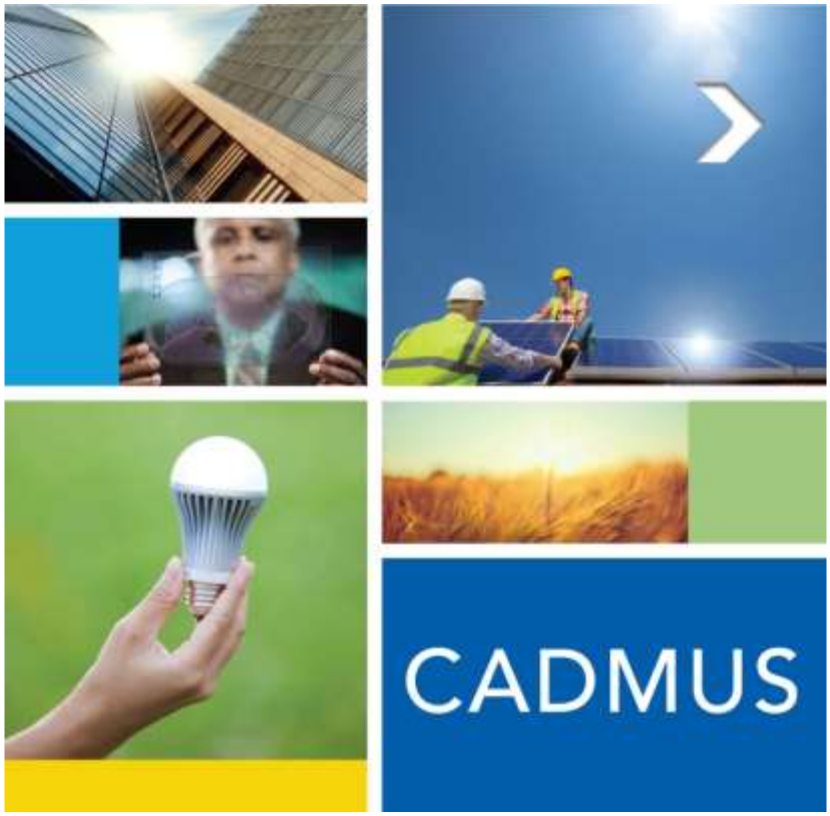

HERO Program Savings Allocation Methodology Study

Final Report

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Pacific Gas and Electric Company, San Diego Gas & Electric, Southern California Edison, and Southern California Gas Company

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Executive Summary

Pacific Gas and Electric Company, Southern California Edison, Southern California Gas, and San Diego Gas & Electric Company (collectively, the investor-owned utilities or IOUs) plan to offer financing pilot programs as part of their demand-side management programs in response to direction from the California Public Utilities Commission. These programs (the first of which launched in 2016) will be evaluated individually to determine their respective contributions to energy savings. Where customers use rebates and utility financing for the same project, the evaluation will require development of a methodology for estimating the relative influence of each incentive type on the customer's decision, with a goal of allocating net project savings between the two contributing programs.

In December 2011, the HERO Program launched in western Riverside County. Administered by the Western Riverside Council of Governments (WRCOG), HERO is a Property Assessed Clean Energy (PACE) financing program. Though not affiliated with the IOUs in any way, HERO provides an early opportunity to test different allocation methods for evaluating the relative impact of rebates and financing. The IOUs engaged Cadmus to conduct such a test.[1] Cadmus reviewed five methodologies for their feasibility and selected three as the most likely approaches for the IOUs to apply in future evaluations. We then tested each of those three methods by applying them to primary data collected through a survey of the general population.

Methodology Review

Cadmus began the process by modelling homeowners' decisions at a high level to understand what factors might be relevant. We then identified these five candidate methodologies for review:

- Self-report
- Quasi-experimental analysis (QEA)
- Analytical hierarchy process (AHP)
- Expanded Self-report
- Discrete choice modeling (DCM)

After reviewing the pros and cons of each methodology, we eliminated quasi-experimental analysis and AHP because of concerns about their feasibility. We then tested the remaining three methodologies ability to evaluate the relative influence of rebates and HERO financing. This study does not attempt to assess net savings, or the absolute impact of either rebates or financing.

Self-report analysis uses responses from a customer survey question about which incentive was more important, rebates or financing. The expanded self-report method asks the respondent to make pairwise comparisons of the two incentives, as well as additional factors, in this case speed and convenience.

[1] Cadmus conducted this study as a companion to the *HERO Program Study*, which evaluated elements of program design and implementation along with HERO's role in the market for energy efficiency financing.

Cadmus applied a matrix algebra-based analysis to the results to compute the relative importance weights of each factor, and from those results determined the relative importance of rebates and financing.

Discrete choice modeling involves econometric analysis of an individual's choice from a limited number of discrete alternatives. For example, DCM can be used to study an individual's decision about what kind of transportation to use, a high school student's decision about whether to attend college, or a homeowner's decision about whether to make an energy efficiency improvement.

Data Collection

To collect data for the tests, Cadmus conducted a broad survey of utility customer homeowners in Riverside and San Bernardino counties, where the HERO Program has been active since 2012 and where Southern California Edison and Southern California Gas provide electric and gas services.

Cadmus developed a single online survey to provide data for testing all three methodologies. For self-report, the survey asked for a single pairwise comparison: "Between financing and rebates, which one was more important in your decision to make improvements? On a scale of 1 to 9, how much more important?"

For expanded self-report, the survey offered additional pairwise comparisons regarding speed and convenience, with the intention that these additional comparisons might allow for a more precise result through triangulation.

For DCM, the survey asked a number of questions about respondents' decision-making and the factors that affected their decisions. Cadmus used the survey responses to construct the model dependent variable and many of the model independent variables. Cadmus employed a nested logit model, which explained a customer's decision to make a high efficiency improvement as a function of customer-specific variables such as the customer's education, income, and awareness of HERO financing, as well as attributes of the alternatives to HERO financing such as the cost of making a high efficiency or standard efficiency improvement.

The survey targeted the general utility customer homeowner population. However, because Cadmus expected the incidence of HERO and rebate participation within the general population to be very low, the study stratified the sample to include as many HERO and rebate participant contacts as possible. Table 1 presents the sample frames and responses.

Table 1. Survey Sample

Population Segment	Sample Frame	Completions
Rebate Participants	1,255	398
HERO Participants	7,296	498
General Population	64,676	2,605
Total	**73,227**	**3,501**

When conducting the self-report and discrete choice analyses, Cadmus weighted the observations so that the frequency of customer types in the analysis sample matched the frequency in the general population.

Findings

Each of the three methods Cadmus tested indicated that, on average, HERO financing had a greater impact on the participant's decision to make high efficiency improvements than rebates. Table 2 presents the results of each test.

Table 2. Allocation Results

	Self-Report	Expanded Self-Report	DCM
Financing	67.0%	64.7%	54.5%
Rebates	33.0%	35.3%	45.0%
Total	**100.0%**	**100.0%**	**100.0%**

The self-report methodology indicated that HERO was more important than rebates by a score of 2.7 on a scale of 1 to 9, where 1 is *Equally Important* and 9 is *Extremely More Important*. This score fell between the descriptors *Moderately More Important* and *Strongly More Important*, and it translated to an allocation split of 67.0% to HERO and 33.0% to rebates.

Expanded self-report also indicated that HERO was more important than rebates, producing an allocation split of 64.7% to HERO and 35.3% to rebates. The expanded self-report method produced importance weights for each of four factors: financing, rebates, convenience, and speed. Table 3 shows the importance weight for each factor, which indicated that respondents considered financing to be more important than the rebates, convenience, or speed of the overall process. (The allocation results rely only on the importance weights of financing and rebates, and are normalized to 100%.)

Table 3. Importance Weights for Key Decision Factors

Factor	Importance Weight (n=96)
Financing	37.0%
Convenience	21.7%
Speed	21.1%
Rebates	20.2%
Total	**100%**

The nested logit model analysis found that HERO financing and rebates had approximately equal effects on the probability that a customer would make a high efficiency improvement. Among customers who made high efficiency improvements, HERO financing increased the probability of a high efficiency improvement by an average of three percentage points or about 9%. Rebates increased the probability of a high efficiency improvement by about three percentage points or 10% points. Each of these estimates assumed that the other form of financing was available, that is, Cadmus estimated the effect of HERO financing assuming that utilities offered rebates for high efficiency improvements and estimated the effect of utility rebates assuming that HERO financing was available for eligible improvements.

The DCM analysis also found that among customers using HERO financing and rebates to make high efficiency improvements, HERO financing was responsible for 55% of the lift in the probability of making a high-efficiency improvement and rebates were responsible for 45%.

The nested logit model predicted average behavior accurately, yielding probabilities that customers would make standard efficiency upgrade or high efficiency upgrades that were very close on average to the choice frequencies of sampled customers. The discrete choice model also yielded HERO financing allocation estimates that were close to the self-report estimates.

Conclusions and Recommendations

HERO financing was more important than rebates in influencing homeowners' decisions.

All three methodologies estimated that financing was on average more important in the decision to make a high-efficiency improvement, as shown in Table 4.

Table 4. Allocation Results

	Self-Report	Expanded Self-Report	DCM
Financing	67%	65%	55%
Rebates	33%	35%	45%
Total	**100%**	**100%**	**100%**

Anecdotal findings from contractors, presented in the companion *HERO Program Study*, support this conclusion. Furthermore, the three utilized methodologies produced similar allocation estimates for HERO financing, ranging between 55% and 67% for upgrade projects that used both HERO financing and utility rebates.

Although these results provide an important benchmark for future allocation studies, **they should not be extrapolated to other financing programs**. The HERO Program has several features that may or may not characterize other programs, including the IOU financing pilots. For example, the broad measure eligibility available through HERO may not be available through the IOU financing pilots. Differences between the HERO program and other utility financing programs mean that the HERO allocation results may not have validity outside of this study.

Recommendation: The IOUs should conduct allocation studies of future IOU financing programs.

Discrete choice modeling has important advantages and disadvantages relative to self-report.

The principal advantages of discrete choice modeling are that it has a theoretical foundation in economics and that it analyzes actual customer choices. The nested logit model is grounded in the utility maximization theory of customer choice, and it attempts to explain the choices that customers made as a function of customer attributes as well as the attributes of available alternatives. Other methodologies, including the self-report methods assessed in this study, may not have as rigorous of a foundation in customer choice theory.

A principal disadvantage of the nested logit approach was its cost of implementation. It required extensive survey data collection and analysis as well as statistical and econometric expertise to implement. Another disadvantage was that the validity of this study's allocation estimates depended on strong assumptions about the exogeneity of awareness of HERO financing that were difficult to verify. In addition, it is likely that some respondents incorrectly characterized their projects as high-efficiency, thereby introducing an unknown level of measurement error into the model. However, future studies using DCMs may use different identification strategies and rely on different assumptions for identifying the impacts of financing. Future studies may also be able to use program tracking data, or other more reliable data, to avoid measurement error from survey respondents.

Recommendation: The IOUs should consider discrete choice modeling as an option for conducting future financing program allocation studies.

Expanded self-report has important advantages and disadvantages relative to discrete choice modeling.

The principal advantages of the self-report methodology are that it is relatively easy and inexpensive to implement and that many energy efficiency stakeholders are familiar with and accept this approach. [2,3] The largest cost of conducting a self-report study is fielding customer surveys. Analysis of self-report data is straightforward and is not time-consuming. Evaluators have applied self-report methodologies for other energy efficiency evaluations, and as a consequence, many stakeholders accept the approach of asking utility customers to assess the relative influence of different factors in their decisions.

The principal disadvantages of this approach are lingering doubts about its accuracy and usefulness for estimating program causal effects. The self-report approach asks respondents to assess the relative importance of different factors in their decisions or to report what their decisions would have been under different circumstances. However, customers may have difficulty understanding the reasons for their decisions or may have acted differently than they say that they would have. Given these challenges, stakeholders may have difficulty accepting results based on self-reporting.

2 Ridge, Richard, Ken Keating, Lori Megdal, and Nick Hall. (2007). Guidelines for Estimating Net-To-Gross Ratios Using the Self Report Approach. Prepared for the California Public Utilities Commission.

3 The TecMarket Works Team. (2006). California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals. Prepared for the California Public Utilities Commission.

Self-report methodologies may be appropriate for financing program evaluations that have limited budgets or short timeliness, that do not want to burden customers with long surveys, or that have stakeholders that are familiar with and accept the self-report methodology.

Recommendation: The IOUs should consider self-report methodologies as options for conducting future financing program allocation studies.

Introduction

Pacific Gas and Electric Company, Southern California Edison, Southern California Gas, and San Diego Gas & Electric Company (collectively, the investor-owned utilities or IOUs) plan to offer financing pilot programs as part of their demand-side management programs in response to direction from the California Public Utilities Commission. These programs (the first of which launched in 2016) will be evaluated individually to determine their respective contributions to energy savings. Where customers use rebates and utility financing for the same project, the evaluation will require a methodology for estimating the relative influence of each incentive type on the customer's decision, with a goal of allocating net project savings between the two contributing programs.

In December 2011, the HERO Program launched in western Riverside County. Administered by Western Riverside Council of Governments (WRCOG), HERO is a Property Assessed Clean Energy (PACE) financing program. Though not affiliated with the IOUs in any way, HERO shares with the IOU pilots a goal of offering more accessible, affordable financing options to encourage home energy upgrades. Because HERO operates in territory where IOU rebates are available, it provides an early opportunity to test different allocation methods for evaluating the relative impact of rebates and financing on a customer's decision to complete an energy improvement.

The IOUs engaged Cadmus to assess different methodologies for evaluating the relative influence of HERO and rebates on homeowners' decisions to complete energy upgrades for the subset of customers that used both HERO financing and a rebate.[4] Cadmus reviewed five possible methodologies and identified the three most feasible approaches for the IOUs to apply in future evaluations. We then tested each of those three methods by applying them to primary data collected through a survey of the general population.

Methodology Review

Cadmus considered various methodologies to answer the basic research question of how to determine the relative influence of rebates and financing on customers that used both for a single project. This question is not typically required for most program evaluations, and stakeholders have little experience applying or reviewing methods for addressing this question. As a result, the first step for this evaluation was a desk-level review of potential methods, in order to narrow the list of candidate methods that Cadmus ultimately tested with actual data.

Defining the Research Question

Although the identification the relative influence of the two programs is closely related to the issue of net savings (isolating savings that are realized as a result of program activity), we do not address net savings in this study. The net savings evaluation must take into consideration program influence among

[4] Cadmus conducted this study as a companion to the *HERO Program Study*, which evaluated elements of program design and implementation along with HERO's role in the market for energy efficiency financing.

those participants that use both rebate and financing incentives, as well as participants that use one or the other or neither. The methods tested in this study do not attempt to measure freeridership or spillover, and do not attempt to identify available project savings. Further, this study does not address the absolute influence of either rebates or financing, regardless of the presence of any other incentive. Rather, this study is focused on a comparative assessment of methods to determine the relative influence of rebates and HERO financing on homeowner decisions to complete an energy efficiency improvement project.

Allocation Methodology Review

Cadmus conducted a review to evaluate the pros and cons of each of five candidate methodologies for allocating net savings for projects that used two incentives:

- Self-report
- Quasi-experimental analysis based on a natural geographic control (QEA)
- Analytical hierarchy process (AHP)
- Expanded self-report
- Discrete choice modeling (DCM)

Our review considered each method's likely ability to meet these criteria:

- Provides an accurate assessment of the relative influence of two incentives
- Uses readily and consistently available data
- Can be performed cost-efficiently

Our desk review ruled out two of the five candidates, leaving these three to be tested using data collected through a trial survey—self-report, expanded self-report, and discrete choice. Table 5 lists the five candidate methodologies and summarizes our desk review analysis of each method. We ranked the expected performance of each method as high, medium, or low against each criterion, or "none" if we expected the method would not meet a given criterion at all.

