

FINAL REPORT

WO21: Residential On-site Study: California Lighting and Appliance Saturation Study (CLASS 2012)

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1 Executive Summary

1.1 Introduction

This is the final report for the 2012 California Residential Lighting and Appliance Efficiency Saturation Study. DNV GL (formerly DNV KEMA) conducted the study on behalf of the four investor owned utilities, including San Diego Gas and Electric, Southern California Gas Company, Southern California Edison and Pacific Gas and Electric. The California Public Utilities Commission managed the study.

The 2012 California Lighting and Appliance Efficiency Saturation Study (CLASS) is a follow-on study to the 2005 CLASS study and the 2000 Statewide Lighting and Appliance Efficiency Saturation Study. Each of these studies were paid for by Public Purpose funds for the purpose of understanding current levels of equipment and lighting saturation and efficiencies in the existing residential sector, as well as future energy savings potential and past accomplishments. The results of the 2012 CLASS are useful to both the Energy Division's (ED) evaluation of residential programs and to the portfolio planning of Investor Owned Utility (IOU) programs that require accurate baseline information.

In addition to updating the information developed from the 2005 and 2000 CLASS studies, the 2012 CLASS expands the body of knowledge acquired through the Energy Commission's 2009 Residential Appliance Saturation Study (RASS), a survey collecting self-reported information from residents, with sample sizes an order of magnitude larger than the CLASS.

The four primary objectives of this study were:

Objective 1: Complete 2000 on-site surveys of single-family, multi-family and mobile home residences in the service territories of the Investor Owned Utilities.

Objective 2: Develop a database of residential building characteristics, lighting and appliance saturations and efficiencies, expanded to represent the population of residential individually-metered population.

Objective 3: Develop a web-based tool to provide utility staff and other parties the ability to conduct "what-if" scenario analyses on the data collected.

Objective 4: Conduct trend and comparison analyses of saturations and efficiencies between the 2012 CLASS data to compare results from the previous CLASS studies.

Key outputs of the study include:

- Distribution of building characteristics such as square footage, room types and window types
- Distribution of type, efficiency, size and age of equipment such as ACs, refrigerators and furnaces
- Distribution of installed watts for lighting by room type and fixture type

- Distribution of household demographic characteristics such as number and ages of occupants

In addition to the direct outputs of the study, several other projects utilized information and resources from the CLASS study for their work as part of the 2010-2012 CPUC Evaluation, Measurement and Verification effort:

- **WO13 Residential Replacement Lamp Market Status Report¹**: WO13 used CLASS lighting inventory data to assess trends of socket saturation and lamp storage in households compared to the inventory results of the 2006-2008 Residential Lighting Metering Study².
- **WO17 Measure Cost Study³**: WO17 data mined manufacturer info to provide equipment shares to the measure cost study (WO17).
- **WO28 Upstream and Residential Lighting Impact Evaluation⁴**: CLASS data was used to update key gross savings parameters in the WO28 impact evaluation.
- **WO32 HVAC Impact Evaluation⁵ and WO54 HVAC Market Effects⁶**: WO32 used CLASS sites to serve as a sample frame for new HVAC installations for a quality installation baseline. The on-site information was reported to both WO32 and WO54 HVAC market effects.
- **WO35 Appliance Recycling Impact Evaluation⁷**: WO35 used CLASS site visits to identify qualifying units and to recruit participants for long-term metering of refrigerators and freezers.

¹ DNV GL, 2014. California Residential Replacement Lamp Market Status Report: Upstream Lighting Program and Market Activities in California Through 2013. Prepared for the CPUC ED. CALMAC Study ID CPU0091.01.

² KEMA, Inc. and Cadmus Group, 2010. Final Evaluation Report: Upstream Lighting Program. Prepared for the CPUC. CALMAC Study ID CPU0015.

³ Itron, 2014. WO17: 2010-2012 WO17 Ex Ante Measure Cost Study Final Report. Prepared for the CPUC ED. CALMAC Study ID CPU0079.01.

⁴ DNV GL, 2014. WO28: California Upstream and Residential Lighting Impact Evaluation – Draft Final Report Prepared for the CPUC ED. Final report expected Q4 2014.

⁵ DNV GL, 2014. WO32: HVAC Impact Evaluation – Draft Final Report. Prepared for the CPUC ED. August 27, 2014. Final report expected Q4 2014.

⁶ Nexus Market Research, 2014. Baseline Characterization Market Effects Study of Investor-Owned Utility Residential and Small Commercial HVAC Quality Installation and Quality Improvement Programs in California (Work Order 054)– Draft Final Report. Prepared for the CPUC ED. August 28, 2014. Final report expected Q4 2014.

