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# Alameda Municipal Power FY2018–FY2019 Residential and Commercial Energy Efficiency Program Evaluation Report

**FINAL**

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# Introduction and Summary

During fiscal years 2018 and 2019 energy efficiency program years Alameda Municipal Power (AMP) offered energy efficiency programs to its residential and commercial customers. This report presents Cadmus' research approach and evaluation findings for the Residential Online Rebate Portal program and the Self-Install Commercial Rebate Program.

The Residential Online Rebate Portal program offered rebates for the following energy-efficient measures:

- LED light bulbs
- LED fixtures
- Refrigerator and freezer recycling (including additional incentives for purchase of new ENERGY STAR® units)
- Electric clothes dryers
- Washing machines
- Electric heat pump water heaters (HPWHs)
- Decorative string lights

The Self-Install Commercial Rebate Program provided incentives based on kWh/year savings. Under this program, customers could work with their in-house staff or hire an independent contractor to install the measures for projects such as the following:

- HVAC
- Interior lighting
- Exterior lighting
- Window film
- Refrigeration

CLEAResult implemented the residential program, and AMP directly administered the commercial program. In FY 2018 and FY 2019, 335 residential customers installed program-rebated measures and 10 commercial customers completed projects that qualified for rebates.

Cadmus conducted the impact evaluation in accordance with the most recent California Energy Commission's (CEC) Publicly Owned Utility (POU) Evaluation, Measurement, and Verification (EM&V) Guidelines. The POU EM&V Guidelines state the following for program evaluations:

- Reliably document program effects
- Improve program designs and operations to more cost-effectively obtain energy resources

For the residential evaluation, Cadmus conducted a program tracking-data review and an online survey to verify that measures had been installed and remained in use. For the commercial program evaluation,

Cadmus conducted desk reviews of project documentation and verification (through virtual site visits) for a sample of commercial projects.

Cadmus calculated evaluated gross savings based on the California Municipal Utilities Association (CMUA) Technical Reference Manual[1] (TRM). The CMUA TRM prescribes methods for estimating savings attributable to California publicly owned utilities' energy efficiency programs. We verified specific measure inputs based on data collected from surveys, desk reviews, and site visits. These efforts determined an energy savings realization rate of 103% for the residential program and 50% for the commercial program. Primary factors contributing to the low realization rate for the commercial program included a combination of errors in reported *ex ante* savings calculations as well as differences between assumed versus actual hours of operation. Table 1 presents the reported and evaluation savings as well as realization rates.

**Table 1. Evaluated Savings**

| Program | Reported Savings (kWh/yr) | Evaluated Savings (kWh/yr) | Realization Rate | Precision[a] |
|---|---|---|---|---|
| Residential Online Rebates | 100,432 | 103,177 | 103% | 9.2% |
| Self-Install Commercial Rebate | 466,682 | 231,410 | 50% | 3.2% |

[a] Overall precision is calculated at 90% confidence.

[1] https://www.cmua.org/files/CMUA-POU-TRM_2017_FINAL_12-5-2017%20-%20Copy.pdf

# Methodology

In conducting the evaluation, Cadmus used the approach presented in Table 2.

**Table 2. Evaluation Activities**

| Activity | Overview |
|---|---|
| Initial Data Review | Review program-tracking data to characterize the sample frame and design a sampling plan. |
| Data Collection Instrument and Sample Design | Design an online survey to collect data from a sample of residential program participants. Develop a site-visit data collection instrument to collect information from commercial program participants. Select site visit and participant survey samples to meet or exceed ±10% precision at a 90% confidence level. |
| Documentation Review (Commercial) | Review program documentation to understand *ex ante* assumptions and operating conditions. |
| Verification Virtual Visits (Commercial) | Verify installed quantities and operation. Confirm that model numbers match documentation, where possible. |
| Participant Survey (Residential) and Interviews (Commercial) | Collect quantitative and qualitative feedback about the program. |
| Savings Analysis | Apply findings from site visits and desk reviews; calculate savings using CMUA POU TRM algorithms, extrapolate realization rates to the population, and compute confidence and precision. |

## *Residential Tracking Data Review*

Cadmus reviewed data in the report provided by the implementer. The review sought to collect the following information for each measure:

- Reported measure quantities
- Reported gross savings (kWh/year)
- Product model numbers for measure TRM input look-ups

Cadmus used product model numbers provided in the program-tracking dataset to determine additional details (e.g., bulb type and efficient wattage) for each product included in the ENERGY STAR Qualified Products List.

## *Data Collection Instrument and Sample Design*

For residential data collection, Cadmus developed an online survey instrument to collect information from residential customers regarding their program participation. The survey asked about specific measures that each customer acquired through the program, including whether it remained installed and operational, equipment specifications (e.g., refrigerator configuration) and asked questions about the program's influence on energy efficiency decisions and purchases. Using contact information provided by AMP, Cadmus sent survey invitations to all 335 participants

For the commercial projects, due to their limited number and significant differences in size, Cadmus designed a stratified sample, consisting of a census of the top five projects, based on reported energy savings, and a random selection of four remaining projects, as shown in Table 3.

**Table 3. Commercial Verification Sample**

| Stratum | Reported Savings | | |
|---|---|---|---|
| | kWh | Percent of Sample | Percent of Population |
| **Top 5 (Census)** | **420,763** | **97.16%** | **90.16%** |
| HVAC | 217,566 | 50.24% | 46.62% |
| Lighting | 93,472 | 21.58% | 20.03% |
| Lighting | 5,731 | 10.56% | 9.80% |
| Lighting | 32,427 | 7.49% | 6.95% |
| Lighting | 31,567 | 7.29% | 6.76% |
| **Random** | **15,885** | **2.84%** | **2.64%** |
| Window Film | 13,073 | 2.19% | 2.03% |
| Refrigeration | 1,394 | 0.32% | 0.30% |
| Lighting | 1,418 | 0.33% | 0.30% |
| **Total** | **436,648** | **100.00%** | **92.80%** |

## *Commercial Documentation Review*

For all sites selected for evaluation, Cadmus reviewed project documentation to understand how reported savings were developed; Cadmus additionally determined which factors needed verification during the site visits. For most projects, documentation included the following:

- Pre- and post-inspection photos
- Completed rebate application forms
- Equipment invoices
- Equipment specification sheets
- Equipment specifications
- Equipment quantities
- Space-use type
- Hours of operation
- Control mechanisms

## *Verification Site Visits (Virtual)*

Cadmus originally intended to conduct in-person visits to each sampled commercial program facility to verify installation and operation of measures installed through the program. However, due to safety concerns raised by the ongoing COVID-19 pandemic, Cadmus pursued virtual site visits, using a video-streaming application. This application connected to a participant's cell phone camera and recorded audio and visual footage (with the participant's permission). Cadmus documented all virtual site-visit inspections using video and screen-capture photos as well as supplementary photos taken by site contacts.

Cadmus conducted virtual site visits for the seven sampled projects. Five projects replaced lighting, one replaced a freezer, and one replaced HVAC and installed new window film. Virtual site visit activities included the following:

- Verification that installed equipment models matched project documentation
- Verification of equipment quantities
- Verification of operation schedule and controls

In most cases, LED fixture model numbers were not visible on installed fixtures or were not observable due to the fixtures' height. To confirm that fixtures listed in the documentation had been installed, Cadmus compared observations of on-site fixtures against fixture cutsheets (available on manufacturers' websites), based on overall appearance, manufacturer (if observable), and LED module quantity.