Table 5. Analysis of Candidate Methodologies Against Key Criteria

Candidate Method	Performance Criteria			Selected for Testing
	Provide Accurate Results	Use Available Data	Perform Cost-Efficiently	
Self-report	Low	High	High	Yes
Quasi-Experimental Analysis	High	***None***	High	No
Analytical Hierarchy Process	***None***	Medium	Medium	No
Expanded Self-Report	Low	High	Medium	Yes
Discrete Choice	Medium	Medium	Low	Yes

A summary of each candidate method follows. Following these summaries, the report discusses the testing of the three selected methods.

Self-Reporting

The most basic approach for determining the relative influence of rebates and financing, that still meets the basic rigor requirements in the California Energy Efficiency Evaluation Protocols, is to simply ask the homeowner.[5] For purposes of this study, self-reporting involves conducting a survey that presents a question to homeowners who participated in both the rebate and HERO financing programs. This question asks which program was more important in respondents' decisions to make improvements and how much more important that program was.

Though easy and widely used, any method that relies on self-reported data is subject to inaccuracy as a result of respondent bias. For example, the standard approach to measuring freeridership uses a survey to ask respondents about a counterfactual situation: "If rebates had not been available, would you still have made improvements?" It can be difficult for people to answer such hypothetical questions, and the answers can be susceptible to social bias (people may not want to admit that social benefit alone was not enough to induce them to complete an improvement). However, neither of these concerns seems as relevant here, because our questions about relative importance do not involve a counterfactual situation and do not imply any social benefit.

Self-report can also be subject to two other concerns.[6] First, peoples' ability to remember a decision from up to three years ago (the period used in our study) can be subject to recall error. Second, people may have difficulty assigning scores to indicate the importance of different factors when their thought process may not have been quantitative. Expanded self-report is expected improve the accuracy of the self-report method by asking respondents to rate the importance of a larger and therefore more complete set of factors. Expanded self-report may also provide evaluators with the opportunity to check the consistency of respondents' self-reports about the importance of different factors. The results of this comparison are included under Expanded Self-Reporting in the Comparative Findings section of this report.

Self-reporting data are collected through participant surveys. Typically, when there is a large, homogenous participant population, analysis requires a sample of approximately 70 respondents to provide results with 10% precision at 90% confidence. Such a survey, consisting of only the two questions, can be very brief and can be conducted by phone or online.

Quasi-Experimental Analysis

One form of quasi-experimental analysis uses "natural experiments" to compare outcomes between customers who have been offered a certain treatment (i.e., an incentive or package of incentives) and a similar group (or control group) who have not been offered that option. In a natural experiment, two

5 The TecMarket Works Team. (2006). California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals. Prepared for the California Public Utilities Commission.

6 Violette, D.M., P. Rathbun. Uniform Methods Project, Chapter 23: Estimating Net Savings: Common Practices. National Renewable Energy Laboratory. September 2014. Accessed online 8/5/2016: http://www.nrel.gov/docs/fy14osti/62678.pdf

groups can be identified retrospectively as control and treatment groups, despite the absence of any intentional experimental design construct. The data are analyzed using a regression model, which produces coefficients that express the impact of the target factors—rebate availability and financing availability—on the probability that a homeowner completes an upgrade. The use of panel data construction (comparisons over time and over similar groups) offers a great deal of explanatory power. For allocating credit between financing and rebates, the treatment groups would probably be offered one or both incentives, while the control would receive no incentive. This would isolate the individual effects of the different incentives. Observing all groups before and after treatment was offered would further substantiate the results.

This methodology has the advantage of relying on observed behaviors rather self-reported survey data. In this approach, results are not biased by the respondents' difficulty in accurately deconstructing and evaluating different factors in their decision-making process.

Cadmus considered a quasi-experimental analysis, based on a geographically-defined control group, as a potential option for this study given the gradual expansion of the HERO Program over areas where rebates had been consistently available. However, this analysis is probably not a feasible choice for evaluating the IOU financing pilots. Because the financing pilots are expected to be rolled out simultaneously (or nearly so) across all of the IOUs' territories, it would be difficult—if not impossible—to identify a natural control group to assess the impacts of financing. Consequently, Cadmus chose not to move forward with this methodology.

Analytic Hierarchy Process

Analytical hierarchy process (AHP) was developed in the 1970s as an approach to prioritizing the factors contributing to a decision. Analytic hierarchy process applies to a wide variety of situations where decisions can be organized into a hierarchy of criteria and alternatives. For example, when purchasing a car, a consumer might choose one car over another based on style, reliability, and fuel economy. Figure 1 illustrates this hierarchy.

Figure 1. Hierarchical Decision-Making

Source: Haas, R., Meixner, O. *An Illustrated Guide to the Analytic Hierarchy Process.* Institute of Marketing and Innovation, University of Natural Resources and Applied Life Sciences, Vienna. Accessed online June 15, 2016: https://mi.boku.ac.at/ahp/ahptutorial.pdf.

Using this sort of hierarchical model, the next step is to determine the relative importance of the criteria via pairwise comparisons, asking questions such as: "Which is more important to you, style or reliability? How much more important?" Once criteria have been ranked, alternatives can be compared based on the criteria, again using pairwise comparisons (i.e., "In terms of style, do you prefer the Civic or the Saturn better? How much better?"). Using matrix algebra, the pairwise importance results can be combined with the pairwise preference results to predict a decision.

Initially, AHP seemed a good fit for modeling energy efficiency decisions. The alternatives could be high-efficiency equipment, standard-efficiency equipment, and no equipment. However, the option of no equipment introduced a difficulty. In the car example, if one option was no car, how would a person rank the style, reliability, and fuel efficiency of "no car"?

The number and dissimilarity of potential criteria further complicated the model. The first two criteria would have to be eligibility for rebates and HERO, but additional criteria might have included awareness of rebates and HERO, interest rates, rebate amounts, improvement costs, energy savings, speed, convenience, appearance (e.g., windows), greenhouse gas reduction, and others.

In addition, using the car example, the relative importance of the criteria would be determined by asking pair-wise questions (a form of self-report) with the objective of predicting a decision. By contrast, in the model involving rebates and financing, Cadmus already knows the decision (e.g., a homeowner purchased high-efficiency equipment) and would therefore want to work backward from that decision to calculate the relative importance of the criteria (rather than through self-reporting). This backward-looking approach would be difficult if not impossible.

For all of these reasons, and after meeting with the IOUs and their other consultants to explore alternative hierarchies and approaches, all participants decided to eliminate AHP from consideration.

Expanded Self-Reporting

Although AHP was ruled out, its pairwise comparison of multiple criteria offers a form of self-reporting that may provide advantages over the simple self-report process described on page 9. In the simple self-report approach, a single pairwise question would be asked: “Which was more important, rebates or HERO? How much more important?” AHP’s convenient mathematical properties, in addition to the ease of obtaining the needed input data, have made the approach popular to solving multi criteria decision making problems (MCDM). The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the importance weights of the decision criteria. When the comparisons are not perfectly consistent, the expanded pairs provide a mechanism for improving consistency. In this modified version of AHP, which Cadmus is calling “expanded self-reporting,” rebates and HERO would be compared not only to each other but to other criteria, thereby offering a form of triangulation that should deliver more accurate results.[7]

This method is “expanded” relative to the self-report method simply due to its use of expanded versus simple pairwise comparisons. This expansion allowed us to triangulate results by anchoring values of rebate and financing not just to each other but to other criteria as well. When an inquiry is made into factors that enter into decision making, it is difficult for respondents to assess the absolute importance of each one. A decision maker may not know the importance of criterion A in absolute terms, but they are more likely to know how it compares to B. The consistency of their responses are affirmed by further comparing the importance of both A and B to C. For example, when getting an eye exam, patients are unable to say which lens or combination of lenses work best, but they can easily determine which is better when comparing two lenses.

The mechanism also helps with recall bias as respondents are more likely to remember which criterion was more important than another and perhaps even by how much, than they are able to rank or make absolute judgements on the importance of any one of them. The expanded pairwise comparison reduces the potential recall bias as it seeks the importance of rebate and financing relative to each other and relative to other factors, which may be easier for the respondent to evaluate.

7 Further discussion of the analytical hierarchy process, and the basis for the matrix algebra analysis used in the expanded self-report method, can be found here:
Saaty, T.L. “Decision making with the analytic hierarchy process.” 2008. Int. J. Services Sciences, Vol. 1, No. 1, pp.83–98.
Triantaphyllou, E., S. H. Mann. “Using the Analytic Hierarchy Process for Decision Making in Engineering Applications: Some Challenges.” 1995. Int. Journal of Industrial Engineering: Applications and Practice, Vol. 2, No. 1, pp.35-44.

Furthermore, the additional factors allow for a calculation of the importance weight of the decision making criteria, while an absolute assessment of importance does not.

Discrete Choice Model

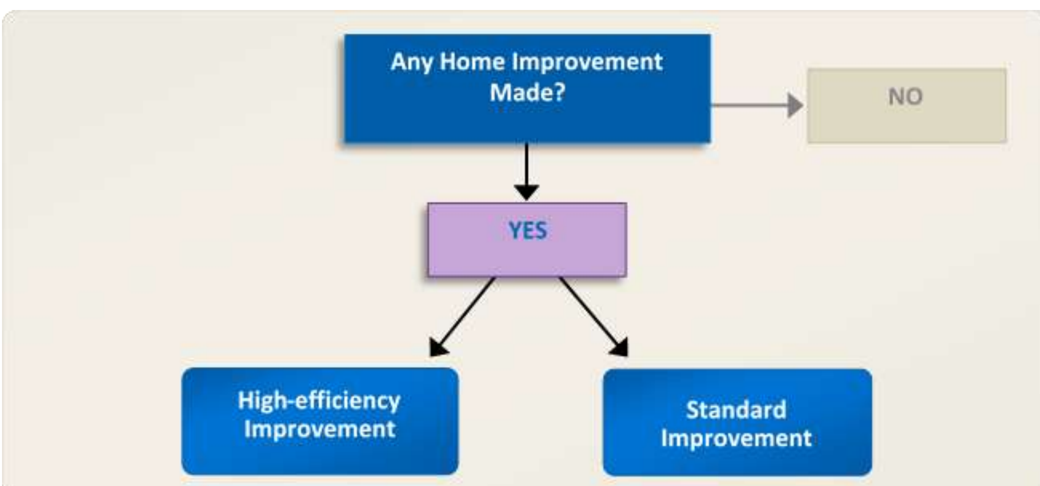
Discrete choice model (DCM) evaluates a decision-maker's behavior when faced with a finite set of discrete alternatives. [8]

This approach requires that alternatives exhibit three key characteristics:

- Alternatives must be *mutually exclusive* from the decision-maker's perspective.
- The choice set of alternatives must be *exhaustive*, including all possible alternatives.
- The number of alternatives must be finite.

A DCM may involve grouping some alternatives into nests to account for similarities between some alternatives. The nesting of alternatives can be represented as a two-level decision. In the case of an energy-efficiency improvement, the first-level decision may be whether or not to make an improvement. At the second level, the decision-maker may choose between making a high efficiency improvement or a standard efficiency improvement. Figure 2 shows the process as a decision tree, showing a high efficiency improvements and a standard efficiency improvement in the same nest.

Figure 2. Decision Tree Modeling Rebates and Financing



The model explains utility customer choices as a function of customer characteristics and attributes of the different alternatives such as the benefits and costs of high efficiency upgrades, standard efficiency upgrades, and no upgrades. The model is estimated using data on actual customer choices and the

[8] The discussion in this paragraph is based on Train, Kenneth E. *Discrete Choice Models with Simulation*. Cambridge University Press. 2009.

characteristics of customers and available alternatives. Nested logit analysis is described in more detail in the Comparative Findings section.

Despite its complexity and greater data requirements, the DCM methodology has advantages over self-report methods. It identifies program impacts using observed variation in customer choices (e.g., people did or did not make improvements) and customer attributes, and it has a theoretical basis in utility maximization theory of customer choice. As a result, Cadmus determined that it was worthwhile to investigate DCM as a methodology for conducting allocation analysis.

Study Limitations

This study provided a proof-of-concept for different allocation methodologies. Cadmus explored new ground in this allocation work and occasionally found it necessary to rely on assumptions or data that may not have met the typical evaluation standards for accuracy. For example, this study did not have detailed information on completed projects, firm estimates for the target population, or the total participation in HERO and rebate programs within the study area.

In addition, numerous factors complicated the analysis of the two programs, such as differences in marketing and delivery methods and differences in how standard and high-efficiency are defined. Consequently, this report presents a few caveats that should be kept in mind when reviewing the study findings:

- Population estimates used for sample weighting are based on the most accurate estimates available, but these may not be accurate—particularly in estimating HERO and rebate participant populations in the target zip code areas of Riverside and San Bernardino counties.
- The findings of this study may not have validity to populations outside of Riverside and San Bernardino counties. Because this report focused on a specific geographic area of Riverside and San Bernardino counties, it remains unclear whether the results would be similar in other areas of California or in other states.
- Differences in eligibility requirements between HERO financing and rebates could impact customers' decisions and could make definitions of high-efficiency upgrades vary by program. This report uses a respondent's perception (i.e., the answer to the question addressing whether or not the upgrade is "high-efficiency" or "standard-efficiency") to categorize improvement projects, which may incorporate error into the results.

Data Collection

To collect data for testing each selected methodology, Cadmus conducted a broad survey of utility customer homeowners in 107 zip codes in Riverside and San Bernardino counties (where the HERO Program has been active since 2012, and where Southern California Edison and Southern California Gas provide electric and gas services). Cadmus selected this area because all homeowners had access to the same HERO financing and rebates options long enough to achieve measureable incidence of awareness and use in the general population.

See Appendix A for the complete survey instrument, and Appendix B for the complete list of target zip codes.

Survey Design

Cadmus designed the survey instrument to satisfy a number of research objectives. These survey questions provided the data needed to test and assess the three candidate allocation methodologies selected in the desk review. As noted in the previous section, these included (in order of complexity) self-reporting, expanded self-reporting, and DCM. A few survey questions informed the study of HERO's design and implementation. (The *HERO Program Study*, a companion report, provides analyses of those data.)

The survey asked respondents basic demographic questions associated with these descriptors:

- Age of home
- Size of home
- Value of home
- Length of time residing in home
- Number of persons living in the home year-round
- Age of respondent
- Educational attainment of respondent
- Household income
- Proclivity to take conservation activities and environmental action

Self-Reporting

The survey asked respondents a two-part, pairwise question designed to determine the relative importance of rebates and financing on their decision to make energy improvements. First, the survey asked which factor was more important, rebates or financing, with the following response options:

- Financing was more important
- Utility rebates were more important
- They were equally important

- Neither was at all important

For those selecting either of the first two options, an additional question asked the respondent to indicate *how much more* important the financing or rebate was, using a 9-point scale, where 1 indicated *Equally Important* and 9 indicated *Extremely More Important*. The 9-point scale allowed the response to also be used for the expanded self-reporting methodology, which relied on multiple pairwise questions. The expanded self-report approach involves matrix algebra that uses a 9-point scale.