⁷ DNV GL, 2014. WO35: Appliance Recycling Impact Evaluation –Final Report. Prepared for the CPUC ED. CALMAC Study ID CPU0092.01.

1.2 Approach

The goal of the study was to gather baseline data on California residential building characteristics in addition to the presence, efficiency, and usage of energy consuming devices found therein. Study results will be used to update the residential baseline information upon which program and portfolio planning and program evaluation rely. To achieve the study objectives, the following steps were taken:

- Developed a sample of homes stratified along variables of interest
- Recruited participants and conducted on-site inspections at a sample of homes in California to characterize:
 - residential building configurations (for example, conditioned square footage, room types) and specific construction components (for example, attic insulation)
 - installed appliances and energy-consuming products including electric and gas-powered products with high unit energy consumption (UEC) and high on-peak demand
 - lighting products installed by location in home and in storage
 - demographics of household
- Merged on-site data with information from other database sources to identify attributes specific to the model of equipment observed
- Expanded data from sample to represent residential individually-metered population

Two sets of expansion weights were developed to expand the sample of sites to represent the population. The initial site weights were developed based on the strata of the sample design, following the same general approach as the 2005 and 2000 CLASS studies, as well as the 2009 and 2003 California Residential Appliance Saturation Studies (RASS). These weights are referred to as “strata weights” throughout this report, with resulting saturation and building characterization estimates most appropriate to compare to results from the previous CLASS studies and the RASS studies.

A second set of expansion weights was created to reduce potential bias in estimates that might be attributed to the differences in the distribution of the CLASS participant sample by home ownership and type of residence compared to the U.S. Census population estimates. The population estimates were used in a calibration weight adjustment model that yielded “Census-adjusted weights” for CLASS participants. Study results based on the Census-adjusted weights describe the current state of households with individually-metered electric accounts within the service territory of PG&E, SCE and SDG&E.

1.3 Key Findings

This section summarizes some of the more interesting findings occurring at the statewide level within the electric IOU territories. All results presented in this section were estimated using the Census-adjusted weights, with error bounds presented at the 90% confidence level. Findings are grouped by lighting, appliance and equipment type, and building characteristics. Readers can find additional information and details in the sections of the report that pertain to the topic of discussion in this section.

Following this chapter is a comparison of the 2012 CLASS results to the 2005 CLASS study. Some very interesting trends that have occurred over the past 7 years are highlighted in that section.

1.3.1 Lighting

Every lighting fixture in each residence was inventoried by fixture type, fixture control type, number of lamps, lamp type, and lamp wattage. Fixtures may comprise one or more sockets, each of which could be filled with a different type of lamp. Interior and exterior lighting data for all installed lamps and lamps in storage were collected for this study. A total of 1,987 residences are included in the lighting analysis.

Number of fixtures and lamps - Overall, homes have approximately 31 fixtures and 47 lamps on average, which indicates that on average, fixtures have more than one socket. As might be expected, apartments and duplexes have significantly fewer fixtures and lamps on average than do single family, unattached residences.

Fixture Types - The most common fixture types are recessed cans, ceiling mount and wall mount. Homes have an average of 6.8 recessed cans, 6.5 ceiling mounted and 6.2 wall mounted fixtures. Also, homes have an average of 4.8 floor/table lamps.

Lamps - Suspended fixtures contain more lamps (3.0 lamps) than any other fixture type, followed by track lighting with an average of 2.7 lamps and ceiling fans⁸ with an average of 2.3 lamps. Approximately 36% of homes have more than 50 lamps, and about 20% have 20 or fewer lamps in use.

Saturation of CFLs and LEDs - The 2012 CLASS found that nearly all homes have one or more CFL installed (97%). Approximately 33% of fixtures contain a compact fluorescent lamp. Compact fluorescent lamps were found less often in dining rooms, laundry rooms, garages and closets. The 2012 CLASS also found that 9 percent of homes had at least one LED installed; LED lamps were most

⁸ Only ceiling fans with integrated light fixtures are included in this report.

commonly found in kitchens, offices, living rooms, and other exterior areas of homes surveyed. In spite of the growth in saturation of CFLs and LEDs, incandescent lamps continue to have the highest saturation of any lamp type (48%), with CFLs a distant second (29%) and LEDs with 1% saturation.

Fixture Control Types - The most prevalent control type for lamps is a manual switch, with 43% of total lamps in homes being manually controlled incandescent lamps, followed by 28% manually controlled compact fluorescent lamps.

