Appliance Recycling Program Impact Evaluation

Volume 1: Report

Work Order 35

California Public Utility Commission, Energy Division

Prepared by KEMA, Inc.
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0. Executive Summary

This is the final report for the evaluation, measurement and verification (EM&V) study of the 2010-2012 Statewide Residential Appliance Recycling Program (ARP). The ARP was a statewide program administered by three California investor-owned utilities (IOUs): Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas and Electric (SDG&E). ARP has been implemented statewide since 2002. The first recycling program in California was implemented by SCE in 1994.

This evaluation effort was guided by the California Public Utilities Commission's Energy Division (CPUC), in coordination with CPUC internal experts, and the three California IOUs. The evaluation was funded through the public goods charge (PGC) for energy efficiency.

0.1 Program Overview

The ARP offers incentives to customers encouraging them to recycle older, less-efficient appliances, predominantly refrigerators and freezers, with the intent of reducing the load on the electrical grid. The overarching goal of ARP is to prevent the continued operation of older, inefficient appliances by offering customers a financial incentive and free pick-up service to encourage them to recycle the old unit. Through offering incentives, the program seeks to remove no longer needed secondary units, to prevent the continued use of older appliances in a secondary role within the participant home when a newer primary appliance is purchased, and to prevent the transfer of these older, less-efficient appliances to another location within the utilities' service territory when no longer needed in the participant home.

Description of Program and Implementers: The ARP program responds to customer requests to have a unit picked up. ARP offers free pick-up and a monetary incentive for all eligible appliances. In order to be eligible to participate in ARP, a refrigerator or freezer must be in working condition, between 10 and 32 cubic feet in volume, and operated by a utility customer. Customers are limited to recycling two units through the program per calendar year.

JACO Environmental (JACO) implemented ARP on behalf of PG&E, while The Appliance Recycling Centers of America, Inc. (ARCA) implemented the program within SDG&E's service territory. The two firms shared implementation responsibilities for SCE.

High Impact Measures: The portfolio evaluation for the 2010-2012 program cycle is designed around the concept of High Impact Measures (HIM). The philosophy behind the HIM approach is to prioritize evaluation efforts to focus on those measures or measure groups that constitute a larger share of the utilities portfolio, with respect to energy and demand savings. This allows the most cost-effective allocation of evaluation resources. At the start of the evaluation cycle, the Appliance Recycling program as a whole produced greater than 4% of the

claimed energy and demand savings at the statewide level (excluding Codes and Standards impacts), and as such was deemed a HIM group, precipitating this study and report.

0.2 Evaluation Objectives

The primary evaluation objective is estimation of ARP impacts. The key components for this process are:

- Verify the numbers of units the programs claim to have recycled,
- Estimate energy consumption for recycled units absent participation,
- Estimate the energy consumption of units (if any) that are in use in place of the recycled units,
- Determine the proportion of units in each disposition path,
- Combine the estimated usage with and without the program across disposition paths to determine gross and net savings, and
- Provide insights into differences found between ex-ante and ex-post savings.

0.3 Overview of Methods

This ARP impact assessment follows an approach that is similar to that used in prior evaluations of the program in that;

- No credit is given for units that would have been destroyed without the program.
- The consumption of units that would not have been destroyed is adjusted for the part-use, or fraction of the year the unit would have been plugged in and running.
- For units that would have been discarded by the participant without the program, but would not have been destroyed, credit is given for preventing the transfer of the unit to use in another home. This credit is based on the difference between the consumption the unit would have had in the receiving home, and the consumption of the alternative unit that home uses, if any, because the program unit was unavailable.
- The annual consumption of units is determined from analysis of in situ metering data collected during the present and prior studies. This data is used to adjust nameplate usage data to account for unit degradation and situational use that differs from test use.

In this study, we partition the savings due to program effects between gross and net somewhat differently from what has previously been done. While this difference affects the presentation of some components, the final net savings estimate is no different.

- Free-ridership accounts for the effect of units that would have been destroyed without the program.

- Gross savings are the difference between the consumption of the unit in use (on the grid) with the program and the consumption the picked-up unit would have had without the program, if not destroyed.
- Net savings equal gross savings minus free ridership, that is, net of units that would have been destroyed without the program.
- The net-to-gross ratio is one minus free ridership.

Although this approach is a departure from prior evaluations, this definition of gross and net savings is consistent with the legal decision outlined in Appendix A. of Decision D. 11-07-030;

> *Energy Division believes that gross saving must be established based upon the difference between the recycled unit energy use, if left on the grid rather than being recycled, and any unit that is placed into service in place of the recycled unit. Energy Division believes that in some situations no unit is placed into service in place of the recycled unit and thus the recycled unit UEC equals the savings, UES. The utilities believe the only probable case that should be considered is the case where UEC and UES are equal and that all other cases should not be considered. However, Energy Division believes that in many instances another unit is placed into service in place of the recycled unit thus causing a reduction in the savings from preventing the recycled unit from staying in service. The overall effect of the recommended Energy Division gross savings adjustment is approximately a 40% reduction in savings.)*

Gross savings is the difference in consumption (on the grid) with and without the program "measure." In this case, the program measure is removal of the participating unit from the grid.

Within this overall framework, this evaluation includes the following enhancements:

- Full-Year Unit Energy Consumption (UEC) of collected units is based on a set of regression models fit to metered consumption data, as in prior studies. Enhancements for this study are:
  - Short-term in situ metering is expanded to full-year usage using annual load shapes developed from a long-term metering study.
  - The model of UEC as a function of unit characteristics includes nameplate UEC, unit age, volume, nameplate amperage, and unit configuration as predictors.
- The disposition of units absent the program is determined from a more comprehensive study of the secondary market.
- The analysis of avoided transfers recognizes that a home that would otherwise have acquired the picked up unit will tend to acquire a better unit as an alternative, even if it still acquires a used unit. This refinement has the effect of increasing gross savings for avoided transfers compared to assuming that a similar unit would have been in place.

A key component of this evaluation recognizes that the effect of the program on the second-hand market is to potentially constrict the supply of units available to that channel. The constriction is partial, as the program units represent only a fraction of the units naturally removed from households in any given year. Furthermore, there are a number of possible responses that potential used-unit acquirers could have in the face of this constriction. The majority, for instance, are purchasing the used unit for use as a primary unit, so it is unlikely that a program-related constriction would lead them to go without a unit altogether. These considerations are essential to properly assessing the effect of the program in the secondary market. Furthermore, given the definition of gross and net savings used for this evaluation, these effects are included in the baseline scenario and, thus, gross savings.

0.3.1 Data Sources

The key data sources used for this evaluation include:

- Program tracking data were used to establish ex ante program savings claims and to extrapolate evaluation UEC estimates to the program population.
- Unit metering data included short-term in situ metering data, used to establish field unit energy consumption, and long-term in situ metering data, used to annualize short-term metering results.
- Program participant survey data were used to establish what customers were likely to do in the absence of the program.
- Acquirer/discarder survey data were used to establish how transferred units are typically transferred and who typically receives used units and how these units are utilized (primary or secondary). These provide the counterfactual for program activities.
- Secondary market actor interview data were used to assess the flow of used refrigerators and freezers through the retail channel and elicit supplier perspectives on the impact of the IOU Appliance Recycling programs on the second-hand market.
- Craigslist data were analyzed to understand the peer-to-peer channel for unit transfers.

0.4 Findings

Table 1 summarizes the tracking data and verification findings. In general, the evaluation team found that the Verification Rate was very close to 100%. In a few cases, the unit was misidentified (tracking data showed a participant recycled two refrigerators, however the participant reported that one refrigerator and one freezer was recycled). Adjustment of these units to the appropriate measure resulted in the verification rates exceeding 100% for some measures. The evaluation team did not verify room air conditioners, and therefore this measure was passed through at 100% verification.

Table 1: Claimed vs. Verified Quantities by Measure and IOU

IOU	Measure	Claimed Units	Verification Rate (%)	Verified Units
PGE	Refrigerator	55,742	98%	54,651
	Freezer	7,147	108%	7,724
	Room AC	815	n/a	815
SCE	Refrigerator	183,225	99%	180,504
	Freezer	15,551	101%	15,666
SDGE	Refrigerator	40,893	99%	40,405
	Freezer	4,420	100%	4,420
	Room AC	744	n/a	744

Table 2 provides the final estimates of IOU level gross and net unit savings. Gross savings are the difference between a baseline per unit UEC without the program and the UEC of the alternative unit on the grid with the program, assuming the program unit would not have been destroyed. Net savings are calculated by removing the savings for the units that would have been destroyed in the absence of the program. In Table 2, the average UECs for a refrigerator as a secondary unit and a freezer are included as reference points.[1] The net-to-gross ratio reflects the relationship between net and gross savings.

Gross and net unit savings for refrigerators are lower than IOU ex ante estimates. For all three IOUs, the mean manufacturing year of recycled units is less than the span since the implementation of the first Federal appliance standard (1993). For SGE&E, this was especially noticeable, where the mean age reported for recycled units was only 13.5 years, compared to 18.1 years for SCE and 21.5 years for PG&E. Although the claimed energy savings for all three IOUs were lower than in previous program cycles, the per unit energy savings for all three IOUs still failed to keep pace with the efficiency improvements in recycled stock due to this change in the proportion of post-standard units. For SDG&E particularly, the discrepancy between high claims and low *ex post* savings was quite high. At the statewide level, ex ante and ex post unit savings were similar for freezers.

Overall, at the program level the evaluation team found that approximately 32% of the refrigerators and 25% of the freezers would have been destroyed in the absence of the program, leading to net-to-gross ratios (NTGRs) of approximately 68% and 75%, respectively. In PG&E territory, a higher proportion of discarder survey respondents reported discarding refrigerators onto the second-hand retail market or destroying them directly. It is believed that some of this

[1] Prior evaluations have referred to this number, the average UEC of the collected unit, as gross savings.

difference is driven by the older age of the units being recycled by PG&E program participants. This resulted in a larger proportion of PG&E units ending up in the "Destroyed" disposition paths, thereby driving down NTGR for PG&E, somewhat compared to the other IOUs.

Table 2: Gross and Net Unit Annual Savings and Net-to-Gross Ratios

IOU	Ex Ante Gross Unit Savings (kWh)	Ex Post Gross Unit Savings (kWh)	Relative Precision at 90% Confidence Level	Net Unit Savings (kWh)	Net Precision at 90% Confidence Level	NTG Ratio
Refrigerators						
PG&E	738	510	26%	344	27%	67%
SCE	835	519	25%	352	26%	68%
SDG&E	957	360	27%	247	26%	69%
Freezers						
All IOUs	818	771	18%	577	22%	75%

Table 3 and Table 4 combine the verification results with the per unit gross and net savings estimates to produce program-level estimates of gross and net savings. These savings estimate are compared to the *ex ante* gross and net savings. The realization rate, comparing *ex post* gross savings to *ex ante* gross savings, is also provided.

Table 3: Refrigerator Gross and Net Annual Electric Impacts - GWh

IOU	Evaluation Result	*ex ante*	*ex post*	Realization rate	Precision at 90% confidence
PG&E	Gross Savings, GWh	41.1	27.9	0.68	±26%
	NTGR	0.61	0.67		
	Net Savings, GWh	25.1	18.8	0.75	±28%
SCE	Gross Savings, GWh	153.1	93.6	0.61	±25%
	NTGR	0.62	0.68		
	Net Savings, GWh	94.1	63.6	0.68	±26%
SDG&E	Gross Savings, GWh	39.1	14.5	0.37	±26%
	NTGR	0.61	0.69		
	Net Savings, GWh	24.0	10.0	0.41	±28%
Totals	Gross Savings, GWh	233.3	136.0	0.58	±25%
	NTGR	0.61	0.68		
	Net Savings, GWh	143.3	92.4	0.64	±27%

Table 4: Freezer Gross and Net Annual Electric Impacts - GWh

IOU	Evaluation Result	*ex ante*	*ex post*	Realization rate	Precision at 90% confidence
Totals	Gross Savings, GWh	22.2	21.4	0.97	±18%
	NTGR	0.7	0.75		
	Net Savings, GWh	15.5	16.0	1.21	±21%

For refrigerators, *ex post* savings were estimated at about 64% of *ex ante* claims. Most of the difference is attributable to lower evaluated gross savings estimates, with NTGRs from the evaluation being similar or somewhat higher than IOU estimates. The evaluation savings reduction for SDG&E is much larger than for PG&E and SCE, which is a combined result of SDG&E's higher unit savings claim and the fact that recycled units in the SDG&E area tend to be newer units.

For freezers, *ex post* net savings estimates are about 20% higher than *ex ante* estimates. This increase was mainly due to verification analysis, which found that in some cases recycled freezers were misclassified as refrigerators in the IOU tracking data. The correction caused an upward adjustment in freezer counts and a corresponding downward adjustment in refrigerator counts. *Ex ante* and *ex post* NTGRs were similar.

Table 5 and Table 6 combine the verification results with the per unit gross and net peak demand savings estimates to produce program-level estimates of gross and net demand savings. These savings estimate are compared to the *ex ante* gross and net demand savings. The realization rate, comparing *ex post* gross peak demand savings to *ex ante* gross peak demand savings, is also provided.

Table 5: Refrigerator Gross and Net Peak Demand Impacts - MW

IOU	Evaluation Result	*ex ante*	*ex post*	Realization Rate	Precision at 90% confidence
PG&E	Gross Savings, MW	9.1	6.2	0.68	±26%
	NTGR	0.61	0.67		
	Net Savings, MW	5.6	4.2	0.75	±28%
SCE	Gross Savings, MW	29.6	18.1	0.61	±25%
	NTGR	0.62	0.68		
	Net Savings, MW	18.2	12.3	0.68	±26%
SDG&E	Gross Savings, MW	6.1	2.3	0.37	±26%
	NTGR	0.61	0.69		
	Net Savings, MW	3.7	1.6	0.41	±28%
Statewide	Gross Savings, MW	44.9	26.6	0.59	±25%
	NTGR	0.61	0.68		
	Net Savings, MW	27.5	18.0	0.66	±27%

Table 6: Freezer Gross and Net Peak Demand Impacts - MW

IOU	Evaluation Result	*ex ante*	*ex post*	Realization Rate	Precision at 90% confidence
Statewide	Gross Savings, MW	4.4	4.3	0.98	±18%
	NTGR	0.70	0.75		
	Net Savings, MW	3.1	3.2	1.05	±21%

Table 7 and Table 8 repeat this comparison of *ex ante* to *ex post* values for the interactive effects for refrigerators and freezers.

Table 7: Refrigerator Gross and Net Interactive Effects - therm

IOU	Evaluation Result	*ex ante*	*ex post*	Realization Rate	Precision at 90% confidence
PG&E	Gross Effects, therms	-414,597	-280,953	0.68	±26%
	NTGR	0.61	0.67		
	Net Effects, therms	-252,904	-189,513	0.75	±28%
SCE	Gross Effects, therms	-3,214,568	-1,966,212	0.61	±25%
	NTGR	0.62	0.68		
	Net Effects, therms	-1,976,959	-1,335,870	0.68	±26%
SDG&E	Gross Effects, therms	-386,649	-143,609	0.37	±26%
	NTGR	0.61	0.69		
	Net Effects, therms	-237,402	-98,432	0.41	±28%
Statewide	Gross Effects, therms	-4,015,814	-2,390,773	0.60	±25%
	NTGR	0.61	0.68		
	Net Effects, therms	-2,467,266	-1,623,815	0.66	±27%

Table 8: Freezer Gross and Net Interactive Effects - therm

IOU	Evaluation Result	*ex ante*	*ex post*	Realization Rate	Precision at 90% confidence
Statewide	Gross Effects, therms	-346,086	-300,264	0.87	±18%
	NTGR	0.70	0.75		
	Net Effects, therms	-242,260	-224,618	0.93	±21%

1. Introduction

This is the final report for the evaluation, measurement and verification (EM&V) study of the 2010-2012 Statewide Residential Appliance Recycling Program (ARP). The ARP was a statewide program administered by three California investor-owned utilities (IOUs): Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas and Electric (SDG&E). ARP has been implemented statewide since 2002. The first recycling program in California was implemented by SCE in 1994.

The major goal of this study was to evaluate the gross and net impacts of residential appliance recycling measures implemented through the statewide core IOU programs during the 2010-2012 program years—as guided by the California Public Utilities Commission's Energy Division (CPUC)—in coordination with CPUC internal experts and the three California IOUs. The evaluation was funded through the public goods charge (PGC) for energy efficiency. The study assessed the gross and net impacts of residential appliance recycling measures implemented through the statewide core IOU programs during the 2010-2012 program years.

1.1 Program Overview

1.1.1 Program Design/Delivery

The ARP offers incentives to customers encouraging them to recycle older, less-efficient appliances, predominantly refrigerators and freezers, with the intent of reducing the load on the electrical grid. The overarching goal of the ARP is to prevent the continued operation of older, inefficient appliances by offering customers a financial incentive and free pick-up service to encourage them to recycle the old unit. The program seeks to remove secondary units that are no longer needed, prevent the continued use of replaced primary appliances as secondary units within participant homes when newer primary appliances are purchased, and prevent the transfer of less-efficient appliances that are no longer needed in the participant home to another user within the utilities' service territory.

JACO Environmental (JACO) implemented the ARP on behalf of PG&E, while The Appliance Recycling Centers of America, Inc. (ARCA) implemented the program within SDG&E's service territory. The two firms shared implementation responsibilities for SCE.

In order to be eligible for the ARP, a refrigerator or freezer must be in working condition, between 10 and 32 cubic feet in volume, and operated by an IOU customer. Participants are limited to recycling two units through the program in a given calendar year. To encourage participation, the ARP offers a monetary incentive for all eligible appliances that is typically between $35 and $50.

1.1.1.1 Program Accomplishments

Table 9 shows the number of recycled appliances and claimed energy and demand savings for the 2010-2012 program cycle. These data were drawn from the final tracking data of the fourth quarter (Q4) of 2012 that were provided to the evaluation team.

Table 9: 2010-2012 Energy and Demand Claims by IOU

IOU	Measure	Units	Energy Savings Claims (kWh)	Peak Demand Claims (kW)	Interactive Effects (therms)
PG&E	Refrigerator	55,742	41,137,792	9,141	-414,597
	Freezer	7,147	4,037,308	942	-22,972
	Room AC	815	35,352	36	0
SCE	Refrigerator	183,225	153,059,770	29,641	-3,214,568
	Freezer	15,551	14,975,072	2,958	-301,119
SDG&E	Refrigerator	40,893	39,149,035	6,090	-386,649
	Freezer	4,420	3,181,047	495	-21,995
	Room AC**	744	-	-	140,058
Total	Refrigerator	279,860	233,346,597	44,872	-4,015,814
	Freezer	27,118	22,193,427	4,395	-346,086
	Room AC	1,559	35,352	36	140,058

** Air conditioning measures typically yield electric savings rather than natural gas savings.

1.1.1.2 High Impact Measure Evaluation Approach

The evaluation of the portfolio for the 2010-2012 program cycle was designed using the High Impact Measures (HIM) approach of prioritizing evaluation efforts to focus on those measures or measure groups that constitute a larger share of the claimed energy and demand savings within the IOU portfolios. The HIM approach was intended to yield a more cost-effective allocation of evaluation resources. Since the ARP as a whole produced greater than 4% of the statewide, claimed energy and demand savings as of the start of the evaluation cycle (excluding Codes and Standards impacts), the program was deemed an HIM that was selected for evaluation.

Since recycled refrigerators dominated the ARP, that component of the program was deemed to be an HIM that would be evaluated at a 90% confidence level with 10% precision. Other appliances recycled by the program (dehumidifiers, air conditioners and freezers) provided a smaller portion of program claims and did not warrant the same rigor. In many respects,

however, refrigerators and freezers are very similar in use and evaluation techniques and, in the course of evaluating refrigerators, the evaluation team also gathered data about recycled freezers to facilitate their evaluation, although with reduced rigor. Dehumidifiers and air conditioners were not evaluated and program impacts for these measures were left unchanged from the *ex ante* claims.

1.2 Evaluation Objectives

Since appliance recycling is an "inverse" measure, the appliance recycling framework defines gross and net savings differently than most energy efficiency programs. Typical energy efficiency program savings accrue from replacing less efficient equipment with more efficient equipment whereby program savings are comprised of the difference between the energy consumption pre- and post- replacement. For appliance recycling programs, however, energy savings accrue from the complete removal of a piece of less-efficient equipment from the grid. A portion of the program savings come from the removal of secondary units from participant homes. These savings are relatively easy to quantify—simply determine the difference in household consumption with and without the recycled unit in use as a secondary unit. The remaining savings accrue from avoided transfers to the secondary refrigerator market—these are more difficult to quantify and require special treatment to evaluate program impacts.

The objectives that feed into the determination of program impacts are:

- Verifying the numbers of units the programs claim to have recycled,
- Estimating energy that recycled units would have consumed had they not been recycled.
- Estimating the energy consumption of units (if any) that are in use in place of the recycled units,
- Determining the proportion of units in each disposition path,
- Combining the estimated usage with and without the program across all disposition paths to determine gross and net savings,
- Providing insights into differences found between *ex ante* and *ex post* savings.

1.3 Report Organization

The remainder of this report is organized as follows:

- Section 2 provides an overview of the methods used in the study.
- Section 3 provides more details on the study methods.
- Section 4 presents detailed impact findings.
- Section 5 presents additional findings from the secondary market study.

- Section 6 presents the overall program impacts and recommendations.

Ten appendices provide supplementary detail, including copies of survey instruments, interview guides, and other supporting material developed in the course of this evaluation.

- Appendix A: Metering Equipment and Protocols
- Appendix B: Climate Zones from CLASS Study
- Appendix C: Participant Survey
- Appendix D: Non-participant Acquirer/Discarder Survey
- Appendix E: Retail Channel of Secondary Market
- Appendix F: Telephone Survey & Interview Response Rates
- Appendix G: Peer-to-Peer Channel of Secondary Market
- Appendix H: Obtaining Nameplate UEC
- Appendix I: Annualization of Short-term Metering Data
- Appendix J: Error Propagation for Gross and Net Savings
- Appendix K: Relationship of Survey Questions to Counterfactual Actions
- Appendix L: Comparison of Response Groups
- Appendix M: Public Comments on Draft Report

2. Overview of Methods

2.1 Conceptual Overview

There are two ways an ARP produces savings:

- In participant households, the removal of program units may cause the participant to forego the energy consumption associated with a non-primary unit where they otherwise would have kept and used the unit in the absence of the program. This avoided consumption includes the removal of a unit that has operated as a secondary unit in the past. It also includes the removal of a recently replaced unit that might have become a secondary unit had the program not intervened.
- The removal of program units may also affect levels of unit energy consumption in non-participant households. The avoided transfer of the used units to the secondary market has an effect on the consumption levels of used-unit acquirers. The possible outcomes include would-be acquirers foregoing a unit altogether, substituting a new unit, or substituting a different used unit all of which are likely to result in reduced energy use compared to the usage of the program unit.

In previous evaluations, the definition of gross and net savings in the context of the ARP has not been consistent. Gross savings was variably defined as equivalent to the UEC with or without a part-use factor, which takes into account units that are in service only part of the year. The net adjustment included both free-riders (a unit that would have been destroyed in the absence of the program) as well second-hand market effects. For this analysis, we offer a reorganization that puts the ARP savings terms in line with the definitions used by other programs. This reorganization does not affect the final analysis, only the way the components are considered and presented.