Expanded Self-Reporting

For the expanded self-reporting method, Cadmus included additional survey questions, using the same structure as the single pairwise question about rebates and financing as in the self-report process described above. Cadmus identified four factors for the expanded self-report method—rebates, financing, convenience, and speed—which resulted in the following six pairwise comparisons:

- Financing versus rebates
- Financing versus convenience
- Financing versus speed
- Rebates versus convenience
- Rebates versus speed
- Convenience versus speed

We considered including more factors, but each additional factor would have added geometrically to the required number of pairwise comparisons. For example, five factors would have required 10 comparisons. Given the survey's length, we limited comparisons to four factors.

The choice of factors was relatively unimportant for allocation purposes, since the additional factors were only used for triangulation in order to achieve a more accurate allocation between financing and rebates. We considered adding two factors that might be the most important in the decision-making process—project cost and energy savings—but instead chose to provide the IOU financing pilots with information on factors over which they might have more control. For example, the financing pilots might be able to influence their programs' speed and convenience more readily than a project's cost and energy savings.

For each factor comparison, if the respondent indicated one was more important than the other, the survey asked the respondent to indicate how much more important using the same 9-point scale described in the previous section.

Discrete Choice Model

The discrete choice analysis explained why a respondent completed a standard-efficiency upgrade, a high-efficiency upgrade, or no upgrade at all (holding constant the effects of certain demographic and project variables). The survey collected demographic and project data from respondents that included the following:

- Whether the respondent completed a project
- Whether the completed upgrade was standard-efficiency or high-efficiency
- The project cost
- The value of rebates used or available
- The payment method (HERO, cash, credit card, etc.)
- A number of demographic variables, including these:
    - Home size (in square feet)
    - Home value
    - Home age
    - Number of occupants
    - Household income

Survey Sample

The survey was targeted to the general population. However, because Cadmus expected the incidence of HERO and rebate participation in the general population to be very low, and a minimum number of respondents was necessary to test the allocation methodologies, Cadmus stratified the sample to include as many HERO and rebate participant contacts as possible. (Survey results were weighted to be representative of the general population.)

Cadmus compiled the survey sample frame from multiple data sources. Southern California Gas provided a list of all electric and gas rebate participants with e-mail addresses on record from 2012 through 2014. We limited this sample to whole-home participants (Energy Upgrade California and its predecessor programs) and prescriptive rebate participants who installed a major measure, including pool pumps and motors, HVAC upgrades, weatherization upgrades, and windows. A minority of these, about 330, had an e-mail address in the rebate program record.

Southern California Edison provided a random sample of 70,000 utility customer contacts with e-mail addresses to serve as the general population sample in the target area. Cadmus compared the remaining rebate participant account numbers to the general population sample and eliminated any rebate participants from the general population sample. (An added benefit of this overlap was that the general population sample was able to provide many missing e-mail address for the rebate sample, since the two datasets were drawn from different databases).

For the HERO participant segment, we identified participating property addresses from county records and California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA) records. Southern California Gas compared these property addresses with its customer database to gather e-mail addresses. We compared this sample to the rebate and general population samples to eliminate duplicate e-mail addresses. Table 6 shows the resulting number of unique e-mail addresses in each group.

Table 6. Unique E-Mails by Segment

Segment	Unique E-Mail Contacts
Rebate Participants	1,255
HERO Participants	7,296
General Population	64,676
Total	**73,227**

Cadmus designed the sample frame to limit respondents to the appropriate population to the extent possible. To further refine the sample, the survey included five screening questions. Any respondent not meeting all five of the following criteria was terminated from the survey:

- Resides in specific zip codes in Riverside and San Bernardino counties
- Owns the home
- Takes electric service from Southern California Edison
- Takes gas service from Southern California Gas
- Is a key decision-maker regarding energy improvements to the home

As expected, a number of respondents from the general population sample source indicated they were actually a HERO or rebate participant, and, while rare, some respondents originally tagged in the sample as part of the HERO or rebate segments indicated they were not participants. Because of the sheer size of the sample frame and the need to aggregate data from multiple sources for many of the identified contacts, we considered it likely that the participation status for some contacts was categorized incorrectly in the original sample frame and that the respondent was the most reliable source to determine participation status. We ultimately categorized each response according to the information provided in the survey.

Survey Implementation

Cadmus issued the survey electronically. Respondents received an e-mail invitation with a link to the online survey form and a reminder e-mail after three days if they had not yet started or completed the survey. Given the available sample frames, the study required a response rate of approximately 40% for the rebate participant sample and 7% for the HERO participant sample. To boost response rates, we offered incentives for the rebate and HERO groups of $20 and $10, respectively. We delivered the incentives as e-mailed gift cards for the respondent’s choice of two retailers (Amazon.com or Target).

The data-collection period began in early May 2016 and concluded in mid-June 2016. Cadmus initially completed a round of testing with a small, random extract of approximately 700 records from the sample frame. We reviewed results from the small test sample to ensure the skip logic embedded in the survey instrument behaved as intended and that there were no questions where substantial numbers of potential respondents were dropping from the survey.

The remaining sample was released in two waves. Table 7 provides the number of e-mail addresses from the original sample frame, and target sample sizes that guided the data-collection effort.

Table 7. Target Sample Sizes and Collected Data

Population Segment	Sample Frame	Target Completions	Actual Completions
Rebate Participants	1,255	500	398
HERO Participants	7,296	500	498
General Population	64,676	3,000	2,605
Total	**73,227**	**4,000**	**3,501**

Sample Summary and Disposition

The following section provides an accounting of the sample population, from initial development of the data file through final development of the data file ultimately used in the analysis described in this report. In the course of the survey, 68,008 sample records were released; the final number of completed interviews analyzed was 3,501, resulting in a 5% response rate overall. As noted, Cadmus organized sample sourcing according to the three primary segments: HERO participants, rebate participants, and the general population. Table 8 provides the sample's final disposition.

Table 8. Final Sample Disposition by Sample Source

Sample Final Disposition Category	HERO Sample	Rebate Sample	General Population Sample	Totals
Sample Frame	7,296	1,255	64,676	73,227
Sample Released	2,099	1,254	64,655	68,008
No Response	1,370	679	57,901	59,950
Response	729	575	6,754	8,058
Partial Completes	48	55	986	1,089
Screened Out/Ineligible	174	119	3,146	3,439
Eligible/Removed	9	3	17	29
Eligible/Final Completes	**498**	**398**	**2,605**	**3,501**
Final Response Rate	**23.7 %**	**31.7 %**	**4.0 %**	**5.1 %**

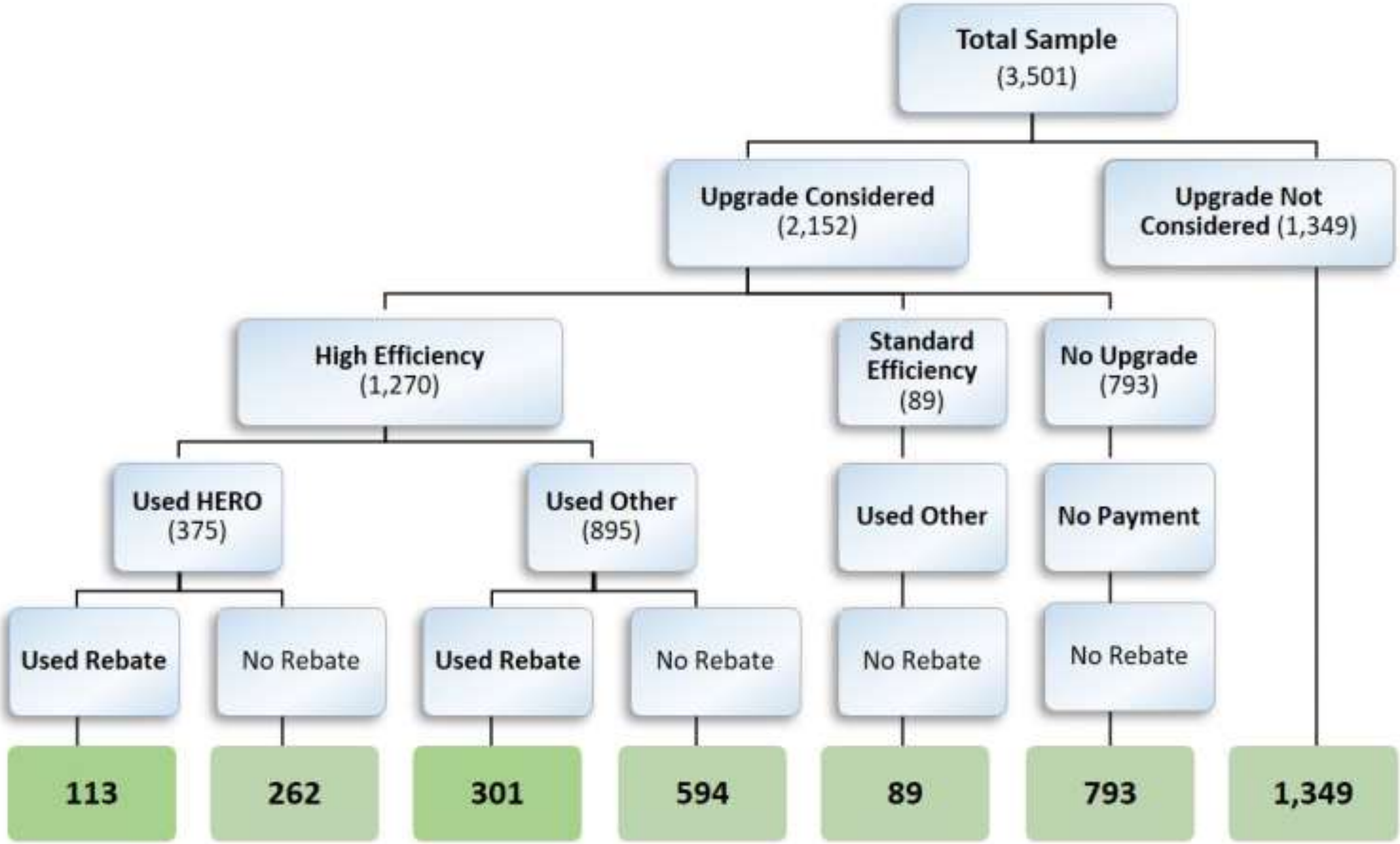
To conduct the analysis, Cadmus categorized the survey data into participation groups—rebate participants, HERO participants, dual participants, and nonparticipants—according to the responses. We also further segmented nonparticipants based on their decisions regarding the following:

- Whether they made a home energy upgrade
- Whether that upgrade was standard-efficiency or high-efficiency

This allowed us to organize the entire set of survey responses into a “decision tree” framework that could be used to inform the DCM analysis.

Figure 3 illustrates the decision tree and the number of unweighted survey responses representing each “branch” in the framework.

Figure 3. Allocation Analysis Sample Distribution/Unweighted Counts



Sample Weighting

To extrapolate survey findings to the population, Cadmus weighted the survey results to account for oversampling HERO and rebate participants. Using U.S. Census Bureau data for Riverside and San Bernardino counties, we estimated the population of owner-occupied, single-family homes in the target area. Within that target area, we estimated the population of HERO participants in the last three years based on the registration of loans in the state's PACE loan loss reserve and on the number of PACE assessments recorded by the counties. We estimated the population of rebate participants in the last three years based on participation data provided by Southern California Edison.

Because we did not have a source for estimating the dual HERO and rebate participant population, we deduced this number from the incidence of individuals in the weighted survey results who identified themselves as participating in both programs.

Adding up these four mutually exclusive and exhaustive groups—HERO participants, rebate participants, participants in both programs, and nonparticipants—resulted in a total estimated population of 640,200. Table 9 provides information associated with development of the case weights. Note that this table's sample counts have been based on respondents' indicated participation (shown in Figure 3).

Table 9. Allocation Analysis Case Weight Development

Segment	Population Estimate	Population Proportion	Sample Count	Sample Proportion	Case Weights (Population% / Sample%)
HERO Only	10,000	1.56%	262	7.48%	0.208725
Rebates Only	8,700	1.36%	301	8.60%	0.158063
HERO/Rebates (both)	4,200	0.66%	113	3.23%	0.203258
Nonparticipants	617,300	96.4%	2,825	80.7%	1.194962
Total	**640,200**	**100%**	**3,501**	**100%**	**–**

Comparative Findings

Using the survey results, Cadmus tested each of the three candidate methods for allocating credit and found that, although the exact allocation percentages differed, all three methods showed that financing had a greater influence on the customer's decision than the rebate. The results from the three methods are presented in Table 10.

Table 10. Allocation Results

	Self-Report	Expanded Self-Report	Discrete Choice Model
Financing	67.0%	64.7%	54.5%
Rebates	33.0%	35.3%	45.5%
Total	**100.0%**	**100.0%**	**100.0%**

These results provide an important benchmark for future allocation analyses, but they are not generalizable to an evaluation of the IOU financing pilots for a variety of reasons. The HERO Program has several features that may or may not also characterize the IOU financing pilots. For example, the broad measure eligibility available through HERO would probably not be available through the IOU financing pilots. In addition, the relative cost of HERO financing compared to other financing options (and the degree to which it is an incentive to the homeowner) may differ from the cost of IOU pilot financing. The impact of these and other program differences on the relative influence of financing versus rebates cannot be predicted by this study.

In the process of applying each method to real data, Cadmus could refine each approach and identify important factors for consideration when applying each method. This section describes our calculations in detail, as well as our findings about potential improvements and implications for future use.

Self-Reporting

The self-reporting method relies on responses to the following two questions:

- Financing versus rebates: which was more important in your decision to make the improvement(s)?
- [If one or the other was more important] How much more important, on a scale from 1 to 9, where 1 indicates *Equally Important* and 9 indicates *Extremely More Important*?

Cadmus began the analysis by converting the 1 to 9 scale to a –8 to +8 scale that would put the responses on a single scale centered on *Equally Important* at 0 (shown in Table 11). (We used the 1 to 9 scale in the survey so that we could use the same responses for the expanded self-reporting methodology, which required that *Equally Important* equaled 1.)

Table 11. Raw Score Conversion

Importance: Program	Importance: Score	Converted Score
Financing More Important	9	+ 8
	8	+ 7
	7	+ 6
	6	+ 5
	5	+ 4
	4	+ 3
	3	+ 2
	2	+ 1
Equal	1	0
Rebates More Important	2	- 1
	3	- 2
	4	- 3
	5	- 4
	6	- 5
	7	- 6
	8	- 7
	9	- 8

Cadmus arbitrarily assigned the negative side of the scale to represent rebate importance; this had no impact on the outcome. In addition, we assigned a 0 to the *Neither Was Important* responses. Of 113 respondents using both HERO and financing (i.e., those for whom savings had to be allocated between financing and rebates), only six provided this response.

After converting the raw scale, we totaled the number of responses (frequency) for each category. Most respondents (56.6%) said financing was more important, while 4.4% said rebates were more important and 38.9% said financing and rebates were equally important. We then calculated an average score weighted by the percentage of responses for each score, as shown in Table 12.