## *Participant Survey and Interviews*

From July 20 through July 27, 2020, Cadmus fielded online surveys with residential program participants. This included emailing initial survey invitations to all 335 customers who participated in the residential program and following up with an additional reminder email for those not responding. Cadmus received completed surveys from 52 participants, for a 15% response rate, covering 14% of the reported savings for this program. These surveys asked participants questions addressing up to three efficiency measures they installed. The questions focused on the following:

- Verification of installation and use of reported measures
- Freeridership
- Spillover
- Early retirement or natural replacement
- Awareness of AMP rebates
- Measure-specific needs (such as heat pump water heater size and location)

Cadmus also interviewed a representative for each commercial building facility, focusing on the respondents' program participation experience and their satisfaction levels with the program.

## *Residential Verified Savings Calculations*

Cadmus calculated verified savings for each measure in the evaluation sample in accordance with the 2017 CMUA TRM, based on inputs determined through model number lookups and customer survey responses. The following sections outlines our approach for each measure. The specific algorithms used are detailed in Appendix A.

### LED Lighting

For LED lighting measures, Cadmus asked respondents about lighting products they purchased, based on general lighting categories rather than asking questions about each individual light bulb model. For each respondent, Cadmus calculated the following proportions:

- Bulbs installed indoors versus outdoors
- Bulbs replacing working versus burned-out bulbs
- Bulbs installed versus in storage

We used model number lookups to determine both bulb type and efficient wattage values for each model number included in the program-tracking data.

The CMUA TRM supporting spreadsheet 204 provided baseline wattage values based on efficient wattage buckets and bulb types. Additionally, it provided operating hours and interactive effects, based on the bulb's location (interior or exterior). Cadmus used the TRM's supporting spreadsheet 104 for nonresidential LED lighting to determine the baseline wattage for LED linear fixtures, as the residential TRM did not include linear fixtures. As the TRM did not distinguish between homes with electric or natural gas heating, Cadmus assumed that interactive effect values provided in the TRM could be applied to all homes, regardless of heating type.

### Decorative String Lighting

To calculate verified savings for LED holiday lights, Cadmus applied inputs and a methodology from the CMUA 2017 TRM's supporting spreadsheet 205, along with inputs provided by online survey participants. Cadmus used product model numbers provided in the program-tracking dataset to determine bulb types for each string lighting product included in the ENERGY STAR Qualified Products List. By matching bulb types to the CMUA TRM supporting file's savings lookup table, Cadmus found kWh savings per foot. Multiplying this with the product length and the verified quantity drawn from the survey, Cadmus calculated the final verified savings.

### Clothes Dryers

Using information provided by survey participants, along with the CMUA TRM's entry for heat pump clothes dryers and the ENERGY STAR appliance calculator, Cadmus calculated verified energy savings for clothes dryers. The CMUA TRM provided a deemed savings value for heat pump clothes dryers, but did not include savings for ENERGY STAR clothes dryers not using heat pump technology. Cadmus conducted a model number lookup for clothes dryers using the latest ENERGY STAR Qualified Products List, based on model numbers in the CLEAResult dataset. Through this research, Cadmus determined which clothes dryers used heat pump technology, verifying these data through survey responses.

For heat pump clothes dryers, Cadmus applied the CMUA TRM's deemed savings value, which was almost 40% higher than verified savings for non-heat pump dryers. For non-heat pump clothes dryers, Cadmus used the cubic foot capacity and combined energy factor (CEF) values from the latest ENERGY STAR Qualified Products List as inputs to the ENERGY STAR appliance calculator; this determined verified energy savings.

### Heat Pump Water Heaters (HWPW)

Cadmus calculated verified energy savings for HPWHs by applying deemed savings from the CMUA TRM's supporting file 307. TRM-deemed savings were based on a water heater's tank size, location

(conditioned versus un-conditioned space), and space-heating type. Cadmus determined these based on the participant survey and model number lookups, using the latest ENERGY STAR Qualified Products List.

### Refrigerator and Freezer Recycling

Cadmus based refrigerator and freezer recycling measure savings on the CMUA TRM's supporting file 207, along with file 208 for customers purchasing an additional ENERGY STAR refrigerator. Using data from the online participant survey, Cadmus verified the quantity of refrigerators and freezers recycled by each respondent as well as the condition of the recycled appliances. The process excluded savings for broken appliances not functioning when recycled.

For new ENERGY STAR refrigerators, Cadmus conducted model number lookups using the latest ENERGY STAR and Consortium for Energy Efficiency (CEE) Qualified Products Lists to determine refrigerator efficiency levels, along with freezer and ice-maker configurations. Using these values, Cadmus looked up deemed savings from the CMUA TRM.

### Clothes Washers

Cadmus calculated evaluated energy savings for clothes washers using the CMUA TRM's supporting file 216 for early retirement measures and 216a for natural replacement measures. Based on the participant survey, Cadmus determined early retirement versus natural replacement. Savings were based on deemed lookup tables, using washer configurations, efficiency levels, water heating fuels, and dryer heating fuels. Cadmus collected this information from model number lookups and online participant survey questions.

## *Commercial Evaluated Savings Analysis*

The following sections briefly describe the methods used to evaluate savings from the different measures installed through the commercial program. The specific algorithms used are detailed in Appendix A.

### LED Lighting

Cadmus based first-year evaluated savings on previously installed fixture wattages, as indicated in the projects' preapproval documentation, provided by AMP. To estimate evaluated kW demand reduction ($\Delta\text{kW}$) and kWh energy savings ($\Delta\text{kWh}$), Cadmus used the engineering algorithms based on the 2017 California Municipal Utilities Association Publicly Owned Utilities Technical Reference Manual (CMUA TRM).

In general, assumptions for coincident demand factors, default savings factors, hours of use, HVAC interactive effects, and fixture quantities were the same for existing and installed cases; Cadmus gathered these inputs based on data collected during virtual site visit interviews, email correspondence,

and the CMUA TRM. Where additional scheduling or controls were in place, Cadmus adjusted the hours of use (HOU) and default savings factor (DSF) accordingly.[2]

## Rooftop AC

Commercial program participants installed cooling equipment that included rooftop AC units. Title 24 code was used for the baseline (as these projects were verified to be natural replacement, based on the documented age of the replaced units). Cadmus utilized a custom calculation for rooftop AC units, with the algorithms included in Appendix A. The California Energy Commission's (CEC)'s Title 24 baseline energy efficiency ratio (EER) was used as a baseline for the savings calculations.[3] The effective full load hours (EFLH) were calculated from the operating schedule (gathered from the virtual site visit) and annual temperature data in Alameda, California. Cadmus created temperature bins, based on the percentage of annual hours in each five-degree interval when air conditioning would be operating. Cadmus allocated the operating hours proportionally to the temperature bins to the EFLH full-load hours. During the virtual site visit, a Cadmus engineer collected the verified tons of cooling (TOC).

## Refrigerated Display Case EC Motor Retrofit

Cadmus calculated evaluated energy savings for freezer motors by applying deemed savings from the CMUA TRM's supporting file 109. TRM-deemed savings were based on the building type, building vintage, and climate zone.

## Reflective Window Film

Cadmus calculated evaluated energy savings for window film by applying deemed savings from the CMUA TRM's supporting file 118. TRM-deemed savings were based on the building type and climate zone.

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[2] CDF, DSF, HOU (when applicable), and IE were gathered from the 2017 CMUA POU TRM, based on verified building type.