In this evaluation, the definition of gross and net savings was formulated so as to be consistent with the legal decision outlined in Appendix A. of Decision D. 11-07-030;

> *Energy Division believes that gross saving must be established based upon the difference between the recycled unit energy use, if left on the grid rather than being recycled, and any unit that is placed into service in place of the recycled unit. Energy Division believes that in some situations no unit is placed into service in place of the recycled unit and thus the recycled unit UEC equals the savings, UES. The utilities believe the only probable case that should be considered is the case where UEC and UES are equal and that all other cases should not be considered. However, Energy Division believes that in many instances another unit is placed into service in place of the recycled unit thus causing a reduction in the savings from preventing the recycled unit from staying in service. The overall effect of the recommended Energy Division gross savings adjustment is approximately a 40% reduction in savings.)*

Gross savings is defined for this evaluation as the difference in consumption with and without the program. Because the program goal is removal of units from the grid, gross savings is defined in terms of change in consumption on the grid. For both participant households and potential transferee households we estimate two UECs: the baseline condition, which reflects consumption that would have occurred had the program not existed, and the program condition, which reflects the removal of the unit from the premise where that consumption would have occurred in the absence of the program. That is, we consider the effect of removing from the participant household units that would have been otherwise kept, and the effect of removing from the stream of units entering the second-hand market units that would have been otherwise transferred.

Table 10 provides a simplified version of the gross savings calculation. For participants who would have kept and used the unit in the absence of the program, gross savings equals the UEC of an average program unit if kept as a secondary unit (adjusted by the typical part-use of a secondary unit). Both with and without the program, the unit consumption would be zero for units kept unused. All remaining units would have been discarded by participants, and thus would be potential transfers to the second-hand market.

Table 10: Simplified Gross Savings Calculation

Unit Disposition	Location	Consumption Without Program (A)	Consumption With Program (B)	Gross Savings (A-B)
Kept in Use	Participant Household	UEC as secondary unit	No consumption	UEC as secondary unit
Kept Unused	Participant Household	No consumption	No Consumption	No Savings
Transferred from Participant Household	Transferee Household	UEC as primary or secondary unit	UEC as primary or secondary unit given removal of program units	$UEC_A - UEC_B$

Without the program, second-hand acquirers would use these units as either primary or secondary units. With the program the average consumption per potential acquiring household is reduced because not all these households will acquire used units absent the availability of the program unit, and those that do may acquire units with a lower UEC (while it's possible that some people might acquire units with higher UECs, our research into the secondary market for refrigerators/freezers showed that units likely to be transferred had a lower mean UEC than all program units). With the program, the combined effect of households that forego a unit, acquire a different used unit or substitute a new unit in place of the recycled program unit will

lower the average UEC of the acquired units in the transferee households. The difference between the consumption with and without the program represents the second-hand market gross savings estimate.

Table 11 incorporates the impacts of free-ridership in the context of the gross savings calculation. The gross savings calculation assumes that, without the program, all units would remain on the grid. The net savings calculation recognizes that a share of units would have been free-riders — destroyed even in the absence of the program. In the net savings calculation, these units have zero consumption with or without the program and thus contribute no savings.

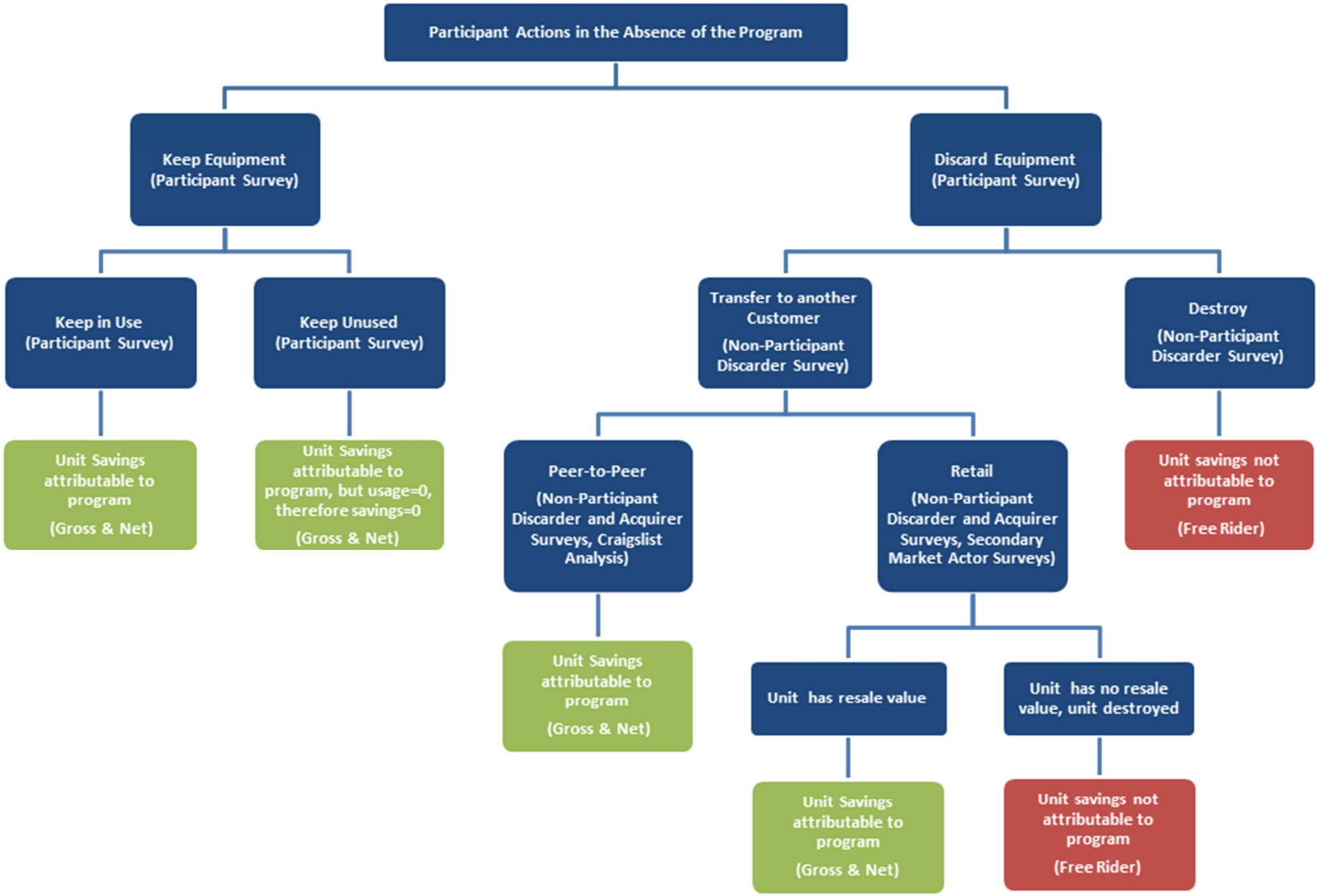
Table 11: Simplified Net Savings Calculation

Unit Disposition	Location	Gross Savings (A)	Free-rider Status (B)	Net Savings (A*B)
Kept in Use	Participant Household	UEC as secondary unit	Not Free-rider NTGR = 1	UEC as secondary unit
Kept Unused	Participant Household	No Savings	Not Free-rider NTGR = 1	No Savings
Transferred - destroyed	Destroyed	Average Savings of all Transferred	Yes NTGR =0	0
Transferred – viable unit	Transferee Household	Δ UEC as primary or secondary unit	Not Free-rider NTGR =1	Δ UEC as primary or secondary unit

The complete calculation makes additional distinctions that are necessary to fully understand the second-hand market effects. For instance, used-unit acquirers who will use the unit as a primary unit respond differently from those who are adding or replacing a secondary unit to a contraction in the market of available used units on the market. In addition, there are at least two primary paths by which used units move to the secondary market: 1) peer-to-peer markets such as through Craigslist or directly to a relative or friend, and 2) a commercial used appliance dealer or similar market actor.

Figure 1 shows an example of the logical process through which we determine the disposition for program units. The evaluation uses survey data to establish the share of units that populate each of these paths. The evaluation used tracking data, metering data and secondary sources to estimate the different consumption levels that accompany each path with and without the program. Gross and net savings estimates are simply these differences weighted by the shares of each path.

Figure 1: ARP Evaluation Schematic



2.1.1 Implications of Modified Definitions of Gross and Net Savings

This evaluation's definition of gross and net ARP savings aligns with the legal ruling cited above. Practically, it has the effect of moving second-hand market effects into the gross savings estimate. Net savings are then the gross savings estimate net of the effects of free-ridership.

It produces a gross savings estimate that captures the realistic potential effect of the program as it is presently structured. The previous definitions of gross savings were equal to the consumption of a secondary unit UEC scaled by a part-use factor. This level of savings is reasonable if a unit is removed from or avoided in the participant household where it would have otherwise have operated as a secondary unit. However, this scenario occurs only in a handful of cases:

- A participant household has a plugged-in secondary unit that is no longer needed (not because another unit has been purchased).
- A participant household replaces its primary unit and plans to keep the secondary unit but the program convinces them they do not need the additional unit.
- A non-participant household is considering picking up a free or inexpensive additional unit (an overflow or beer fridge) but cannot locate one because the program has limited supply.

In each of these cases, the consumption without the program would be that of a secondary unit while with the program there would be no consumption in place of this unit. This result produces savings of the full UEC of a secondary unit, adjusted by the percentage of the year that secondary units are installed and operational (part-use factor). In fact, as shown in Section 4.3.2, these kinds of scenarios represent only a small percentage of the disposition of program units absent the program. At the participant household, the vast majority of units would have been disposed of, or potentially transferred to the second-hand market, without the program. On the second-hand market, the majority of used unit acquisitions are for use as primary units, making it unlikely that the acquirer could or would "do without."

To some degree, the ARP limits supply to the second-hand market. As a result, some households may go without a unit altogether but most will find a facsimile substitute. If they go without, get a new unit instead, or find another used unit that has lower consumption, the program will have produced savings equal to the difference in consumption between the program unit and the unit that was actually acquired.

This definition of gross savings is the consumption reduction on the grid due to the ARP given this second-hand market dynamic, assuming every unit that would have been discarded without

the program would have ended up elsewhere on the grid. Net savings is gross savings net of free-rider units that would have been destroyed even in the absence of the program.

2.2 Data Sources

Table 12 list primary data sources and the analysis component they address. These data sources are discussed further below.

Table 12: Data Sources Used for Analysis Component

Data Source	Unit Disposition from Participant Household	Disposition to Secondary Market	Used-unit Acquirer Response	Program UECs	Program Alternative UECs
Program Tracking Data	•				
Participant Survey	•				
Non-participant Surveys					
Discarder	•	•			
Acquirer			•		
Secondary Market Study					
Retail Channel Interviews		•			
Peer-to-peer Channel Data		•			
Unit Metering					
***Short-term in situ* metered sample of program units**				•	•
***Long-term in situ* metered sample**				•	•
Laboratory metering of program units				•	
UEC Datasets				•	
New Unit UECs					•

Program tracking data. Program tracking data was provided by each of the three IOUs via the CPUC Energy Division. These separate data sets were analyzed, cleaned, re-categorized, reformatted, and merged into one program tracking database. A subsequent data request was made directly to the three IOUs to acquire unit characteristic data recorded by the program implementers at the time of pick up. Program tracking data was used to establish *ex ante* program savings claims and to extrapolate evaluation UEC estimates to the program population.

UEC Datasets. UEC datasets were used to associate nameplate UECs with program units in the utility tracking data and with non-program units included in the long-term metering sample. The nameplate data were assigned to units based on make and model number. An analysis was conducted to impute nameplate UECs when data were missing.

Unit Metering. Metering energy consumption of refrigerators and freezers was used to establish UECs for the program units. There were three types of metering performed as part of the evaluation: *in situ* metering of actual program units, laboratory metering of removed program units, and *in situ* metering of non-program units (for a longer metering period as these units were not slated for immediate removal from the home).

> **Short-term, in situ metering of program units**. Metering of program units in a sample was used to establish differences between actual UECs and nameplate UECs, which results due to unit degradation and situational usage compared to test condition usage. The evaluation team coordinated with implementation contractors (JACO/ARCA) to meter a sample of program units for approximately two weeks prior to being picked up and recycled.
>
> **Laboratory metering of program units**. Program units included in the short-term metering cohort were removed to the laboratory for testing, prior to being recycled through the program. The laboratory process meters the energy consumption of program units using the DOE testing protocol for refrigerators and freezers. Past evaluations of appliance recycling programs have included this metering as a component of the program evaluation plan. The emphasis in the past several evaluations has been to move towards *in situ* metering of program units to estimate energy savings, for this evaluation, the laboratory metering is a parallel metering process for research ends, but was not included in the UEC calculation step as a direct input.
>
> **Long-term, in situ metering of non-program units.**. Long-term metering was used in an analysis to annualize the results of the short-term metering. The evaluation team collaborated with the residential on-site study (California Lighting and Appliance Saturation Survey or CLASS study - WO21) to meter a sample of refrigerators and freezers in homes included in that study. The metering period captured a full year of data. The units in this sample were selected to ensure that equipment with a

characteristic profile (age, configuration, size, etc.) typical of appliance recycling program units are adequately represented in the long-term metering sample.

Participant Survey. For appliance recycling measures, a sample was drawn for conducting customer telephone surveys. These surveys were used to establish what the participant customer would have done in the absence of the program, whether they would have kept or discarded the program unit and how they would have utilized a kept unit.

Non-participant Acquirer/Discarder Survey. A sample of households who have recently acquired and/or discarded a used refrigerator or freezer were surveyed to explore the characteristics of the secondary market for used refrigerators and to examine acquisition and disposal patterns for refrigerators/freezers outside of the program. Acquirer surveys were used to establish how transferred units are typically used (primary/secondary, full-year/part-year). Discarder surveys were used to establish who typically receives used units and in what proportion.

Interviews of Market Actors in Used Refrigerator/Freezer Market. Market data were purchased from the salesgenie.com website of InfoUSA® to identify businesses that handled used refrigerators. Telephone interviews were conducted with a variety of supply-side actors in the used refrigerator/freezer market to provide additional information on net-to-gross (NTG) issues and market effects. The interview elicited supplier perspectives on the impact of the IOU Appliance Recycling programs on the second-hand market for refrigerators and freezers, and gathered information to assess the stock of refrigerators and freezers made available for sale.

Craigslist Posts. To learn about the peer-to-peer channel for unit transfers, we explored several websites and determined that, by far, the greatest number of relevant advertisements were posted at *craigslist.org*. These postings were captured by subscribing to the automated RSS feeds of Craigslist for all regions in California, all relevant posting categories (e.g., "free stuff"), and all postings that contained the words refrigerator or freezer (including "fridge" and several variations of common misspellings).

2.3 Analysis Steps

2.3.1 Verification

Verification is the confirmation that the data in the tracking data reflects the actual program activity that occurred. Verification was performed using the participant interviews. Respondents were asked to confirm that they participated in the program and that the recorded unit was removed by the program. While confirming that the removal took place, the interviews also attempted to confirm that the unit characteristics were also captured accurately and reliably.

2.3.2 Gross Savings Estimation

Gross savings is defined as the difference in consumption with and without the program. For both participant households and potential transferee households we estimate two UECs. The baseline condition reflects consumption that would have occurred had the program not existed, units that would have stayed at the participant household

The program condition reflects the removal of the unit either from the participant household or from the stream of units entering the second-hand market.

This has the effect of moving second-hand market effects into the gross savings estimate. Net savings are then the gross savings estimate net of the effects of free-ridership. In this case, free-ridership is defined by units that would have been destroyed in the absence of the program.

2.3.2.1 UEC Calculation

An initial step in quantifying program savings is establishing a UEC for each program unit. The evaluation team calculated the full-year UEC for the program units using a multi-step process:

- First the team determined nameplate UEC for each program unit, either through model number matching or imputation using unit characteristics in the program tracking data;
- Second, the team developed a regression model to extrapolate the short-term metered data gathered from a sample of program units to full-year consumption, utilizing long-term metering results;
- Finally, the team developed a second regression model to generate a mean UEC for recycled units by IOU. This model essentially utilizes the results of the metering data to adjust the nameplate UEC for the program units to account for degradation over time and situational use that differs from nameplate UEC test conditions.

The full-year UEC must be adjusted to account for the fact that not all units operate year round. The "part-use" factor is the percentage of the calendar year that an appliance is plugged in and operational. For primary units, part-use is always 100%, however for secondary units, some proportion of units are not operational for the entire year. A utility specific part-use factor was calculated from the usage reported by program participants in the Participant survey. This was calculated from the mean usage for secondary units.

To arrive at the gross baseline consumption the full year UEC is multiplied by the part-use factor for the relevant disposition path.

2.3.2.2 Disposition Paths – Counterfactual to the Program

As previously stated, to calculate the savings for transferred units, a program alternative UEC was determined for units transferred on the secondary market.

Units removed from the Grid by the Program

As a first step towards determining program alternative UECs, different potential outcomes were identified for program units in the absence of the program:

- Units that would have been kept and used by program participants
- Units that would have been kept but not used by program participants
- Units that would not have been kept by participants

The units that would not have been kept by the participants are further divided into three groups:

- Units that would have been disposed of by program participants in such a manner that it would have resulted in the destruction of the unit (taken to the dump, disposed of through a municipal waste system, etc.)
- Units that would have been transferred on the private, peer-to-peer market
- Units that would have been transferred into the retail second-hand market

For units that would have transferred into the retail second-hand market there are two potential outcomes:

- Units that would have transferred to another location and been placed into service on the grid, and
- Units with no resale value that would have been destroyed by market actors in the second-hand market.

Alternative Units on the Grid Due to Program Removals

To get a complete picture of the savings generated by the ARP it is necessary to capture the program impact on the second-hand market. More specifically, the evaluation team studied the following question: In removing used units from circulation, what effect did the program have on those who would have purchased those second-hand units? Possible program alternative actions include:

- No unit is acquired.
- A new refrigerator is purchased.
- An alternative used unit is acquired.

The program generates higher savings from transferred units if either no unit or a new unit is purchased. In both cases, the resulting consumption will be lower than if that customer had purchased a standard second-hand unit. If no unit is acquired, then the full potential savings of the recycled unit is realized. If a new unit is purchased, the savings is the difference between the recycled unit and the standard consumption of a new unit.

A second-hand unit acquirer who still buys a second-hand unit despite program impacts on the second-hand market generates savings equal to any difference in average consumption between program units and the typical used unit available on the second-hand market.

2.3.3 Net Savings Estimation

To calculate net savings, free-riders are removed from the gross savings. For the appliance recycling program, free-riders are defined as the units in the "Destroyed" scenario. Net savings for the program is the gross savings from units that would have remained on the grid in the absence of the program.

2.3.4 Peak Demand Savings

Peak demand savings (kW savings) were estimated for the ARP by applying the IOU-specific peak-to-energy relationships from program tracking data, which were reviewed to ensure these data correctly utilized DEER values, to ex post energy savings estimates.

2.3.5 Interactive Effects

Interactive effects result when the ARP causes declines in refrigerator and freezer energy consumption, and associated heat output, in conditioned space. The heat reduction leads to increased heating requirements in the home during cooler seasons and decreased cooling requirements in the home during warmer seasons. Interactive effects for the ARP were calculated by applying DEER interactive effects derived from program tracking data to the direct savings estimates determined in this evaluation.

2.4 Study Limitations

All estimations of program impacts include some degree of uncertainty in the reported numbers. Key sources of uncertainty can be broken down into the following broad categories:

Measurement: No measurement is 100 percent accurate, and all measurements contain some error between the true and observed value. This uncertainty affects the following measurements:

- The Unit Energy Consumption level (UEC) was recorded using metering equipment on a sample of program units. The specifications for the instrumentation may indicate that it is accurate to within ±5%, meaning that any reading taken by the instrument may be up

to 5% different from the true value, in either direction. Additional error may be introduced from an instrument that has not been properly calibrated or has been used in conditions outside of the range of those specified by the manufacturer. Data management can also introduce errors through omitted, adjusted, or lost data. This risk was managed by prescribing the required accuracy of the instrumentation, the appropriate calibration methods and operating conditions, and the project data management strategies, including periodic checks. Measurement error is primarily a concern if it contributes to biased measurements rather than adding additional variation. There is no reason to believe the UEC estimates are biased.

- The results of the participant and non-participant CATI surveys. While this risk was managed by posing questions in a clear and non-leading manner, some bias regarding expected responses due to social norms may exist.

Sampling: Sampling uncertainty occurs when data are gathered from a sample of the population and the results are extrapolated to the entire population. This uncertainty was a factor for the following data collection efforts:

- The participant CATI survey was administered on a sample of the program population.
- The non-participant CATI survey was administered on a sample of the IOU population that excluded program participants of the last three years.
- The market actor interviews were administered on a sample of the secondary market actor populations within IOU territories.
- The units that were part of the short-term and long-term metering studies.

The uncertainties associated with the first two data collection efforts were managed by setting sample size targets that yielded a confidence level of at least 90% and a relative precision of no more than 10%. The uncertainty for the market actor interviews was managed by setting sample size targets that met a confidence level of at least 80% and a relative precision of no more than 20% for those market actors thought to have more significant roles in the secondary market. To manage the inherent conflict between the task budget and the uncertainty of the results, these requirements were relaxed significantly for those market actors thought to have relatively insignificant roles in the secondary market. For all four data collection efforts, some bias was possible due to the fact that the surveys and interviews were executed in English, only.

To manage non-response bias, the survey research firm made up to five attempts to contact each customer in the participant and non-participant samples, including calling at different times of day and different days of the week; in the market actor category samples, DNV GL also made up to five attempts to contact each sample point to manage non-response bias for the secondary market interviews.

While the uncertainty around recruitment of appliances for metering was not specifically controlled, the process used was similar to the recruitment for prior evaluations. Hence, response bias in metering recruitment is expected to be consistent with prior evaluations.

Estimation: Estimates must be made when values necessary to complete a calculation are not available from direct measurement. This uncertainty was a factor for the following data development effort:

- Some of the values for tracking-system related UECs were imputed because we were not able to match model numbers from the tracking system to the standard datasets containing UEC estimates. Therefore, the mean UECs values for the full program population include a combination of UECs that are derived from effective matching of model numbers and UECs that were imputed using other unit information such as appliance configuration and age. However, the rate of imputation is small compared to the full population, so the additional uncertainty introduced by having some imputed values is also small. This uncertainty is currently captured in the standard errors presented in Table 34.

Modeling: Modeling uncertainty is introduced when savings are estimated using engineering or simulation models. The accuracy of any model is based on the ability of the model to account for all variations in energy use by employing appropriate analysis techniques, including all relevant variables, and excluding those variables deemed irrelevant. This uncertainty category was a factor for the following modeling efforts:

- Regression analysis to annualize short-term metering results
- Regression analysis to adjust nameplate and imputed nameplate UECs to reflect in situ metered UECs

The uncertainties associated with these modeling techniques was managed using regression diagnostics using review and selection of preferred models based on variable statistics (t-stats) and overall model fit (R^2).

3. Detailed Methods

This section builds upon the methods overview discussion in Section 2 and provides more detail on key data collection and analysis steps.

3.1 Data Collection

As introduced above in the methodology overview section, data were collected from a number of sources to support the ARP evaluation. In this subsection, we provide additional detail on some of the key data elements.

3.1.1 Metering

Metering was utilized to establish UECs for the gross and net savings analysis. Metering equipment and sample design are discussed next.

3.1.1.1 Metering Equipment and Protocols

Each of the units metered in this evaluation study, whether for the long or short-term sample used the same metering equipment set-up. To capture energy consumption, the evaluation team decided to design and construct a plug load energy monitoring device using components already familiar to our implementation and analysis approach. The custom device utilizes the following components:

- WattNode® Pulse kWh Transformer, WNB-3Y-208-P
- Onset® Micro Station Data Logger, H21
- Magnelab Current Transformer, CTM-0360-015
- Onset® Temperature Probe
- Onset® Pulse Input Adaptor

All of the above components have been used in numerous projects in the past and have proved to be reliable, consistent, and accurate. The assembled device can safely monitor plug-load energy consumption for up to the life of the batteries that are installed in the data logger—anywhere between 12-15 months. The Onset® data logger has the capacity to record true power at 5-minute intervals for a year, and also has 4 channels for additional sensors such as temperature and humidity. Each data logger was installed in-line with the appliance power cord (e.g. the data logger plugged into the wall, the refrigerator/freezer plugged into the data logger) and recorded energy consumption data at five-minute intervals.