Table 12. Weighted Average Score Calculation

Importance			Score				
Program	**Frequency**	**%**	**Descriptor**	**#**	**Frequency**	**%**	**Weighted (# x %)**
Financing More Important	64	56.6 %	Extremely More	**+ 8**	9	8.0 %	0.637
				+ 7	10	8.8 %	0.619
			Very Strongly More	**+ 6**	12	10.6 %	0.637
				+ 5	6	5.3 %	0.265
			Strongly More	**+ 4**	14	12.4 %	0.496
				+ 3	7	6.2 %	0.186
			Moderately More	**+ 2**	4	3.5 %	0.071
				+ 1	2	1.8 %	0.018
Equal	44	38.9 %	Equal	**0**	44	38.9 %	0.000
Rebates More Important	5	4.4 %		**- 1**	0	0.0 %	0.000
			Moderately More	**- 2**	2	1.8 %	-0.035
				- 3	0	0.0 %	0.000
			Strongly More	**- 4**	1	0.9 %	-0.035
				- 5	0	0.0 %	0.000
			Very Strongly More	**- 6**	0	0.0 %	0.000
				- 7	0	0.0 %	0.000
			Extremely More	**- 8**	2	1.8 %	-0.142
Total	**113**	**100.0 %**	**-**	**-**	**113**	**100.0 %**	**2.717**

The +2.717 score indicated that, on average, respondents considered financing *Moderately More* to *Strongly More* important than rebates.

We next converted the –8 to +8 scale to an allocation scale by assuming that a score of 0 (*Equal*) indicated that 50% of energy savings should be allocated to each program and a score of +/-8 indicated that 100% should be allocated to the applicable program. Table 13 presents the resulting scale.

Table 13. Allocation Scale

Score	Allocated to Financing	Allocated to Rebates
+ 8	100 % Financing	0 % Rebates
+ 7	93.75 %	6.25 %
+ 6	87.50 %	12.25 %
+ 5	81.25 %	18.75 %
+ 4	75.00 %	25.00 %
+ 3	68.75 %	31.25 %
+ 2	62.50 %	37.50 %
+ 1	56.25 %	43.75 %
0	50.00 %	50.00 %
- 1	43.75 %	56.25 %
- 2	37.50 %	62.50 %
- 3	31.25 %	68.75 %
- 4	25.00 %	75.00 %
- 5	18.75 %	81.25 %
- 6	12.25 %	87.50 %
- 7	6.25 %	93.75 %
- 8	0 % Financing	100 % Rebates

Using this scale, a +2.717 score indicated that, on average, 67.0% of energy savings would be allocated to financing and 33.0% to rebates.

This average allocation percentage is informative, but in actual practice an allocation percentage will need to be calculated for each project. Energy savings vary from project to project and may even be skewed (e.g., when projects are bigger, financing may be more important). Because of this, the net energy savings from each project would have to be multiplied by that project's allocation percentage then summed across all projects to arrive at the total net energy savings allocated to each program.

Expanded Self-Reporting

As described in the Methodology Review section, expanded self-reporting uses the pairwise comparison framework from the self-report method, but expands this approach to include additional factors.

Each respondent's scores have to be analyzed separately. Table 14 presents a hypothetical example of how Cadmus entered a respondent's comparative answers into a matrix. If rebates were more important than financing by a score of 2 on the 1 to 9 scale, the score (2) was entered in the light blue box. The inverse (1/2) was entered in the green box. The yellow box indicates that financing was more important than convenience by a score of 3, with the inverse entered in the orange box. The gray boxes all contain 1 because a criteria compared to itself (e.g., financing compared to financing) would be equally important (a score of 1).

Table 14. Example of Matrix with a Hypothetical Respondent's Scores

Criteria	Financing	Rebates	Convenience	Speed
Financing	1	2	1/3	4
Rebates	1/2	1	5	1/6
Convenience	3	1/5	1	7
Speed	1/4	6	1/7	1

Cadmus then "squared" the matrix, which involved multiplying rows and columns to arrive at a new matrix, as shown in Table 15. To calculate the value of cell c2 in the squared matrix, we multiplied and added the values in the original matrix as follows: (a2*c1) + (b2*c2) + (c2*c3) + (d2*c4). Using the values in Table 14, we would add: (2*3) + (1*1/5) + (1/5*1) + (6*7) = 6 + 1/5 + 1/5 + 42 = 48.4.

Table 15. Squaring a Table

Row/Column	1	2	3	4
a	a1	a2	a3	a4
b	b1	b2	b3	b4
c	c1	c2	c3	c4
d	d1	d2	d3	d4

The white and gray cells in Table 16 present the square of the matrix in Table 14.

Table 16. Example Squared Matrix Using Hypothetical Respondent's Scores

Criteria	Financing	Rebates	Convenience	Speed	Sum	Normalized Importance Weight	Importance Weight Iterated 4x
Financing	4	28.1	11.2	10.7	54.0	0.2087	0.2115
Rebates	16.0	4	10.2	37.3	67.6	0.2612	0.2464
Convenience	7.8	48.4	4	26.0	86.3	0.3336	0.3186
Speed	3.9	12.5	30.4	4	50.8	0.1965	0.2234
Total					258.6	1.000	1.000

After squaring the matrix, Cadmus summed each row, as shown in the light blue columns to the right of the squared matrix (Table 16 above). The importance weight in the next column indicates the relative importance of each criterion and is normalized to sum to 1. The column of normalized importance weights is called an eigenvector. This eigenvector is an estimate that can be refined by squaring the previously squared matrix and calculating a new eigenvector. Each iteration makes the estimate more precise, as measured by the difference in the values of each succeeding eigenvector. We iterated this squaring process four times, at which point the differences in values were usually less than 0.0001.

We then averaged the eigenvectors from each respondent to arrive at average importance weights for the four criteria, as shown in Table 17. Financing was the most important criterion, with convenience, speed, and rebates following within 1.5 percentage points of each other.

Table 17. Importance Weights for Decision Criteria

Criteria	Average Importance Weight (n=96)	Allocation of Financing and Rebates
Financing	37.0%	64.7%
Convenience	21.7%	
Speed	21.1%	
Rebates	20.2%	35.3%
Total	**100%**	**100%**

The average importance weights for financing and rebates can then be normalized to each other to arrive at their importance relative to each other. Table 17 shows the final result, indicating that financing is more important than rebates and should receive 64.7% of energy savings. In other words, holding speed and convenience constant, financing importance is 64.7% and rebates' is 35.3%. These are the relative importance of the two criteria.

As discussed for the self-report methodology, calculating the total net energy savings allocated to each program would not be as simple as multiplying the total savings by these average allocation percentages. Energy savings vary from project to project, so the savings from each project would have to be multiplied by that project's allocation percentage and then summed across all projects.

The allocation results for self-report and expanded self-report appeared to corroborate each other, as shown in Table 18.

Table 18. Comparison of Allocation Results

Criteria	Self-Report	Expanded Self-Report
HERO	67.0%	64.7%
Rebates	33.0%	35.3%
Total	**100.0%**	**100.0%**

Self-report relied on a single comparison (i.e., importance of finance compared to rebates, on a 1 to 9 scale) that may have been difficult for people to remember and quantify. The additional pairwise comparisons of expanded self-report offered the ability to triangulate to a more precise result.

The closeness of the results for both methodologies would seem to indicate that, on average, people seem able to make such comparisons with good internal consistency. However, the allocation results for individual projects tell a different story. Cadmus looked at the *absolute* difference between the results for self-report and expanded self-report *for each project*, and found that the average absolute difference was 11 percentage points. This indicates that people may indeed have some difficulty with recalling past decisions and quantifying the relative importance of different criteria in an internally consistent manner.

This is an important finding, because calculating the total net energy savings allocated to each program would involve using the allocation results for each individual project rather than the average allocation result, as shown above Table 18.

Discrete Choice Modeling

Discrete choice modeling (DCM) provides a third option in assessing the relative contribution of financing and rebates, albeit one that is more complicated in its execution and more significant in its data requirements. As noted in the introduction, this method evaluates a decision-maker's behavior against a number of competing alternatives (generally referred to as a "choice set"). For this method to be effective, the choice set must be mutually exclusive, it must be exhaustive, and the number of alternatives must be finite.

DCM is often used for transportation demand modeling, specifically for consumer behavior related to the choice of transportation mode (e.g., car, public transit, walking).[9] The method has also been used extensively for product development and research, particularly in assessing the relative importance of product attributes on the decision to purchase. Cadmus applied DCM as a third alternate method to assess the relative impact of HERO financing and utility rebate programs. This section provides a detailed description of the analytical approach and results.

Data File Preparation

Cadmus used the following process to prepare the survey data for analysis under the DCM method. First, we transformed the survey data, which was organized as one record equal to one respondent (individual), into a format in which each respondent contributed three records, one for each potential choice. We defined these choices as completing a high-efficiency upgrade, completing a standard-efficiency upgrade, or doing nothing (i.e., considering but not completing an upgrade or not considering an upgrade).

This created a number of variables, which indicated a binary response depending on whether a certain condition was met:

- Whether an upgrade was performed involving HVAC equipment – 1=Yes, 0=No
- Whether an upgrade was performed involving window installation – 1=Yes, 0=No
- Whether an upgrade was performed involving insulation – 1=Yes, 0=No
- Whether the individual was aware of the HERO financing program – 1=Yes, 0=No
- Whether the individual was aware of utility-provided rebates – 1=Yes, 0=No

The file also included a number of demographic variables:

- Age of home

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9 Ben-Akiva and Steven R. Lerman, 1987. *Discrete Choice Analysis: Theory and Application to Travel Demand.* Cambridge: MIT Press.

- Size of home
- Value of home
- Tenure in home
- Number of occupants living in home full-time
- Respondent age
- Respondent educational attainment
- Household income

Once we constructed the data file in this manner, we applied the DCM procedure using a nested logit approach. The next section provides some background on this approach, with subsequent sections providing results and discussion.

Modeling Approach

Following the approach of Grover and Fraser,[10] Cadmus employed a nested logit model for the discrete choice part of the allocation study. A nested logit model is a random utility model widely used to model customer choices among discrete alternatives. The nested logit model partitions a consumer's choice set into mutually exclusive groups of alternatives, known as nests. Each nest contains similar alternatives that provide similar utility.

For example, researchers have applied nested logit models to analyze consumer transportation choice. Customer choice set of walk, bike, private car, carpool, bus, or train can be partitioned into these nests:

Nest 1: {walk, bike}

Nest 2: {private car}

Nest 3: {bus, train}

Each nest contains alternatives with similar attributes, benefits, and costs. These similarities make it more or less likely that the customer will choose an alternative from a particular nest than from others. For example, walking and biking are expected to be the slowest forms of transportation, while private car or car pool are expected to be fastest. Walking and biking also require physical exertion. An individual who valued exercise but not commuting time might therefore place higher value on the

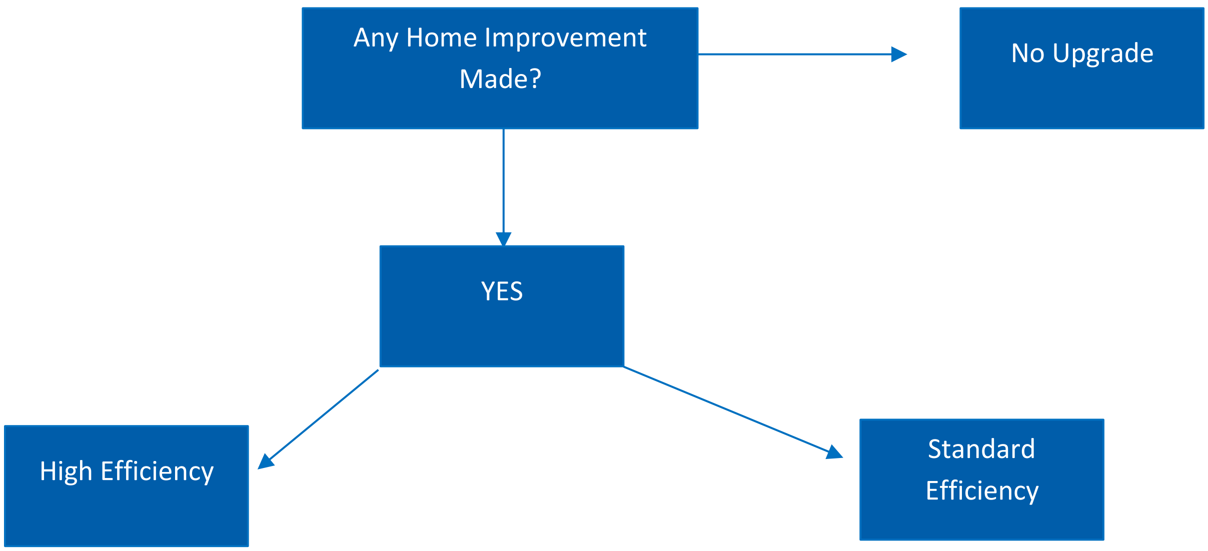
10 Grover, Steven, and Jenny Frazer. "Who Dunnit? Determining Savings Attribution When Both Rebates and Financing Are Available?" 2015 International Energy Program Evaluation Conference, Long Beach. Evergreen Economics, Portland, OR.

Other examples of applying nested logit models to analysis of energy efficiency investments include Seiden, Ken and Helen Platis. "Freerider and Freedriver Effects from a High-Efficiency Gas Furnace Program." 1999 International Energy Program Evaluation Conference, Long Beach, CA. Itron. *Small Commercial Contract Group Direct Impact Evaluation Report* (CALMAC ID CPU0019.01). Prepared for the California Public Utilities Commission. 2010.

alternatives in Nest 1. Similarly, a customer may have a distaste for public transportation, making it more likely that he or she chooses an alternative from Nest 1 or Nest 2.

Cadmus modeled the analysis of utility customer home efficiency improvements using the nested logit approach. We defined the customer choice set as having these three alternatives—no upgrade, high-efficiency upgrade, standard efficiency upgrade.

Figure 4. Diagram of Customer Choice of Home Efficiency Improvements



Cadmus also nested the efficiency improvements, with one nest including one alternative, No Upgrade, and the second nest including High Efficiency improvement and Standard Efficiency improvement:

Nest 1: {No Upgrade}

Nest 2: {High Upgrade, Standard Upgrade}

The advantage of nesting alternatives is that it relaxes the assumption of "independence of irrelevant alternatives (IIA)," which other models of customer choice such as the multinomial logit commonly impose. The IIA assumption says that unobserved factors influencing a decision-maker's utility from one alternative do not influence utility from other alternatives.[11] To see why this assumption can be problematic, consider a customer's decision to undertake a standard- or high-efficiency upgrade. According to IIA, the utility from these two choices must be independent. However, this assumption is unlikely to hold because high-efficiency and standard-efficiency projects share many of the same attributes, so utility from these alternatives is expected to be correlated. The nested model allows for such correlation, relaxing the IIA assumption and thereby adding important realism to the model.

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[11] Greene, William H. *Econometric Analysis.* Prentice-Hall: New Jersey. 2012.

Suppose customer i, i=1, 2, …, N, chooses between J>1 alternatives, denoted by j, j=1, 2, …, J. The general form of utility for customer i from choice j is as follows:

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

where V_{ij} is the utility of the customer from observed attributes of the choice and the characteristics of the individual. ε_{ij} is the utility for the customer from choice j from unobservable random factors. ε_{ij} is assumed to follow the generalized extreme value (GEV) distribution, which allows for utility of alternatives in the same nest to be correlated.

Expressing V_{ij} as a function of customer characteristics and the alternative characteristics, we obtain the following customer utility equation:

$$U_{ij} = X_{ij}\beta_j + Z_i\gamma_j + \varepsilon_{ij}$$

where:

X_{ij} is a vector of attributes of the alternative j for customer i. For example, X_{ij} could include the net present value of alternative j for customer i or whether a rebate was available for alternative j for customer i.

β is a vector of coefficients indicating the effects of the attributes of alternative j on customer utility

Z_i is a vector of customer characteristics affecting customer i's utility from alternative j. For example, the vector Z_i could include household income, the age of the home, the approximate project cost, or awareness of HERO.