[3] https://www.energy.ca.gov/sites/default/files/2020-05/04_MechanicalSystems.pdf

# Commercial Program Evaluation Findings

## *Documentation Review*

Cadmus reviewed project documentation for all sites selected for evaluation, seeking to understand how reported savings had been developed and to determine which factors needed verification during the site visits. For most projects, the documentation provided the following variables:

- Equipment quantities and specifications
- Space-use type
- Hours of operation
- Control mechanisms

Upon reviewing the nameplates for the HVAC project, Cadmus determined that the measures would qualify as natural replacements due to the existing units' age.

In some instances, the provided documentation did not provide sufficient detail on the control devices, such as whether and where they were installed, the source of the hours of operation assumption, and the site's building type. The refrigeration project did not indicate the number of motors replaced in the savings calculations, but Cadmus conducted further research into the equipment specifications and we were able to verify that two motors were replaced.

## *Verification Site Visits*

Cadmus was able to verify all the information necessary for the savings analysis through the virtual site visits, including equipment quantity, equipment specifications, and control systems. We conducted an interview at the end of the virtual visit to determine operational hours.

The largest factor that affected the realization rate was one large HVAC project, for which Cadmus found errors in the assumptions for EFLH, baseline EER and system EER used to calculate reported savings. Consequently, Cadmus made the following adjustments to this project's savings inputs:

- Calculated the effective full load hours (EFLH) based on a temperature bin analysis, reflecting that package units only operate at 100% load during the hottest temperatures of the year. (The reported savings calculation assumed units would operate at a 100% load during scheduled operating hours.)
- Corrected the baseline EER, basing it on Title 24 efficiency.[4]
- Used the rated full-load EER for the system-rated EER, based on standardized testing conditions and providing an accurate comparison to Title 24 values, converting to kW/ton based on unit conversion factors (kW/ton = 12/EER).

[4] Title 24 Table 110.2-A.

After Cadmus made these adjustments, the evaluated savings for this HVAC project were significantly lower than the reported savings.

Other large factors affecting the realization rate included operational schedule adjustments for lighting projects and the presence of lighting controls. Cadmus adjusted the operational hours for projects in the evaluation sample, based on verified operational schedules, some of which were based on the building structure (e.g., the presence of ambient light) or building operating hours (e.g., open to close). Generally, these verified hours were shorter than the operational hours used to compute reported savings, resulting in a lower realization rate. The additional savings attributable to verified lighting controls were generally offset by the adjusted operational schedules. Cadmus based operational hours for external lighting on deemed TRM values, which correspond to nighttime hours in Alameda (Climate Zone 3).

## *Evaluated Savings*

Based on the virtual site observation results as well as the project documentation review, Cadmus calculated energy savings for the evaluation sample. For the census stratum, Cadmus calculated a realization rate for each site. For the random stratum, Cadmus calculated a realization rate for the verified sites and applied it to remaining sites in the random stratum. Table 4 shows the program savings and realization rates.

**Table 4. Evaluated Savings**

| Stratum | Reported Savings (kWh/yr) | Evaluated Savings (kWh/yr) | Realization Rate | Precision[a] |
|---|---|---|---|---|
| Census | 420,763 | 182,264 | 43% | 0.0% |
| Random | 45,919 | 49,196 | 107% | 18.8% |
| Total | 466,682 | 231,410 | 50% | 3.2% |

[a] Overall precision is calculated at 90% confidence.

Table 5 provides reported savings, evaluated savings, and realization rates for each project as well as general observations noted.

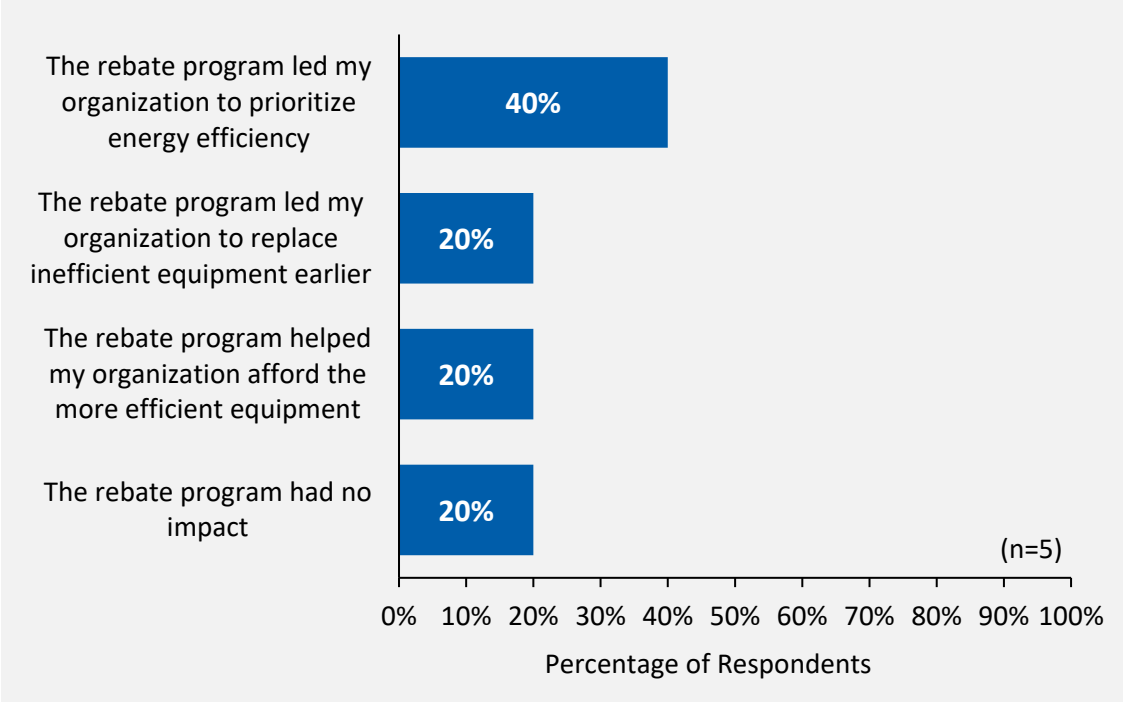
**Table 5. Site Visit Sample Savings Details**

| Stratum | Project Type | Reported Savings (kWh) | Evaluated Savings (kWh) | Realization Rate (kWh) | Reported Savings (kW) | Evaluated Savings (kW) | Realization Rate (kW) | % of Total Sample Evaluated Savings | General Observations |
|---|---|---|---|---|---|---|---|---|---|
| Top 5 (Census) | HVAC | 217,566 | 19,278 | 17% | 69.73 | 19.93 | 57% | 10% | *Ex ante* calculations assume full operational load shape. Applied custom calculations. |
| | Lighting | 93,472 | 53,234 | 57% | 27.25 | 27.25 | 100% | 27% | Operating hours adjusted for seasonal lighting changes. |
| | Lighting | 45,731 | 45,731 | 100% | - | - | N/A | 23% | |
| | Lighting | 32,427 | 32,746 | 101% | 5.87 | 5.19 | 88% | 17% | Operating hours adjusted for schedule and installed lighting controls. |
| | Lighting | 31,567 | 31,275 | 99% | 5.93 | 4.76 | 80% | 16% | Operating hours adjusted for schedule and installed lighting controls. |
| Random | Window Film | 6,524 | 6,524 | 100% | 0.00 | 4.13 | N/A | 3% | *Ex ante* did not report demand savings. |
| | Window Film | 2,970 | 2,978 | 100% | 1.80 | 1.89 | 105% | 2% | Building type unclear in documentation, but confirmed during verification. |
| | Lighting | 1,394 | 2,249 | 161% | 0.39 | 0.39 | 100% | 1% | Operating hours adjusted for schedule and installed lighting controls. |
| | Refrigeration | 1,418 | 1,420 | 100% | 0.15 | 0.15 | 99% | 1% | |

## *Program Influence and Participant Satisfaction*

Subsequent to the virtual site visits, Cadmus contacted commercial program participants by phone, seeking feedback regarding the program's influence. This produced responses from five out of seven participants. The interview questions focused on freeridership, program influence, and general satisfaction, as shown in Figure 1. Two participants reported pursuing additional energy-efficient equipment—one for LEDs and one for new refrigeration motors. All participants indicated satisfaction with the rebate program.