A temperature probe was connected to the data logger and recorded ambient temperature in the space occupied by the unit at the same frequency. At the time the metering equipment was installed and removed, temperature probes were used to record the cabinet temperature of the fresh and frozen compartments. In addition, the temperature control settings for both the fresh and frozen compartments were recorded at both the installation and retrieval visits. The data logger was installed in such a way as to be unobtrusive and out of the way of participants and the temperature probe was installed on the exterior side of the appliance, away from any direct sources of light or heat. Copies of metering protocols and forms are available in Appendix A. Metering Equipment and Protocols.

3.1.1.2 Short-term In Situ Metering

Short-term in situ metering of a sample of program units provides the basis for the adjustment of nameplate consumption to *in situ* usage. A sample of units was recruited from the stream of recycled units entering the program. The short-term metering sample was designed to represent the distribution of refrigerators participating in the 2010-2012 ARP, as well as complement the sample metered as part of previous evaluations.

The sample design for short-term participant utilized stratification by climate zone (details about the climate zone mapping can be found in Appendix B. Climate Zones from CLASS Study), by the location of the refrigerator or freezer in conditioned versus unconditioned space, and by the unit configuration. The sample is allocated based on the proportional number of units recycled by the three IOUs (adjusted slightly to make the number of units metered in the various bins equivalent) as shown in. Table 13 shows the targeted metering sample and metering completes.

Table 13: Short-term In Situ Metering Sample

Climate Group	Space Location	Description	Targets	Completes
Inland	Conditioned	Bottom Freezer Refrigerator	0	1
		Side by Side Refrigerator	15	4
		Top Freezer Refrigerator	15	11
	Unconditioned	Side by Side Refrigerator	15	12
		Top Freezer Refrigerator	15	12
		Upright Freezer	10	3
Mild	Conditioned	Bottom Freezer Refrigerator	0	1
		Side by Side Refrigerator	7	3
		Top Freezer Refrigerator	7	2
	Unconditioned	Side by Side Refrigerator	8	4
		Top Freezer Refrigerator	8	7
	Total		**100**	**60**

3.1.1.3 Laboratory Metering per DOE Protocol

Historically, the primary source of unit level gross savings estimates has been DOE laboratory metering of units conducted just prior to disposal. The laboratory test procedures were developed to ensure that appliance manufacturers produce units that meet the minimum level of energy efficiency standards. Federal code of regulations **DOE 10CFR430.23 (a) (b)** outline required testing protocols for refrigerators and freezers (Energy Conservation Program for Consumer Products [10 CFR 430.23(a)(b) 1977] n.d.).

The main purpose of the end of life DOE laboratory metering was to provide a standardized comparison of energy consumption at the birth (manufacturing) and death (recycling). By retesting the energy consumption of the units with the same protocol, the tested energy consumption can be compared to the rated energy consumption for that unit to arrive at an estimate of unit performance degradation over time.

As in situ data has become more readily available, recent evaluations have recommended moving away from the use of lab-metered data as a basis for gross savings estimation in favor of estimating UEC through the use of in situ metering. In this evaluation, we supply the laboratory UEC estimates as additional data points, but use the in situ estimates as the basis of the gross savings estimation.

3.1.1.4 Long-term In Situ Metering

Long-term in situ metering task was designed to provide updated data in a key area of methodological uncertainty. While in situ metering for program units is essential to characterizing program UEC, the annualization of those data is a sometimes overlooked source of error in the estimation process. The 2004-2005 ARP evaluation provided a methodologically sound approach to annualizing short-term metering results; however it relied on annual unit load shapes that are no longer representative of the units being metered. New long-term in situ metering of unit representative of ARP units provided the necessary data to annualize short-term in situ metering data with the least possible error.

The long-term metering was performed in coordination with the 2010-2012 Residential on-site surveys for the California Lighting and Appliance Saturation Study (CLASS). The CLASS visited and surveyed a sample of approximately 2,000 houses in the three California IOU territories. For a subset of these homes the evaluation team installed meters that recorded refrigerator and freezer energy consumption for a full year on qualifying appliances. These meters were retrieved a year later and the data reviewed and analyzed to assist in the improvement of the process to annualize the short-term meter data from program units. To coordinate with the CLASS study, the sample was stratified, similar to the short-term metering sample, by climate zone, location of the unit in conditioned versus unconditioned space and by the unit configuration. Table 14 below shows the targeted metering sample and metering completes.

Table 14: Long-term In Situ Metering Sample

Climate Group	Space Location	Description	Metering Target	Metering Completes
Mild	Conditioned	Side by Side Refrigerator	6	7
		Top Freezer Refrigerator	6	6
	Unconditioned	Side by Side Refrigerator	6	0
		Top Freezer Refrigerator	6	2
Inland	Conditioned	Side by Side Refrigerator	12	7
		Top Freezer Refrigerator	12	10
	Unconditioned	Side by Side Refrigerator	12	2
		Top Freezer Refrigerator	12	10
		Upright Freezer	8	8
	Total		80	52

3.1.2 Telephone Surveys and Interviews

Surveys were utilized to ascertain the likely disposition of program units in the absence of the program including participant surveys and non-participant acquirer/discarder surveys.

Interviews of market actors were used to gain an understanding of how used refrigerators and freezers flow through the secondary market. Both survey instruments and the market actor interview guides were reviewed by the CPUC and IOU staff and their recommendations were incorporated before beginning the data collection processes. In order to minimize non-response bias, DNV GL instructed the surveying firm to make up to ten attempts to contact each customer, including calling at different times of day and different days of the week. Survey instruments were also designed including measures to reduce bias, such as reading response options in a random and rotating order when necessary. The interviewers were trained to read questions *verbatim*, and offered response options only when instructed. The survey instruments for each survey are included in Appendix C and D, Disposition reports, tables showing the number of dialing attempts needed to achieve a completed survey and response rates for each survey are included in Appendix F.

3.1.2.1 Participant Survey

A survey of program participants was conducted to help verify program claims and to gather detail to help inform the net-to-gross (NTG) analysis. Participants were asked to verify whether the unit claimed was actually picked up for recycling, to answer questions about the unit characteristics, its use in the household prior to being recycled, and about the likely disposition path of the unit if the program had not removed it from the household.

The sample for this survey was drawn from the final Q4 2012 program tracking data and stratified by IOU, unit vintage and whether the participant recycled one refrigerator, one freezer or two units (any combination of two refrigerators and/or freezers). For this third stratum, the age of the older of the two units recycled was used for stratification. Table 15, Table 16, and Table 17 show the allocations of survey targets and final completes for the three utilities. The survey was administered by a telephone surveying firm using a computerized surveying script. The survey instrument for this survey is shown in Appendix C. Participant Survey Instrument.

The overall target sample sizes were limited by budget. Since freezers were not determined to be a high impact measure, the study team, in conjunction with the IOUs, determined that a limited freezer sample would be appropriate so that more survey resources could be directed toward refrigerators. Over 1,100 surveys were completed in total.

Table 15: Participant Survey: Population and Sample Allocation by Group and Vintage for PG&E

Strata 1 and 2: Allocations by Age of Unit					
Unit Recycled	**Mfg. Year**	**Participant Population**	**Survey Targets**	**Survey Completes**	**Precision @ 90% CL**
One Refrigerator	Pre-1980	9,502	38	38	13.3%
	1981-1992	20,830	83	83	9.0%
	1993-2000	14,027	56	56	11.0%
	2001-2012	4,862	19	19	18.9%
	Totals	**49,221**	**196**	**196**	**5.9%**
One Freezer	Pre-1980	1,999	8	8	29.1%
	1981-1992	2,482	10	10	26.0%
	1993-2000	835	3	3	47.5%
	2001-2012	248	1	2	58.2%
	Totals	**5,564**	**22**	**23**	**17.2%**
Stratum 3: Allocations by the Greater of the Ages of Two Recycled Units					
Units Recycled	**Maximum Mfg. Year**	**Participant Population**	**Survey Targets**	**Survey Completes**	**Precision @ 90% CL**
Two Units (could be any combination of refrigerators and/or freezers)	Pre-1980	497	4	4	41.1%
	1981-1992	1,678	11	11	19.1%
	1993-2000	1,360	10	10	24.9%
	2001-2012	325	3	3	50.6%
	Totals	**3,860**	**28**	**28**	**9.2%**

Table 16: Participant Survey: Population and Sample Allocation by Group and Vintage for SCE

Strata 1 and 2: Allocations by Age of Unit					
Unit Recycled	**Mfg. Year**	**Participant Population**	**Survey Targets**	**Survey Completes**	**Precision @ 90% CL**
One Refrigerator	1989	59,048	201	201	5.8%
	1993	39,021	133	133	7.1%
	1996	37,408	127	127	7.3%
	2000	20,418	69	71	9.8%
	Totals	**155,895**	**530**	**532**	**3.6%**
One Freezer	1989	6,815	23	24	16.8%
	1993	1,902	6	6	33.6%
	1996	1,767	6	6	33.6%
	2000	1,119	4	4	41.1%
	Totals	**11,603**	**39**	**40**	**13.0%**
Stratum 3: Allocations by the Greater of the Ages of Two Recycled Units					
Units Recycled	**Maximum Mfg. Year**	**Participant Population**	**Survey Targets**	**Survey Completes**	**Precision @ 90% CL**
Two Units (could be any combination of refrigerators and/or freezers)	1989	7,115	48	48	11.9%
	1993	2,739	19	19	19.1%
	1996	1,604	11	11	24.9%
	2000	389	3	2	50.6%
	Totals	**11,847**	**81**	**80**	**9.2%**

Table 17: Participant Survey: Population and Sample Allocation by Group and Vintage for SDG&E

Strata 1 and 2: Allocations by Age of Unit					
Unit Recycled	**Mfg. Year**	**Participant Population**	**Survey Targets**	**Survey Completes**	**Precision @ 90% CL**
One Refrigerator	Pre-1980	326	1	2	58.2%
	1981-1992	6,214	28	28	15.5%
	1993-2000	11,328	52	52	11.4%
	2001-2012	15,709	72	72	9.7%
	Totals	33,577	153	154	6.6%
One Freezer	Pre-1980	141	1	2	58.2%
	1981-1992	988	5	5	36.8%
	1993-2000	938	4	4	41.1%
	2001-2012	1,202	5	5	36.8%
	Totals	**3,269**	**15**	**16**	**20.6%**
Stratum 3: Allocations by the Greater of the Ages of Two Recycled Units					
Units Recycled	**Maximum Mfg. Year**	**Participant Population**	**Survey Targets**	**Survey Completes**	**Precision @ 90% CL**
Two Units (could be any combination of refrigerators and/or freezers)	Pre-1980	79	1	1	82.3%
	1981-1992	880	8	8	19.1%
	1993-2000	1,377	13	13	24.9%
	2001-2012	1,195	11	11	50.6%
	Totals	**3,531**	**33**	**33**	**9.2%**

The dispositions for the participant survey are provided in Appendix F. Telephone Survey & Interview Response Rates.

3.1.2.2 Non-participant Acquirer /Discarder Survey

The purpose of the Acquirer /Discarder survey was to interview program non-participants who acquired or discarded a refrigerator or freezer during the 2010-2012 program cycle to understand their transfer methods. Their responses about the actual methods used to discard

their refrigerator or process whereby they acquired a refrigerator provides the counterfactual basis for the transfer of used units on the secondary market in the absence of the program.

The target sample size for this survey was 1,000, where we hoped to interview a minimum of 300 used unit acquirers. The sample for this survey was drawn from a database of residential customers for the three IOUs. The customer database was stratified by climate zone group and low income status. The survey was administered by a telephone surveying firm using a computerized surveying script. Table 18 shows the survey targets and completes by strata.

Table 18: Non-participant Sample Table

IOU	Climate Zone Group	Low Income	Survey Target	Acquirer Completes	Discarder Completes	Survey Completes	Precision @ 90% CL
PG&E	Inland	no	119	86	54	119	7.5%
	Inland	yes	66	42	32	66	10.1%
	Mild	no	198	85	68	125	7.4%
	Mild	yes	57	44	24	54	11.2%
		Totals	**440**	**257**	**178**	**364**	**4.3%**
SCE	Inland	no	220	158	95	207	5.7%
	Inland	yes	127	76	41	101	8.2%
	Mild	no	74	47	26	60	10.6%
	Mild	yes	17	10	9	17	19.9%
		Totals	**438**	**291**	**171**	**385**	**4.2%**
SDG&E	Inland	no	26	15	9	20	18.4%
	Inland	yes	12	6	4	8	29.1%
	Mild	no	64	24	16	30	15.0%
	Mild	yes	20	15	8	16	20.6%
		Totals	**122**	**60**	**37**	**74**	**11.2%**
Overall			**1,000**	**608**	**386**	**803**	**2.9%**

In calling respondents, the survey firm had great difficulty in getting completed surveys in the San Diego territory, resulting in a lower-than-planned number of completed surveys for SDG&E. Low response rates can lead to a higher likelihood that results for the sample might differ from actual results for the population, but we cannot determine the potential effects of this difference. The dispositions for the survey are provided in Appendix F. Telephone Survey & Interview Response Rates.

Respondents were identified as acquirers and/or discarders independently based on screening questions. Any respondent who answered affirmatively to either the acquirer or discarder screening questions were asked the associated battery of questions. The "Acquirer Completes" and "Discarder Completes" in the table above show the number of response sets completed for these sections of the survey. Note that since some respondents could be Acquirer only, Discarder only, or both Acquirers AND Discarders, the survey completes for each stratum is not equal to the sum of Acquirer and Discarder completes.

The survey instrument for this survey is presented in Appendix D. Non-participant Acquirer/Discarder Survey Instrument.

3.1.2.3 Secondary Market Actor Interviews

When considering how to determine the flow of used refrigerators and freezers through the secondary market, we divided the market into two channels: the "retail" channel and the "peer-to-peer" channel. Interviews were conducted to gather information on the retail channel.

The "retail" channel is comprised of commercial entities, referred to as market actors, that have a role in the transfer of second-hand units. Using purchased market data, we located companies and charities that identified themselves, using SIC and NAICS codes, as having a business that might participate in the transfer of used refrigerators and freezers. While the most important category of market actors is likely to be the used appliance retailer, it was decided that, to get a more thorough understanding of how appliances transfer through the retail secondary market, several market actor categories should be interviewed. Some other categories we identified as potentially impacting the secondary market for used refrigerators and freezers are new retailers (both individual companies and retail chains), who often pick up a used unit when delivering a newly purchased unit, haulers, charity and thrift stores (individual companies and chains such as Goodwill), appliance rental centers, auction houses, and appliance recycling centers.

The key research questions for this analysis included:

- What is the volume of the retail channel of the secondary refrigerator/freezer market? What proportion of the market is controlled by which market actors?
- What is the 'market flow' (where second-hand refrigerator come from and go)?
- How many refrigerators would be given away, re-sold, dumped or recycled without the program?
- What are the main advertising and marketing streams?

To answer the above questions, a master interview guide was designed and then tailored to each market actor category. The market actor categories interviewed included:

- Appliance Recycling Facilities

- Retailers of used units, sometimes in addition to new units (non-chain)
- Retailers of new units, only (non-chain)
- Retail Chains
- Charity Chains
- Small Charities
- Haulers
- Auction Houses and Liquidators
- Rental Businesses of Appliances

These market actors were asked to indicate what proportion of their incoming/outgoing used units came from or went to the various market actor categories as well as the following user categories:

- Individuals
- Rental Property Owners
- Commercial Users (of residential-grade units)

To establish a population database for each market actor category within the secondary market study, current business data were purchased from the *salesgenie.com* website of infoUSA®, Inc. during June and July of 2013. The nearly 9,000 business records purchased were selected based upon relevant SIC and NAICS codes and sub-codes. After removing those records deemed irrelevant either because 1) the company name indicated that the business was not one of the secondary market actors or 2) the company zip code was outside of IOU territories, the combined population was reduced to more than 1,300 records that were used to create the sample frames for each of the nine market actor categories to be interviewed. The process for culling the purchased data to establishing a sample frame for each market category is described further in Appendix E. Retail Channel of Secondary Market, subsection E.1.

A representative sample was randomly selected from each market actor sample frame. For the more numerous market actors, the sample frame and sample were usually stratified by either IOU, annual sales volume, or both. This was done to improve the representation of the range of business sizes of the sample. The final sample for each market actor category is shown in Table 19.

The evaluation team observed that the total business annual sales was not a reliable indicator of secondary unit transactions, therefore stratum weighting based on annual sales from the market data was not applied to the results. All reported secondary market study confidence intervals are based upon a 90 percent confidence level. The master interview guide for the market actors is provided in Appendix E. Retail Channel of Secondary Market, subsection E.2.

Table 19: Sample of Secondary Market Actor Interviews in IOU Territories

Retail Channel Market Actor Category	Preliminary Population in Purchased Data	Qualified Population	Interview Sample, n
Appliance Recycling	10	43	6
Used Retailers	342	209	32
New Retailers, only	178	196	30
New Retail Chains	8*	786	27
Haulers	228	75	11
Charity & Thrift Stores	96	6	3
Charity & Thrift Stores, Chains	7*	92	9
Appliance Rental Companies	20	12	2
Auction Houses/Liquidators	468	171	4
Overall	**1,357**	**1,590**	**124**

*Chains had initially been counted by their overarching corporate name; for the qualified population, they were counted by individual locations, instead.

3.1.3 Peer-to-Peer Channel Research

"Peer-to-peer" transfers occur between individuals, with or without the exchange of money. The transferred unit can be given away or sold through a variety of ways: to friends and family members, via private transfers organized through word of mouth ("my friend has a fridge", or the unit left on the side of the road, free for the taking), by email exchanges, and through newspaper or online listing services such as Craigslist. These kinds of transfers are hard to identify for research purposes, with online methods of transfer (via email lists or online classifieds such as Craigslist) the only viable means of gathering systematic data regarding such transfers. A review of online forums for appliance sales revealed that postings on craigslist.org dominated the online portion of the market. The evaluation team gathered craigslist.org postings pertaining to refrigerators or freezers throughout the state of California for more than ten months to gain insights into the annual private transfers that are facilitated by the internet.

The key research questions for this task included:

- What is the volume of the peer-to-peer channel of the secondary refrigerator/freezer market?

- What are some of the characteristics of units being transferred in the peer-to-peer channel?
- What proportion of the advertisements is posted by retailers rather than individuals?

To learn about the peer-to-peer channel, we tracked the advertisements regarding used refrigerators and freezers at the following websites for one month:

- www.craigslist.org
- www.freecycle.org
- www.classifiedads.com
- www.applianceexchange.com
- www.pennysaver.com

At the end of the month, we determined that the advertisements posted on Craigslist dwarfed the other websites and that it was most efficient to track the Craigslist advertisements.

To capture the Craigslist advertisements for further analysis, we subscribed to the RSS feeds of all Craigslist regions located within California that met the search criteria that we had established. Over a span of ten months, from June 2013 through March of 2014, slightly over 404,000 postings were received. Of those, a sample of 143,000 was used to analyze the peer-to-peer channel of the secondary market. More detail regarding the steps in this process are provided in Appendix G. Peer-to-peer Channel of Secondary Market.

3.2 Verification Methods

When a unit is removed, the program confirms that it was "installed and operational" in accordance with program assumptions, and hence "verified". To verify the removal of specific refrigerators and freezers claimed by the IOUs in the program tracking database, the evaluation team contacted a sample of program participants via the Participants survey. These participants were asked to confirm that the units documented in the program tracking data were removed by the program for recycling. Responses from participants were weighted up to the program population to calculate the verification rate by utility.

3.3 UEC Calculation

The evaluation team took the following steps to determine full-year UEC based on unit characteristics:

- Determine nameplate UEC for each program unit;
- Annualization of short-term meter data; and

- Applying annualized meter data to adjust nameplate UECs for each program unit.

The full-year UEC must also be adjusted by a part-use factor to account for the fact that all secondary units are not in operation for the entire year. The part-use factor was calculated from usage reported by program participants as the mean usage for secondary units. The part use factor is not applied until the final disposition of the unit, as a primary or secondary unit, is established, as shown in Section 3.4.3.

3.3.1 Nameplate UEC Determination

Determination of nameplate UECs has been required for all new units since the 1970s. There are multiple databases that catalog these nameplate UECs. This section describes the method used to match tracking data model numbers to this database to obtain these nameplate UECs, and the imputation process used to develop UECs when model number matching was not possible.

3.3.1.1 Model Number Matching

As a first step, the evaluation team obtained nameplate UECs for the following units:

- Short-term metered program units from the current evaluation
- Long-term metered non-program units from the CLASS evaluation
- Short-term metered program units from the 2004-2005 evaluation
- Short-term metered units from the 2008-09 evaluations
- Non-metered program units

For the relatively small number of metered units, the team matched model numbers manually to several refrigerator databases[2] to obtain the nameplate UEC. The large number of non-metered program units made manual matching prohibitive. To obtain nameplate UEC estimates for these units, the evaluation team used a matching algorithm. The first step in the model matching process identified units with valid model number data[3]. To those units with model numbers, we applied a multi-step matching algorithm, which was applied to refrigerators and freezers separately:

Step 1: Exact Match

Step 2: Character by character match with stars (*) as wildcard characters

[2] These databases included the California Energy Commission and the Kouba-Cavallo online database of refrigerator and freezer model numbers (http://www.kouba-cavallo.com/refmods.htm)

[3] Non-valid or Missing values included nonsense model numbers (eg 1111111, abcdef).

Step 1: Exact Match

This consisted of a simple merge between the tracking data model numbers looking for exact matches. Those units not matched with this first step went to the second step in our matching process.

Step 2: Character by character match with stars (*) as wildcard characters

This approach involved establishing subsets of model numbers and creating a Cartesian product of CEC and tracking model numbers for those that shared the same first character. The model number matching algorithm resulted in match rates that varied significantly across appliance types and IOU. Additional detail about the wildcard matching process can be found in Appendix H. Obtaining Nameplate UEC.

Some difficulties that affect the ability to match model numbers are that tracking data may be missing model numbers because no number was available or because of incomplete data gathering. The data may have typographical errors, model number could have been correct for a version of the model number not captured in the UEC databases (model numbers may even have different versions for different colors, with letters or numbers embedded in the model number), or model numbers are not captured at all in the nameplate UEC database, which will particularly be the case for the very old units.

In a few cases, manual matching was applied the remaining unmatched units to improve the overall match rate for the utilities, by manually looking up the most frequently occurring of the unmatched model numbers.

3.3.1.2 Imputing Label UEC

For the approximately 60% of units with missing model numbers, we used key unit characteristics to impute the label UEC. Significance testing in prior evaluation studies has shown that the following variables can be strong predictors of nameplate UEC:

- Configuration
- Size in cubic feet
- Label amps
- Ice/water service through the door
- Defrost type
- Age

In regressing on the matched models, the best fit was obtained by excluding the “ice/water service through the door” and “defrost type” variables from the set above. This regression model

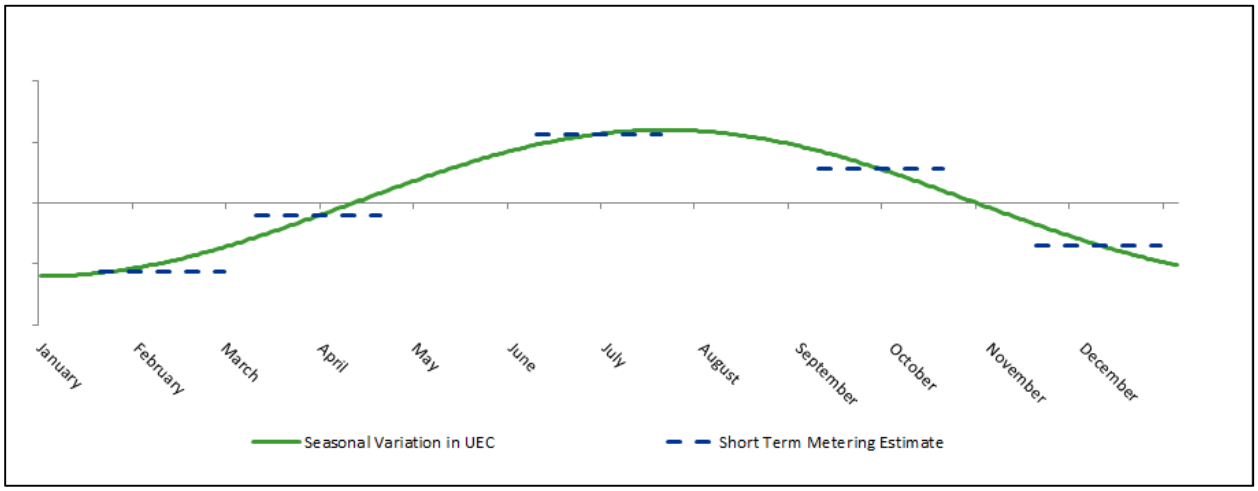
was then applied to the unmatched set of units to impute "nameplate" UEC for these units. Although the percentage of units for which we were able to match nameplate UECs varied widely across IOUs, the data used to impute nameplate UEC for non-matched units were nearly universally available from the pick-up data provided by ARCA and JACO, giving us added confidence in the validity of the imputed nameplate UEC values.