γ is a vector of coefficients indicating the effects of the individual customer characteristics on utility from alternative j.

The model assumes customers choose an alternative to maximize utility. Specifically, let the set of J alternatives be denoted by Θ. Then customers choose the alternative j in Θ {j, j=1, 2, …, J} such that $U_j > U_i$, for all i≠j. The probability distribution assumptions about the model error term yield logit probabilities for the customer indicating the probability of choosing an alternative conditional on having chosen a particular branch as well as the unconditional probability of having chosen a particular branch.[12] The logit probabilities are a function of the parameters and variables in the customer utility equation.

Model Explanatory Variables

Cadmus modeled the decision to make an efficiency improvement as a function of these customer-specific variables:

- Age of the home

[12] See Chapter 17. Greene, William H. *Econometric Analysis.* Prentice-Hall: New Jersey. 2012.

- Household income
- Education of the household head
- Expected project costs
- Awareness of HERO financing
- Awareness of utility rebates

We selected these variables based on the results of a preliminary analysis of customer survey data. The analysis involved testing the correlations of the customer improvement decision with different customer characteristics using simple logit analysis.

Home Vintage, Household Income, Education, and Project Cost

Older homes were more likely to need upgrades, and therefore the probability of undertaking an upgrade should have increased with the age of the home. High-income households could have better afforded improvements, and therefore household income should have been positively correlated with the probability of undertaking them. Highly educated customers may have had greater awareness and understanding of the benefits of HERO financing and utility rebates. In addition, customers would have been less likely to undertake more expensive projects, everything else the same; therefore, project costs should have been negatively correlated with the likelihood of undertaking the project.

Expected Project Costs

For the expected costs of standard-efficiency and high-efficiency projects, we used the cost of insulating the home to standard levels and the cost of installing standard-efficiency windows, two of the most frequently reported upgrades in the survey.[13] Because the model considers many different kinds of high-efficiency improvement—not just insulation and windows—the costs of insulation and windows projects served as a proxy for these other project costs. It was less important that the proxy cost equal the actual project cost than that it be correlated with the actual cost. Windows and insulation project costs should be a good proxy, because they were estimated as a function of the size and age of the home. The cost of many home projects analyzed in this study will depend on home size and vintage.

We estimated the insulation and windows costs for each sampled home using the project costs from survey responses for customers who reported having completed projects. Specifically, we regressed project cost on the following variables:

- Separate intercepts for each project type (insulation, windows)
- Three-way interaction variables between project type, an indicator for standard efficiency, and floor area of the home

[13] We estimated but did not include HVAC costs in the regression because these costs were highly correlated with insulation costs.

- Three-way interaction variables between project type, an indicator for high efficiency, and floor area of the home
- Three-way indicator variables between project type, an indicator for standard efficiency, and home age
- Three-way indicator variables between project type, an indicator for high efficiency, and home age

We then used the estimated regression to predict the costs for each home of making standard-efficiency improvements to insulation and windows as a function of the floor area and age of the home.

Also, Cadmus modeled the decision to make an improvement as a function of the following improvement-specific variables:

- Net present value (NPV) of the improvement[14]
- Eligibility for a utility rebate for the improvement multiplied by awareness of utility rebates
- Eligibility for HERO financing for the improvement multiplied by awareness of HERO financing

We estimated the net present value for each of the alternatives (not making an upgrade, making a standard-efficiency upgrade, and making a high-efficiency upgrade) and for home insulation and windows. We used publicly available data to calculate the project energy savings and costs for each home as a function of the home's age in 2014 and floor area. We then estimated the net present value of making each type of investment for each home.

To estimate the net present value of standard-efficiency and high-efficiency improvements for each customer, we needed accurate estimates of savings and cost. To represent the high-efficiency alternative, we selected a commonly installed piece of equipment (or level of installation) for each project type. To represent the standard-efficiency alternative, we considered the code minimum or average installed baseline for that equipment as of 2014. (For example, we designated U-factor 0.25 as the representative high-efficiency alternative for windows and U-factor 0.57 as the standard-efficiency alternative.) For windows, we determined savings estimates by home vintage and floor area. Savings estimates by home vintage were not available for air-conditioning or insulation.

To model the relationship of project cost and savings to home size, Cadmus used data from Southern California Edison for 2013 and 2014 rebate projects in Riverside and San Bernardino counties. Table 19 shows the representative high-efficiency and standard-efficiency alternatives for each project type, whether the cost and savings estimates varied by home square feet or home age, and the data sources used to compile the cost and savings estimates.

14 Although many homeowners may not think explicitly in terms of net present value, they often do consider payback period, which is closely correlated. We estimated net present value absent any influence of financing or rebates.

Table 19. Assumptions for Energy Savings and Cost Estimates

Measure Type	Representative High-Efficiency Alternative	Representative Standard-Efficiency Alternative	Varies by Home Sq Ft	Varies by Home Age	Data Sources
Air Conditioning	SEER 16	SEER 13	x		1,3
Windows	U-factor of 0.25	U-factor of 0.57	x	x	2,3
Ceiling insulation	Insulating to R-38	Insulating to R-19	x		1,3

Data Sources:

1. Energy and Resource Solutions. Savings Estimation Technical Reference Manual for the California Municipal Utility Association. May 5, 2014. Accessed online July 13, 2016: http://cmua.org/energy-efficiency-technical-reference-manual/
2. California Database for Energy Efficiency Resources (DEER), 2005 version. Accessed offline. Note that the current version of DEER does not include full cost or incremental cost for most residential measures. In order to have cost and price values for a high-efficiency and standard-efficiency alternative that were based on the same set of assumptions, Cadmus used the 2005 version of DEER, which included the results of a 2005 measure cost study. We adjusted the 2005 costs to equal 2014 dollars.
3. Project data for the Advanced Home Upgrade, Home Upgrade, and Basic Upgrade rebate program activity in 2013 and 2014 in the target zip codes, provided by Southern California Edison.

Availability and Awareness of HERO Financing and Utility Rebates

The decision to make an improvement would also have depended on the availability of utility rebates and HERO financing. Rebates and HERO financing were available to all customers in the study area (except those who might not be eligible) and would have increased the probability of the customer undertaking a high-efficiency improvement. Grover and Fraser recommend including rebate and financing variables in the nested logit model.[15]

There were several practical challenges with incorporating these variables in the nested logit model. First, we did not have data on the availability of rebates and HERO financing for each customer and high-efficiency project. However, even if such data could have been collected for customers who undertook projects, such data would have been unavailable for customers who reported not having considered an improvement. Thus, we assumed HERO financing and rebates were available for all high-efficiency alternatives, even if some projects or respondents would have been ineligible. To the extent survey respondents incorrectly characterized their projects as “high-efficiency”, responses introduced measurement error into the model, and possibly biased the impact estimates.

Second, we assumed that all high-efficiency projects were eligible for HERO financing and utility rebates, which eliminated any variation between customers in the availability of these forms of financial assistance. However, this variation is needed to identify the impacts of HERO financing and utility rebates. Therefore, to introduce the necessary variability, we assumed that awareness of HERO

[15] Grover, Steven, and Jenny Frazer. “Who Dunnit? Determining Savings Attribution When Both Rebates and Financing Are Available?” 2015 International Energy Program Evaluation Conference, Long Beach. Evergreen Economics, Portland, OR.

financing or rebates was necessary for the availability of these forms of assistance. We constructed awareness variables and interacted them with the corresponding indicator variables for availability of HERO financing and utility rebates. Because approximately 50% of customers reported they were aware of rebates or HERO financing, there was sufficient variation to identify the effects of rebates and HERO financing on the probability of making a high-efficiency improvement.

A related challenge was that many high-efficiency projects that were eligible for HERO financing were also eligible for utility rebates and vice versa. This co-linearity could make it difficult to identify the separate effects of HERO financing and utility rebates on the probability of making high-efficiency improvements. We also managed this identification problem by using variation between customers in their awareness of utility rebates and awareness of HERO financing. As many customers reported having been aware of rebates but not HERO financing and other customers reported having been aware of HERO financing but not rebates, these cross-customer differences provided us with the variation necessary to identify the separate effects of rebates and HERO financing.

An additional issue regarding identification of HERO financing effects is the assumed exogeneity of HERO financing and rebates. The nested logit model assumes that the availability of HERO financing and rebates was not dependent on the improvement decision. The exogeneity assumption would be violated if the model omitted variables correlated with the improvement decision and the availability of HERO financing or rebates. For example, many projects that received HERO financing appeared to be very beneficial and might have been undertaken even if HERO financing had been unavailable. Thus, it is important that the model control for the expected benefits of the improvement. Also, the customers most likely to have been eligible for HERO financing were also most able to finance the projects through other means. For example, 10% home equity is a requirement for HERO financing. It is therefore important that the model control for household income or wealth. Other omitted factors such as environmental consciousness may be more difficult to control for. Environmental consciousness could be correlated with the motivation to undertake high-efficiency projects and with awareness and the use of HERO financing. Thus, it is important that the model control for awareness.

We attempted to minimize the potential for omitted variable bias by including variables such as the household’s income, education level, awareness, and the net present value of the project in the model. Nevertheless, the model may not control adequately for all significant factors correlated with the availability of HERO financing and the improvement decision, resulting in some degree of bias of the impact estimates.

Measuring HERO Financing Treatment Effects and Allocation

To estimate the impacts of HERO financing and utility rebates on the probability of making a high-efficiency upgrade, we calculated the difference between a customer’s probability of making a high-efficiency upgrade if HERO financing had been available with the probability of making a high-efficiency upgrade if HERO financing had been unavailable.[16] This is the equation for estimating the impact of HERO financing:

HERO Financing Treatment Effect =

$$\text{Prob}\{\text{HE Upgrade} \mid \text{HERO} = 1, \text{Z}, \text{X}^{-kj}\} - \text{Prob}\{\text{HE Upgrade} \mid \text{HERO} = 0, \text{Z}, \text{X}^{-kj}\}$$

where:

| indicates "conditional on" or "given" for a probability

HE indicates "High Efficiency"

HERO =1 indicates that HERO Awareness * High Efficiency Project = 1

HERO=0 indicates that HERO Awareness * High Efficiency Project = 0

Z is defined as before

and X^{-jk} is the vector of customer-specific variables affecting the upgrade decision except for the HERO * awareness variable.

We expressed the impact of HERO financing on the probability of making a high-efficiency improvement relative to the baseline rate if such financing had been unavailable:

% HERO Financing Treatment Effect =

$$\frac{\text{Prob}\{\text{HE Upgrade} \mid \text{HERO} = 1, \text{Z}, \text{X}^{-kj}\} - \text{Prob}\{\text{HE Upgrade} \mid \text{HERO} = 0, \text{Z}, \text{X}^{-kj}\}}{\text{Prob}\{\text{HE Upgrade} \mid \text{HERO} = 0, \text{Z}, \text{X}^{-kj}\}}$$

This expression shows the HERO financing treatment effect in percentage terms.

To estimate the above expression, we estimated the nested logit model and simulated the conditional probabilities for each customer using the estimated model coefficients and the customer characteristics in the vectors X_{ij} and Z_i. We then calculated the customer average conditional probabilities and used them to estimate the average impact of HERO financing and utility rebates on high-efficiency upgrades. We estimated the impact of utility rebates on the probability of high-efficiency improvements similarly.

To isolate the effect of HERO financing on the probability of making high-efficiency improvements, we estimated the effect of HERO financing assuming utility rebates were not available and compared this

16 As noted already, because of data limitations, we assumed that all high efficiency improvements were eligible for HERO financing, so in the model, HERO financing would have been unavailable to the customer only if the customer had been unaware of it.

estimate to the estimated combined effects of HERO financing and utility rebates. Specifically, we used the following equation to calculate HERO financing allocation score:

HERO Financing Allocation Score=

$$\frac{\text{Prob}\{\text{HE Upgrade} \mid \text{HERO} \ = 1, \text{Rebate} = 0, \text{Z}, \text{X}^{-kj}\} - \text{Prob}\{\text{HE Upgrade}|\text{HERO} \ = 0, \text{Rebate} = 0, \text{Z}, \text{X}^{-kj}\}}{\text{Prob}\{\text{HE Upgrade} \mid \text{HERO} \ = 1, \text{Rebate} = 1, \text{Z}, \text{X}^{-kj}\} - \text{Prob}\{\text{HE Upgrade}|\text{HERO} \ = 0, \text{Rebate} = 0, \text{Z}, \text{X}^{-kj}\}}$$

Where:

Rebate = 1 indicates that the interaction term HERO Awareness * High Efficiency Project = 1

All of the other variables are defined as above.

If the effects of HERO financing and utility rebates were both positive, the HERO financing allocation score will lie between zero and one.

Results

Table 20 shows summary statistics for the nested logit model estimation sample. Cadmus used survey data for 3,213 customers to estimate the model.

Table 20. Summary Statistics for Estimation Sample

Variable	Mean	Std. Dev.	Min	Max
Age of Home (Years)	29.6	18.1	3.5	76
Ln(Household Income) ($)	11.2	0.7	9.9	12.6
Completed bachelors or higher degree (Yes=1, No=0)	0.426	0.495	0	1
Insulation project cost ($)	1,027.0	1,443.3	0	9,222.5
Windows project cost ($)	5,642.1	1,762.3	1,619.9	12,469.8
Aware of HERO (Yes=1, No=0)	0.489	0.500	0	1
Aware of utility rebates (Yes=1, No=0)	0.568	0.495	0	1
Aware of HERO * High Efficiency Project	0.163	0.369	0	1
Aware of utility rebates * High Efficiency Project	0.189	0.392	0	1
NPV of insulation ($)	719.6	753.9	0	4,172
NPV of windows ($)	-4,054.4	3,461.7	-16,875.0	0.0
Sample weight	0.997	0.401	0.158	1.195
N of sampled customers	3,213			

Notes: Estimation sample means. See text for description of data and sources.

The average respondent home was approximately 30 years of age. About 43% of respondents reported having completed a bachelor's or higher degree. The average costs of standard-efficiency insulation and windows projects were $1,027 and $5,642, respectively. Approximately 49% of respondents reported having been aware of HERO financing, and 57% reported having been aware of utility rebates. The net present value of the average insulation project was $719 and of the average windows project was about $4,000. These averages include both standard-efficiency and high-efficiency projects.

Table 21, on the next page, shows estimates of the nested logit model coefficients. The upgrade equation shows coefficients for variables affecting the first-level decision of whether to upgrade or not. The high-efficiency and standard-efficiency equations show the coefficient for variables affecting the choice between the second-level alternatives. A category for no upgrade is omitted, meaning that the impacts of the variables in high-efficiency and standard-efficiency are measured relative to no upgrade. The model coefficients cannot be interpreted directly as marginal effects of the independent variables, because the marginal effects depend not just on the coefficients but also on the first-level unconditional probabilities, the second-level conditional probabilities, and the dissimilarity parameter.[17] However, because the dissimilarity parameter lies in the interval [0,1], the signs of the coefficients indicate the directions of the impacts.

Most of the explanatory variables—including household income, educational attainment, and project costs—hypothesized to have influenced the first-level (upgrade) decision had statistically significant and expected effects. Household income and education attainment increased the likelihood the homeowner would make an improvement, while the costs of insulating the home and making windows upgrades reduced the likelihood. Awareness of utility rebates increased the likelihood of making a high-efficiency improvement, while awareness of HERO financing reduced the likelihood. The negative effect of awareness of HERO financing may reflect the fact that customers who were most likely to be aware of HERO were least financially able to undertake high-efficiency projects.