**Figure 1. Program Role in Purchasing Commercial Equipment**



# Residential Program Evaluation Findings

## *Data Review*

Cadmus found a number of lighting measure records in the evaluation sample with incomplete or incorrect model number documentation. Because the tracking data did not include bulb wattages, and we were unable to look up model numbers in the ENERGY STAR Qualified Products List, we were unable to evaluate savings for theses records. Therefore, Cadmus removed these records from our evaluation sample when calculating the realization rate and corresponding precision.

## *Evaluated Savings*

Table 6 shows reported and evaluated annual savings for the Residential Online Rebate Program. Cadmus evaluated a total of 103,177 kWh/yr for the 2018–2019 program period, with 35,726 kWh/yr from lighting measures and 69,415 from non-lighting measures. The evaluation determined an overall realization rate of 103%, with a realization rate for lighting measures of 114% and 97% for non-lighting measures.

**Table 6. Evaluated Savings**

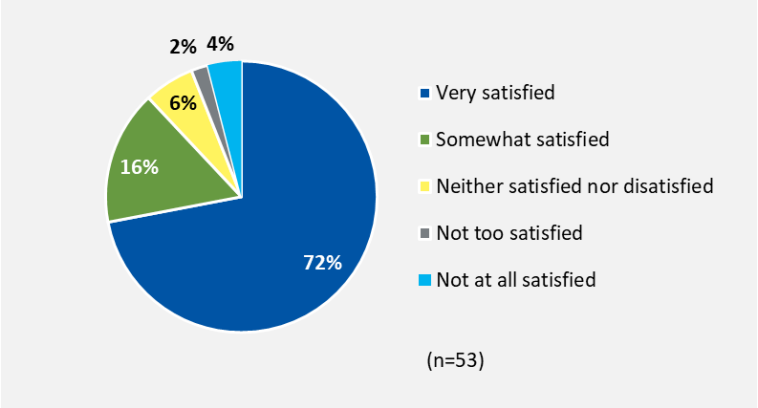
| Measure Category | Reported Savings (kWh/yr) | Evaluated Savings (kWh/yr) | Realization Rate | Precision[a] |
|---|---|---|---|---|
| Lighting | 31,249 | 35,726 | 114% | 13.1% |
| Non-Lighting | 69,183 | 67,451 | 97% | 12.5% |
| All Measures | 100,432 | 103,177 | 103% | 9.2% |

[a] Overall precision is calculated at 90% confidence.

## *Customer Satisfaction*

As shown in Figure 2, 88% of respondents said they were satisfied with the Online Rebate Portal program. More respondents said they were *very satisfied* (72%) than *somewhat satisfied* (16%). Only 6% of respondents said they were not satisfied with the program. Two of these three respondents indicated they encountered problems with the rebate and debit card; one reported having to inquire multiple times regarding their rebate's status.

**Figure 2. Residential Online Rebate Program Satisfaction**

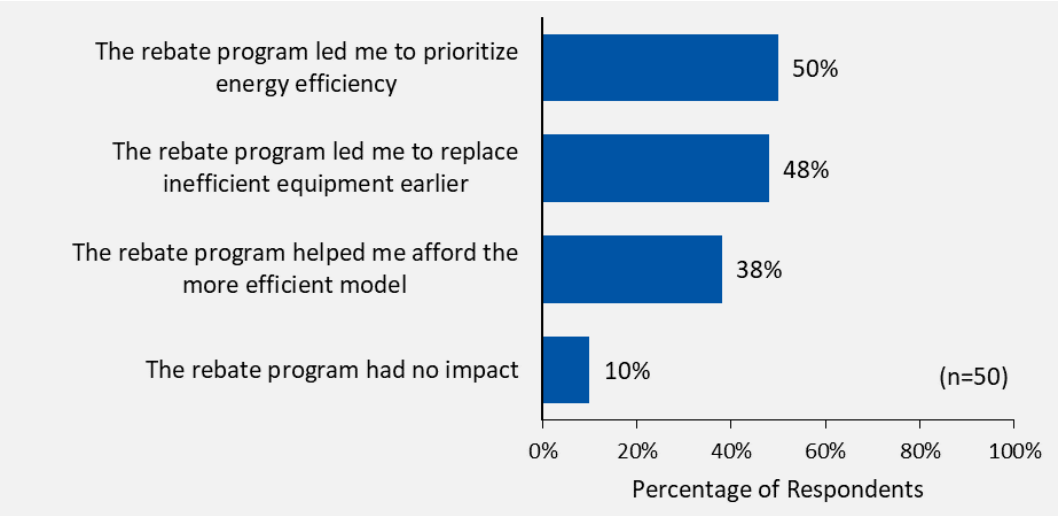


Source: Survey Question, "In general, how satisfied were you with Alameda Municipal Power's Online Rebate program?"

## *Program Influence*

Figure 3 shows the role that the Residential Online Rebate Program played in survey respondents' decisions to purchase equipment. Over one-half of the respondents reported that the rebate program led them to prioritize energy efficiency (50%), while smaller proportions reported that the program led them to replace inefficient equipment earlier (48%) or helped them to afford a more efficient model (38%). Fewer respondents reported that the program did not impact their purchasing decisions (10%).

**Figure 3. Program Role in Purchasing Residential Equipment**



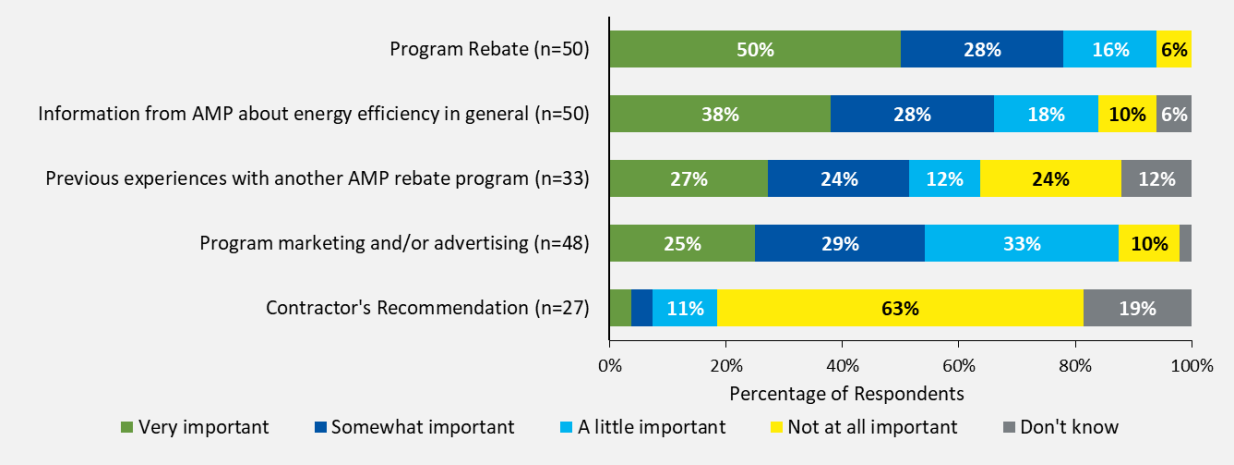

Source: Survey Question, "What was the role of Alameda Municipal Power's Online Rebate Program in your decision to purchase a your new [MEASURE]?"