1.3.2 Refrigerators

Data were gathered for all refrigerators accessible at a home, but only the primary and secondary refrigerators are included in the report due to the small number of homes with three or more refrigerators. Only about 4% of homes have three or more refrigerators.

Number of Refrigerators- Twenty-seven percent of households have two or more refrigerators, with 23% having two and 4% having three or more.

Primary Refrigerator Type - All homes that were visited over the course of this study except one have a primary refrigerator. The largest proportions of the primary refrigerators found are the standard top-mounted freezer type, accounting for 49.9% of all the primary refrigerators. The second most prevalent type of refrigerator found was side-by-side type, comprising 35.7% of the sample. Bottom-mounted freezer type refrigerators were found in 12.5% of homes visited.

Primary Refrigerator Size - The sizes of refrigerators were obtained from manufacturer data if the unit is matched to an efficiency database. The average manufacturer reported size for all refrigerators obtained from the efficiency database is 21.1 cubic feet.

Primary Refrigerator Age –The overall average age of the sampled refrigerators is 8.5 years. The manufacture dates range for 2000 to 2005 accounts for about 39% of all refrigerators. No refrigerators were found manufactured prior to 1985.

Primary Refrigerator Nameplate Unit Energy Consumption (UEC) – The overall average nameplate UEC for primary refrigerators is 598 kWh/year. This encouraging result is likely due to new federal energy standards and continued utility rebate and recycling programs.

Secondary Refrigerators –Over one-fourth (27%) of homes had two or more refrigerators, with standard top freezer as the most common (44%) as second refrigerators. Compact refrigerators comprised 24% of observed second refrigerators. The average size of all secondary refrigerators sampled is 16.8 cubic feet. The average age of secondary refrigerators is 10 years. The average overall nameplate UEC is 579 kWh/year.

Self-Standing Freezers- Approximately 15% of all homes sampled have one self-standing freezer. The majority of primary freezers found were the chest type (54%), and upright type freezers comprised the remainder. The average size of chest units is approximately 8.0 cubic feet smaller than

the average size of the upright units. The average age of the combined upright and chest freezers was 10.1 years, although the average age of sampled upright freezers (11.1 years) was older than chest freezers (9.0 years).

1.3.3 Heating Systems

Almost two-thirds (65%) of the homes have one heating system, 25% have two systems and 8% have 3 systems or more.

Primary Heating System Type – The largest proportion of all primary heating systems were found to be split forced air furnaces, totaling 40.8% of the population of primary heating systems. Space units used as the primary heating system were far less common than central units.

Primary Heating System Fuel – Among all the system types found, the vast majority (82%) consumed natural gas. Only 13% of all primary heating systems consumed electricity. Among all forced air furnaces, 96% consumed natural gas.

Primary Heating System Age – The estimated ages were obtained from a combination of the dates that were obtained from the manufacturer information and the surveyor estimates during the on-site visit. Overall, all types of primary heating systems were on average 15.5 years old.

Primary Heating System Efficiency – Only the units that matched with one of the efficiency databases were included in the analysis. The average Annual Fuel Utilization Efficiency (AFUE) for central heating systems is much higher than the AFUE for space heating systems at 80.7 and 73.1 AFUE, respectively. Eighty-two percent of central systems are within the 78-84.99 AFUE range, while 87% of space heating systems fall between 66-77.99 AFUE.

1.3.4 Cooling Systems

About two-thirds of homes surveyed have some type of cooling system, with 50% of all homes having a central system and 15% having a space cooling system.

Cooling System Type – Approximately 77% of primary cooling systems surveyed were found to be central systems, and of these, over half of systems (56%) surveyed were central split system ACs. The next most prevalent type of system was the window/wall AC, which were found in 19% of homes surveyed.

Cooling System Age – The average central air conditioning system type is 15.5 years old. The average space air conditioning system is 8.8 years old.

Cooling System Size – The most common central air-conditioner size is the 3-ton category, 20%, and the next most common sizes are the 2.5 ton category (16%) and the 4.5 ton capacity (16%). About 50% of all central air-conditioners fall within the 2.5-3.5 ton capacity range. The majority

(62%) of window/wall space units were in the 0.1 to 0.99 ton range. All fourteen of the central common building cooling systems surveyed were found to be in the range of 1.0-1.49 tons.

Cooling System Efficiency – The largest share of combined central system air conditioners are in the 10 to 11.99 SEER range accounting for 44% of central systems with a 4% error bound. Similarly, 95.3% of all types of space cooling systems are in the 9 to 10.99 EER range. No space cooling systems were found with EER of less than 6 or higher than 12. For split system units above 5 tons, the most saturated capacity range, the efficiency is 13.5 SEER. The most efficient packaged central units in the 4.0 to 4.49 SEER range with an average efficiency of 13.1 SEER.