In the second-level decision, the net present value of windows and insulation had the expected positive and statistically significant effects on the likelihood of undertaking a high-efficiency improvement. Customers were more likely to undertake projects with high net present values. Both HERO financing (p value=0.14) and utility rebates (p=0.12) had the expected positive effects on the likelihood of making high-efficiency improvements and were marginally significant at the 10% significance level.

17 Greene, William H. *Econometric Analysis.* Prentice-Hall: New Jersey. 2012.

Table 21. Nested Logit Model Estimated Coefficients

Decision Level	Variable	Estimated Coefficients (Standard Error)
Upgrade	Age of Home (Years)	-0.07888232
		(0.01842433)***
	Ln(Household Income) ($)	0.35823854
		(0.07735387)***
	Completed bachelors or higher degree (Yes=1, No=0)	0.26988312
		(0.09520532)***
	Insulation project cost ($)	-0.00043659
		(0.00006845)***
	Windows insulation cost ($)	-0.00150746
		(0.00067387)**
	Aware of HERO (Yes=1, No=0)	-0.74544647
		(0.12135318)***
	Aware of utility rebates (Yes=1, No=0)	1.91571598
		(0.13993911)***
High-Efficiency	Aware of HERO * High Efficiency Project	0.07739802
		(0.05312196)
	Aware of utility rebates * High Efficiency Project	0.07361345
		(0.04801106)
	NPV of insulation ($)	0.0385166
		(0.00985765)***
	NPV of windows ($)	0.00281149
		(0.00076844)***
Standard-Efficiency	NPV of insulation ($)	0.01376124
		(0.00374329)***
	NPV of windows ($)	0.00304494
		(0.00088489)***
Upgrade Dissimilarity	Constant	0.16140017
		(0.08073542)**
Wald $\chi 2$ (d.f.=13) test statistic		630.56, p value<0.0001
Log pseudo-likelihood		-1881.13
N of customers		3,213

Note: Model estimated by full information maximum likelihood. Data were weighted using customer sampling weights. Upgrade tau is the dissimilarity parameter for the Upgrade nest. See text for explanation. Upgrade shows the variables affecting the level 1 decision of whether to upgrade or not. High and Standard show the impacts of variables on level 2 decision among alternatives. The omitted alternative was no upgrade. Standard errors in parentheses clustered on customer. ***,**, * indicate statistically significant at the 10%, 5%, and 1% levels.

The bottom of Table 21 shows an estimate of the dissimilarity parameter for the upgrade nest. The dissimilarity parameter equals $\sqrt{1-\rho}$, where ρ is the correlation coefficient of the utility of alternatives in the nest. A ρ parameter between zero and one is consistent with a model of random utility maximization. If ρ is greater than zero but less than one, it would also indicate that the utility of an alternative was correlated with the utility of other alternatives in the nest. A ρ parameter equal to zero would mean that the utility of an alternatives is uncorrelated with the other alternatives in the nest. In this case, the nested logit model would then be degenerate to the conditional logit model, which does not allow for correlation of utility across alternatives. Values of ρ outside of the interval [0,1] indicate that the specification is not consistent with a random utility model and that the model may need to be re-specified.

Table 21 shows that the estimate of the dissimilarity panel was equal to 0.16, indicating that the nested logit model specification was consistent with a random utility model of customer choice. The specification also indicates a high degree of correlation between the utility of the standard-efficiency and high-efficiency alternatives, which is not surprising because these alternatives share many of the same attributes.

The Wald $\chi 2$ test statistic tests the overall statistical significance of the model. The Wald $\chi 2$ (d.f. =13) equals 630.6 and has a p-value of less than 0.0001, meaning we can strongly reject the hypothesis that the model variables had no effect on the efficiency improvement decision.

A way of assessing the validity of the nested logit model specification is to compare the model-predicted choice probabilities with the self-reported frequencies in the sample. Table 22 reports these average model predicted probabilities and sample frequencies:

- A customer makes a high-efficiency or standard-efficiency upgrade
- A customer makes a high-efficiency upgrade conditional on making an upgrade
- A customer makes a high-efficiency upgrade
- A customer makes a standard-efficiency upgrade

Table 22. Comparison of Model Predicted Choice Probabilities and Sample Frequencies

	Survey Sample Frequencies	Model Predicted	Difference
Prob(upgrade)	0.269	0.264	0.005
Prob(HE upgrade | upgrade)	0.887	0.873	0.014
Prob(HE upgrade)	0.238	0.233	0.005
Prob(SE upgrade)	0.030	0.030	0

Notes: Survey sample frequencies calculated using self-reported improvement decisions in survey. Model predicted frequencies based on estimates from nested logit model.

The nested logit model predicted the choices of sampled customers very closely. Table 22 shows three of four differences between the sample reported and the model predicted probabilities were less than one percentage point. Only the difference in the probability of making a high-efficiency upgrade conditional on making an upgrade exceeded one percentage point (0.014). This suggests that on average the nested logit model predicts well for the customers in the analysis sample.

Estimated HERO Financing and Utility Rebate Treatment Effects

Table 23 shows the estimates of the HERO financing and utility rebate treatment effects. We estimated the treatment effects for all sampled customers and sampled customers who reported making high-efficiency improvements. The latter estimate is the most relevant for assessing treatment effects, because it measures impacts on customers who made high-efficiency improvements. Also, we estimated both treatment effects assuming that the other financing option was available and customers were aware of it.

Panel A shows the HERO financing treatment effects. For all sampled customers, the model estimated that during the previous three years the baseline rate of improvements was 22.3%. HERO financing increased the probability that a customer would make a high-efficiency improvement by 2.2 percentage points or 9.9%.

For sampled customers who made high-efficiency improvements, the model predicts a baseline rate of high-efficiency improvement of 32.9%. HERO financing increased the probability that a customer would make a high-efficiency improvement by three percentage points or 9%.

Table 23. Estimated HERO Financing and Utility Rebate Impacts

	All Sampled Customers	Sampled Customers Who Made High-Efficiency Improvements
Panel A. Effect of HERO Financing		
Probability of High-Efficiency Upgrade With HERO Financing	0.245	0.359
Probability of High-Efficiency Upgrade With No HERO Financing	0.223	0.329
HERO Financing Treatment Effect	0.022	0.030
% HERO Financing Treatment Effect	9.9%	9.0%
Panel B. Effect of Utility Rebates		
Probability of High-Efficiency Upgrade With Utility Rebate	0.238	0.342
Probability of High-Efficiency Upgrade With No Utility Rebate	0.216	0.312
Utility Rebate Treatment Effect	0.022	0.031
% Utility Rebate Treatment Effect	10.2%	9.8%

Notes: Estimates based on results of nested logit model. See text for estimation details. HERO financing treatment effects estimated assuming rebates existed for high-efficiency improvements. Utility rebate treatment effects estimated assuming HERO financing existed for high-efficiency improvements. % treatment effects estimated as the ratio of the treatment effect to the baseline probability of upgrading.

Panel B reports the treatment effects of utility rebates. For all sample customers, the baseline probability of a high-efficiency improvement was 21.6%. Utility rebates increased the probability of making a high-efficiency improvement by 2.2 percentage points or 10.2%. For customers who made high-efficiency improvements, utility rebates increased the probability of making such improvements by 3.1 percentage points or 9.8%.

We also isolated the separate impacts of HERO financing and utility rebates for all sampled customers and sampled customers making high-efficiency improvements. As described in the methodology section, we estimated the effect of HERO financing assuming utility rebates were not available and compared this to the estimated combined effects of HERO financing and utility rebates (Table 24).

Table 24. Estimated HERO Financing Allocation

	All Sampled Customers	Customers Who Made High-Efficiency Upgrades
Probability of High-Efficiency Upgrade with HERO Financing and Rebate	0.250	0.360
Probability of High-Efficiency Upgrade with HERO Financing and No Rebate	0.229	0.332
Probability of High-Efficiency Upgrade with No HERO Financing and No Rebate	0.204	0.299
% Allocation to HERO Financing	54.0%	54.5%
Notes: Estimates based on results of nested logit model. See text for details about estimating allocation. Any differences between reported allocation score and the allocation score calculated using the individual reported probabilities is due to rounding error.		

For all sampled customers, the collective effect of HERO financing and utility rebates was to increase the probability of making a high-efficiency improvement by 4.6 percentage points (0.250–0.204) or 22%. HERO financing increased the probability of making a high-efficiency improvement by 0.025 percentage points or 11.9%. Thus, HERO financing was responsible for about 54% of the lift in the probability of making a high-efficiency improvement.

For customers who made high-efficiency upgrades, the nested logit model predicts that HERO financing was responsible for 55% of the lift in the probability of making a high-efficiency improvement.

The nested logit model and the self-report methodologies produced similar allocation scores. The nested logit model allocated 55% of credit for high-efficiency improvements to HERO financing. The self-report and expanded self-report estimate allocated 67% and 65%, respectively, of the credit to HERO financing. Therefore, the nested logit and self-report allocation scores are close, but it is not possible to know which is more accurate because the true allocation score is not known. [18]

[18] Cadmus did not estimate the uncertainty of the allocation score, so it is possible that the differences between the nested logit and self-report estimates are not statistically significant. To estimate the uncertainty of the HERO financing, it would be necessary to estimate bootstrap standard errors.

Assessment of the Nested Logit Modeling Approach

The principal advantage of the nested logit model approach is that it is based on a random utility model of customer choice and analysis of observed customer choice. Cadmus' model explained customer choices about efficiency investments as a function of demographics, the expected costs and net present value of the project, and the availability of HERO financing and utility rebates for each customer. The nested logit predicted average behavior accurately, yielding probabilities that customers would make upgrade or high efficiency upgrades that were very close on average to the choice frequencies of customers in the analysis sample. The discrete choice model also yielded HERO financing allocation estimates that were close to the self-report estimates.

Cadmus encountered some challenges in implementing the nested logit model, many of which are described in Grover and Fraser.[19] One challenge was that we found it necessary to estimate the benefits and costs of high-efficiency and standard-efficiency projects for each customer in the analysis sample, including customers who did not make improvements, because actual project cost data were not available. The project's benefits and costs are an important factor in customer choice, so estimating them cannot be avoided. We therefore used the project costs reported in the surveys and market data on energy savings and costs for representative improvements to estimate the benefits and costs. Future evaluations that employ DCM should continue to collect project cost data in the customer surveys.

A second challenge was that our analysis modeled customer choice about multiple types of improvements including HVAC, insulation, windows, water heaters, pool pumps, and air sealing. These projects ranged in size of costs and energy savings, complicating how they were captured in the model. We decided to incorporate benefits and costs for insulation and windows projects in the nested logit model, with the expectation that these projects would be broadly representative of the relative benefits and costs of many home improvements. In future discrete choice analyses, focusing the modeling on a single improvement type, such as HVAC, instead of multiple project types would simplify the analysis.

A third challenge was that it was impossible to know whether nonparticipant customer projects were or would have been eligible for HERO financing or utility rebates. Our inability to determine project eligibility meant the analysis treated some ineligible projects as eligible, introducing error in the measurement of the HERO financing and rebate availability variables and possibly attenuating the impact estimates. In future analysis, evaluations that focused on a single type of improvement instead of multiple improvements would be able to assess eligibility more accurately.

A fourth challenge was that we were unable to separately estimate the impacts of HERO financing and rebates. We had to assume that all high-efficiency projects were eligible for both HERO financing and rebates, which eliminated any variation in eligibility among high-efficiency projects. Fortunately, we found variation in customer awareness of HERO financing and rebates, because some customers were

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[19] Grover, Steven, and Jenny Frazer. "Who Dunnit? Determining Savings Attribution When Both Rebates and Financing Are Available?" 2015 International Energy Program Evaluation Conference, Long Beach. Evergreen Economics, Portland, OR.

aware of one option but not the other. We could use this variation in awareness to estimate the impacts separately.

Finally, the nested logit model makes strong assumptions about the availability of HERO financing and rebates, treating these variables as having been exogenous to the improvement decision. Omission of independent variables correlated with both the investment decision and the availability of HERO financing or rebates would have violated this assumption. In the nested logit model, the availability of HERO financing and rebates was a function of customer awareness of these forms of financial assistance. If customer awareness depended on the improvement decision—for example, if customers who were most likely to make high-efficiency improvements were also most likely to have been aware of HERO financing—the exogeneity assumption would have been violated and the impact estimates would be biased. Cadmus attempted to reduce the potential for this kind of bias by including customer characteristics expected to influence the improvement decision as model independent variables.

Overall Findings

Overall, based on implementing the discrete choice model, Cadmus made the following findings about the discrete choice modeling approach for allocating credit to energy efficiency financing programs:

- Discrete choice modeling is resource intensive, as it requires extensive survey data collection and analysis as well as statistical and econometric expertise to implement;
- Discrete choice modeling appears to be a viable option for California to allocate credit to HERO financing and energy efficiency programs;[20]

[20] California could also consider two other analysis approaches based on observed customer choice. The first is randomized encouragement designs (REDs), which are the gold standard of evaluation of opt-in programs such as HERO financing and utility rebates. The evaluation would randomize a large number of eligible customers into treatment and control groups and be designed to encourage customers in the treatment group to use HERO financing to make high-efficiency improvements. Evaluators would collect billing data and compare the energy consumption of treatment (encouraged) and control (not encouraged) group customers to estimate HERO financing impacts. For examples of randomized encouragement designs used in evaluation of demand-side management programs, see Fowlie, M., M. Greenstone, and C. Wolfram. “Do Energy Efficiency Investments Deliver? Evidence from the Weatherization Assistance Program.” E2e Working Paper 020. 2012. Also, see Potter, J., S. George, and L. Jimenez. *Smart Pricing Options Final Evaluation.* Prepared for U.S. Department of Energy. 2014. Available at https://www.smartgrid.gov/files/SMUD-CBS_Final_Evaluation_Submitted_DOE_9_9_2014.pdf.

- Discrete choice modeling may have more credibility than the self-report and expanded self-report methods, especially to external stakeholders. A model of utility maximization underlies the discrete choice model and discrete choice modeling involves analysis of actual customer choices.

The second is a spatial discontinuity design. Evaluators would identify geographic boundaries such as a utility service area, municipal, or county boundary separating areas eligible and ineligible for HERO financing. Evaluators would then compare rates of high-efficiency improvements and energy consumption of homes lying on either side of the boundary to estimate the HERO Program effects. By looking at homes close to the boundary, it is likely that homes on either side will have similar demographic and housing characteristics and that the impact estimates will be unbiased. For an example of a spatial discontinuity design, Ito, Koichiro. "Do Consumers Respond to Marginal or Average Price? Evidence from Nonlinear Electricity Pricing." *American Economic Review* 104 (2), pp. 537-563. 2014.

Conclusions and Recommendations

This section presents conclusions and recommendations associated with the findings from all three methodologies.

HERO financing was more important than rebates in influencing homeowners' decisions.

All three methodologies estimated that financing was on average more important in the decision to make a high-efficiency improvement, as shown in Table 24.

Table 25. Allocation Results

	Self-Report	Expanded Self-Report	DCM
Financing	67%	65%	55%
Rebates	33%	35%	45%
Total	**100%**	**100%**	**100%**

Anecdotal findings from contractors, presented in the companion *HERO Program Study*, support this conclusion. Furthermore, the three utilized methodologies produced similar allocation estimates for HERO financing, ranging between 55% and 67% for upgrade projects that used both HERO financing and utility rebates.