3.3.2 Annualization of Short-term Meter Data

The goal of in situ metering is to meter units under typical working conditions. It can be difficult to get access to appliance recycling program units after the customer has contacted the program but prior to the unit being picked up. In addition, units may have been moved and/or are no longer actually in use. Due to these logistical challenges, in situ metering of program units is typically for a short period (10-14 days). In order to generate gross saving estimates, the analysis needs to convert short-term metered consumption data into an annual in situ UEC.

Figure 2 below presents a conceptual summary of the challenge of annualization. The green line shows the actual annual consumption of a unit metered for an entire year. A short-term metering period would capture the consumption during just a short section of the green line. This is represented in the figure as a dotted line crossing the actual consumption line for various hypothetical metering periods. A simple or naive annualization process would assume constant unit consumption across the year (projecting the level of consumption during the metering period horizontally until it intersects the vertical axis). If a majority of units were metered during either summer or winter, the naïve annualization would overestimate or underestimate actual UEC.

Figure 2: Seasonal Error Inherent in Naïve Annualization



A more sound approach takes into account seasonal, temperature-based variation in the consumption patterns of units. We reviewed the approaches to annualizing short-term meter data that were used in the 2005 and 2009 evaluations, and compared them to the approach developed for this evaluation.

These approaches estimate models of hourly consumption as a function of hourly temperature and unit characteristics. Appendix I. Annualization of Short-term Meter Data, subsection H.2, discusses the different annualization approaches.

The evaluation team found that an annualization model based on observations of long-term metered units, using a model specification that provides an appropriate monthly adjustment to consumption, yields significantly lower seasonal error in estimates of annual UEC. The next section summarizes DNV GL's regression-based approach to annualizing short-term metering data using a regression based lookup table. In particular, the approach involves regressing hourly load on a set of variables that capture seasonal variation in consumption.

3.3.2.1 DNV GL Annualization

We based our annualization approach on that used in the 2004-2005 statewide ARP evaluation, but also took advantage of a new set of units that were metered for at least one full year. Compared to the annual end-use load shapes used for the 2004-2005 statewide ARP, which were already quite old at the time of that evaluation[4], the new long-term metering data more accurately represent the typical annual load shapes of the units entering the ARP.

While the new sample of units was smaller than the sample used for the 2004-2005 statewide ARP evaluation, we ran a single regression across all the units in the sample and included two dummy variables, refrigerator configuration and usage type, to control for any differences across these categories.

We tested two models: a base model that included a set of monthly dummy variables and a second model that included monthly interactions with temperature. The latter model was selected because, as was pointed out in the 2004-2005 evaluation, the addition of monthly dummy variables makes the hourly temperature*month interaction term more indicative of a month-specific consumption/temperature slope.

The model developed by DNV GL for the 2010-2012 evaluation employed new data from a sample of units metered for a minimum of 12 months to update the 2004-2005 evaluation models. Another difference from the 2004-2005 model is that the 2010-2012 model uses a

[4] The load shapes were based on metering performed in the 1990s on older units at that time. At this point, those load shapes represent load characteristics of units older than almost all the units picked up by the ARP.

single regression, with configuration data included as explanatory variables, rather than individual regressions for each type of unit configuration. The main effects accounted for by this regression are shown in Table 20. The complete list of effects accounted for by this regression—over 200 effects—is available in Appendix I. Annualization of Short-term Meter Data, subsection I.1. Load shape Regression Model.

Table 20: Annualization Regression - Main Effects Table

Parameter	Estimate	Biased	SE	t-Value	Probability > |t|
Intercept	-182.546	1	15.351	-11.890	<.0001
mean_wh	1.004	0	0.002	488.500	<.0001
month (1)	22.781	1	11.595	1.960	0.0494
month (2)	55.621	1	12.773	4.350	<.0001
month (3)	3.008	1	13.298	0.230	0.821
month (4)	-31.570	1	13.298	-2.370	0.0176
month (5)	-37.315	1	13.571	-2.750	0.006
month (6)	-48.061	1	13.756	-3.490	0.0005
month (7)	-103.381	1	14.082	-7.340	<.0001
month (8)	-38.763	1	14.380	-2.700	0.007
month (9)	-46.508	1	14.190	-3.280	0.001
month (10)	-55.573	1	12.066	-4.610	<.0001
month (11)	28.484	1	11.873	2.400	0.0164
month (12)	0.000	1	.	.	.
configuration (SS)	-123.153	1	18.640	-6.610	<.0001
configuration (TF)	26.070	1	14.675	1.780	0.0757
configuration (UP)	0.000	1	.	.	.
use type (F)	0.000	1	.	.	.
use type (P)	274.435	1	12.645	21.700	<.0001
use type (S)	0.000	1	.	.	.
conditioned space dummy (0)	-16.529	1	4.040	-4.090	<.0001
conditioned space dummy (1)	0.000	1	.	.	.
outdoor temperature	2.883	1	0.258	11.160	<.0001
volume	9.412	1	0.944	9.980	<.0001
R-Squared					0.552
Adjusted R-Squared					0.551

3.3.3 Determining UEC for Non-metered Program Units

After establishing an annual estimate of in situ UEC from the short-term metered units, the final step in determining gross program level unit consumption requires estimating unit level annual consumption for all non-metered program units. This was done by modeling the estimated end-of-life, in situ UEC as a function of nameplate UEC and other characteristics to arrive at a consumption estimate for each unit in the program tracking data. This regression applied to the program tracking data provided the full year per unit UEC estimates.

3.4 Determining Unit Savings

As described in Section 2.1, the determination of per unit savings is based on the theoretical concept of disposition paths, the myriad of potential outcomes that were prevented as a result of program activity. For each scenario identified, the evaluation team calculated the energy consumption on the grid that would have occurred had the program not recycled a particular unit and the energy consumption that occurred on the grid as a result of the program activities. Gross savings is the difference between these two consumption values. There were several discrete steps in this process:

- Determining the likely disposition of programs units had they not been recycled,
- Determining the alternative units placed into service because program units were recycled,
- Estimating energy consumption for each alternative with and without the program, and
- Calculating gross savings.

The following sections outline the process used for this analysis step.

3.4.1 Determining Disposition of Collected Units Absent the Program

Participant responses provide the most accurate information on whether a unit would have been kept or discarded had the program not recycled the unit. Participants were also asked whether any kept units would have been used, or kept unused. The percentage of units that would have been kept and used determines the percentage of units that generate direct savings. Table 21 shows the participant responses to these questions.

Table 21: Participant Keep/Discard Decision in the Absence of the Program

Participant Decisions without Program (n=1,088)	Proportion	Standard Error
Keep	16%	1.2%
Discard	84%	1.2%
Of those that would Keep, (n=172)		
Keep in Use	86%	2.8%
Keep Unused	14%	2.8%

The percentage of units that would have been disposed of represents the set of potential transfers.Units that would have been disposed of may or may not become transfers that will generate savings. While it is possible to ask program participants how they might have discarded their unit in the absence of the program, the Discarder survey provides a better counterfactual for data on how a typical non-participant discarder actually disposed of a unit during the program period. Non-participant discarders results are based on actual actions as opposed to hypothetical conjecture on the part of participants, and are a better reflection on what actually happens when faced with the logistical challenge of disposing of an appliance as large as a refrigerator or freezer.

The non-participant disposal choices are categorized as either destroyed or transferred to the second-hand market. Units that would have been hauled to a dump are considered to be units that would have been destroyed. Units that would have been given or sold to private parties are considered to be units that would have been transferred to the peer-to-peer channel of the secondary market. The remainder consists of units that, through one method or another, would have ended up in the hands of a used appliance dealer or other market actor within the secondary market. Table 22 shows the transfer destination of units discarded during the program period.

Table 22: Non-participant Discarder Disposal Decisions

Disposal Decision (n=848)	Proportion	Standard Error
Destroy	22%	2%
Peer-to-Peer Transfer	40%	21%
Retail Transfer	38%	21%

The data collected through interviews of market actors on the secondary market was analyzed to determine the overall size of the used refrigerator/freezer market for the retail channel by determining the volume of used appliances acquired by each market actor category. Market actors were asked to provide both the proportions from whom they received units, and to whom units were transferred. These results were used to determine the flow through the retail channel of the secondary market and ultimately the final destination of the units, either back onto the grid or destruction. Table 23 below summarizes these findings. Due to the complexity of characterizing the retail second-hand market, the results of this step are presented at the aggregate level, not disaggregated by IOU.

Table 23: Used Refrigerators/Freezers Leaving Retail Channel, by Destination

Final Destinations of Used Units Returned to Users by Retail Channel of Secondary Market (n=42)	Proportions to Final Destinations, percent	
	Proportion	Standard Error
Individuals	89%	60%
Rental Property Owners	5%	3%
Commercial Users	3%	5%
Others	3%	1%
Total	**100%**	

The proportions shown in Table 22 and Table 23 are combined to create a decision tree outlining the potential paths "from" the participant household. The second half of the transfer alternative looks at the proportions of units that would have been placed into service on the grid as a primary unit, with full usage, or as a secondary unit, where it may not be plugged in or operational all the time.

3.4.2 Determining Alternative Units on the Grid Due to the Program

The acquirer survey asked questions of program non-participants who acquired a used refrigerator or freezer during the program period. These used unit acquirers were asked questions to understand purchasing patterns, where do used unit acquirers get the appliances they purchased, how are they using these units in their home, and to explore the elasticity of purchasers in the second-hand market, if used units are not available. Combining the responses to these questions is used to address the program issue: In removing used units from circulation, what effect did the program have on those who would have purchased those second-hand units? Possible program alternative actions identified by the evaluation team include:

- No unit is acquired.
- A new refrigerator is purchased.
- A used unit is still acquired (either free or purchased).

The proportional responses to this question categorized by the transfer channel (peer-to-peer vs. retail) and whether the unit they acquired was being used as a primary or secondary unit, determines the alternative unit placed into to service due to the program (because the program unit was not available to be transferred on the secondary market). Table 24 summarizes the distribution of responses for peer-to-peer and retail transfers.

Table 24: Acquirer Usage and Counterfactual from Peer-to-Peer Transfers

Channel	Usage	%	SE	n	Action if Acquired Unit Was Unavailable	%	SE	n	Acquired Unit was…	%	SE	n
Peer-to-Peer Transfer	Primary	77%	24%	323	Looked for a similar free unit elsewhere	4%	*1%*	236				
					Purchased a similar used unit elsewhere	38%	*3%*	236				
					Purchased a new unit from a retailer	32%	*3%*	236				
					Kept existing unit	25%	*3%*	236	Replacing existing	79%	*6%*	61
									Adding a unit	21%	*6%*	61
	Secondary	21%	1%	323	Looked for a similar free unit elsewhere	6%	*3%*	67				
					Purchased a similar used unit elsewhere	28%	*6%*	67				
					Purchased a new unit from a retailer	17%	*5%*	67				
					Not purchased a unit	50%	*6%*	67				
Retail Transfer	Primary	91%	3%	125	Purchased a similar used unit elsewhere	44%	*5%*	105				
					Purchased a new unit from a retailer	34%	*5%*	105				
					Kept Existing Unit	21%	*4%*	105	Replacing existing	92%	*6%*	22
									Adding a unit	8%	*6%*	22
	Secondary	9%	3%	125	Purchased a similar used unit elsewhere	59%	*16%*	11				
					Purchased a new unit from a retailer	34%	*15%*	11				
					Not purchased a unit	7%	*8%*	11				

The results from the Participant and Non-participant Discarder/Acquirer surveys and the Secondary Market Actor interviews were analyzed to determine the proportionate dispositions of used units in each IOU territory across the various disposition paths.

To summarize the steps above, the program unit could have been kept by the participant (either in use or unused), been destroyed by the participant personally or transferred from their home. Units leaving the participant home could have been transferred on the peer-to-peer or retail channel of the second-hand market to individuals who would have purchased them to use as either a primary or secondary unit (and what these individuals would have done if they couldn't have purchased a specific used unit), or to another user on the grid, such as to a commercial entity (for example to put in a break room for employee use), purchased by landlords or apartment managers to install in rental units, etc.

Some proportion of the units transferred to the second-hand market would have been destroyed by the second-hand market actors. Market actor interviews were probed to investigate how "resale" value is determined, age, unit condition or other characteristics, and to understand what percentages of units received by market actors are resold vs. destroyed.

The percentages of outcomes differ by IOU, but the final disposition path decision tree constructed by the evaluation team has the following form, shown graphically in Table 25. Each scenario has a final proportion calculated, from the percentage breakdowns of all the steps getting to that scenario. So, for example the % "Transferred" * the % "Peer-to-Peer" * the % "Primary Unit" * the % "Acquired Similar Free Unit" would be multiplied to get the proportion of program units that would end up in the fourth disposition path in the list below.

Table 25: Disposition Path Decision Tree

Disposition Path					
Keep in Use by Participant					
Keep Unused Used by Participant					
Transferred	Destroyed by Discarder				
	Peer-to-Peer	Primary Unit	Replaced by similar free unit		
			Replaced by similar purchased unit		
			Replaced by new unit		
			Kept existing Unit	Replacing existing	
				Add a new unit	
		Secondary Unit	Replaced by similar free unit		
			Replaced by similar purchased unit		
			Replaced by new unit		
			Not replaced		
	Retail	Individual	Primary Unit	Replaced by similar purchased unit	
				Replaced by new unit	
				Kept existing unit	Replacing existing
					Add a new unit
			Secondary Unit	Replaced by similar purchased unit	
				Replaced by new unit	
				Not replaced	
		Primary Unit	Units purchased to install in rental units		
			Commercial spaces		
			Other		
		Destroyed by Secondary Market Actors			

Appendix K contains the decision tree with a graphical representation showing which surveys (including question numbers) are responsible for each part of the counterfactual decision tree. This decision tree with the final proportions by IOU is presented in Table 38 and Table 39 below.

3.4.3 Part Use Adjustment

Although the majority of refrigerators and freezers are plugged in and operational all the time, surveys of appliance owners find that there are some units that are only used occasionally, to provide extra refrigeration in the event of parties or during certain times of the year. To account for the fact that these units are only used for a part of the year, a "part use" adjustment factor is

applied to correct the UEC estimate for these secondary units. The evaluation team calculated utility-specific part use factors from participant survey data for secondary units, by calculating an average usage (months used per year). Primary units were assumed to have a part use factor of 1.0 (on all of the time). For disposition paths where the unit is operating as a secondary unit, the calculated part use factor was applied to both the baseline consumption and program alternative consumption.

To calculate utility level part use adjustment factors, the evaluation team calculated the mean usage for secondary units by IOU. The IOU specific part-use factors are presented in Table 41, located in Section 4.3.2.

3.4.4 Baseline Consumption without the Program

For each of the disposition paths identified above, a full-year consumption without the program (e.g. energy that would have been consumed if the program unit had NOT been recycled), is determined. For all disposition paths, the full year per unit consumption calculated by IOU in Section 3.3.3 is applied. This full year consumption is adjusted by the part-use factor. Units that are in the "kept in use by the participant" scenario use the mean usage for secondary units reported by program participants; units in the "kept unused" scenario have a zero usage factor; units that will be destroyed get the mean proportionally weighted usage for all transferred units; and transferred units either get the mean usage for secondary units or full usage for primary units, depending on the position of the unit as a primary or secondary appliance in the transfer household. Baseline consumption is the full year consumption multiplied by the relevant part-use.

3.4.5 Baseline Consumption with the Program

For each of the disposition paths identified above, a second consumption estimate was also calculated: the energy consumed by the unit (if any) placed into service for that disposition path, since the program unit was in fact not available to be transferred. This was estimated in two steps, first by establishing the full year UEC for the unit placed into service for each disposition path, then adjusting the full year consumption by the relevant part-use factor.

3.4.5.1 Full year Transfer Alternative Consumption

To determine the full year gross equipment UEC for transfer alternative units, those units that acquirers on the second-hand market are likely to purchase because the program units are unavailable, the evaluation team calculated the mean age of units purchased by non-participant acquirers as shown in Table 26.

Table 26: Mean Age of Used Units Acquired by Non-participants

Unit	Means Acquired	Mean Age
Refrigerators	Free (n=17)	8.2
	Purchased (n=30)	6.2
Freezers	Free (n= 123)	9.4
	Purchased (n= 285)	5.9

This mean age was used to subset the program units into those viable on the second-hand market for the "acquired a similar unit for free" and "purchased a similar used unit" with program disposition paths. The cutoff age for program units to match the mean and as a purchased unit is shown in Table below.

Table 27: Cut-off Age for Viable Program units in the Second-hand Market

Unit	Means Acquired	Cut-off Age
Refrigerators	Free (n=25,742)	≤ 10 years
	Purchased (n=12,013)	< 10 years
Freezers	Free (n= 3,159)	≤ 11.5 years
	Purchased (n= 508)	< 8 years

It is worth noting that there are scenarios where a household may keep an old, high consumption unit because the neighbor recycled their recently replaced 12-year-old unit through the program. In this case, the avoided transfer due to the program would be a net increase in consumption on the grid. However since these scenarios are impossible to predict, this potential negative impact of the program is left out of this analysis.

3.4.5.2 Application of Part-Use Adjustment

This full year transfer UEC is adjusted by the relevant part-use factor for each disposition path to arrive at the final part-use adjusted UECs for the baseline and program alternatives for each IOU. The part-use factor for each disposition path is identical for the "with" and "without" consumptions, with the exception of "Kept in Use" scenario, where the usage is zero for this second consumption.

3.4.6 Gross Savings

For all disposition paths, the gross savings is simply the baseline consumption with the program subtracted from the baseline consumption without the program. Table 42 through Table 45

show the calculation steps and values used to estimate gross savings by disposition path for each IOU for refrigerators and at the statewide level for freezers.

3.4.7 Net Savings

Net savings are calculated by multiplying the gross savings for all disposition paths by the free-rider factor for each scenario.

Free-rider factor is a simple yes/no Boolean applied to each disposition path. The "Destroy" disposition path is a free-rider and has a free-rider factor of one, all other disposition paths (whether they produce gross savings or not) are not free-riders and have a free-rider factor of zero.

3.4.8 Per-Unit Net and Gross Savings

Per-unit net and gross savings are calculated by multiplying the proportional weights for each disposition paths by the gross and net savings for each scenario, then summed to arrive at the program level per-unit savings. Table 46 shows the Gross and Net savings by IOU.

3.4.9 Peak Demand Savings

Peak demand savings (kW savings) were estimated for the ARP by applying the IOU specific peak-to-energy relationships from the program tracking data to ex post energy savings estimates. Review of program tracking data showed that the peak demand savings were correctly applied from DEER to the measure level. The IOU-specific demand ratio was calculated from the tracking data to take into account the climate zone spread across the units recycled by each utility. This factor was then used to calculate a scaled demand savings from the consumption savings estimated in this evaluation. The calculation to create this peak-to-energy relationship factor for each IOU is:

$$kW_{evaluation} = kWh_{evaluation} \times (kW_{tracking}/kWh_{tracking})$$

3.4.10 Interactive Effects

As mentioned in Section 2, interactive effects take into account the effects on the homes' cooling and heating systems that result from energy usage and associated heat reduction directly related to ARP savings. This is due to the resulting absence of heat that had been produced by the recycled units in conditioned spaces, thereby changing the energy needed to heat and cool the home. Interactive effects for the ARP were calculated by applying DEER interactive effects derived from program tracking data to the direct savings estimates determined in this

evaluation. By using the relationship between ex ante kWh savings and interactive effects, the analysis considered climate zone, location of the affected unit (conditioned or unconditioned space), and saturation of space cooling and space heating equipment for each IOU.

$$therm_{evaluation} = kWh_{evaluation} \times (therm_{tracking}/kWh_{tracking})$$

4. Detailed Impact Findings

This section presents detailed results of the key analysis steps as well as detail on the gross and net program savings. Topics are covered in the following order:

- Measure verification
- UEC calculation
- Unit savings estimation
- Net unit savings and NTGR
- Overall program savings
- Secondary market study results

4.1 Verification

Participants were asked to confirm whether the program removed their units for recycling. In general the evaluation team found that the Verification Rate was very close to 100%. In a few cases, the unit was misidentified (tracking data showed a participant recycled two refrigerators, however the participant reported that one refrigerator and one freezer was recycled). Adjustment of these units to the appropriate measure resulted in the verification rates exceeding 100%. The evaluation team did not verify room air conditioners, and therefore this measure was passed through at 100% verification. Table summarizes the verification findings.

Table 28: Claimed vs. Verified Quantities by Measure and IOU

IOU	Measure	Claimed Units	Verification Rate (%)	Verified Units
PG&E	Refrigerator	55,742	98%	54,651
	Freezer	7,147	108%	7,724
	Room AC	815	n/a	815
SCE	Refrigerator	183,225	99%	180,504
	Freezer	15,551	101%	15,666
SDG&E	Refrigerator	40,893	99%	40,405
	Freezer	4,420	100%	4,420
	Room AC	744	n/a	744

4.2 UEC Calculation

As discussed in Section 2, the key steps in determining the appropriate UEC of each program unit were determining the nameplate UEC for all program units, annualizing short-term metering results to provide estimates of annual in situ appliance usage, and applying the annualized metering results to all program units through an adjustment to the nameplate UECs.

4.2.1 Nameplate UEC Determination

This analysis step involved: model number matching of all units with sufficient data in order to associate the nameplate UEC with each unit, and imputation of the nameplate UEC for the remaining program units where there was insufficient data to perform a direct model number match.

4.2.1.1 Model Number Matching

The PG&E tracking data, supplied by JACO, had relatively high quality model number data. Approximately 98% of units have a model number of some sort and we were able to match almost 80% of those units. Both the quality of model number data and the ultimate match rate were lower for SCE and SDG&E and for all freezer data. The final results of our matching process can be seen in Table 29 below summarized by appliance type and IOU.

Table 29: Total Number of Units and Match Percentage

Appliance Type	IOU	Units with Model Data	Exact Matches (%)	Wildcard Matches (%)	Total Match (%)
Refrigerator	PGE	54,560	51%	28%	79%
	SCE	108,200	7%	62%	69%
	SDGE	17,761	4%	44%	48%
	All IOUs	**180,521**	**20%**	**50%**	**70%**
Freezer	PGE	6,801	12%	29%	41%
	SCE	8,224	9%	35%	44%
	SDGE	1,819	6%	21%	27%
	All IOUs	**16,844**	**10%**	**31%**	**41%**

4.2.1.2 Imputing Label UEC

As discussed above, a regression approach was utilized to impute nameplate UEC values when there were insufficient data to match units to informational datasets. Table 30 summarizes the

degree to which unit characteristic information was present in the tracking data for the three IOUs. It shows that while nameplate UEC was missing in a number of cases, other unit descriptors were mostly available.