Figure 4 shows the role that different factors played in survey respondents' decisions to purchase efficient equipment through the Online Rebate Program. Over one-half of survey respondents indicated that they found four of the five factors either very important or somewhat important in their decisions to install new equipment; these factors included the following:

- Program rebate (78%)
- Information from AMP about energy efficiency in general (66%)
- Marketing and/or advertising about the program (54%)
- Previous experiences with another AMP rebate program (52%)

A contractor's recommendation was the only factor that fewer than one-half of respondents indicated had a very important or somewhat important role in their equipment purchases (8%).

**Figure 4. Factors Affecting Decision to Install Residential Equipment**




Source: Survey Question, "How important were the following in your decision to install your new [MEASURE]?"

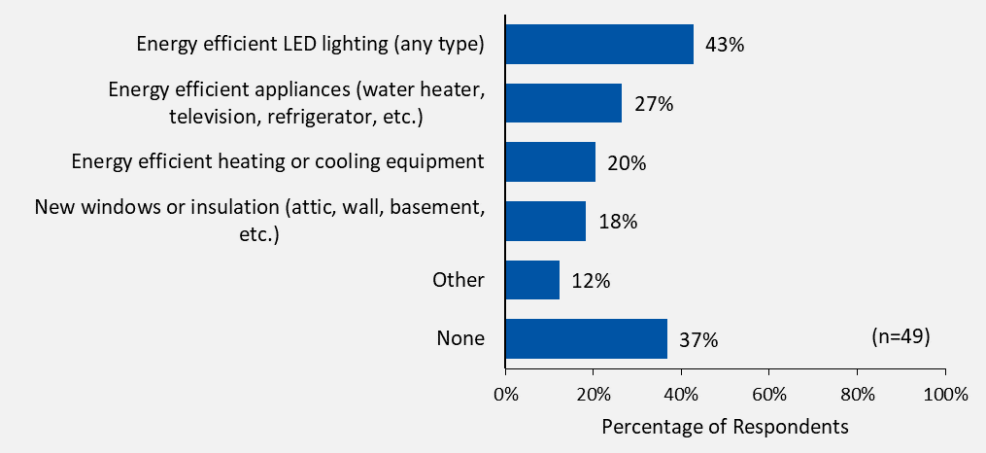
Cadmus asked survey respondents whether they had made additional energy efficiency equipment purchases or upgrades to their homes outside of the Online Rebate Program. Figure 5 shows the most common responses. These responses included the following:

- Purchasing energy-efficient LED lighting (43%)
- No purchases or upgrades (37%)
- Energy efficiency appliances (such as water heaters or refrigerators) (27%)
- Installing efficient heating or cooling equipment (20%)

Additionally, the "other" category included one of the following responses:

- Window shade insert for heat reduction
- Solar panels
- Recessed light covers
- Installing attic vents with a new roof
- Car charger for plug-in hybrid
- Energy efficiency vehicle

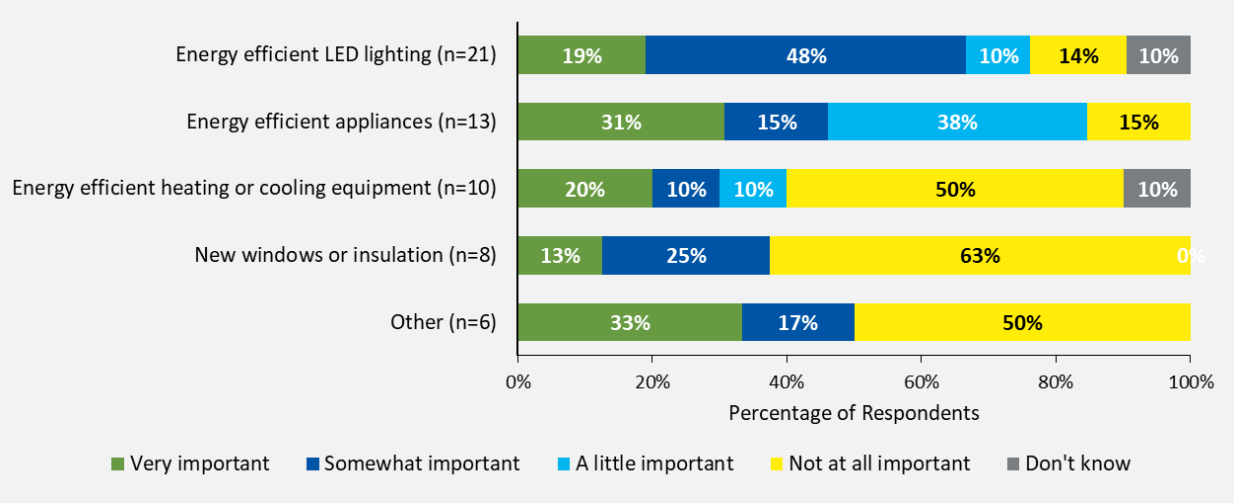
**Figure 5. Additional Energy Efficiency Equipment Purchases or Upgrades**




Source: Survey Question, "Have you made additional energy efficiency upgrades to your home or purchased and installed any of the following? Please select the upgrades that you have made."

For respondents purchasing additional energy-efficient equipment or upgrades, Cadmus asked a follow-up question concerning the importance of their Online Rebate Program experience in their decisions. Figure 6 shows the customers' responses.

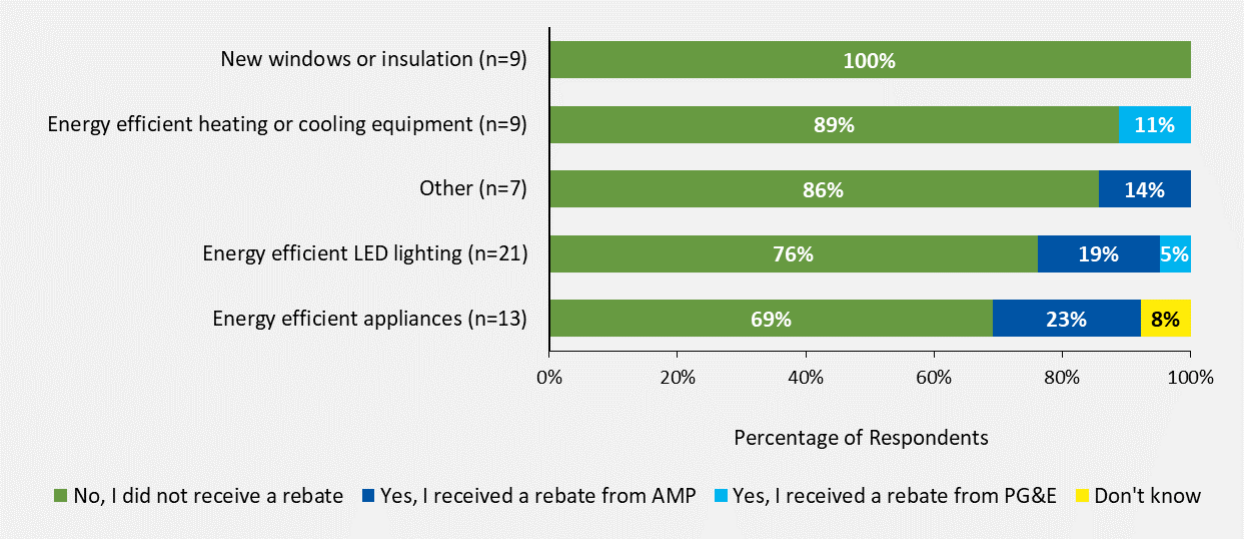
**Figure 6. Importance of Program in Additional Equipment Purchases or Upgrades**




Source: Survey Question, "How important was your experience with the Residential Online Rebate Program in your decision to install the following equipment?"