Although these results provide an important benchmark for future allocation studies, **they should not be extrapolated to other financing programs**. The HERO Program has several features that may or may not characterize other programs, including the IOU financing pilots. For example, the broad measure eligibility available through HERO may not be available through the IOU financing pilots. Differences between the HERO program and other utility financing programs mean that the HERO allocation results may not have validity outside of this study.

Recommendation: The IOUs should conduct allocation studies of future IOU financing programs.

Discrete choice modeling has important advantages and disadvantages relative to self-report.

The principal advantages of discrete choice modeling are that it has a theoretical foundation in economics and that it analyzes actual customer choices. The nested logit model is grounded in the utility maximization theory of customer choice, and it attempts to explain the choices that customers made as a function of customer attributes as well as the attributes of available alternatives. Other methodologies, including the self-report methods assessed in this study, may not have as rigorous of a foundation in customer choice theory.

A principal disadvantage of the nested logit approach was its cost of implementation. It required extensive survey data collection and analysis as well as statistical and econometric expertise to implement. Another disadvantage was that the validity of this study's allocation estimates depended on strong assumptions about the exogeneity of awareness of HERO financing that were difficult to verify.

However, future studies using DCMs may use different identification strategies and rely on different assumptions for identifying the impacts of financing.

Recommendation: The IOUs should consider discrete choice modeling as an option for conducting future financing program allocation studies.

Expanded self-report has important advantages and disadvantages relative to discrete choice modeling.

The principal advantages of the self-report methodology are that it is relatively easy and inexpensive to implement and that many energy efficiency stakeholders are familiar with and accept this approach. [21,22] The largest cost of conducting a self-report study is fielding customer surveys. Analysis of self-report data is straightforward and is not time-consuming. Evaluators have applied self-report methodologies for other energy efficiency evaluations, and as a consequence, many stakeholders accept the approach of asking utility customers to assess the relative influence of different factors in their decisions.

The principal disadvantages of this approach are lingering doubts about its accuracy and usefulness for estimating program causal effects. The self-report approach asks respondents to assess the relative importance of different factors in their decisions or to report what their decisions would have been under different circumstances. However, customers may have difficulty understanding the reasons for their decisions or may have acted differently than they say that they would have. External stakeholders, such as California state legislators not familiar with this approach, may have difficulty accepting results based on self-reporting.

Self-report methodologies may be appropriate for financing program evaluations that have limited budgets or short timeliness, that do not want to burden customers with long surveys, or that have stakeholders that are familiar with and accept the self-report methodology.

Recommendation: The IOUs should consider self-report methodologies as options for conducting future financing program allocation studies.

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[21] Ridge, Richard, Ken Keating, Lori Megdal, and Nick Hall. (2007). Guidelines for Estimating Net-To-Gross Ratios Using the Self Report Approach. Prepared for the California Public Utilities Commission.

[22] The TecMarket Works Team. (2006). California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals. Prepared for the California Public Utilities Commission.

Appendix A. Survey Instrument

HERO Program Study Online Survey

[Highlighted sections vary by survey audience]

Introduction

On behalf of Southern California Edison and Southern California Gas, thank you for participating in this survey about home energy improvement. Your input is important in our ongoing efforts to help make it easy for homeowners to save on energy. Please know that your answers will be kept completely confidential.

Depending on the path your answers take, the survey should only take about 5 to 10 minutes. You can leave the survey at any time and come back later to pick up where you left off. Be sure to enter your name and email address at the end of this survey in order to receive your $20 e-gift card as our thank you for your help.

1. **To begin, please note the 5-digit zip code where you live (below): ___________**

2. **Do you own or rent your home?**
   - ◯ Own *(1)*
   - ◯ Rent *(2)*
   - ◯ Not sure *(3)*

3. **Do you get your electricity from Southern California Edison?**
   - ◯ Yes, I get my electricity from Southern California Edison. *(1)*
   - ◯ No, I do not get my electricity from Southern California Edison. *(2)*
   - ◯ Not sure. *(3)*

4. **Do you get your gas from Southern California Gas?**
   - ◯ Yes, I get my gas from Southern California Gas. *(1)*
   - ◯ No, I do not get my gas from Southern California Gas. *(2)*
   - ◯ Not sure. *(3)*

5. **Are you one of the key decision-makers about energy improvements to your home?**
   - ◯ Yes, I am one of the key decision-makers. *(1)*
   - ◯ No, I am not one of the key decision-makers. *(2)*
   - ◯ Not sure. *(3)*

Next *[**Programming Note**: If the entered zip code is on our list of 107 targeted zip codes, and if the other questions are all answered 1, **skip to Question 6**. Otherwise, for Gen Pop sample frame, skip to Question 31 (Screened out thank you). For HERO and Rebate sample frames, skip to Question 29 (Choose gift card).]*

---

6. **In the last three years, have you researched the idea of upgrading or replacing any of the following features of your home, or talked with a contractor about them? Please select all that apply. If you've thought about improvements in general but have not researched or talked with a contractor about any of these specific improvements, please select "None of these specific improvements".**
   - ☐ Heating, ventilation, or air conditioning *(1)*
   - ☐ Windows *(2)*
   - ☐ Insulation *(3)*
   - ☐ Air sealing or duct sealing *(4)*
   - ☐ Water heater *(5)*
   - ☐ Pool pump and motor *(6)*
   - ☐ None of these specific improvements *(7)*
   - ☐ Not sure *(8)*

Next *[**Programming Note**: If 7 or 8, continue to 6a. Otherwise, **skip to Question 7**.]*

---

a. **Why have you not considered any of these improvements? Please select all that apply.**
   - ☐ Not really necessary – my home's energy efficiency is good enough *(1)*
   - ☐ Energy cost savings not big enough *(2)*
   - ☐ Not convenient *(3)*
   - ☐ Not affordable *(4)*
   - ☐ Not a good deal financially *(5)*
   - ☐ Financing would be difficult to get *(6)*
   - ☐ Would not want to finance *(7)*
   - ☐ Rebates are not big enough *(8)*
   - ☐ Not urgent *(9)*
   - ☐ Concerns about contractors *(10)*
   - ☐ Other, please describe: ______________________________________ *(11)*

b. **Are you aware that the HERO Program is available to help homeowners finance energy efficiency improvements like these?**
   - ◯ Yes, I am aware that the HERO Program can finance such improvements. *(1)*
   - ◯ No, I am not aware of the HERO Program. *(2)*

c. **Are you aware that utility rebates are available to help offset the cost of making improvements like these?**
   - ◯ Yes, I am aware that utility rebates can help offset the cost of such improvements. *(1)*
   - ◯ No, I am not aware of utility rebates. *(2)*

Next *[**Programming note**: **Skip to Question 20**, the first demographic question.]*

---

7. Did you decide to make any of the improvements you considered? Please select any that are underway or completed. If you made more than one round of improvements, for example a new furnace two years ago and air sealing and new insulation last year, please select ONLY the improvements in the most recent round (in this example, you would select air sealing and insulation). If you have not decided to make any of the improvements, please select the last answer.

- ☐ Heating, ventilation, or air conditioning *(1)*
- ☐ Windows *(2)*
- ☐ Insulation *(3)*
- ☐ Air sealing or duct sealing *(4)*
- ☐ Water heater *(5)*
- ☐ Pool pump and motor *(6)*
- ☐ I have not decided to make any of the improvements *(7)*

Next *[**Programming Note**: If 7, continue to 7a. Otherwise, **skip to Question 8**.]*

---

a. Why have you decided not to make the improvement(s)? Please select all that apply.

- ☐ Not really necessary – my home's energy efficiency is good enough *(1)*
- ☐ Energy cost savings not big enough *(2)*
- ☐ Not convenient *(3)*
- ☐ Not affordable *(4)*
- ☐ Not a good deal financially *(5)*
- ☐ Financing would have been difficult to get *(6)*
- ☐ Did not want to finance *(7)*
- ☐ Rebate was not big enough *(8)*
- ☐ Not urgent *(9)*
- ☐ Concerns about contractors *(10)*
- ☐ Other, please describe: ______________________________________ *(11)*

b. What was the total cost of the improvements you considered? If you don't remember the exact amount, just fill in the approximate amount to the best of your memory.

- ➢ Total cost: $_________ *(1)*

c. When you were considering the improvement(s), were you aware of the HERO Program that is available to help homeowners finance energy efficiency improvements like these?

- ◯ Yes, I applied for HERO and was approved, but chose not to use it. *(1)*
- ◯ Yes, I applied for HERO financing but was not approved. *(2)*
- ◯ Yes, I was aware of HERO financing but none of the items I considered were eligible. *(3)*
- ◯ Yes, I was aware of HERO but chose not to apply. *(4)*
- ◯ No, I was not aware of HERO financing. *(5)*

d. When you were considering the improvement(s), were you aware of utility rebates that are available to help offset the cost of making improvements like these?

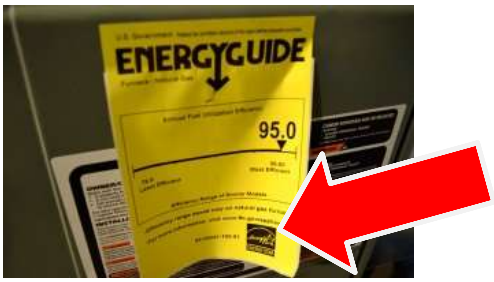
- ◯ Yes, I was aware of utility rebates, but the item(s) I considered were not eligible. *(1)*
- ◯ Yes, I was aware of utility rebates, but did not choose to apply. *(2)*
- ◯ No, I was not aware of utility rebates. *(3)*

Next *[**Programming note**: **Skip to Question 20**, the first demographic question.]*

For the rest of the questions, please respond only about the improvement(s) you just selected on the list, NOT about any other energy improvements you may have made such as solar panels or kitchen/laundry appliances.

For the improvement(s) you selected, you probably had a choice between standard efficiency and high-efficiency alternatives. Which did you choose? An improvement was probably a high-efficiency improvement if it was:

- **Eligible for utility rebates, or**
- **Eligible for the HERO financing program, or**
- **More efficient than other alternatives that were available, or**
- **ENERGY STAR-labeled. Not sure? Check for an ENERGY STAR logo on the yellow Energy Guide sticker.**



Do you think any of the improvements you chose were high efficiency?

- ◯ Yes, I think I chose at least one high-efficiency improvement. *(1)*
- ◯ No, I think I chose standard efficiency. *(2)*
- ◯ Not sure. *(3)*

8. **Which of the following factors were important in your decision to make the improvement(s)? Please select all that apply.**
   - ☐ Equipment was broken or about to break *(1)*
   - ☐ Home too hot, cold, or drafty *(2)*
   - ☐ Save money on utilities *(3)*
   - ☐ Conserve natural resources for future generations *(4)*
   - ☐ Climate change *(5)*
   - ☐ Part of home remodel *(6)*
   - ☐ Increase home value *(7)*
   - ☐ Attractive financing *(8)*
   - ☐ Attractive utility rebates *(9)*
   - ☐ Friend recommended making improvements *(10)*
   - ☐ Contractor recommended making improvements *(11)*
   - ☐ Other: ____ *(12)*

9. **What was the total cost of the improvements you completed or have under contract? If you don't remember the exact amount, just fill in the approximate amount to the best of your memory.**
   - ➢ Total cost: $__________ *(1)*

10. How did you pay for the improvement(s)? Please select the primary method that applies.

- ◯ Cash *(1)*
- ◯ Credit card – with the intent to pay off the balance immediately *(2)*
- ◯ Credit card – with the intent to pay off the balance over time *(3)*
- ◯ HERO financing *(4)*
- ◯ Home equity loan *(5)*
- ◯ Unsecured loan *(6)*
- ◯ Financing from contractor or manufacturer *(7)*
- ◯ Mortgage refinance *(8)*
- ◯ Other: ______________________________ *(9)*

11. How satisfied were you with that payment method?

Strongly Satisfied				Neutral				Strongly Dissatisfied
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
◯	◯	◯	◯	◯	◯	◯	◯	◯

Next [***Programming note:*** *If 4 is not selected in Question 11,* ***skip to Question 12b****.]*

---

a. Would you have made the same improvement(s) anyway even if HERO financing had not been available?

- ◯ Yes, I would have made the same improvements and paid another way – cash, credit card, etc. *(1)*
- ◯ No, I would have made fewer or less efficient improvements without HERO. *(2)*
- ◯ No, I would not have made any improvements without HERO. *(3)*
- ◯ Not sure. *(4)*

Next [***Programming note: Skip to Question 13****.]*

---

b. When you were considering the improvement(s), were you aware of the HERO Program that is available to help homeowners finance energy efficiency improvements like these?

- ◯ Yes, I applied for HERO financing and was approved, but chose not to use it. *(1)*
- ◯ Yes, I applied for HERO financing, but was not approved. *(2)*
- ◯ Yes, I was aware of HERO, but the improvements I made were not eligible. *(3)*
- ◯ Yes, I was aware of HERO, but chose not to apply. *(4)*
- ◯ No, I was not aware of HERO. *(5)*

Next [***Programming note:*** *If 5,* ***skip to Question 13****.]*

---

c. Was your awareness of HERO financing one of the reasons you started thinking about making improvement(s)?

◯ Yes, HERO financing was one of the reasons I started thinking about improvements. *(1)*
◯ No, HERO financing was not one of the reasons I started thinking about improvements. *(2)*

d. Why did you decide not to use HERO financing? Please select all that apply.

☐ My improvements were not eligible *(1)*
☐ My improvements were eligible but my application was not approved *(2)*
☐ HERO process was not convenient or fast enough *(3)*
☐ Interest rate too high *(4)*
☐ Payments too high *(5)*
☐ Not comfortable with repaying through my property tax bill *(6)*
☐ Not recommended by contractor *(7)*
☐ Other: ____ *(8)*

Next

---

13. Which of the following factors were important in choosing how you paid for the improvement(s)? Please select all that apply.

