meter-to-model ratio to participants undermines the notion that participants are different from non-participants. That is, one would expect that participants have characteristics and behaviors that separate them from non-participants. If that is not the case, how do we explain participation for some individuals and not others? This casts doubt on the results since there is no data available to inform us as to whether this is a valid assumption or how the results would vary with alternative</p>



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					assumptions. Again, should the study continue to be used in the VRT process?
				Response 22	<p>(1) In this evaluation study, the original sample plan was drawn up based upon our past experiences with RNC EM&amp;V. Based upon the costs and precision of past studies, an estimate of precision and the required sample size for this study was made based on the budget available. Unfortunately, past performance does not guarantee future results. When participation in the program turned out to be lower than expected, the amount of claimed savings from this program dropped. Instead of allocating resources and budget to study programs that were saving less energy, we decided to revise our sample plan.</p> <p>Despite the revised sample plan, the desired relative precision was achieved on 3 out of the 6 meter-to-model ratios (See Table 3.13) Additionally, the two end use/climate region combinations with the largest relative precisions were for combinations that contributed the lowest amount of savings to the overall total savings (the AC Coastal and Heat Coastal combinations both had small savings compared to total savings) reducing the impact of the larger relative precisions. So while the effects of revising the sample plan appear to have increased the uncertainty of the results, it does not compromise the validity of the results.</p> <p>(2) The variation in the metered-to-modeled ratio hinges on occupant behavior. Occupants are not program participants. The participants in the program are builders. A builder builds a participating home, and then sells it. Depending on how it is marketed, it may or may not be sold to an energy-conscious occupant. And an energy-conscious purchaser may or may not have different behavior on average—he/she might have average or greater need for heating and cooling services and simply want to reduce his energy costs. So the connection between participation and occupant behavior is not a direct one.</p> <p>The question is, do people who buy homes from participating builders behave differently than people who buy from non-participating builders?</p> <p>The evaluation of the 04-05 California Energy Star Homes Program found that almost half of</p>

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					<p>Energy Star homes owners did not know that their home was Energy Star at the time they purchased it (from "Evaluation, Measurement, and Verification of the 2004 &amp; 2005 California Statewide Energy Star® New Homes Program: "Twenty nine respondents currently knew their home was an ENERGY STAR® home, and fourteen did not. However, when asked if they knew their home was an ENERGY STAR® home before they purchased or rented it, only 24 said they knew their home was an ENERGY STAR® home while 19 said they did not know.") We can assume that those who did not know--who did not purposefully choose a high efficiency home--have the same behavior, on average, as owners of non-participating homes. Of the ones who did know, we do not know what percentage would actually behave differently than non-participants.</p> <p>The two main behavioral factors in home energy use are occupancy and set-points. One would not expect occupancy to vary by energy and environmental attitudes. Set-points, however, could vary significantly. Of the two effects, however, occupancy is much more significant. Based on these factors, we believe that the difference in behavior between participants and non-participants is relatively small and unknown in direction.</p>