Cadmus asked each of these respondents whether they received a rebate for these energy efficiency upgrades. As shown in Figure 7, most respondents did not receive a rebate.

**Figure 7. Rebate Received for Additional Equipment Purchases or Upgrades**

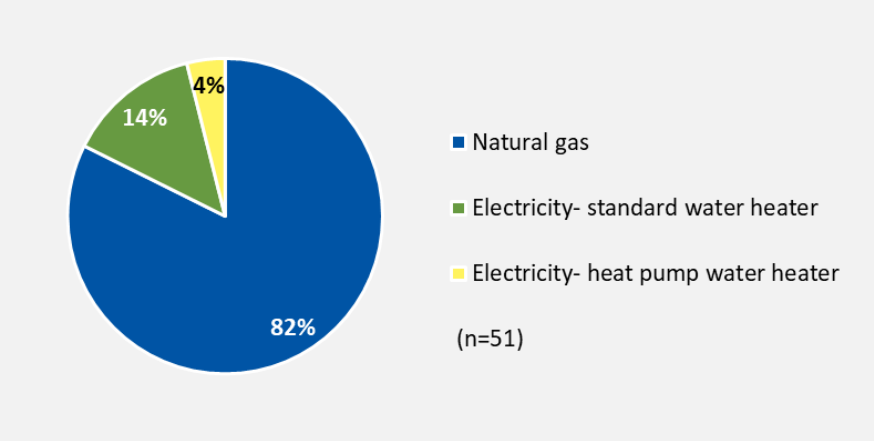



Source: Survey Question, "For each of the additional energy efficiency upgrades you made to your home, please tell me if you received a rebate for the upgrade."

## *Home Characteristics*

Cadmus asked all survey participants a series of questions concerning their homes' characteristics. Figure 8 shows the proportion of fuel types used for water heating, as reported by survey respondents. Most homes used natural gas water heating (82%), while smaller proportions used electric resistance heating (14%) and HPWHs (4%).

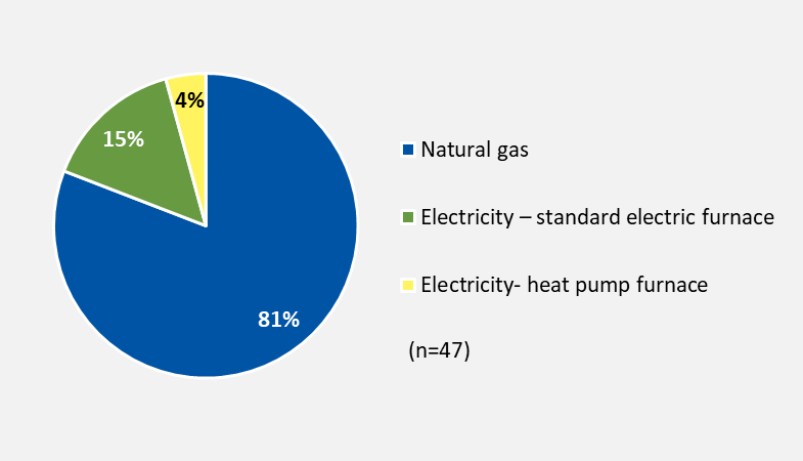
**Figure 8. Residential Water Heating Fuel Type**




Source: Survey Question, "What fuel do you use to heat water in your home?"

As shown in Figure 9, the majority of survey respondents reported using natural gas (81%) as their home-heating fuel source, while smaller proportions reported using an electric furnace (15%) or an electric heat pump (4%).

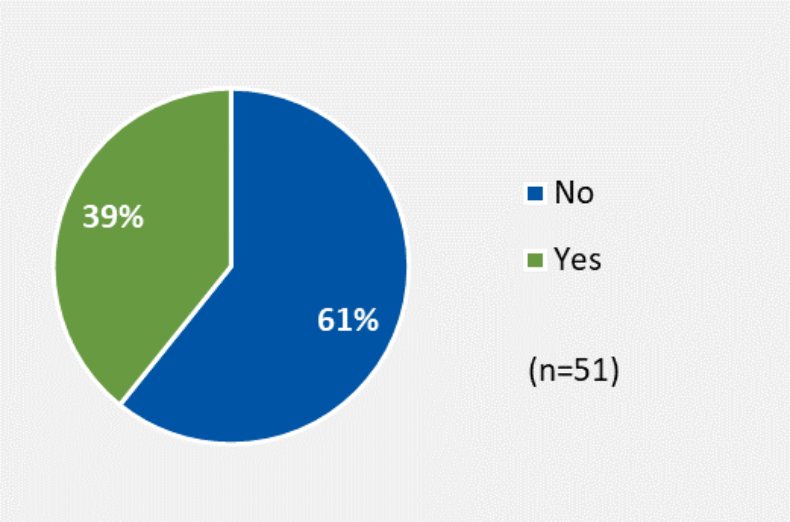
**Figure 9. Residential Home Heating Fuel Type**




Source: Survey Question, "What fuel source do you use to heat your home?"

When asked if they drove an electric vehicle, more than two-thirds of respondents (39%) reported they did not, as shown in Figure 10.

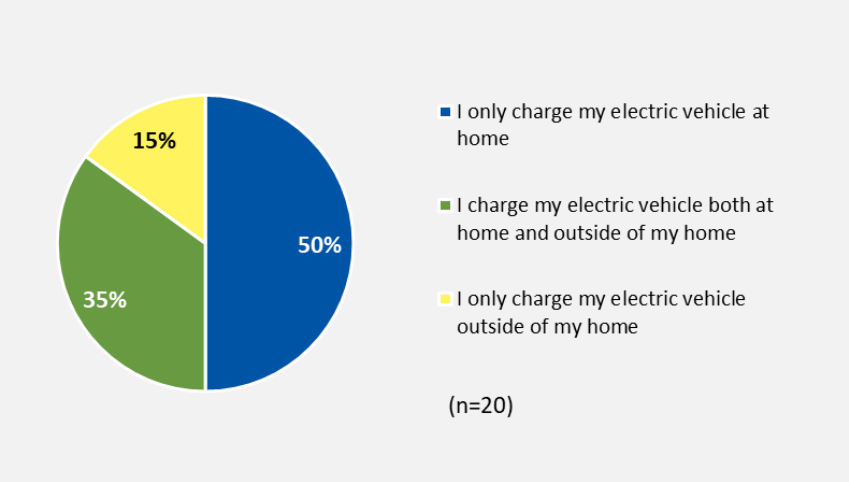
**Figure 10. Residential Customers Who Drive an Electric Vehicle**




Source: Survey Question, "Do you currently drive an electric vehicle?"

Cadmus asked customers who indicated that they drove electric vehicle a follow-up question about where they charged their vehicle. One-half of these respondents reported only charging their vehicle at home, while another 15% reported only charging their vehicle at work. The remaining 35% reported charging their vehicle at home and at work. Figure 11 shows the breakdown.

**Figure 11. Residential Vehicle Charging Locations**




Source: Survey Question, "Do you charge your electric vehicle at home?"