Table 30: Data Coverage for Nameplate UEC Imputation

IOU	Unit Characteristic	Available in Tracking Data
PG&E	Nameplate UEC	76.3%
	Nameplate Amps	96.5%
	Volume (Cu. Ft.)	99.0%
	Unit Age	95.1%
SCE	Nameplate UEC	39.9%
	Nameplate Amps	97.4%
	Volume (Cu. Ft.)	99.8%
	Unit Age	100.0%
SDG&E	Nameplate UEC	20.5%
	Nameplate Amps	98.7%
	Volume (Cu. Ft.)	98.7%
	Unit Age	99.9%

The regression developed by the evaluation team to impute Label UECs for unmatched units is shown in Table 31 for refrigerators and Table 32 for freezers.

Table 31: Label UEC Imputation Regression for Refrigerators
Dependent Variable = Nameplate UEC, kWh per Year

Parameter	Estimate	Standard Error
Intercept	125.03	6.72
Volume	7.17	0.31
Age	25.69	0.14
Amps	4.65	0.51
Configuration (bottom freezer)	-16.19	4.79
Configuration (other)	-128.68	200.15
Configuration (single door)	-54.76	9.31
Configuration (side-by-side)	210.38	2.40
Manual defrost	-86.69	3.03
R-squared	0.318	

Table 32: Label UEC Imputation Regression for Freezers
Dependent Variable = Nameplate UEC, kWh per year

Parameter	Estimate	SE
Intercept	191.69	17.54
Volume	20.98	0.80
Age	13.80	0.44
Amps	-3.29	1.95
Configuration (chest)	-154.57	6.73
Manual defrost	-22.15	5.74
R-squared		0.297

A comparison of the imputed and non-imputed values is presented in Table 33.

Table 33: Comparison of Imputed vs. Non-imputed Values for Refrigerators

Variable	IOU	Tracking Data		Imputed		N	
		Mean	SE	Mean	SE	Units with Tracking Data	Units Imputed
Nameplate UEC	PG&E	907	1.75	943	3.17	42,599	13,224
	SCE	829	1.24	841	0.93	72,767	109,777
	SDG&E	790	3.53	736	1.69	8,455	32,766
Nameplate Amps	PG&E	7.0	0.01	7.0	0.04	53,892	1,931
	SCE	6.9	0	6.5	0.03	177,769	4,775
	SDG&E	6.4	0.01	6.6	0.07	40,677	544
Volume	PG&E	20.1	0.01	18.2	0.18	55,286	537
	SCE	19.7	0.01	17.9	0.19	182,177	367
	SDG&E	20.1	0.02	19.2	0.17	40,667	554
Age	PG&E	21.4	0.04	23.8	0.12	53,093	2,730
	SCE	18.2	0.01	17.9	3.08	182,538	6
	SDG&E	13.1	0.03	17.6	1.07	41,186	35

4.2.2 Annualization of Short-term Meter Data

The current evaluation team followed a modified version of the 2004-2005 evaluation approach. We believe that the benefit of having actual load shapes for units outweighs the cost of using data from units that likely differ (perhaps substantially) from the population of recycled units. Appendix I. Annualization of Short-term Meter Data, subsection I.1 Load Shape Regression Model, presents the full regression results and a brief discussion of how the evaluation team compared the modeling techniques used in the different evaluations.

Tables provided in Appendix I. Annualization of Short-term Meter Data present the full regression results. Since the full model contained nearly 200 terms (including interactions) the results are grouped by main effects, and categories of interaction terms.

Table 34 shows a comparison between the Nameplate UEC and the predicted UEC from the DNV GL annualization of in situ metering data. The predicted UEC based on the in situ metering data is greater than the nameplate UEC due to the effects of degradation of the equipment over time combined with the difference in metering conditions between the

laboratory testing environment and the participant home. Utilizing in situ metering to capture this difference in equipment performance improves the estimates of program impacts.

Table 34: Comparison of Nameplate UEC to In Situ and Lab-Predicted UEC

Appliance Type	IOU	n	Nameplate UEC	90% CI	Predicted In Situ UEC	90% CI	Lab UEC	90% CI
Refrigerators	PG&E	85	1,112	± 73	1,175	± 66	1,605	± 133
	SCE	205	1,073	± 43	1,209	± 41	1,617	± 82
	SDG&E	81	954	± 69	999	± 63	1,402	± 122
Freezers	All IOUs	19	965	± 97	1,413	± 83	1,382	± 164

4.2.3 Determining UEC for Non-metered Program Units

In selecting the variables for this model, we began with the specification used in the 2004-2005 evaluation, and used independent variables that were available in the pick-up data. Table 35 below summarizes the results of the regression used to extrapolate the in situ UEC estimates obtained from the metering data to the program population. Parameter estimates that were significant at the 0.05 level are indicated with a "†".

Table 35: Regression to Extrapolate In Situ Results to Program Population
Dependent Variable = Annualized Metered UEC (kWh per Year);
Base Variable for Configuration = Top Freezer

Variable	Estimate	Standard Error
Intercept	-578.12	411.88
Nameplate UEC†	0.43	0.09
Ln(Age)	136.96	147.90
Volume†	24.85	9.79
Label Amps	33.95	26.96
Cohort 2005 Dummy†	240.04	82.79
Cohort 2009 Dummy	-72.13	79.48
Freezer Dummy	-73.72	243.47
Upright Configuration Dummy	371.79	262.52
Side-By-Side Configuration Dummy	289.41	235.68
Bottom Freezer Configuration Dummy	414.57	980.98
Other Refrigerator Configuration Dummy	-944.07	557.87
Age Over 15 Years Dummy	-617.77	525.95
Label Amps* Side-By-Side Configuration Dummy	-34.03	31.62
Label Amps* Bottom Freezer Configuration Dummy	-57.82	161.57
Label Amps* Other Refrigerator Configuration Dummy	179.12	104.21
Ln(Age)* Age Over 15 Years Dummy	231.98	195.62
R-Square	0.382	

To obtain a program level average full year UEC estimate, the evaluation team applied the regression estimates above to the IOU average values of the corresponding regressors. Table 36 summarizes these average values.

Table 36: Summary of Statistics by IOU for In Situ UEC Regression Variables

Appliance Type	Statistic	PGE	SCE	SDGE
Refrigerators	Average Nameplate UEC	915	836	747
	Average Age	21.5	18.2	13.2
	Average Volume	20.1	19.7	20.1
	Average Rated Amps	7.0	6.9	6.4
	% Top Freezer	62%	61%	62%
	% Side-by-Side	32%	35%	32%
	% Bottom Freezer	4%	3%	3%
	% Other Configurations	2%	2%	3%
Freezers	Average Nameplate UEC	856	749	695
	Average Age	26.3	19.5	15.8
	Average Volume	17.9	16.7	17.5
	Average Rated Amps	6.1	5.0	5.7
	% Upright	82%	79%	62%
	% Chest	18%	21%	38%

Table 37 summarizes the full year UEC estimates for refrigerators and freezers. Standard errors were constructed by multiplying the variance matrix of model parameter estimates with the appropriate population mean values. A final full year per unit UEC estimate was calculated from the mean of all program units for each IOU.

Table 37: Full Year Average Unit Energy Consumption Estimates

Appliance Type	IOU	Number of Observations	Full Year UEC	90% CI	Relative Precision
Refrigerator	PGE	55,823	1,036	113	11%
	SCE	182,544	958	114	12%
	SDGE	41,221	815	124	15%
Freezer	All IOUs	27,373	1,032	203	20%

Note that the values presented above are not the final gross consumption or savings estimates, but are inputs to the gross and net savings calculations. Adjustments such as part use factors and energy consumed by units acquired in lieu of recycled units are applied to the values above to arrive at gross and net savings estimates.

4.3 Unit Savings

To develop unit savings, the evaluation team identified the various paths a program unit may have travelled absent the program and then calculated the energy consumption that would have occurred on the grid with and without the program. Gross savings is the difference between these two consumption values.

4.3.1 Disposition of Collected Units and Alternative Transfer Units

Using the methods discussed in Sections 2 and 4, a complete disposition of program units, assuming no program (the counterfactual actions of participants), was estimated for each IOU. Table 38 and Table 39, for refrigerators and freezers respectively, show our disposition path diagram, now populated with the proportions of program units that end up in each disposition path. These percentages vary by IOU as shown, and are used to calculate the final per unit gross and net savings. To derive the proportions in each disposition path, the proportions of each of the nested steps were multiplied together, leading to a final outcome. These proportions are laid out in Table 21 through Table 23 in Section 3.4.1 above.

Table 38: Proportion of Refrigerators by Counterfactual Action

Counterfactual Action						Final Proportion	SE	n
Keep in Use by Participant						14%	2.8%	172
Keep Unused Used by Participant						2%	2.8%	172
Transferred	Destroyed by Discarder					18%	2.1%	848
	Peer-to-Peer	Primary Unit	Replaced by similar free unit			1%	0.7%	236
			Replaced by similar purchased unit			10%	5.1%	236
			Replaced by new unit			8%	4.4%	236
			Kept existing Unit	Replacing existing		5%	2.7%	61
				Add a new unit		1%	0.8%	61
		Secondary Unit	Replaced by similar free unit			0%	0.3%	67
			Replaced by similar purchased unit			2%	1.2%	67
			Replaced by new unit			1%	0.7%	67
			Not replaced			4%	1.9%	67
	Retail	Individual	Primary Unit	Replaced by similar purchased unit		7%	5.9%	105
				Replaced by new unit		6%	4.5%	105
				Kept existing unit	Replacing existing	3%	2.7%	22
					Add a new unit	0%	0.3%	22
			Secondary Unit	Replaced by similar purchased unit		1%	0.8%	11
				Replaced by new unit		1%	0.5%	11
				Not replaced		0%	0.2%	11
		Primary Unit	Units purchased to install in rental units			1%	0.9%	42
			Commercial spaces			1%	0.4%	42
			Other			1%	0.5%	42
		Destroyed by Secondary Market Actors				11%	8.9%	42
					Total	99%		

Table 39: Proportion of Freezers by Disposition Path

Counterfactual Action					All IOUs	SE	n
Keep in Use by Participant					14.2%	3.4%	15
Keep Unused Used by Participant					1.8%	1.5%	15
Destroyed by Discarder					12.6%	3.5%	74
Transferred	Peer-to-Peer	Primary Unit	Acquired similar free unit		0.0%	0.0%	18
			Purchased similar unit		5.6%	2.4%	18
			Purchased new unit		4.5%	2.4%	18
			Kept existing unit		24.0%	4.5%	18
	Retail	Primary Unit	Individual	Purchased similar unit	5.2%	1.3%	31
				Purchased new unit	3.6%	1.1%	31
				No unit acquired	12.5%	2.0%	31
		Primary Unit	Units purchased to install in rental units		1.3%	0.2%	42
			Commercial spaces		0.7%	0.1%	42
			Other		0.8%	0.1%	42
		Destroyed by Secondary Market Actors			13.2%	1.9%	42
Total					100.00%		

4.3.1 Full Year Alternative Transfer Consumption

Table 40 shows the mean full-year UEC applied to each counterfactual action. For gross savings determination, the transfer UEC that was applied to the "Destroyed" counterfactual action equaled the mean part-use, adjusted UEC of all other transferred scenarios (excluding destroyed) weighted by the probability of each scenario outcome.

Table 40: Full Year Average UEC for Alternative Disposition Paths

Unit	Transfer Alternative	PG&E	SCE	SDG&E
Refrigerators	Purchased Nothing		0	
	Similar "Free" Used Unit (≤ 10 years)	791	737	724
	Similar "Purchased Unit" (< 10 years)	783	635	660
	Destroyed	454	390	420
	Kept Existing (would have replaced)*	889	737	760
	New Refrigerator**		452	
Freezers (All IOUs)	Purchased Nothing		0	
	Similar "Free" Used Unit (≤ 11.5 years)		782	
	Similar "Purchased Unit" (< 8 years)		744	
	Destroyed		393	
	New Freezer**		443	

* Alternative consumption for "Kept Existing, would have replaced" is the weighted average of the full program UEC and the UEC for a "Similar "Free" Used Unit".

** NAECA 2011 Shipment Weighted Energy Consumption for Refrigerators and Freezers

Source for new unit UEC: AHAM Energy Efficiency and Consumption Trends 2012

4.3.2 Part-Use Factors

Part-use factors depend on the type of usage for the appliance in absence of the program: for those placed into service as a primary unit, the part-use factor applied is 1.0; for those placed into service as a secondary unit, the part-use factor is calculated from the mean usage of secondary units reported by program participants as shown in Table 41. This adjustment is used to account for the fact that some units will not be operated 100% of the year.

Table 41: Part-Use Factors for Secondary Units, by IOU

IOU	Mean	Standard Error
Primary Units		
All IOUs	1.00	n/a
Secondary Units		
PG&E (n= 51)	0.91	0.04
SCE (n= 166)	0.97	0.01
SDG&E (n= 58)	0.95	0.02

4.3.3 Summary of Gross Savings by IOU and Disposition Path

Table 42, Table 43, and Table 44 show the process used to calculate the energy consumption and gross savings for refrigerators in all counterfactual actions by IOU. Table 45 shows consumption and gross savings for freezers for all counterfactual action.

For all of these tables, the process is the same:

- Column A shows the proportion of program units that will end up in each counterfactual action category, drawn from Table 38 or Table 39 as appropriate.
- Column B shows the full-year consumption of the program units from Table 37.
- Column C shows the counterfactual part-use factor for program units reported in Table 41, based on the following assumptions:
  - Kept in Use: all units are secondary units
  - Kept: all usage is zero
  - Destroyed: part-use is the weighted mean usage of all transferred units (excluding Destroyed).
- Column D shows the consumption of the program unit for each the counterfactual action: baseline part-use factor multiplied by the full-year consumption (B*C).
- Column E shows the alternative unit annual consumption from Table 40.
- Column F shows the alternative-unit part-use factor, again from Table 41.
- Column G shows the alternative unit consumption for each counterfactual action, adjusted for part-use (E*F).
- Column H presents the gross savings: program unit consumption minus alternative consumption for each counterfactual action (D-G).
- The final row of each table gives the overall averages for each column, weighted by the counterfactual actions.

Table 42: Refrigerator Consumption by Scenario for PG&E

Counterfactual Action					Statewide Proportions (%)	Program Units Consumption under the Counterfactual			Alternative Unit Consumption under the Counterfactual			Gross Unit Energy Savings, kWh
						Full UEC	Usage	Adj. UEC	Full UEC	Usage	Adj. UEC	
					(A)	(B)	(C)	(D= (B*C))	(E)	(F)	(G= (E*F))	(H=(D-G))
Keep in Use by Participant					13.7%	1036	0.91	939	1036	0.00	0	939
Keep Unused Used by Participant					2.3%	1036	0.00	0	1036	0.00	0	0
Transferred	Destroyed by Discarder				18.2%	1036	0.98	1017	457	0.98	454	563
	Peer-to-Peer	Primary Unit	Replaced by similar free unit		1.2%	1036	1.00	1036	791	1.00	791	245
			Replaced by similar purchased unit		9.9%	1036	1.00	1036	783	1.00	783	253
			Replaced by new unit		8.4%	1036	1.00	1036	452	1.00	452	584
			Kept existing Unit	Replacing existing	5.2%	1036	1.00	1036	889	1.00	889	147
				Add a new unit	1.4%	1036	0.91	939	0	0.91	0	939
		Secondary Unit	Replaced by similar free unit		0.4%	1036	0.91	939	791	0.91	717	222
			Replaced by similar purchased unit		2.0%	1036	0.91	939	783	0.91	710	229
			Replaced by new unit		1.2%	1036	0.91	939	452	0.91	410	530
			Not replaced		3.6%	1036	0.91	939	0	0.91	0	939
	Retail	Individual	Primary Unit	Replaced by similar purchased unit	7.4%	1036	1.00	1036	783	1.00	783	253
				Replaced by new unit	5.7%	1036	1.00	1036	452	1.00	452	584
				Kept existing unit: Replacing existing	3.3%	1036	1.00	1036	889	1.00	889	147
				Kept existing unit: Add a new unit	0.3%	1036	0.91	939	0	1.00	0	939
			Secondary Unit	Replaced by similar purchased unit	0.9%	1036	0.91	939	783	0.91	710	229
				Replaced by new unit	0.5%	1036	0.91	939	452	0.91	410	530
				Not replaced	0.1%	1036	0.91	939	0	0.91	0	939
		Primary Unit	Units purchased to install in rental units		1.1%	1036	1.00	1036	783	1.00	783	253
			Commercial spaces		0.6%	1036	1.00	1036	783	1.00	783	253
			Other		0.7%	1036	1.00	1036	783	1.00	783	253
		Destroyed by Secondary Market Actors			11.3%	1036	0.98	1017	457	0.98	454	563
Totals					**99.4%**	**1036**	**0.94**	**977**	**637**	**0.82**	**467**	**510**

Table 43: Refrigerator Consumption by Scenario for SCE

Counterfactual Action						Statewide Proportions (%)	Program Unit Consumption under the Counterfactual			Alternative Unit Consumption under the Counterfactual			Gross Unit Energy Savings, kWh
							Full UEC	Usage	Adj. UEC	Full UEC	Usage	Adj. UEC	
						(A)	(B)	(C)	(D=(B*C))	(E)	(F)	(G=(E*F))	(H=(D-G))
Keep in Use by Participant						13.7%	958	0.97	927	958	0.00	0	927
Keep Unused Used by Participant						2.3%	958	0.00	0	958	0.00	0	0
Transferred	Destroyed by Discarder					18.2%	958	0.97	954	391	1.00	390	564
	Peer-to-Peer	Primary Unit	Replaced by similar free unit			1.2%	958	1.00	958	737	1.00	737	221
			Replaced by similar purchased unit			9.9%	958	1.00	958	635	1.00	635	323
			Replaced by new unit			8.4%	958	1.00	958	452	1.00	452	506
			Kept existing Unit	Replacing existing		5.2%	958	1.00	958	737	1.00	737	221
				Add a new unit		1.4%	958	0.97	927	0	0.97	0	927
		Secondary Unit	Replaced by similar free unit			0.4%	958	0.97	927	737	0.97	713	214
			Replaced by similar purchased unit			2.0%	958	0.97	927	635	0.97	615	313
			Replaced by new unit			1.2%	958	0.97	927	452	0.97	437	490
			Not replaced			3.6%	958	0.97	927	0	0.97	0	927
	Retail	Individual	Primary Unit	Replaced by similar purchased unit		7.4%	958	1.00	958	635	1.00	635	323
				Replaced by new unit		5.7%	958	1.00	958	452	1.00	452	506
				Kept existing unit	Replacing existing	3.3%	958	1.00	958	737	1.00	737	221
					Add a new unit	0.3%	958	0.97	927	0	0.97	0	927
			Secondary Unit	Replaced by similar purchased unit		0.9%	958	0.97	927	635	0.97	615	313
				Replaced by new unit		0.5%	958	0.97	927	452	0.97	437	490
				Not replaced		0.1%	958	0.97	927	0	0.97	0	927
		Primary Unit	Units purchased to install in rental units			1.1%	958	1.00	958	635	1.00	635	323
			Commercial spaces			0.6%	958	1.00	958	635	1.00	635	323
			Other			0.7%	958	1.00	958	635	1.00	635	323
		Destroyed by Secondary Market Actors				11.3%	958	0.97	954	391	0.99	390	564
Totals						**99.4%**	**958**	**0.95**	**922**	**558**	**0.83**	**404**	**519**

Table 44: Refrigerator Consumption by Scenario for SDG&E

Counterfactual Action					Statewide Proportions (%)	Program Unit Consumption under the Counterfactual			Alternative Unit Consumption under the Counterfactual			Gross Unit Energy Savings, kWh
						Full UEC	Usage	Adj. UEC	Full UEC	Usage	Adj. UEC	
					(A)	(B)	(C)	(D= (B*C))	(E)	(F)	(G= (E*F))	(H= (D-G))
Keep in Use by Participant					13.7%	815	0.95	776	815	0.00	0	776
Keep Unused Used by Participant					2.3%	815	0.00	0	815	0.00	0	0
Transferred	Destroyed by Discarder				18.2%	815	0.99	804	423	0.10	420	384
	Peer-to-Peer	Primary Unit	Replaced by similar free unit		1.2%	815	1.00	815	724	1.00	724	91
			Replaced by similar purchased unit		9.9%	815	1.00	815	660	1.00	660	155
			Replaced by new unit		8.4%	815	1.00	815	452	1.00	452	363
			Kept existing Unit	Replacing existing	5.2%	815	1.00	815	760	1.00	760	55
				Add a new unit	1.4%	815	0.95	776	0	0.95	0	776
		Secondary Unit	Replaced by similar free unit		0.4%	815	0.95	776	724	0.95	689	87
			Replaced by similar purchased unit		2.0%	815	0.95	776	660	0.95	628	148
			Replaced by new unit		1.2%	815	0.95	776	452	0.95	430	346
			Not replaced		3.6%	815	0.95	776	0	0.95	0	776
	Retail	Individual	Primary Unit	Replaced by similar purchased unit	7.4%	815	1.00	815	660	1.00	660	155
				Replaced by new unit	5.7%	815	1.00	815	452	1.00	452	363
				Kept existing unit: Replacing existing	3.3%	815	1.00	815	760	1.00	760	55
				Kept existing unit: Add a new unit	0.3%	815	0.95	776	0	0.95	0	776
			Secondary Unit	Replaced by similar purchased unit	0.9%	815	0.95	776	660	0.95	628	148
				Replaced by new unit	0.5%	815	0.95	776	452	0.95	430	346
				Not replaced	0.1%	815	0.95	776	0	0.95	0	776
		Primary Unit	Units purchased to install in rental units		1.1%	815	1.00	815	660	1.00	660	155
			Commercial spaces		0.6%	815	1.00	815	660	1.00	660	155
			Other		0.7%	815	1.00	815	660	1.00	660	155
	Destroyed by Secondary Market Actors				11.3%	815	0.99	804	423	0.99	420	384
Totals					**99.4%**	**815**	**0.96**	**779**	**552**	**0.66**	**419**	**360**

Table 45: Freezer Consumption by Scenario for all IOUs

Counterfactual Action				Statewide Proportions (%)	Program Unit Consumption under the Counterfactual			Alternative Unit Consumption under the Counterfactual			Gross Unit Energy Savings, kWh
					Full UEC	Usage	Adj. UEC	Full UEC	Usage	Adj. UEC	
				(A)	(B)	(C)	(D= (B*C))	(E)	(F)	(G= (E*F))	(H= (D-G))
Keep in Use by Participant				14.2%	1032	0.94	975	1032	0.00	0	975
Keep Unused Used by Participant				1.8%	1032	0.00	0	1032	0.00	0	0
Transferred	Destroyed by Discarder			12.6%	1032	0.94	975	235	0.94	222	753
	Retail	Peer-to-Peer	Replaced by similar free unit	0.0%	1032	0.94	975	782	0.94	739	237
			Replaced by similar purchased unit	5.6%	1032	0.94	975	744	0.94	703	272
			Replaced by new unit	4.5%	1032	0.94	975	443	0.94	419	557
			Not replaced	24.0%	1032	0.94	975	0	0.94	0	975
		Individual	Replaced by similar purchased unit	5.2%	1032	0.94	975	744	0.94	703	272
			Replaced by new unit	3.6%	1032	0.94	975	443	0.94	419	557
			Not replaced	12.5%	1032	0.94	975	0	0.94	0	975
		Primary Unit	Units purchased to install in rental units	1.3%	1032	0.94	975	744	0.94	703	272
			Commercial spaces	0.7%	1032	0.94	975	744	0.94	703	272
			Other	0.8%	1032	0.94	975	744	0.94	703	272
		Destroyed by Secondary Market Actors		13.2%	1032	0.94	975	235	0.94	222	753
Total				**100.0%**	**1032**	**0.93**	**958**	**363**	**0.79**	**187**	**771**

Table 46 summarizes the average per-unit gross savings for each IOU.