☐ Convenient financing process *(1)*
☐ Paying cash would have been difficult *(2)*
☐ Financing I chose did not require a high credit score *(3)*
☐ Did not want another mortgage lien or a tax lien on property *(4)*
☐ Financing interest rate was reasonable *(5)*
☐ Manageable financing payments *(6)*
☐ Utility bill cost savings offset the financing payments *(7)*
☐ HERO assessment can transfer to buyer when home is sold *(8)*
☐ Friend recommendation *(9)*
☐ Contractor recommendation *(10)*
☐ Other: ____ *(11)*

14. Did you use a utility rebate to help offset the cost of the improvement(s)?

◯ Yes, I used a utility rebate. *(1)*
◯ No, I did not use a utility rebate. *(2)*
◯ Not sure. *(3)*

Next [***Programming Note:*** *If 2 or 3,* ***skip to Question 14d****.*]

---

a. **How satisfied were you with the utility rebate?**

Strongly Satisfied				Neutral				Strongly Dissatisfied
1	2	3	4	5	6	7	8	9
◯	◯	◯	◯	◯	◯	◯	◯	◯

b. **What was the total rebate amount for the improvement(s) you installed? If you don't remember the exact amount, just fill in the approximate amount to the best of your memory.**
   - Total amount: $_________ *(1)*

c. **Would you have made the same improvement(s) anyway even if utility rebates had not been available?**
   - ◯ Yes, I would have made the same improvement(s) even without a utility rebate. *(1)*
   - ◯ No, I would not have made any improvements without utility rebates. *(2)*
   - ◯ No, I would have made fewer or less efficient improvement(s) without utility rebates. *(3)*
   - ◯ Not sure. *()*

Next *[**Programming Note: Skip to Question 15**.]*

---

d. **When you were considering the improvement(s), were you aware of utility rebates that are available to help offset the cost of improvements like these?**
   - ◯ Yes, I was aware of utility rebates, but chose not to use one. *(1)*
   - ◯ Yes, I was aware of utility rebates, but none of the improvements I installed were eligible *(2)*
   - ◯ No, I was not aware of utility rebates. *(3)*

Next *[**Programming Note:** If 3, **skip to Question 15**.]*

---

e. **Was your awareness of utility rebates one of the reasons you started thinking about making improvements?**
   - ◯ Yes, utility rebates were one of the reasons I started thinking about improvements. *(1)*
   - ◯ No, utility rebates were not one of the reasons I started thinking about improvements. *(2)*

f. **What was the total rebate amount available for the improvement(s) you installed? If you don't remember the exact amount, just fill in the approximate amount to the best of your memory.**
   - Total amount: $_________ *(1)*

g. **Why did you decide not to use a utility rebate? Please select all that apply.**
- ☐ My improvements were not eligible *(1)*
- ☐ Rebate process was not convenient *(2)*
- ☐ Rebate amount too small *(3)*
- ☐ Not recommended by contractor. *(4)*
- ☐ Other: _______________________ *(5)*

Next

---

15. The next questions ask you to compare the importance of four factors in your decision to make the improvement(s). The four factors are:
- **Financing – How important were the available financing options (HERO, credit card, etc.) in your decision?**
- **Rebates – How important were the available utility rebates?**
- **Convenience – How important was the overall convenience of the improvement process?**
- **Speed – How important was the overall speed of the improvement process?**

a. **Financing versus Rebates – Which was more important in your decision to make the improvement(s)?**
- ◯ Financing was more important *(1)*
- ◯ Utility rebates were more important *(2)*
- ◯ They were equally important *(3)*
- ◯ Neither was at all important *(4)*

Next [***Programming Note:*** *If 3 or 4, **skip to Question 14b**.*]

How much more important?

Equally Important				Strongly More				Extremely More
1	2	3	4	5	6	7	8	9
◯	◯	◯	◯	◯	◯	◯	◯	◯

Next

---

b. **Financing versus Convenience – Which was more important in your decision to make the improvement(s)?**
- ◯ Financing was more important *(1)*
- ◯ Convenience of the overall process was more important *(2)*
- ◯ They were equally important *(3)*
- ◯ Neither was at all important *(4)*

Next [***Programming Note:*** *If 3 or 4,* ***skip to Question 14c****.]*

How much more important?

Equally Important				Strongly More				Extremely More
1	2	3	4	5	6	7	8	9
◯	◯	◯	◯	◯	◯	◯	◯	◯

Next

---

c. **Financing versus Speed – Which was more important in your decision?**
- ◯ Financing was more important *(1)*
- ◯ Speed of the overall process was more important *(2)*
- ◯ They were equally important *(3)*
- ◯ Neither was at all important *(4)*

Next [***Programming Note:*** *If 3 or 4,* ***skip to Question 14d****.]*

How much more important?

Equally Important				Strongly More				Extremely More
1	2	3	4	5	6	7	8	9
◯	◯	◯	◯	◯	◯	◯	◯	◯

Next

---

d. <u>Rebates versus Convenience</u> – Which was more important in your decision?

- ◯ Utility rebates were more important *(1)*
- ◯ Convenience of the overall process was more important *(2)*
- ◯ They were equally important *(3)*
- ◯ Neither was at all important *(4)*

Next [***Programming Note:*** *If 3 or 4,* ***skip to Question 14e****.*]

How much more important?

Equally Important				Strongly More				Extremely More
1	2	3	4	5	6	7	8	9
◯	◯	◯	◯	◯	◯	◯	◯	◯

Next

---

e. <u>Rebates versus Speed</u> – Which was more important in your decision?

- ◯ Utility rebates were more important *(1)*
- ◯ Speed of the overall process was more important *(2)*
- ◯ They were equally important *(3)*
- ◯ Neither was at all important *(4)*

Next [***Programming Note:*** *If 3 or 4,* ***skip to Question 14f****.*]

How much more important?

Equally Important				Strongly More				Extremely More
1	2	3	4	5	6	7	8	9
◯	◯	◯	◯	◯	◯	◯	◯	◯

Next

---

f. **Convenience versus Speed – Which was more important in your decision?**
- ◯ Convenience of the overall process was more important *(1)*
- ◯ Speed of the overall process was more important *(2)*
- ◯ They were equally important *(3)*
- ◯ Neither was at all important *(4)*

Next *[**Programming Note:** If 3 or 4, **skip to Question 15**.]*

How much more important?

Equally Important				Strongly More				Extremely More
1	2	3	4	5	6	7	8	9
◯	◯	◯	◯	◯	◯	◯	◯	◯

Next

---

16. Did the improvement(s) you made lead you to change how you use energy in your home? For instance, now that your home is more efficient, you may feel you can use energy a little more freely (such as turning the air conditioning a bit lower on a hot day). On the other hand, you may want to be even more conscious about how you use energy.
- ◯ I feel like I can use energy a little more freely. *(1)*
- ◯ I try to be even more energy conscious. *(2)*
- ◯ No change in how I use energy. *(3)*
- ◯ Not sure. *(4)*

17. Did your experience with making the improvement(s) influence any of your friends to make improvements?
- ◯ Yes, my improvement(s) influenced a friend to make improvements. *(1)*
- ◯ No, my improvement(s) did not influence any friends to make improvements. *(2)*
- ◯ Not sure. *(3)*

18. Do you have any suggestions for how the HERO Program could be improved?
- ◯ No suggestions. *(1)*
- ◯ Suggestions: ____ *(2)*

19. Do you have any suggestions for how the utility rebate program could be improved?
- ◯ No suggestions. *(1)*
- ◯ Suggestions: ____ *(2)*

Next

Almost done – the remaining questions are easy.

20. Approximately how old is your home?

- ◯ 1 – 6 years (built 2010 or later) *(1)*
- ◯ 7 – 16 years (built 2000 – 2009) *(2)*
- ◯ 17 – 37 years (built 1979 – 1999) *(3)*
- ◯ 38 – 56 years (built 1960 – 1978) *(4)*
- ◯ 57 – 76 years (1940 – 1959) *(5)*
- ◯ Over 76 years (built before 1940) *(6)*

21. Approximately how big is your home?

- ◯ Under 500 square feet *(1)*
- ◯ 500 – 999 square feet *(2)*
- ◯ 1,000 – 1,499 square feet *(3)*
- ◯ 1,500 – 1,999 square feet *(4)*
- ◯ 2,000 – 2,999 square feet *(5)*
- ◯ 3,000 – 3,999 square feet *(6)*
- ◯ 4,000 – 4,999 square feet *(7)*
- ◯ Over 4,999 square feet *(8)*

22. What is the approximate value of your home?

- ◯ Under $50,000 *(1)*
- ◯ $ 50,000 – $ 99,999 *(2)*
- ◯ $ 100,000 – $ 199,999 *(3)*
- ◯ $ 200,000 – $ 299,999 *(4)*
- ◯ $ 300,000 – $ 499,999 *(5)*
- ◯ $ 500,000 – $ 699,999 *(6)*
- ◯ $ 700,000 – $ 999,999 *(7)*
- ◯ $ 1,000,000 – $ 1,499,999 *(8)*
- ◯ $ 1,500,000 – $ 1,999,999 *(9)*
- ◯ $ 2,000,000 – $ 2,999,999 *(10)*
- ◯ Over $ 2,999,999 *(11)*

23. How long have you lived in your home?

- ◯ Under 2 years *(1)*
- ◯ 3 – 5 years *(2)*
- ◯ 6 – 9 years *(3)*
- ◯ 10 – 19 years *(4)*
- ◯ 20 – 29 years *(5)*
- ◯ Over 29 years *(6)*

24. How many people live in your home year-round?

- ◯ Only occupied part-time *(1)*
- ◯ 1 *(2)*
- ◯ 2 *(3)*
- ◯ 3 *(4)*
- ◯ 4 *(5)*
- ◯ 5 *(6)*
- ◯ 6 - 7 *(7)*
- ◯ 8 - 9 *(8)*
- ◯ 10 or more *(9)*

Next

---

25. Using a scale from 1 to 9, where 1 means "strongly disagree" and 9 means "strongly agree", to what extent do you agree or disagree with the following statements:

a. "It is important to conserve energy as much as possible."

Strongly Disagree				Neutral				Strongly Agree
1	2	3	4	5	6	7	8	9
◯	◯	◯	◯	◯	◯	◯	◯	◯

b. "I am committed to actions that help the environment."

Strongly Disagree				Neutral				Strongly Agree
1	2	3	4	5	6	7	8	9
◯	◯	◯	◯	◯	◯	◯	◯	◯

c. "I actively look for ways to reduce my carbon footprint."

Strongly Disagree				Neutral				Strongly Agree
1	2	3	4	5	6	7	8	9
◯	◯	◯	◯	◯	◯	◯	◯	◯

26. What is your age?

- ◯ Under 30 years *(1)*
- ◯ 30-39 years *(2)*
- ◯ 40-49 years *(3)*
- ◯ 50-59 years *(4)*
- ◯ 60-69 years *(5)*

◯ Over 69 years *(6)*

27. What is the highest educational level you completed?

◯ Elementary School *(1)*
◯ Some High School *(2)*
◯ High School Degree *(3)*
◯ Associate's Degree *(4)*
◯ Bachelor's Degree *(5)*
◯ Master's Degree *(6)*
◯ Doctorate *(7)*

28. What was your household's approximate income last year?

◯ Under $20,000 *(1)*
◯ $ 20,000 – $ 39,999 *(2)*
◯ $ 40,000 – $ 59,999 *(3)*
◯ $ 60,000 – $ 79,999 *(4)*
◯ $ 80,000 – $ 99,999 *(5)*
◯ $ 100,000 – $ 149,999 *(6)*
◯ $ 150,000 – $ 199,999 *(7)*
◯ $ 200,000 – $ 299,999 *(8)*
◯ Over $299,999 *(9)*

Next *[**Programming Note**: For Gen Pop sample frame, **Skip to Question 30**.]*

---

29. Please select which e-gift card you would like to receive. Your gift card will be delivered via email within two weeks.

◯ **$20 Amazon gift card – easy to redeem for online shopping.** *(1)*
◯ **$20 Target gift card – easy to redeem in stores or online.** *(2)*

Please enter your name and the email address where you would like to receive your card.

First Name: ____ *(1)*
Last Name: ____ *(2)*
Email Address: ____ *(3)*

Next *[**Programming Note:** For people screened out in the first five questions, **skip to Question 31**.]*

---

30. Thank you very much for your time and your willingness to help. Your input is appreciated in our ongoing efforts to make it easy for homeowners like you to save on energy.

Before you exit, here are two good links with information on reducing your home's energy costs. We hope you'll find them helpful. Click either of these links to open a new window.

- Visit Southern California Edison's Home Energy Guide.
- Visit the Southern California Gas Save Energy at Home website.

Exit the survey by simply closing this window.

---

*[**Programming Note:** This is the Thank You screen for people screened out in the first five questions.]*

---

31. The rest of this survey focuses on people who live in other zip codes or face different energy decisions.

Thank you very much for your time and your willingness to help. Your input is appreciated in our ongoing efforts to make it easy for homeowners like you to save on energy.

Before you exit, here are two good links with information on reducing your home's energy costs. We hope you'll find them helpful. Click either of these links to open a new window.

- Visit Southern California Edison's Home Energy Guide.
- Visit the Southern California Gas Save Energy at Home website.

Exit the survey by simply closing this window.

Appendix B. Population of Interest Zip Codes

The zip codes listed below identify the areas in Riverside and San Bernardino counties where HERO has been available since 2012, and Southern California Edison and Southern California Gas are the utility providers. Survey samples targeted single-family homeowners within these 107 zip codes.

91701
91708
91709
91710
91730
91737
91739
91752
91758
91759
91761
91762
91763
91764
91784
91786
92230
92242
92252
92256
92267
92268
92277
92278
92280
92284
92285
92304
92309
92310
92313
92316
92318
92320
92321
92322
92323
92325
92332
92335
92336
92337
92338
92339
92341
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Appendix C. Public Comments and Response on Draft Report

Commenter	Comment	Response
Jonathan Kevles, Renew Financial	The link in the Draft document to the "HERO Survey Instrument FINAL 2016" does not work. Please post or send to me directly a copy of this document. If available, I would also like to see as much detail of the responses as possible - such as the actual responses and the comments/suggestions that were provided. Thank you.	The final survey instrument was inserted into the PDF and the revised documents were uploaded to PDA on 9/9/2016. Due to confidentiality requirements, detailed survey responses are not available for distribution.
Ralph Prahl, CPUC	The report should put greater emphasis on the potential for measurement error in the DCM estimates as a result of survey respondent error when assessing whether their project was high-efficiency or not.	Cadmus has updated the executive summary and the main body of the HERO Allocation Methods Study text to highlight this issue.
Alex Hill, Dunsky Energy Consulting	First, you describe the HERO-supported projects as High-efficiency based on the program requirements. However, I do not see anywhere in the document where you list in detail the HERO measure technical requirements to support this. Would it be possible to provide measure by measure HERO requirement details, perhaps in an appendix, in a future draft. This would be very helpful to situate the projects being supported by HERO vis-à-vis utility incentives and other programs.	For a couple of reasons, we were not able to define the minimum requirements for measure in either the utility rebate programs or HERO. First, the study covered a three year period, over which time, the minimum requirements changed in both programs (the rebate "program" is actually several programs). Second, the utility rebate programs offer both prescriptive and savings-based incentive. Under the savings-based model, the actual specifications of a given measure can vary. Cadmus expanded discussion of this issue on page 14 of the Allocation report.

Alex Hill, Dunsky Energy Consulting	Second, did you include questions to the HERO customers pertaining to the level of energy efficiency of specific measure installed? For instance, if you have data on the number that reported installing Energy Star rated equipment would be helpful. Alternatively, did you consider performing site-visits to HERO customers to assess the degree to which installed features exceed current code requirements? If not, can you explain why you chose not to include that in the study – again this may help provide context to other financing evaluations in the State.	We described Energy Star in the survey, and used a picture of the Energy Star logo to help guide people to determine if their project was high-efficiency. However, the Energy Star logo was only one qualification we provided to define a high-efficiency project – other criteria included being eligible for rebate or HERO financing, or being generally more efficient than other available models/options. The criteria we identified needed to encompass measures ranging from insulation to pool pumps, and be meaningful to both HERO and rebate participants and non-participants – one of the challenges of this study. As noted above and through the Allocation report, the lack of precision in the definition of "high-efficiency" may have introduced measurement error in the findings. This was exploratory research, not an actual impact evaluation. As such, we did not budget for site visits. In addition we were trying throughout most of the project to encourage Renovate America's cooperation. They were hesitant to even allow surveys of their participants (and ultimately did not want to be a part of a survey of their customers) and would likely have strongly resisted site visits.
Alex Hill, Dunsky Energy Consulting	Finally, are you planning to release the raw survey results for each question (again, perhaps as an appendix)? Sometimes this can provide deeper insight for the reader, and may be helpful for the REEL impact evaluation effort in the future.	Due to confidentiality requirements, detailed survey responses are not available for distribution.
Nikhil Gandhi, CPUC	The following statement added while addressing comments appears biased and inequitable to the self-report method. External stakeholder may have difficulty in understanding results from any of the three methods used. Suggest strike from the final version to be posted. "External stakeholders, such as California state legislators not familiar with this approach, may	Cadmus has deleted this statement from the text.

	have difficulty accepting results based on self-reporting."	