## Conclusions and Recommendations

**Conclusion 1:** Some residential-measure tracking-data quality issues reduced the precision of evaluated savings. Additional tracking data fields could be included to facilitate evaluations.

> **Recommendation 1:** AMP should consider reviewing the implementer tracking-data requirements and providing additional instruction to implementers regarding model number collection to improve model number accuracy. In addition, adding efficient wattages and baseline assumptions to the tracking data would facilitate the evaluation and the identification of discrepancies sources between reported and evaluated savings.

**Conclusion 2:** The residential program-tracking database neither labeled the recycled appliance type for refrigerator and freezer recycling measures nor included a data field that indicated the number of new ENERGY STAR refrigerators purchased. This introduced uncertainties to the evaluation analysis.

> **Recommendation 2:** AMP should examine the possibility of adding fields to the program dataset to indicate recycled appliance types and quantities of new ENERGY STAR refrigerators for refrigerator and freezer recycling measures.

**Conclusion 3:** Data entry errors in the commercial program savings calculations led to inaccuracies in reported savings at the project level, significantly impacting the program's realization rate.

> **Recommendation 3:** Consider using a summary document that clearly identifies the equipment installed, where it was installed, and any assumptions used to calculate energy savings. Cadmus can provide a workbook for AMP's use to compute *ex ante* HVAC savings.

**Conclusion 4:** Residential and commercial participants were happy with the program and said it encouraged them to install energy-efficient measures.

**Conclusion 5:** ENERGY STAR heat pump dryers offered significantly higher savings than ENERGY STAR standard electric dryers.

> **Recommendation 5:** Consider implementing tiered incentives for measures (such as heat pump dryers) that offer substantial incremental savings but have a higher incremental cost.

# Appendix A. Evaluation Method Details and Algorithms

## *Decorative String Lighting*

$$\Delta kWh = Quantity \times Savings\ per\ Foot \times Length$$

Where:

| | | |
|---|---|---|
| Quantity | = | Verified quantity |
| Savings per Foot | = | Default savings per foot of string lighting in kWh/ft |
| Length | = | Length of string lighting in feet, collected from model number lookups |

**Table 7. Savings Values for LED String Lighting**

| Holiday Light Type | Energy savings (kWh/ft) | Default Length |
|---|---|---|
| 5MM | 0.24 | 17.3 |
| C5 | 0.24 | 17.3 |
| C6 | 0.29 | 24 |
| C7 | 0.3 | 17 |
| C9 | 0.3 | 17 |
| G12 | 0.29 | 24 |
| Mini-lights | 0.24 | 17.3 |

Source: 2017 CMUA TRM Supporting File 205.

## *Clothes Dryers*

$$\Delta kWh_{HPWH} = 446\ kWh$$

$$\Delta kWh_{ESTAR} = lbs \times Loads\ per\ Week \times Weeks \times CEF$$

Where:

| | | |
|---|---|---|
| $\Delta kWh_{HPWH}$ | = | Default annual energy savings for a heat pump dryer |
| $\Delta kWh_{ESTAR}$ | = | Calculated annual energy savings for a non-heat pump ENERGY STAR dryer |
| lbs | = | Average load (in labs), default value of 8.5 lbs |
| Loads per Week | = | Average loads per week, default value of 5.4 |
| Weeks | = | Weeks per year |
| CEF | = | Combined energy factor, collected from model number lookups |

## Heat Pump Water Heaters

**Table 8. Savings Values for Heat Pump Water Heaters**

| Space-Heating Type | Tank Size (Gal) | Climate Zone | Verified Savings (kWh/Year) |
|---|---|---|---|
| Heat Pump | 50-80 | 3 | 1,266 |
| Gas | 50-80 | 3 | 1,725 |
| Electric | 50-80 | 3 | 343 |
| Garage/Basement | 50-80 | 3 | 1,504 |
| Heat Pump | 80+ | 3 | 1,504 |
| Gas | 80+ | 3 | 1,964 |
| Electric | 80+ | 3 | 308 |
| Garage/Basement | 80+ | 3 | 1,628 |

Source: 2017 CMUA TRM Supporting File 220.

## LED Lighting

$$\Delta kWh = \Delta kW \times Hrs \times IE$$

Where:

$\Delta kW$ = Reduction in efficient bulb wattage compared to baseline

Hrs = Operating hours by building type/location

IE = HVAC interactive effects, energy

**Table 9. Savings Inputs for LED Lighting**

| Building Type | IE—Energy | Hrs |
|---|---|---|
| Residential Interior | 0.97 | 541 |
| Residential Exterior | 1.00 | 1,249 |

Source: 2017 CMUA TRM Supporting File 204.

**Table 10. Wattages for LED Lighting**

| Lighting Type | Efficient Wattage Min | Efficient Wattage Max | Baseline Wattage |
|---|---|---|---|
| LED lamp 7-9 W replacing 35 W halogen downlight | 7.0 | 10.0 | 35.0 |
| LED lamp 10-13 W replacing 50 W halogen downlight | 10.0 | 14.0 | 50.0 |
| LED lamp 14-18 W replacing 75 W halogen downlight | 14.0 | 19.0 | 75.0 |
| LED lamp 19-21 W replacing 90 W halogen downlight | 19.0 | 21.0 | 90.0 |
| LED lamp 7-9 W replacing 35 W halogen downlight | 7.0 | 10.0 | 35.0 |
| LED lamp 10-13 W replacing 50 W halogen downlight | 10.0 | 14.0 | 50.0 |
| LED lamp 14-18 W replacing 75 W halogen downlight | 14.0 | 19.0 | 75.0 |
| LED lamp 19-21 W replacing 90 W halogen downlight | 19.0 | 21.0 | 90.0 |
| LED 6-9 W replacing 29 W halogen | 6.0 | 10.0 | 29.0 |
| LED 10-13 W replacing 43 W halogen | 10.0 | 15.0 | 43.0 |
| LED 15-21 W replacing 53 W halogen | 15.0 | 22.0 | 53.0 |
| LED 22 W replacing 72 W halogen | 22.0 | 23.0 | 72.0 |
| LED 6-9 W replacing 9-13 W CFL | 6.0 | 10.0 | 10.0 |

| Lighting Type | Efficient Wattage Min | Efficient Wattage Max | Baseline Wattage |
|---|---|---|---|
| LED 10-13 W replacing 13-15 W CFL | 10.0 | 15.0 | 14.0 |
| LED 15-21 W replacing 13-15 W CFL | 15.0 | 21.0 | 14.0 |
| LED 22 W replacing 23-30 W CFL | 21.0 | 22.0 | 26.2 |
| LED 4 W replacing 20 W MR16 | 4.0 | 4.0 | 20.0 |
| LED 6 W replacing 20 W MR16 | 6.0 | 6.0 | 20.0 |
| LED 7 W replacing 35 W MR16 | 7.0 | 7.0 | 35.0 |
| LED 7 W replacing 50 W MR16 | 7.0 | 7.0 | 50.0 |
| LED wallpack (existing W<250) | 13.2 | 22.4 | 205.0 |
| LED wallpack (existing W<250) | 0.0 | 13.2 | 120.0 |
| LED wallpack (existing W≥250) | 22.4 | 55.0 | 295.0 |
| LED troffer, 2'X2' and 2'X4' | 38.0 | 39.0 | 59.0 |
| LED troffer, 2'X2' and 2'X4' | 19.9 | 34.0 | 59.0 |
| LED troffer, 2'X2' and 2'X4' | 34.0 | 38.0 | 59.0 |
| LED troffer, 2'X2' and 2'X4' | 0.0 | 18.0 | 33.0 |
| LED troffer, 2'X2' and 2'X4' | 18.0 | 19.9 | 33.0 |

Source: 2017 CMUA TRM Supporting File 104 and 204.