Table 46: Per Unit Gross Savings by IOUs

IOU	Aggregate Gross Unit Savings	Relative Precision at 90% Confidence Level
PG&E	510	26%
SCE	519	25%
SDG&E	360	27%
Freezers	771	18%

4.4 Net Unit Savings and Net-to-Gross Ratio

Table 47, Table 48 and Table 49 show the process used to calculate the net savings and net-to-gross ratio for refrigerators in all counterfactual scenarios, by IOU. Table 50 shows the net savings and net-to-gross ratio for freezers for all counterfactual scenarios.

For all of these tables, the process is the same;

- Column A shows the proportion of program units for each counterfactual action drawn from Table 38 or Table 39, as appropriate.
- Column B shows the gross savings from Table 42, Table 43, Table 44, or Table 45.
- Column C shows the free-rider factor where:
  - All Destroyed units are considered free-riders, where the free-rider factor = 1
  - All other counterfactual scenarios are not considered free-riders, where the free-rider factor = 0.
- Column D presents the net savings (B*(1-C)).
- Column E presents the proportionally weighted gross savings by counterfactual action, (B*A).
- Column F presents the proportionally-weighted net savings by counterfactual action, (D*A).
- The penultimate row of each table gives the proportionally-weighted, per-unit gross and net savings, weighted by counterfactual actions. This is derived by summing the proportionally-weighted gross and net savings in columns E & F.
- The final rows show the program net-to-gross ratio (NTGR).

Table 47: Gross and Net Savings for PG&E Refrigerators

Counterfactual Action					Statewide Proportions (%) (A)	Gross Unit Energy Savings (B)	Free-Rider Factor (C)	Net Savings D=(B*(1-C))	Gross Unit Savings, weighted by path E=(B*A)	Net Unit Savings, weighted by path F=(D*A)
Keep in Use by Participant					13.7%	939	1	939	129	129
Keep Unused Used by Participant					2.3%	0	1	0	0	0
Transferred	Destroyed by Discarder				18.2%	563	0	0	102	0
	Peer-to-Peer	Primary Unit	Replaced by similar free unit		1.2%	245	1	245	3	3
			Replaced by similar purchased unit		9.9%	253	1	253	25	25
			Replaced by new unit		8.4%	584	1	584	49	49
			Kept existing Unit	Replacing existing	5.2%	147	1	147	8	8
				Add a new unit	1.4%	939	1	939	13	13
		Secondary Unit	Replaced by similar free unit		0.4%	222	1	222	1	1
			Replaced by similar purchased unit		2.0%	229	1	229	5	5
			Replaced by new unit		1.2%	530	1	530	6	6
			Not replaced		3.6%	939	1	939	34	34
	Retail	Individual	Primary Unit	Replaced by similar purchased unit	7.4%	253	1	253	19	19
				Replaced by new unit	5.7%	584	1	584	33	33
				Kept existing unit: Replacing existing	3.3%	147	1	147	5	5
				Kept existing unit: Add a new unit	0.3%	939	1	939	3	3
			Secondary Unit	Replaced by similar purchased unit	0.9%	229	1	229	2	2
				Replaced by new unit	0.5%	530	1	530	3	3
				Not replaced	0.1%	939	1	939	1	1
		Primary Unit	Units purchased to install in rental units		1.1%	253	1	253	3	3
			Commercial spaces		0.6%	253	1	253	1	1
			Other		0.7%	253	1	253	2	2
		Destroyed by Secondary Market Actors			11.3%	563	0	0	64	0
Weighted Program Average									**510**	**344**
NTGR										**67%**

Table 48: Gross and Net Savings for SCE Refrigerators

Counterfactual Action					Statewide Proportions (%) (A)	Gross Unit Energy Savings (B)	Free-Rider Factor (C)	Net Savings D= (B*(1-C))	Gross Unit Savings, weighted by path E= (B*A)	Net Unit Savings, weighted by path F= (D*A)
Keep in Use by Participant					13.7%	927	1	927	127	127
Keep Unused Used by Participant					2.3%	0	1	0	0	0
Transferred	Destroyed by Discarder				18.2%	564	0	0	102	0
	Peer-to-Peer	Primary Unit	Replaced by similar free unit		1.2%	221	1	221	3	3
			Replaced by similar purchased unit		9.9%	323	1	323	32	32
			Replaced by new unit		8.4%	506	1	506	43	43
			Kept existing Unit	Replacing existing	5.2%	221	1	221	11	11
				Add a new unit	1.4%	927	1	927	13	13
		Secondary Unit	Replaced by similar free unit		0.4%	214	1	214	1	1
			Replaced by similar purchased unit		2.0%	313	1	313	6	6
			Replaced by new unit		1.2%	490	1	490	6	6
			Not replaced		3.6%	927	1	927	34	34
	Retail	Individual	Primary Unit	Replaced by similar purchased unit	7.4%	323	1	323	24	24
				Replaced by new unit	5.7%	506	1	506	29	29
				Kept existing unit: Replacing existing	3.3%	221	1	221	7	7
				Kept existing unit: Add a new unit	0.3%	927	1	927	3	3
			Secondary Unit	Replaced by similar purchased unit	0.9%	313	1	313	3	3
				Replaced by new unit	0.5%	490	1	490	3	3
				Not replaced	0.1%	927	1	927	1	1
		Primary Unit	Units purchased to install in rental units		1.1%	323	1	323	4	4
			Commercial spaces		0.6%	323	1	323	2	2
			Other		0.7%	323	1	323	2	2
		Destroyed by Secondary Market Actors			11.3%	564	0	0	64	0
Weighted Program Average									**519**	**352**
NTGR										**68%**

Table 49: Gross and Net Savings for SDG&E Refrigerators

Counterfactual Action					Statewide Proportions (%) (A)	Gross Unit Energy Savings (B)	Free-Rider Factor (C)	Net Savings D=(B*(1-C))	Gross Unit Savings, weighted by path E=(B*A)	Net Unit Savings, weighted by path F=(D*A)
Keep in Use by Participant					13.7%	776	1	776	106	106
Keep Unused Used by Participant					2.3%	0	1	0	0	0
Transferred	Destroyed by Discarder				18.2%	384	0	0	70	0
	Peer-to-Peer	Primary Unit	Replaced by similar free unit		1.2%	91	1	91	1	1
			Replaced by similar purchased unit		9.9%	155	1	155	15	15
			Replaced by new unit		8.4%	363	1	363	31	31
			Kept existing Unit	Replacing existing	5.2%	55	1	55	3	3
				Add a new unit	1.4%	776	1	776	11	11
		Secondary Unit	Replaced by similar free unit		0.4%	87	1	87	0	0
			Replaced by similar purchased unit		2.0%	148	1	148	3	3
			Replaced by new unit		1.2%	346	1	346	4	4
			Not replaced		3.6%	776	1	776	28	28
	Retail	Individual	Primary Unit	Replaced by similar purchased unit	7.4%	155	1	155	12	12
				Replaced by new unit	5.7%	363	1	363	21	21
				Kept existing unit: Replacing existing	3.3%	55	1	55	2	2
				Kept existing unit: Add a new unit	0.3%	776	1	776	2	2
			Secondary Unit	Replaced by similar purchased unit	0.9%	148	1	148	1	1
				Replaced by new unit	0.5%	346	1	346	2	2
				Not replaced	0.1%	776	1	776	1	1
		Primary Unit	Units purchased to install in rental units		1.1%	155	1	155	2	2
			Commercial spaces		0.6%	155	1	155	1	1
			Other		0.7%	155	1	155	1	1
		Destroyed by Secondary Market Actors			11.3%	384	0	0	44	0
Weighted Program Average									**360**	**247**
NTGR										**69%**

Table 50: Gross and Net Savings for Recycled Freezers (all IOUs)

Counterfactual Action					Proportion of Program Units in Disposition Path	Gross Unit Energy Savings	Free-rider Factor	Net Unit Energy Savings	Proportionally Weighted Gross Unit Savings	Proportionally Weighted Net Unit Savings
Keep in Use by Participant					14.0%	975	1	975	138	138
Keep Unused Used by Participant					2.0%	0	1	0	0	0
Destroyed by Discarder					13.0%	762	0	0	96	0
Transferred	Peer-to-Peer	Secondary Unit		Acquired similar free unit	0.0%	237	1	237	0	0
				Purchased similar unit	5.6%	272	1	272	15	15
				Purchased new unit	4.5%	557	1	557	25	25
				No unit acquired	24.0%	975	1	975	235	235
	Retail	Secondary Unit	Individual	Purchased similar unit	4.1%	272	1	272	11	11
				Purchased new unit	2.8%	557	1	557	16	16
				No unit acquired	9.8%	975	1	975	96	96
		Secondary Unit		Units purchased to install in rental units	0.9%	272	1	272	2	2
				Commercial spaces	0.4%	272	1	272	1	1
				Other	0.7%	272	1	272	2	2
		Destroyed by Secondary Market Actors			18.4%	762	0	0	140	0
Weighted Program Average									**778**	**542**
NTGR										**70%**

Table 51 summarizes the gross and net unit savings across IOUs in a single table. There are a couple factors driving differences in savings and NTGR across the utilities.

Note that, for all IOUs, the NTGR presented above is the per-unit NTGR, when combined with the verification adjustments the final program level NTGR by IOU is slightly different.

Table 51: Summary of *Ex Post*, Per-Unit Gross and Net Savings

IOU	*ex ante* Gross Unit Savings (kWh)	*ex post* Gross Unit Savings (kWh)	Gross Precision at 90% Confidence Level	Net Unit Savings (kWh)	*Net* Precision at 90% Confidence Level	NTG Ratio	*Precision for NTGR*
Refrigerators							
PG&E	738	510	26%	344	27%	67%	45%
SCE	835	519	25%	352	26%	68%	43%
SDG&E	957	360	27%	247	26%	69%	48%
Freezers							
All IOUs	818	771	18%	577	22%	75%	38%

4.5 Peak Demand Savings and Interactive Effects by IOU

Table 46 summarizes the average per unit gross and net peak demand savings for each IOU. The table also shows the calculated peak-to-energy relationship factor applied to the unit energy savings from this evaluation to estimate peak demand savings.

Table 52: Per-Unit Peak Demand Savings by IOU

IOU	Measure	Peak-to-Energy Demand Factor (kW/kWh)	Gross Unit Energy Savings (kWh)	Gross Peak Demand Savings (kW)	Net Unit Energy Savings (kWh)	Net Peak Demand Savings (kW)
		(A)	(B)	C=(A*B)	D	E=(A*D)
PG&E	Refrigerator	0.00022	510	0.11334	344	0.07645
	Freezer	0.00023	771	0.17990	577	0.13458
SCE	Refrigerator	0.00019	519	0.10044	352	0.06824
	Freezer	0.00020	771	0.15226	577	0.11390
SDG&E	Refrigerator	0.00016	360	0.05599	247	0.03837
	Freezer	0.00016	771	0.12005	577	0.08981

Table 46 summarizes the average per unit gross and net peak demand savings for each IOU. The table also shows the calculated peak-to-energy relationship factor applied to the unit energy savings from this evaluation to estimate peak demand savings.

Table 53: Per Unit Interactive Effects by IOU

IOU	Measure	Interactive Effects Ratio (therms/kWh)	Gross Unit Energy Savings (kWh)	Gross Interactive Effects (therms)	Net Unit Energy Savings (kWh)	Net Interactive Effects (therms)
		(A)	(B)	C=(A*B)	D	E=(A*D)
PG&E	Refrigerator	-0.01008	510	-5.14087	344	-3.46770
	Freezer	-0.00569	771	-4.38646	577	-3.28136
SCE	Refrigerator	-0.02100	519	-10.89292	352	-7.40080
	Freezer	-0.02011	771	-15.50029	577	-11.59525
SDG&E	Refrigerator	-0.00988	360	-3.55422	247	-2.43613
	Freezer	-0.00691	771	-5.33035	577	-3.98745

5. Secondary Market Study Findings

The secondary market study was undertaken to help ascertain the likely disposition of appliances, had they not been taken out of service by the ARP. As previously indicated, the secondary market of used units is comprised of two channels: the "retail" channel and the "peer-to-peer" channel. To study the retail channel, we interviewed a sample of 124 businesses, out of an estimated population of 1,588 businesses that handle used refrigerators/freezers within nine market actor categories. To study the peer-to-peer channel, we analyzed a random sample of 94,865 unique and qualified Craigslist postings of the slightly more than 404,000 RSS feeds containing the words refrigerator, fridge or freezer that were gathered over a ten month span.

5.1 Retail Channel

5.1.1 Size and Flow of Retail Market Channel

To learn the size and the flow of the used refrigerator/freezer market in IOU territories, we divided the market actors into groups to interview as described herein.

Retailers of refrigerators and freezers were divided into three categories:

1. Retailers that sold used units (perhaps in addition to new). This population of 209 stores was stratified by total annual sales and IOU so that a representative sample of stores was reached.
2. Retail chains—those with at least four stores in IOU territories—that sold new units and sometimes picked up the used unit from a customer that had purchased a new one. (No retail chains interviewed reported selling used units.) Again, this population of 786 stores was stratified by total annual sales and IOU so that a representative sample of stores was reached.
3. Independent retailers that only sold new units, but often pick up used units that are being replaced. Again, this population of 196 stores was stratified by total annual sales and IOU so that a representative sample of stores was reached.

Charities were divided into two categories:

1. Independent charities that accepted donations of and resold used units. This population of six sites was not stratified.
2. Charity Chains—those with at least four sites in IOU territories—that accepted donations of a resold used units. This population of 32 sites was stratified by IOU so that a representative sample of sites was reached.

Auction houses/liquidators were added as a market actor to include in the study once they had been mentioned by interviewees during some of our early interviews of other market actors. While this market actor had not been included in the original research plan, it was decided to add them to learn more about their role in the secondary market. The population of 171 auction houses located within IOU territories was stratified by total annual sales volume.

Haulers, appliance recycling centers, and appliance rental companies were each stratified by IOU territory with sampling targets established in each stratum.

During each interview, market actors were asked to indicate the quantity of used refrigerators/freezers they acquired each month. By multiplying the mean of their responses by the estimated population of each market actor, we estimated the total annual volume of units that entered the retail channel of the secondary market as shown in Table 54. In some instances, interviewees were reluctant to provide volumes as that was considered proprietary information.

Table 54. Used Refrigerators/Freezers Taken in by Market Actors

Market Actors Accepting Used Units into Retail Channel, (number that provided volume information)	Annual Volume of Used Refrigerators/Freezers		Proportions Received by Market Actors, percent	
	Volume	Standard Error	Proportion	Standard Error
Used & New Retailers (n=15)	25,246	4,400	20.9%	5.6%
New, only, Retailers (n=5)	7,420	2,905	6.2%	1.1%
Retail Chains (n=3)	16,934	10,162	14.0%	3.0%
Charities (n=2)	3,296	2,097	2.7%	0.5%
Charity Chains (n=9)	23,123	8,691	19.2%	4.9%
Auction Houses/Liquidators (n=4)	14,073	8,865	11.7%	2.4%
Haulers (n=11)	5,939	1,674	4.9%	0.9%
Rental Companies (n=1)	2,047	44	1.7%	0.3%
Appliance Recyclers (n=6)*	22,559	11,478	18.7%	4.7%
Total (n=56)	**120,636**	**20,594**	**100.0%**	**9.7%**

*Values were gathered, but not included in Retail Channel volume as this is not a supply-side market actor.

Upon removing the 22,559 units that were destroyed directly by users, the size of the supply-side market is shown in Table 55. Hence, 98,077 is the estimated size of the annual retail channel as shown in Table 55.

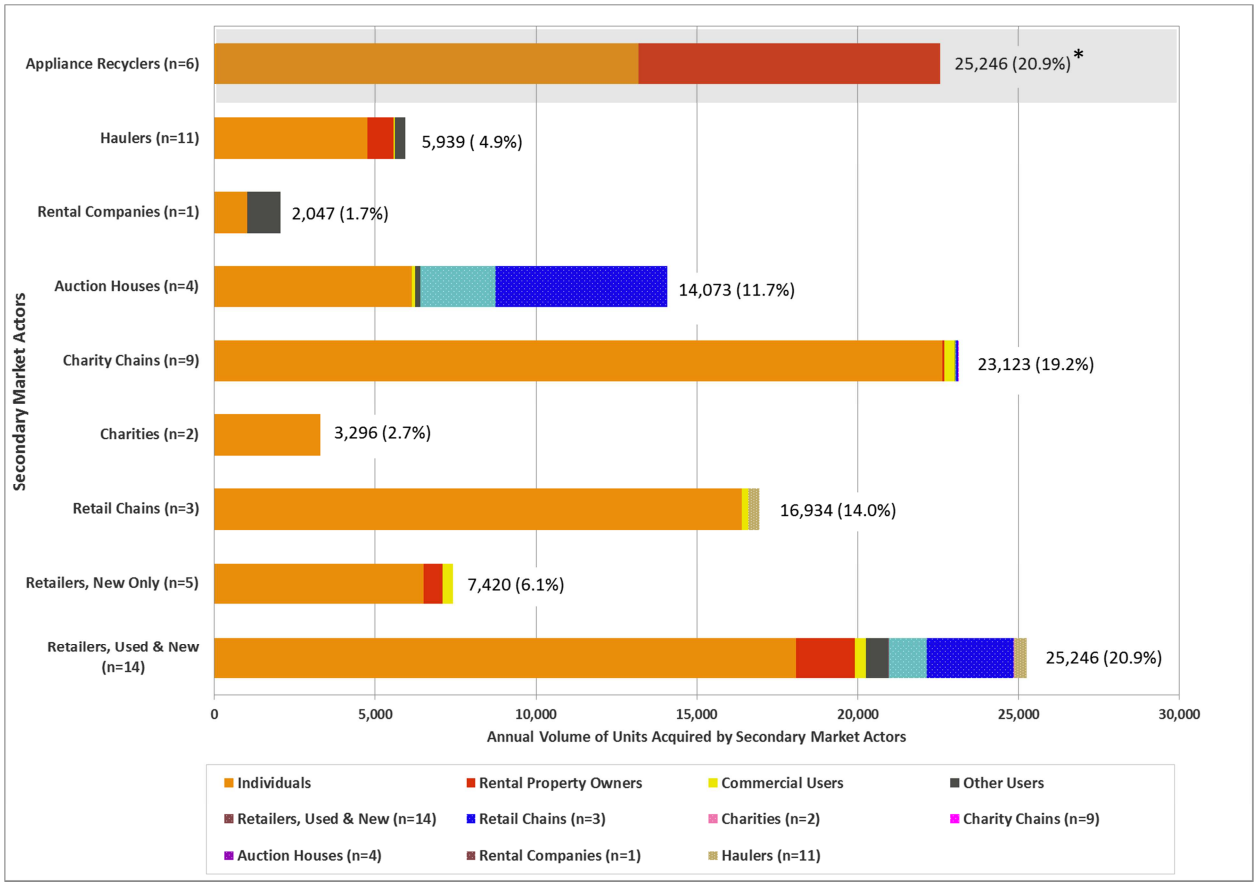
Table 55. Used Refrigerators/Freezers Entering Supply-Side Retail Market

Supply-side Market Actors that Receive Used Refrigerators/Freezers, (market actors that provided quantities)	Annual Volume of Used Refrigerators/Freezers		Proportions Received by Market Actors, percent	
	Volume	Standard Error	Proportion	Standard Error
Used & New Retailers (n=15)	25,246	4,400	25.7%	6.3%
New, only, Retailers (n=5)	7,420	2,905	7.6%	3.2%
Retail Chains (n=3)	16,934	10,162	17.3%	10.8%
Charities (n=2)	3,296	2,097	3.4%	2.2%
Charity Chains (n=9)	23,123	8,691	23.6%	9.8%
Auction Houses/Liquidators (n=4)	14,073	8,865	14.3%	9.4%
Haulers (n=11)	5,939	1,674	6.1%	2.0%
Rental Companies (n=1)	2,047	44	2.1%	0.4%
Total (n=50)	**98,077**	**17,099**	**100.0%**	**19.0%**
Relative Precision		**2.2%**		**0.6%**

As can be seen in Table 54, rental companies proved to have a tiny role in the retail channel of the secondary market, but auction houses acquire approximately 14 percent of the units and proved to play a larger role than had been anticipated. Only three of the 27 retail chains interviewed were willing to provide annual volumes. This resulted in a high standard error for that market actor.

Each of the market actors were asked to indicate the proportion of units that they acquired came from other market actors and from each of four categories of users: individuals, rental property owners, commercial users, and others. The proportions and overall quantities acquired are shown in Figure 3.

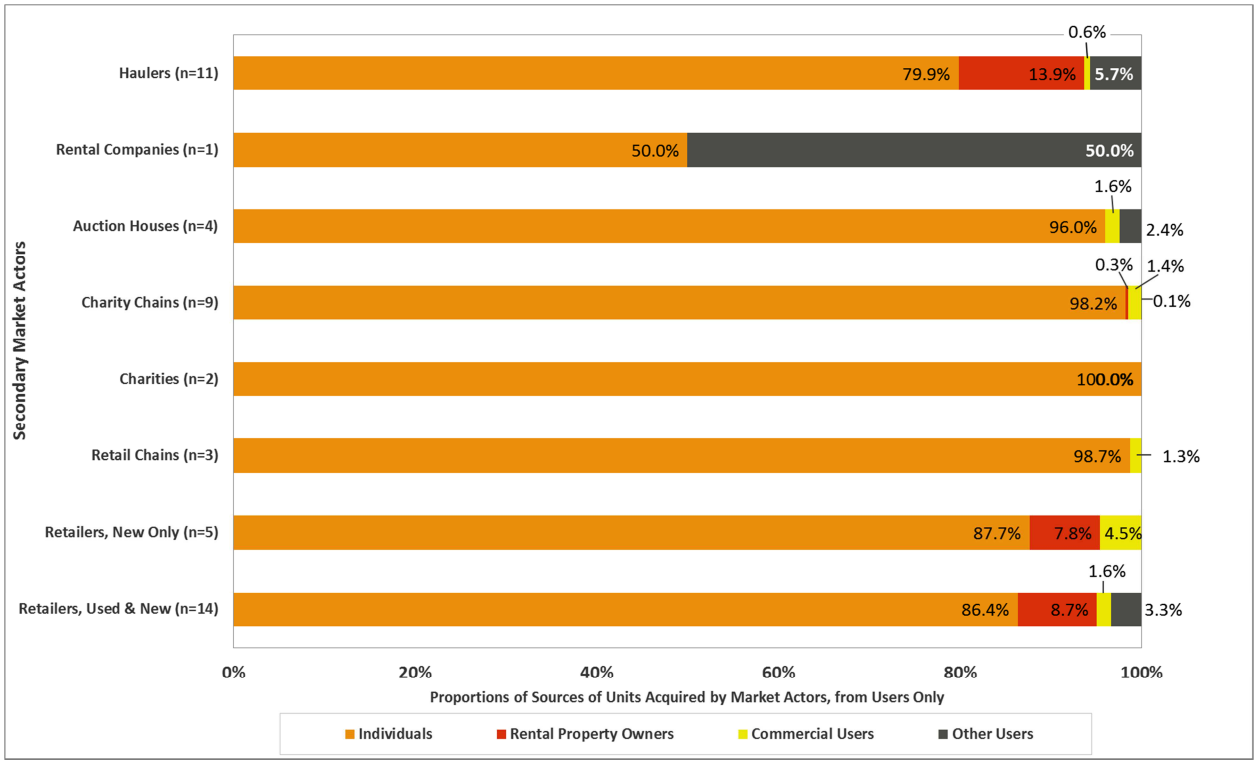
Figure 3. Annual Quantities Acquired by Market Actors from Various Sources



* Shaded area represents units reported to have been disposed of by users, directly; this is not, however, part of the "retail channel".

Some market actors reported receiving units from other market actors, or intermediaries. Since this interaction is somewhat complicated, it is tricky to determine the proportions of units that were discarded by the four user categories considered for this study. Using the results shown in Figure 3, the users that discarded the units that entered the retail channel were determined by distributing them according to the proportions acquired from users, only, by the market actor that had supplied them, as shown in Figure 4.