1.3.5 Water Heaters

Data were gathered on many water heater characteristics, including system type, size, age, efficiency, fuel type, output, and insulation. The following summarizes some of the key findings related to water heating equipment.

Water Heater Type - The heavy majority of water heaters (84%) currently in homes are storage type water heaters, but 4% of homes were found to have instantaneous water heating.

Water Heater Fuel Type - The large majority of water heaters are gas, either natural or propane, totaling 81% of all water heaters found. About 7% of the water heaters are electric, while fuel type is not known for 12%.

Water Heater Size - The average size of all types of water heaters is 42.9 gallons. The largest proportion of gas units are in the 40 to 49 gallon range, whereas electric units have a wide distribution of capacities from 30 to 59 gallons.

Water Heater Age - The average age of all water heaters for which an age was obtained is 8.0 years old.

Water Heater Efficiency- The average energy factor for the popular 40 gallon gas fired water heater is 0.58, which is very near the standard of 0.59 from the National Appliance Energy Conservation Act Standards (NAECA) implemented in 2004. The average energy factors for electric models of the two most popular sizes (40 and 50 gallon), are both 0.89, and are also close to the respective standards of .92 and .90.

1.3.6 Clothes Washers

An estimated 81% of all homes have a clothes washer. Washers are most common in single family detached homes, where about 96% of individual dwelling units have a washing machine.

Clothes Washer Type – Approximately 30% of all washers found were horizontal axis washing machines. Single-family homes were the residence type with the highest proportion of horizontal-axis washers, at 30%.

Clothes Washer Age- Manufacture date was obtained from the nameplate, or when not available, customer-reported age is reported. Approximately 55% of clothes washers were reported to have been manufactured since 2006, with an average age of 7.2 years.

Clothes Washer Efficiency –Current federal standards in effect for clothes washers manufactured beginning in 2007 are the same for horizontal axis and standard axis machines at 1.26 MEF, with the ENERGY STAR minimum set at 2.0 MEF. For washers observed in this study, the average MEF is 1.6 for standard washing machines and 2.2 MEF for horizontal axis washers. Overall, 41% of the combined total standard and horizontal axis washers exceeded the ENERGY STAR minimum requirement of 2.0 MEF.

1.3.7 Clothes Dryers

Overall, 77% of homes have a clothes dryer. As one would expect, this saturation estimate closely compares to the saturation of washing machines. Clothes dryer fuel saturation findings indicate that 62% are gas, 35% are electric and 3% are propane. The average age of clothes dryers is 7.8 years old.

1.3.8 Dishwashers

Approximately 71% of all homes have a dishwasher. Dishwashers are more prevalent in townhomes and single-family detached homes than other residence types.

Dishwasher Age - The largest share of dishwashers (35.4%) was reported to have been manufactured between 2006 and 2009, and about 54% have been manufactured since the year 2006. The average age is 7.7 years.

Dishwasher Efficiency- No dishwashers with energy factors less than 0.275 were found. The majority of dishwashers fall within the range of 0.580 to 0.775 EF, containing 66% of the dishwashers. The average EF is 0.61.

1.3.9 Ranges and Ovens

This was the first time that data was collected on ranges and ovens as part of a CLASS study. Of the 1,987 total ranges sampled, about two-thirds of the ranges used natural gas (67%) as fuel, 30% used electricity and 4% used propane as fuel. Similarly, just over half (57%) of ovens used natural gas as fuel. Electric ovens made up 40% and propane 3% of ovens sampled.

1.3.10 Televisions and Connected Devices

Data on televisions and connected devices were also not covered in previous CLASS studies. In 2012, 99% of households had one or more televisions, with the average of 2.5 televisions per home. Of the single family detached homes surveyed, most (83%) had more than one TV. Although information was collected on all accessible TVs in homes, this section reports on only the most-used TV from each home. Almost half of the most-used televisions surveyed were LCD televisions (48%), followed by Cathode Ray Tube (CRT) televisions at 27%, followed by plasma (9%), LED (9%), and projection (7%). About 57% of the most-used TVs had screen measuring 36 or more inches diagonally. Approximately half of LCD, plasma, and unknown flat panel televisions were manufactured between 2006 and 2009.

The most common peripheral was the DVD player; three-quarters of homes had at least one TV with a DVD player, and it was connected to the most-used TV in over half of the homes. Detached single family homes had the highest average number of peripherals, at 4.7, and apartments in buildings with 5 or more units had on average 3 peripherals, the lowest.