## *Refrigerator and Freezer Recycling*

**Table 11. Savings Values for Recycled Refrigerators and Freezers**

| Recycled Equipment | Verified Savings (kWh/Year) |
|---|---|
| Refrigerator | 308 |
| Freezer | 337 |

Source: 2017 CMUA TRM Supporting File 207.

**Table 12. Savings Values for New ENERGY STAR Refrigerators**

| Efficiency Level | Refrigerator Configuration | Verified Savings (kWh/Year) |
|---|---|---|
| ENERGY STAR | Top-mounted freezer-no ice | 40 |
| ENERGY STAR | Top-mounted freezer-with ice | 50 |
| ENERGY STAR | Side-mounted freezer-with ice | 65 |
| ENERGY STAR | Side-mounted freezer-with through door ice | 89 |
| ENERGY STAR | Bottom-mounted freezer-no ice | 50 |
| ENERGY STAR | Bottom-mounted freezer-with ice | 63 |
| ENERGY STAR | Bottom-mounted freezer-with through door ice | 78 |
| ENERGY STAR | Compact all<7.75 cubic ft.-refrigerators-automatic defrost. | 33 |
| CEE Tier II | Top-mounted freezer-no ice | 60 |
| CEE Tier II | Top-mounted freezer-with ice | 75 |
| CEE Tier II | Side-mounted freezer-with ice | 98 |
| CEE Tier II | Side-mounted freezer-with through door ice | 135 |
| CEE Tier II | Bottom-mounted freezer-no ice | 75 |
| CEE Tier II | Bottom-mounted freezer-with ice | 95 |
| CEE Tier II | Bottom-mounted freezer-with through door ice | 118 |
| CEE Tier II | Compact all<7.75 cubic ft.-refrigerators-automatic defrost. | 49 |

| Efficiency Level | Refrigerator Configuration | Verified Savings (kWh/Year) |
|---|---|---|
| CEE Tier III | Top-mounted freezer-no ice | 81 |
| CEE Tier III | Top-mounted freezer-with ice | 100 |
| CEE Tier III | Side-mounted freezer-with ice | 130 |
| CEE Tier III | Side-mounted freezer-with through door ice | 180 |
| CEE Tier III | Bottom-mounted freezer-no ice | 100 |
| CEE Tier III | Bottom-mounted freezer-with ice | 128 |
| CEE Tier III | Bottom-mounted freezer-with through door ice | 157 |
| CEE Tier III | Compact all<7.75 cubic ft.-refrigerators-automatic defrost. | 65 |

Source: 2017 CMUA TRM Supporting File 208.

## *Clothes Washers*

**Table 13. Savings Values for Clothes Washers**

| Washer Type | Efficiency Level | Water Heating Type | Dryer Heating Type | Natural Replacement Savings (kWh/Year) | Early Retirement Savings (kWh/Year) |
|---|---|---|---|---|---|
| Top Load | ENERGY STAR | Electricity | Electricity | 93 | 351 |
| Top Load | ENERGY STAR | Electricity | Natural Gas | 101 | 101 |
| Top Load | ENERGY STAR | Natural Gas | Electricity | 13 | 270 |
| Top Load | ENERGY STAR | Natural Gas | Natural Gas | 20 | 20 |
| Top Load | CEE Tier 2 | Electricity | Electricity | 161 | 499 |
| Top Load | CEE Tier 2 | Electricity | Natural Gas | 101 | 101 |
| Top Load | CEE Tier 2 | Natural Gas | Electricity | 81 | 418 |
| Top Load | CEE Tier 2 | Natural Gas | Natural Gas | 20 | 20 |
| Top Load | CEE Tier 3 | Electricity | Electricity | 189 | 526 |
| Top Load | CEE Tier 3 | Electricity | Natural Gas | 101 | 101 |
| Top Load | CEE Tier 3 | Natural Gas | Electricity | 108 | 446 |
| Top Load | CEE Tier 3 | Natural Gas | Natural Gas | 20 | 20 |
| Front Load | ENERGY STAR | Electricity | Electricity | 36 | 133 |
| Front Load | ENERGY STAR | Electricity | Natural Gas | 28 | 28 |
| Front Load | ENERGY STAR | Natural Gas | Electricity | 14 | 111 |
| Front Load | ENERGY STAR | Natural Gas | Natural Gas | 6 | 6 |
| Front Load | CEE Tier 2 | Electricity | Electricity | 96 | 193 |
| Front Load | CEE Tier 2 | Electricity | Natural Gas | 28 | 28 |
| Front Load | CEE Tier 2 | Natural Gas | Electricity | 74 | 171 |
| Front Load | CEE Tier 2 | Natural Gas | Natural Gas | 6 | 6 |
| Front Load | CEE Tier 3 | Electricity | Electricity | 121 | 218 |
| Front Load | CEE Tier 3 | Electricity | Natural Gas | 28 | 28 |
| Front Load | CEE Tier 3 | Natural Gas | Electricity | 99 | 196 |
| Front Load | CEE Tier 3 | Natural Gas | Natural Gas | 6 | 6 |

Source: 2017 CMUA TRM Supporting File 217.

## Commercial LED Lighting

$$\Delta kW = (fixture\ watt_{base} \times fixture\ qty_{base} - fixture\ watt_{ee} \times fixture\ qty_{ee}) \times CDF \times IE_d \div 1{,}000$$

$$\Delta kWh = (fixture\ watt_{base} \times fixture\ qty_{base} \times DSF_{base} \times HOU_{base} - fixture\ watt_{ee} \times fixture\ qty_{ee} \times DSF_{ee} \times HOU_{ee}) \times IE \div 1{,}000$$

Where:

| | | |
|---|---|---|
| CDF | = | Verified coincident demand factor |
| $DSF_{base, ee}$ | = | Verified lighting control default savings factor (DSF), for existing lighting ($DSF_{base}$) or for installed lighting ($DSF_{ee}$) |
| fixture $watt_{base, ee}$ | = | Verified fixture wattage, existing (fixture $watt_{base}$) or installed (fixture $watt_{ee}$) |
| fixture $qty_{base, ee}$ | = | Verified fixture quantity, existing (fixture $qty_{base}$) or installed (fixture $qty_{ee}$) |
| $HOU_{base, ee}$ | = | Verified annual hours of use (HOU), for existing lighting ($HOU_{base}$) or installed lighting ($HOU_{ee}$) |
| $IE_d$ | = | Verified HVAC interactive effects (IE), demand |
| IE | = | Verified HVAC IE, energy |

## Rooftop AC

$$EER = \frac{BTU_{cooling}}{Watts_{input}}$$

$$1\ ton_{cooling} = 12{,}000\ BTU$$

$$\Delta kW = (1/EER_{base} - 1/EER_{ee}) \times 12{,}000/1{,}000 \times TOC$$

$$\Delta kWh = (1/EER_{base} - 1/EER_{ee}) \times 12{,}000/1{,}000 \times TOC \times EFLH$$

Where:

| | | |
|---|---|---|
| $EER_{base, ee}$ | = | Verified energy efficiency ratio (EER), for Title 24 HVAC ($EER_{base}$) or for installed HVAC ($EER_{ee}$) |
| EFLH | = | Calculated effective full load hours (EFLH), based on temperature analysis |
| TOC | = | Verified tons of cooling (TOC) |