Figure 4. Proportions Received or Picked Up by Market Actors from Users, only



For those units that were acquired by one market actor from other market actor categories, as shown in Figure 3, the proportions of units reported by the second market actor to have been acquired directly from users, as shown in Figure 4, were used to estimate the units that originated from each user category for the first market actor. For instance, since auction houses reported that they acquired approximately 17 percent of units from independent retailers of new units, and 88 percent of units acquired from users by independent retailers of new units came from individuals, 88 percent of 17 percent, or 15 percent, of those second-hand units were assumed to have initially come from individuals.

Using the combined results of the interviews of eight market actor categories, the annual volume of used units entering the retail channel of the secondary market from users were estimated as shown in Table 56.

Table 56. Used Refrigerators/Freezers Entering Retail Channel from Users

Primary Sources of Used Units to Retail Channel (n=50)	Annual Volume of Used Refrigerators/Freezers		Proportions from Primary Sources, percent	
	Volume	Standard Error	Proportion	Standard Error
Individuals	90,514	16,331	92.3%	22.7%
Rental Property Owners	3,676	808	3.7%	1.0%
Commercial Users	1,632	911	1.7%	1.0%
Others[5]	2,255	501	2.3%	0.6%
Totals	**98,077**	**16,384**	**100%**	**22.7%**
Relative Precision		**2.1%**		**1.4%**

Later in the interviews, market actors were also asked to indicate the proportions of units that were then transferred to either users of second-hand refrigerators/freezers or to other market actors. In many cases, units were transferred to *other* market actors (e.g., retail chains sent all used units to appliance recyclers), so the proportions of units supplied by market actors to their final destinations differed from those that they had initially acquired from users. We also found that some of those interviewed indicated that they send units thought to have no retail value to junkyards or scrapyards.

Table 57. Annual Volume Exiting Retail Channel, in IOU Territories

Final Destinations of Used Units Leaving Retail Channel of Secondary Market (n=42)	Annual Volume of Used Refrigerators/Freezers		Proportions to Final Destinations, percent	
	Volume	Standard Error	Proportion	Standard Error
Individuals	56,139	28,135	57.2%	33.7%
Rental Property Owners	3,392	1,244	3.5%	1.6%
Commercial Users	1,729	725	1.8%	0.9%
Others	2,047	77	2.1%	0.6%
Recycled/Destroyed	34,770	1,260	35.4%	10.3%
Totals	**98,077**	**28,200**	**100%**	**34.7%**
Relative Precision		**3.6%**		**2.2%**

[5] Other includes units from housing foreclosures, abandoned storage units, contractors and anonymous drop-offs.

Upon removing those units that were recycled or destroyed by market actors, we present the number of units that are returned to users in Table 58.

Table 58. Annual Volume Returned to Users by Retail Channel, in IOU Territories

Final Destinations of Used Units Returned to Users by Retail Channel of Secondary Market (n=42)	Annual Volume of Used Refrigerators/Freezers		Proportions to Final Destinations, percent	
	Volume	Standard Error	Proportion	Standard Error
Individuals	56,139	28,135	46.5%	59.6%
Rental Property Owners	3,392	1,244	2.8%	3.1%
Commercial Users	1,729	725	1.4%	1.7%
Others	2,047	77	1.7%	1.4%
Totals	**63,308**	**28,172**	**100.0%**	**59.6%**
Relative Precision		**5.6%**		**3.8%**

For a graphical representation of the flow of units into and through the retail channel, a Sankey diagram is provided in Figure 5. The units 1) enter the retail channel of the secondary market from the top of the diagram, supplied by users to market actors, 2) change hands between market actors in the middle of the diagram, and 3) exit the market at the bottom of the diagram when they are either acquired by different users or recycled/destroyed.

In conclusion, the main findings regarding the annual quantities that enter the supply-side retail channel of the secondary market within IOU territories include:

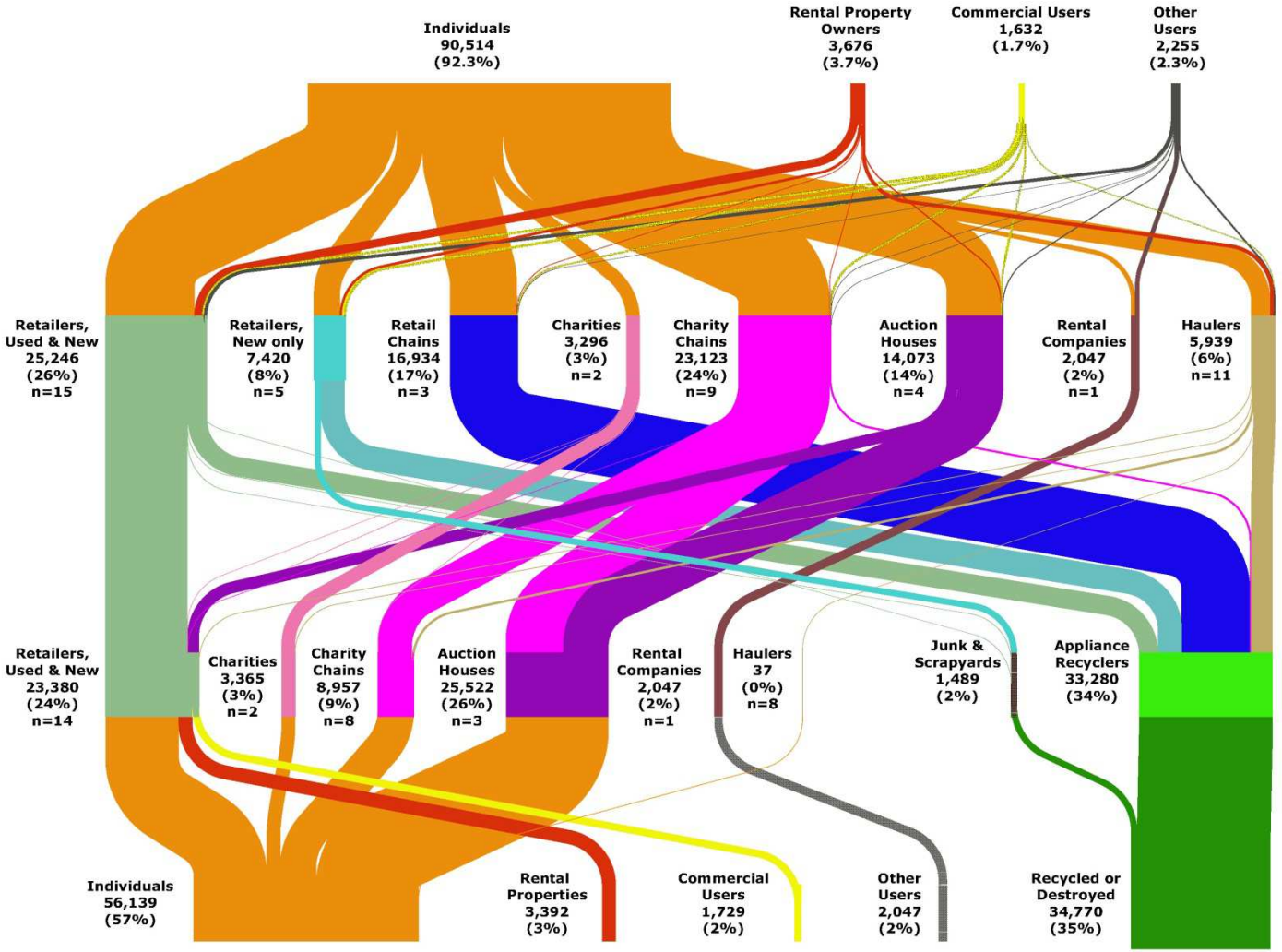
- Approximately 35 percent of the units taken in by market actors are recycled or destroyed.
- Auction houses initially acquire about 14 percent of the discarded units that enter the retail channel, but after receiving more units from charities, they ultimately sell about 40 percent of the units that are sold back to users.
- Used Retail stores account for about 37 percent of the units that are sold back to users.
- Charities, both independent and chains, account for about 20 percent of the units that are sold back to users.
- Although every market actor interviewed was asked how many units left California, nobody reported knowing of any units leaving the state.

Figure 5. Flow of Second-hand Units Through Supply-side Actors of Secondary Market

98,077 Second-hand Refrigerators & Freezers Enter the Retail Channel of the Secondary Market

Many are exchanged between Secondary Market Actors

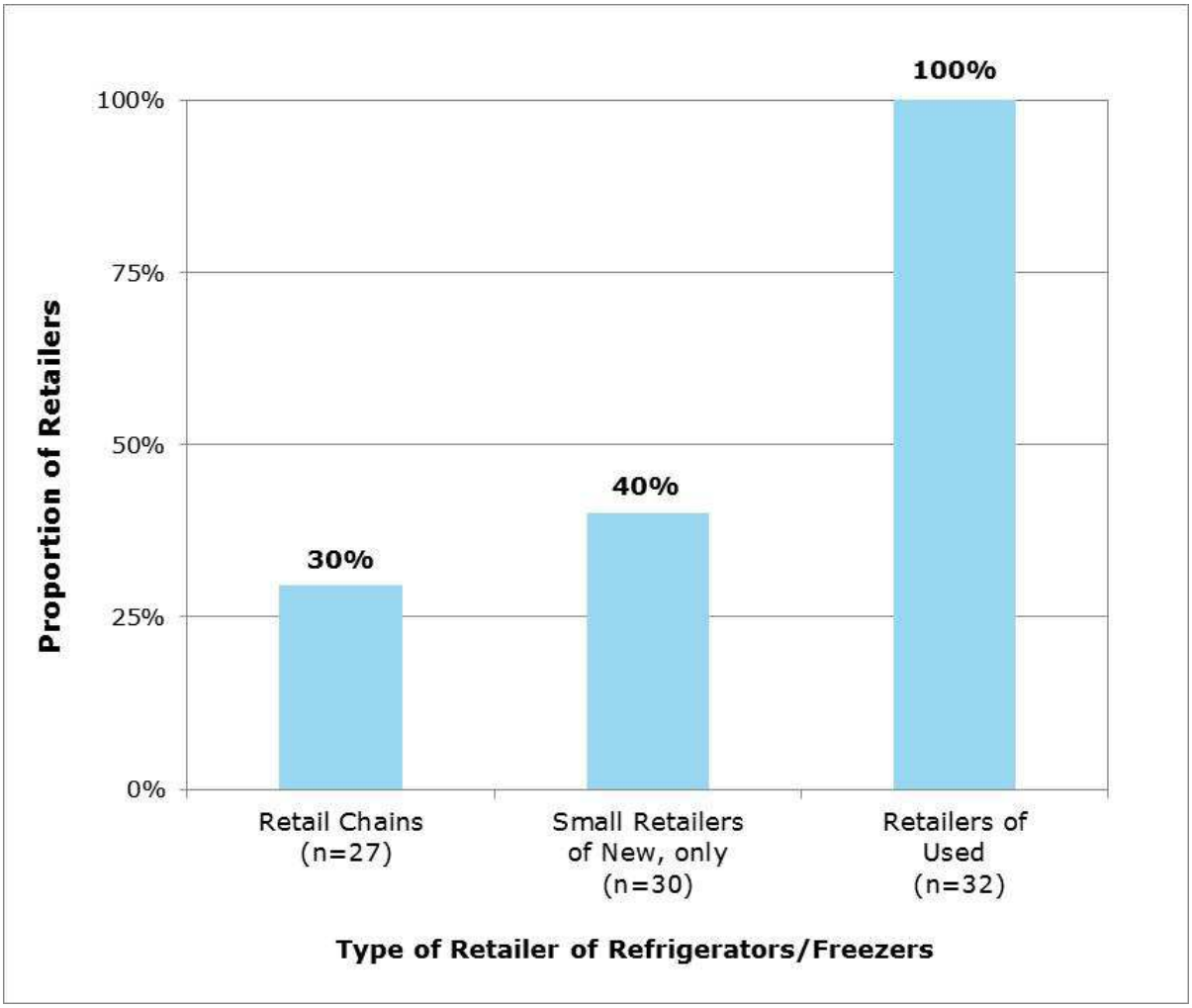
63,308 (65%) Return to Users Upon Leaving the Retail Channel



5.1.2 Collection of Used Units by Retailers

Since the Appliance Recycling program design considers the extent to which retailers pick up used units when a customer purchases a new unit, retailers were asked whether they do so. The results are shown in Figure 6.

Figure 6. Proportions of Retailers that Pick Up Used Units



5.1.3 Condition and Age of Incoming Units to Retail Channel

One of the key research questions for the secondary market study was to determine the criteria used by market actors when deciding whether to recycle or resell used units. The condition of the units that were considered to have market value, according to the market actors interviewed that sell used units, was important to determine the net-to-gross ratio. Figure 7 and Figure 8 shows the proportions of incoming units according to used retailers and charity chains,

respectively, by condition "bin" and, of those, the proportion that were not resold, but recycled or disposed of.

Figure 7. Condition of Incoming Used Units to Used/New Retailers

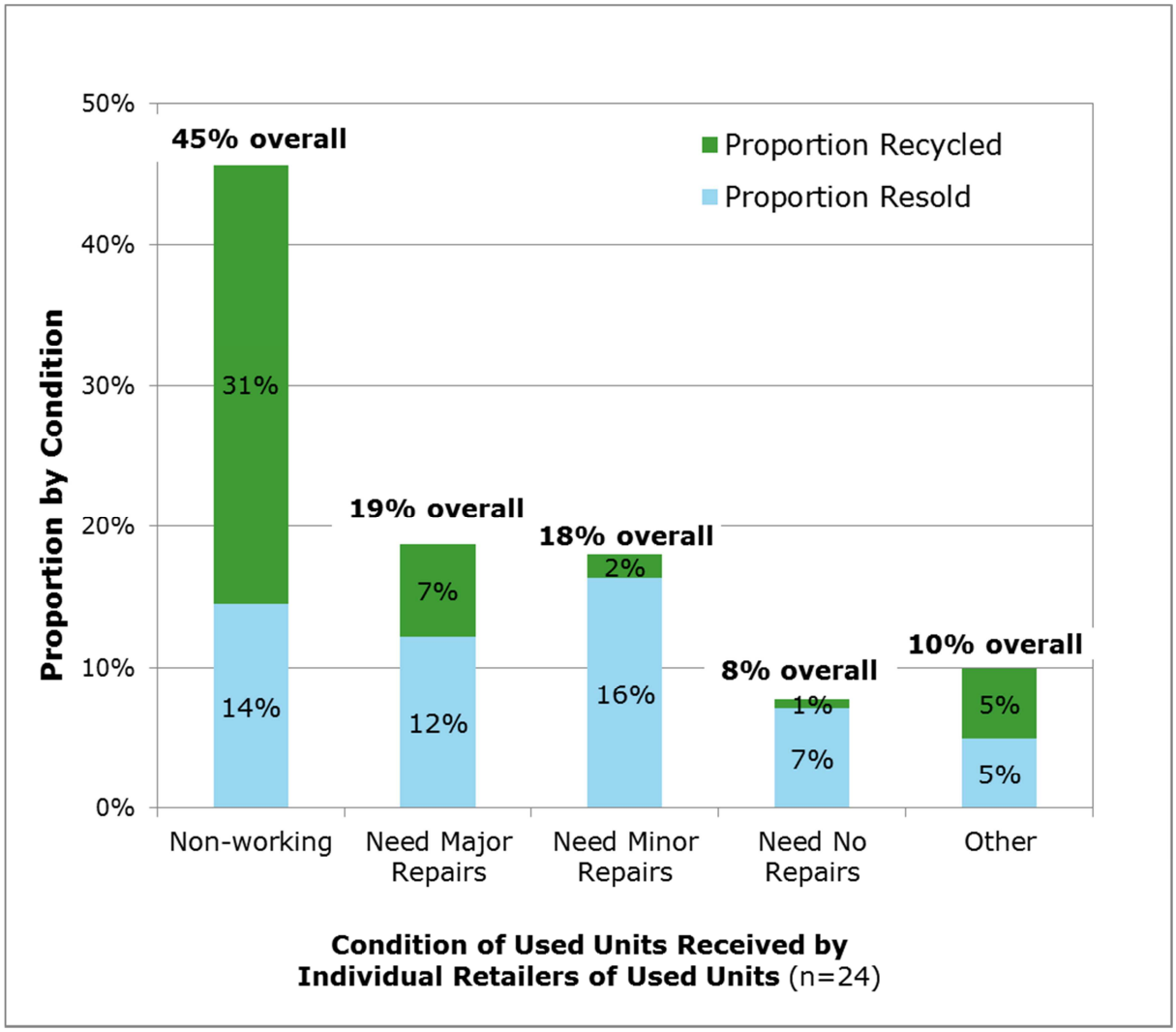
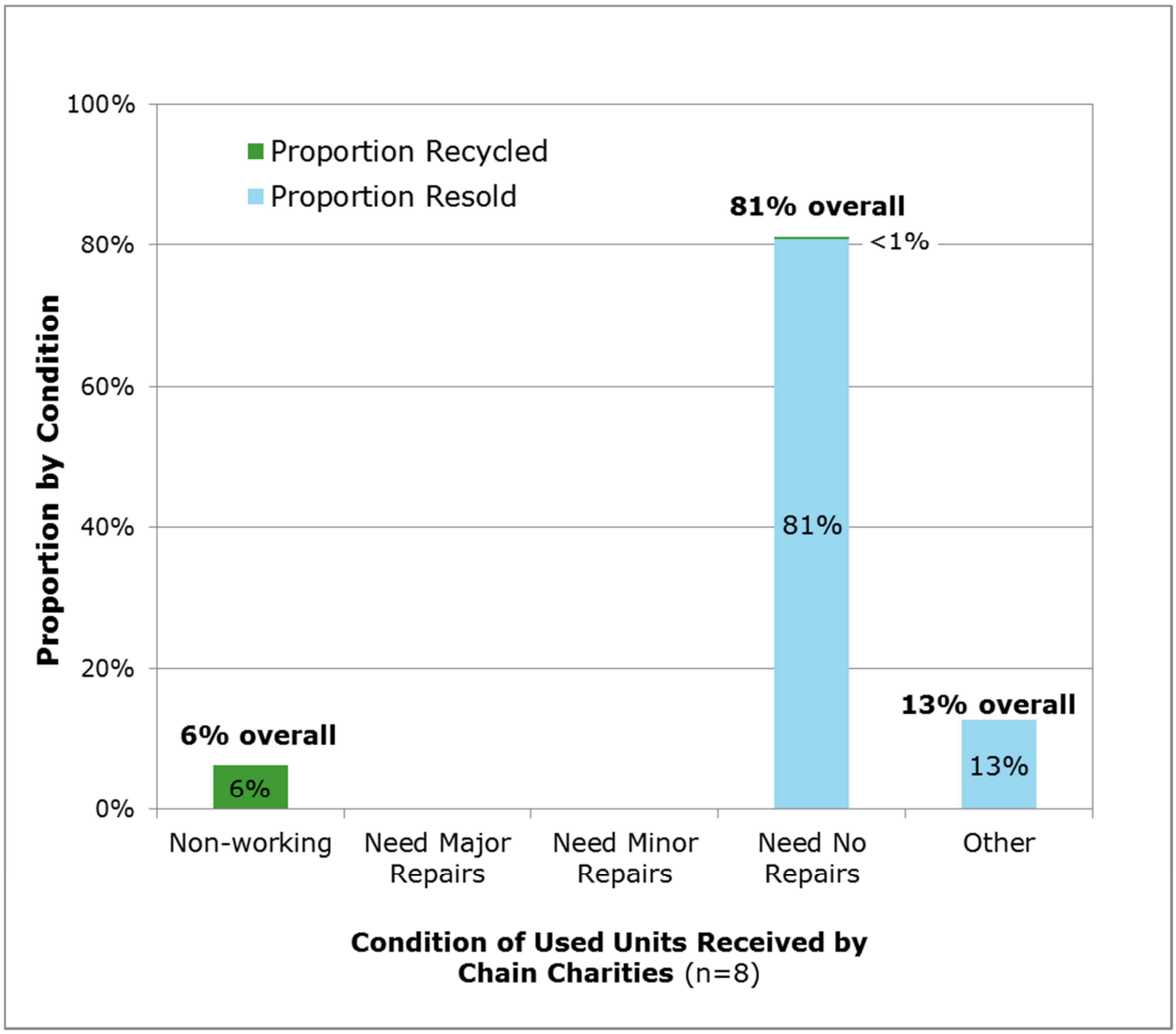


Figure 8. Condition of Incoming Used Units to Charity Chains

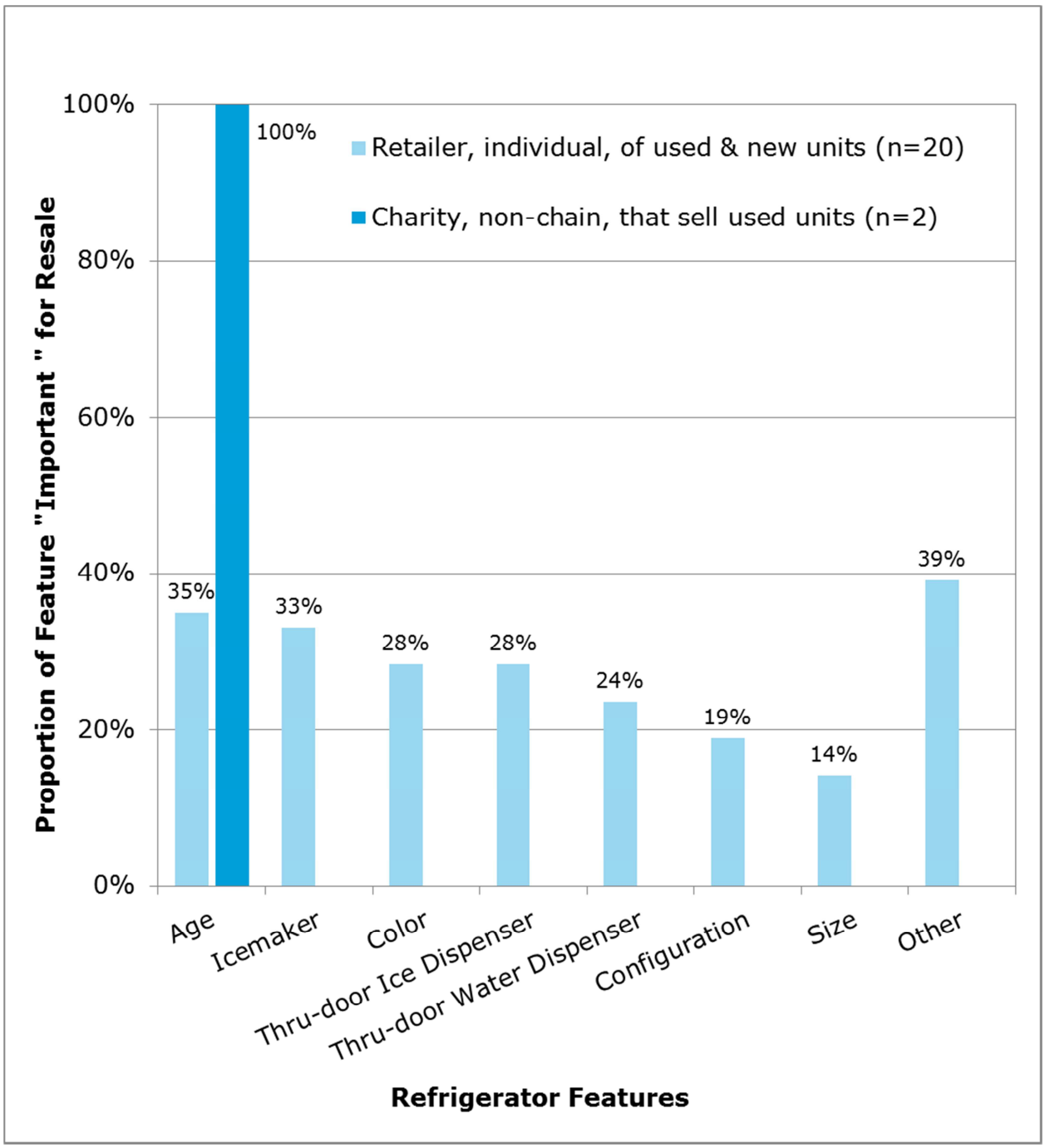


The charity chains interviewed did not report receiving units that needed repairs, and only reported 6% that were non-working. It is expected that this market actor would lack the technical acumen to assess the extent of repairs needed and would simply send a non-working unit directly to an appliance recycler.