1.3.11 Personal Computers and Connected Devices

Personal computers and their peripherals were also not surveyed in the previous CLASS studies. For this report, only the two most-used PCs available in the home were examined. Most homes were found to have one or more PCs (87%), with 51% of homes having two or more PCs. A larger proportion of households residing in apartment buildings with 2-4 units and in mobile homes were less more likely to not have a PC compared to the other residence types.

Over half (59%) of homes had a multi-function inkjet printer, although a smaller percentage (47%) had it connected to their most-used PC. Overall, surveyed homes had 1.8 computer peripherals on average. Eighty-two percent of all homes have at least one computer connected to the internet.

1.3.12 Building Envelope

The largest share of window frame types in homes was found to be metal, constituting 48% of the homes, followed by 43% of homes having vinyl windows. About one-third of all homes have metal framed, single paned windows. Interestingly, of homes surveyed, 72% of mobile homes and just over half (53%) of apartments in buildings with five or more units have metal framed, single paned windows. A larger percentage of newer homes built have double paned windows than the older homes. This was similar with Low-E glazing; residences built between 2000 and 2012 have the highest percentage of low-E glazing, 55%. This is probably due to new construction activity and window upgrade renovations.

Insulation data was collected with some difficulty during the site visits, when the attic was inaccessible due to it being located in another apartment unit, blocked by furniture, etc. Sixty-five percent of all homes have attic insulation, 15% have none and the presence of attic insulation is unknown in 19% of

homes. The average R-Value among all homes with an estimated or verified R-Value for attic insulation is 20.8. Approximately 23% of homes surveyed have no exterior wall insulation, while 49% of homes were found to have all the exterior walls insulated.

1.3.13 Spa and Pool Equipment

During the on-site visits for this study, 9% of homes were found to have spas and 8% of homes had pools. The most prevalent fuel used for spas was electric fuel, accounting for 52% of the sample. Approximately 46% of pools did not use heating fuel; those that did used primarily natural gas (33%) or solar (15%).

1.4 Limitations

Sampling unit bias is a major concern with surveys in general and with on-site surveys in particular. On-site surveys are time-consuming and invasive. Households that agree to participate in these surveys are more likely to include a person that is available to be at home during the day, and/or to be more interested in energy use/energy efficiency than average. While it would be nearly impossible and prohibitively expensive to eliminate all bias, several steps were taken to minimize bias in the study. Sampling techniques were implemented to improve representativeness of the sample for households with individually-metered electric accounts. Recruiting calls and on-site visits were conducted during extended business hours, including early mornings, evenings and weekends. Telephone recruiters and surveyors fluent in Spanish were used when initial contact indicated language was a barrier. All participants received a \$100 gift card.

Although these steps most likely reduced bias, the sample as expanded to the population by using strata weights yielded a population profile different from the Census on home ownership and type of residence. An additional set of weights was developed to reduce the potential bias in the study results. Results presented in this report are clearly labeled with the weights that were used to compute the results.

As described in Chapter 3 Study Methodology, the sample design incorporated household average daily consumption as a stratification variable. Note that the use of kWh only, without additional information or normalization, can represent several scenarios. For example, a house with small kWh usage could be a) a house with high conservation and/or high efficiency, b) a small house, c) a house with no air conditioning, or d) a house that uses gas as heating fuel and domestic hot water heating fuel. The sample design did not distinguish between these types of households, so it is possible that households with very different characteristics may be grouped within the same strata.

The information collected on-site, nameplate data such as model number in particular, is likely to be more complete for equipment that is newer and/or more accessible to the surveyor. Nameplate data may be less legible on older equipment. Heating and cooling equipment that is installed on roofs or otherwise inaccessible would have made it impractical, if not impossible, to collect model numbers.

The efficiency information presented in the report was obtained through matching model numbers collected during the on-site visit to reference databases. Newer appliances are more likely to be matched than older equipment. This potentially introduces an unintentional bias towards newer and generally more efficient equipment. More information on matching the model numbers to the databases is reported.

The reference databases used to obtain efficiency information do not account for efficiency degradation over time. Thus, efficiency levels reported for older appliances are likely higher than actual efficiencies of the equipment.

Participants were asked to estimate the total square feet of living space. For sites where the participant was unable to provide an estimate of the total square feet of living space, public real estate records were searched on the address. Single-family homes were more likely to be found in real estate records, as sales transaction data is recorded. Apartments and rental units were less likely to be obtained from public records, unless a description of the specific unit was found in the records.