5.1.4 Importance of Unit Attributes to Retailers

While not a critical finding, we thought it would be interesting to ask market actors about the refrigerator/freezer characteristics and attributes that are valued by buyers in the secondary market. Market actors were asked to indicate which were important to them, by answering "yes" or "no" to each prompt, as shown in Figure 9.

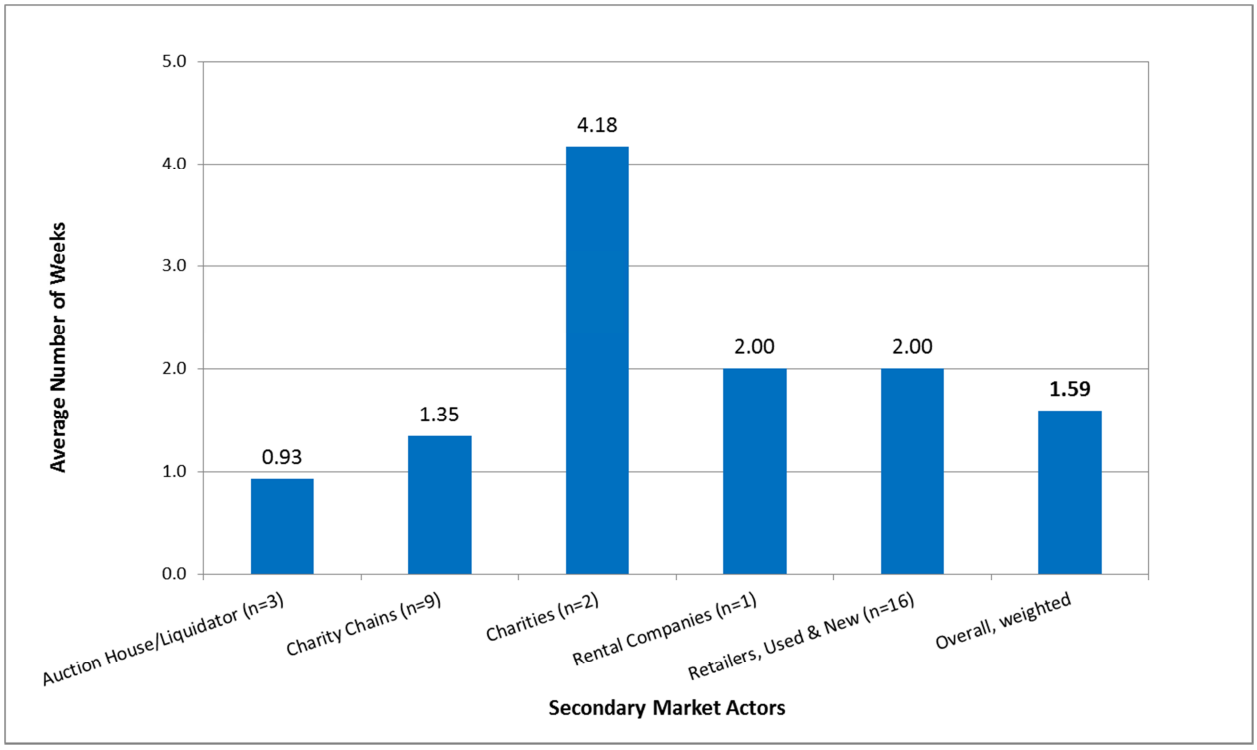
Figure 9. Importance of Various Attributes to Resellers of Used Units



5.1.5 Sales Information Provided by Market Actors

While not a key research question, we explored the average length of time that each market actor finds necessary to sell used units. Figure 10 shows the average length of time, in weeks, by market actor. Across the market actor categories and weighted by annual volume of used units, a used unit takes an average of less than two weeks to sell.

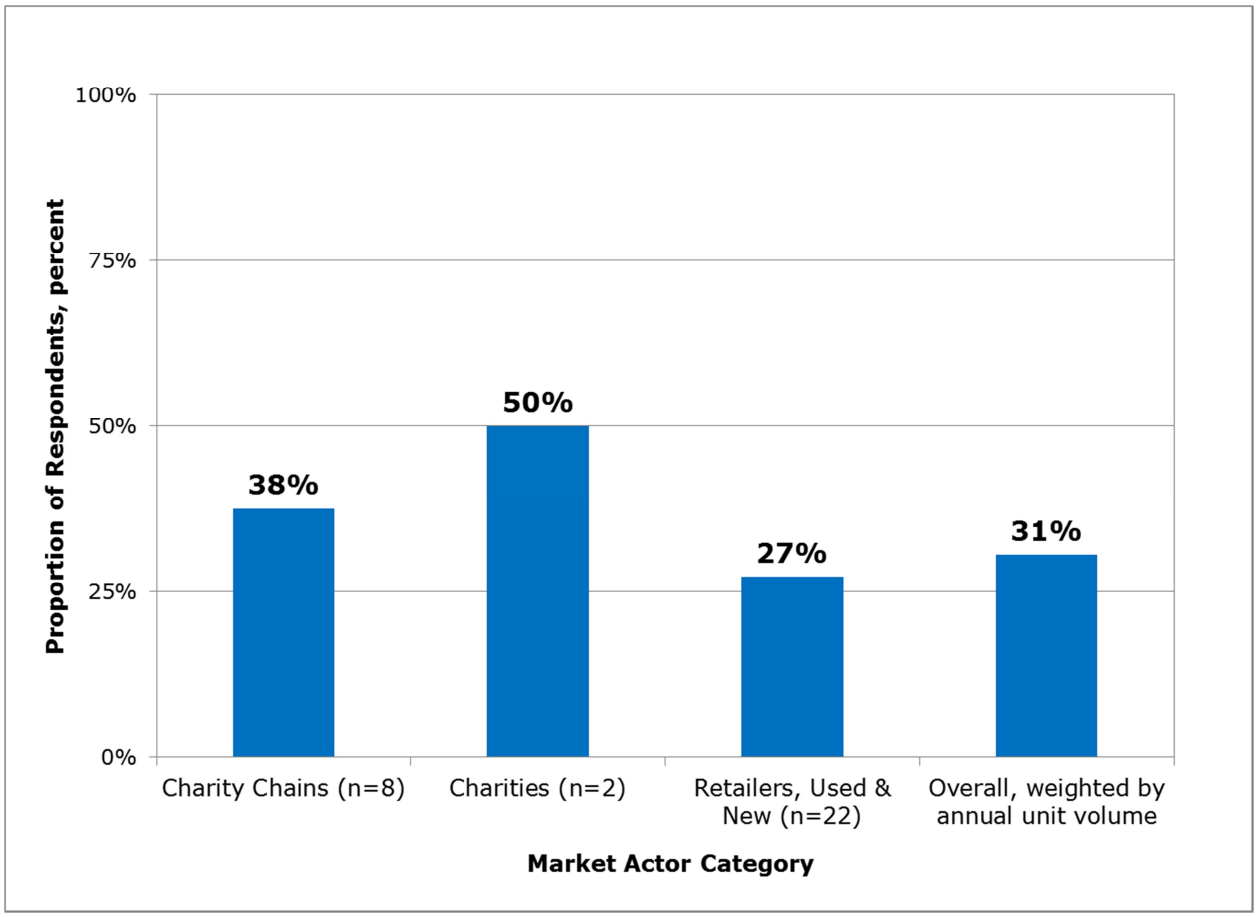
Figure 10. Average Time to Sell Used Units



If the program were to try to intercept the units at the auction houses, quick action would be required since they sell the units in less than one week, on average.

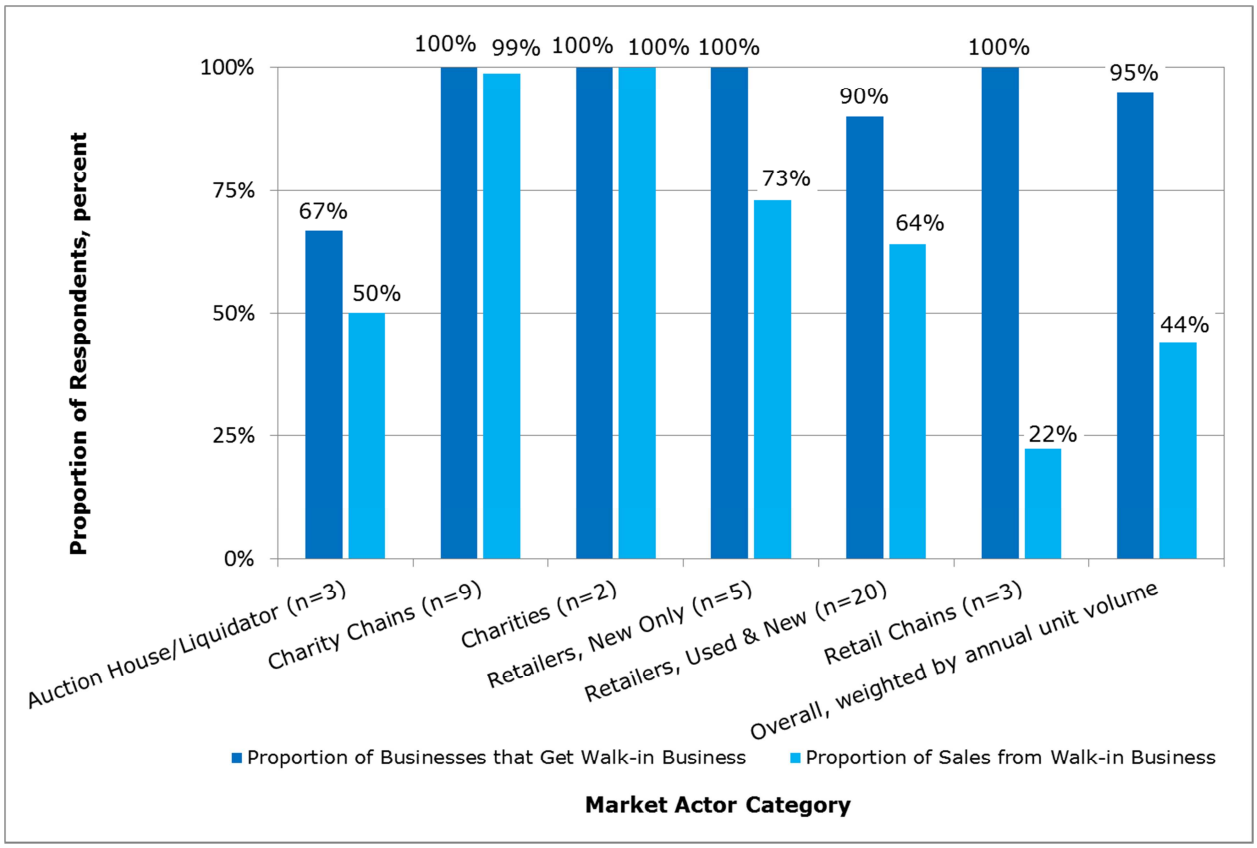
Interviewees were also asked what proportion of customers shopping for used units had viewed Craigslist prior to visiting their place of business. The responses are shown in Figure 11.

Figure 11. Proportion of Customers That Had Viewed Craigslist Prior to Visit



They were also asked to indicate what proportion of customers were walk-in customers and, from there, what proportion of their sales resulted from walk-in customers. These results are shown in Figure 12 by market actor category.

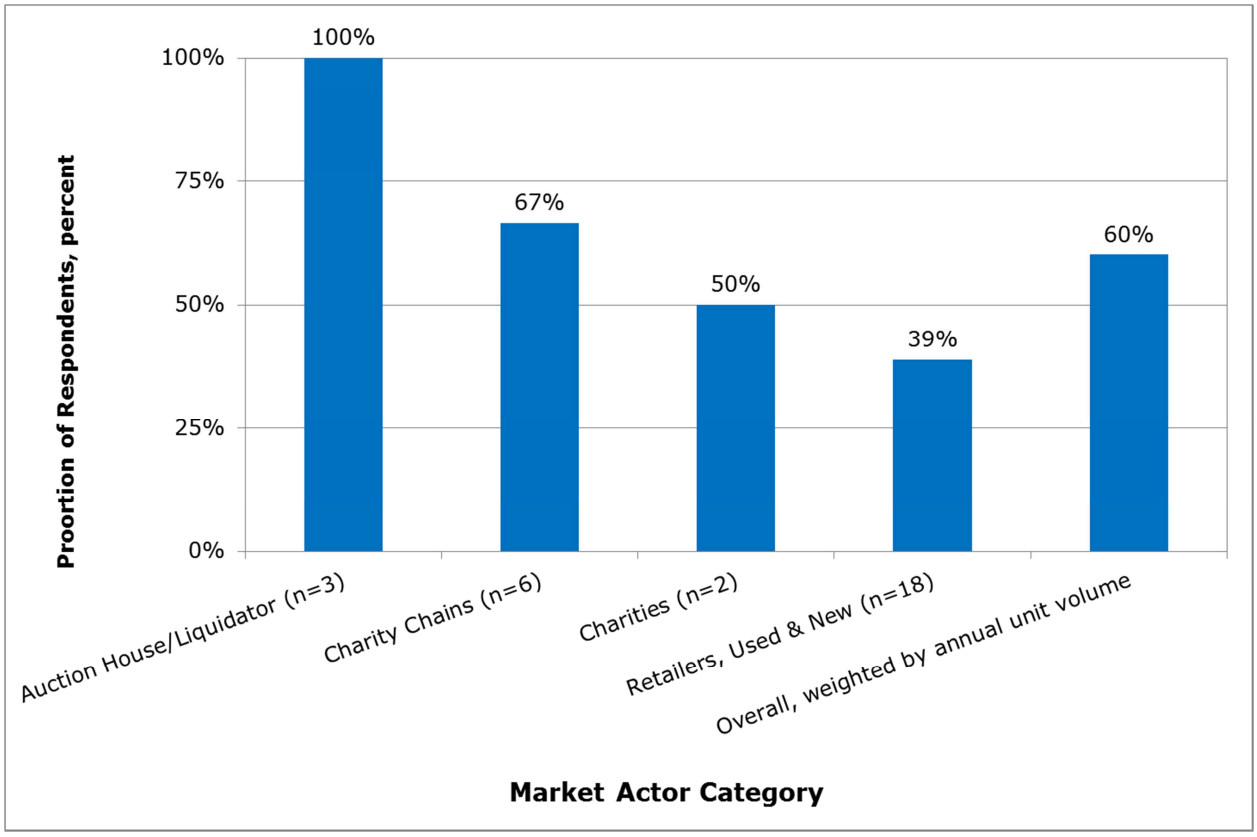
Figure 12. Proportion of Walk-in Customers and Resulting Sales



5.1.6 Advertising Means Used by Retail Channel

Since Craigslist was found to be a major means of advertising to sell used refrigerators/freezers, market actor interviewees were asked whether they advertise on this website. The proportions that do are shown in Figure 13.

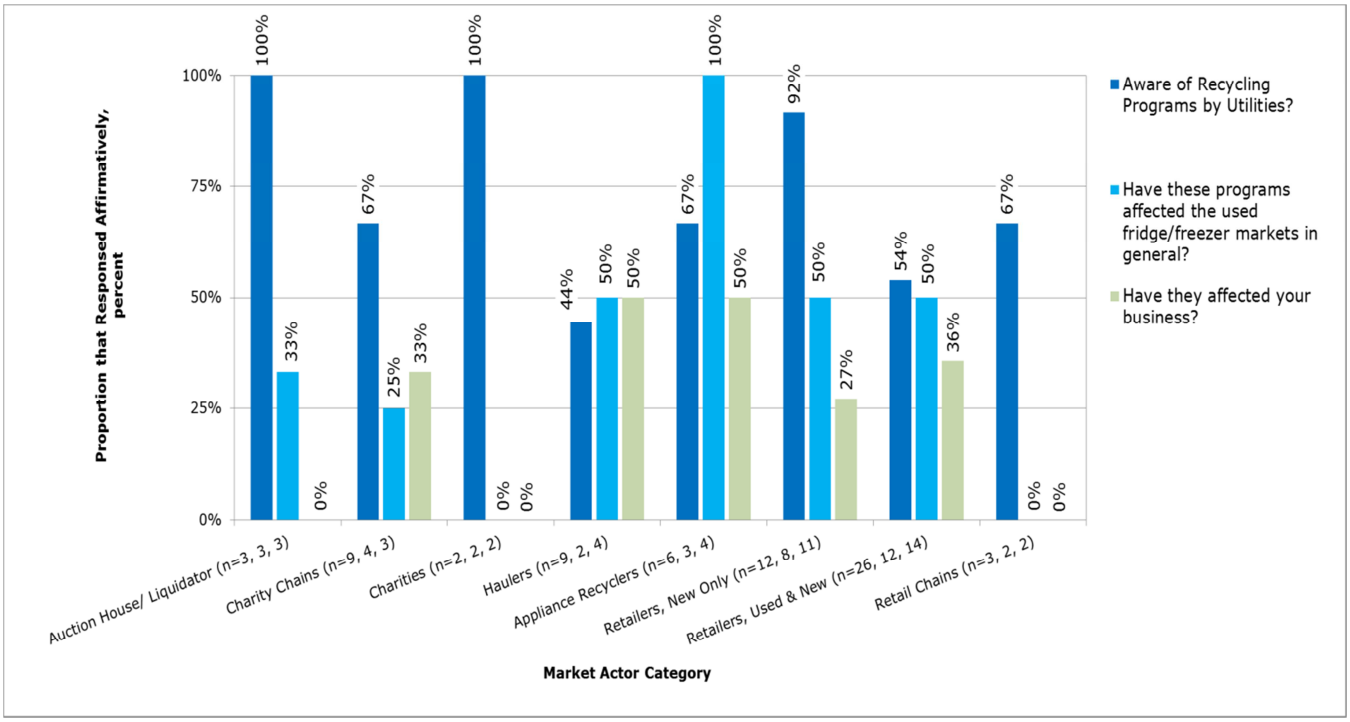
Figure 13. Proportion of Market Actors that Advertise on Craigslist



5.1.7 Program Awareness and Market Shifts in Retail Channel

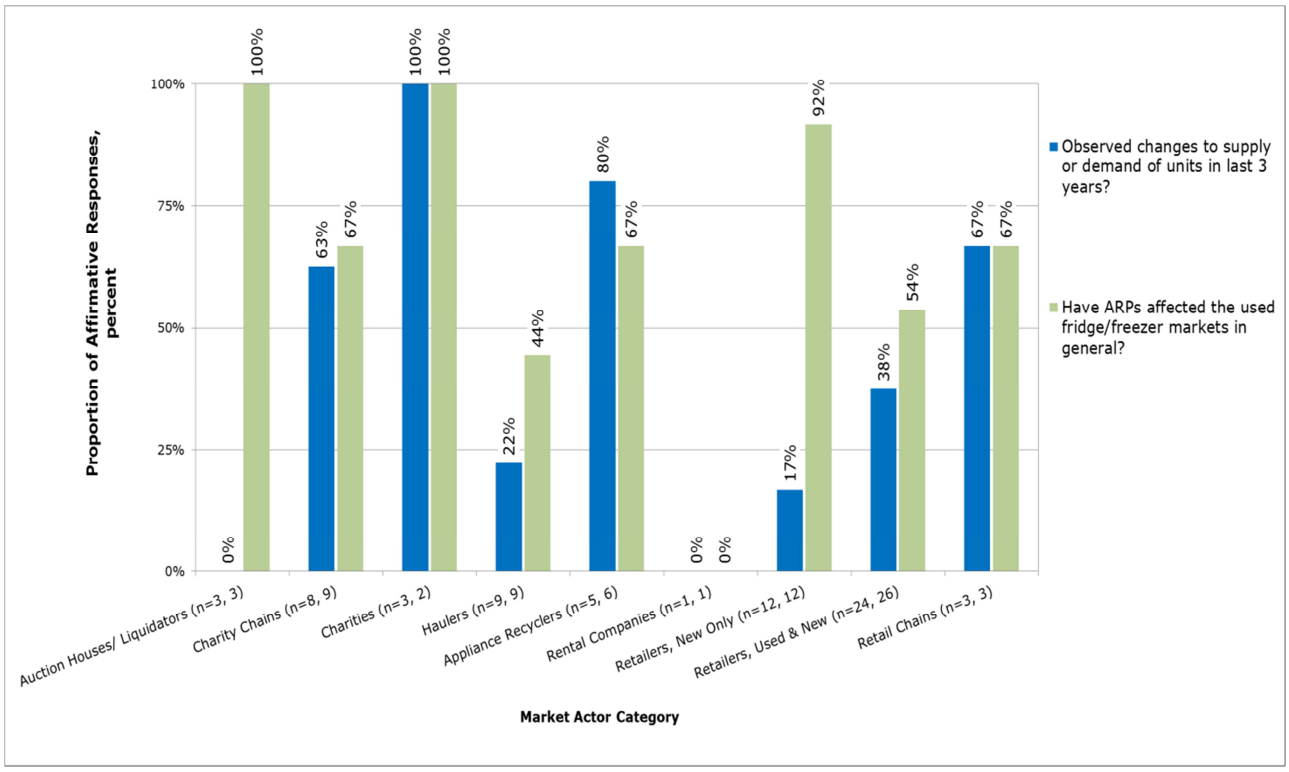
Each market actor interviewed was asked whether they were aware of the appliance recycling program offered by their IOU. If so, they were asked 1) whether they thought that the program had affected the secondary market as a whole, and 2) whether the program had impacted their business. The proportions of those interviewed that responded with a "yes" are shown in Figure 14.

Figure 14. Market Actor Awareness of IOU Appliance Recycling Program



The market actors were also asked whether they had noticed changes to the secondary market over the last three years. The proportions that indicated that they had are shown in Figure 15. Among the charities that had experienced changes, they reported receiving fewer donations of refrigerators per year than they used to and almost no donations of freezers any more. Other market actors indicated that, for as long as the economy has been weak, the number of customers looking for used units had increased.

Figure 15. Market Actors that Reported Secondary Market Changes



5.2 Peer-to-Peer Channel

5.2.1 Size of Peer-to-Peer Channel on Craigslist

Over a period of ten months, slightly more than 404,000 individual posts were collected from Craigslist forums throughout the state of California. This was accomplished by subscribing to all the Craigslist RSS feeds in California and searching for combinations of words (and frequent miss-spellings) for refrigerators and freezers. Due to the combined size of the saved Craigslist posts and the complexity of the algorithm to assess whether each posting was relevant and to extract basic unit characteristics, it was necessary to select a random sample of 143,000 posts, which were used for the analysis to estimate the size of the peer-to-peer channel. To do so, we used the following information:

- Upon examination, we determined that 66.3% of the sampled postings were unique and qualified as sales of used refrigerators or freezers. Of those, 68% were unique postings from individuals and 32% were posted by dealers. Unfortunately, since dealers often re-issue posts, we were unable to identify "unique" appliances that were being sold by dealers within the analysis budget for this task.

- Using 2010 US Census Data and the number of individually-metered electric accounts in IOU territories, we estimated that 92.1% of the Craigslist postings originated within IOU territories.
- There is no guarantee that a unit posted for sale will actually be sold or transferred to another location on the grid, so the actual number of transferred units is expected to be somewhat lower than the total of nearly 216,000 used refrigerators and freezers per year.

In Table 59, we estimate the size of the peer-to-peer channel of the secondary market by expanding the qualifying sampled feeds to the IOU territory population.

Table 59. Estimated Peer-to-Peer Market Volume through Craigslist

Advertisements in Craigslist Sample (n=143,000)	Estimated Annual Volume	Proportion
Qualified CA Advertisements in Sample	85,800	66%
Breakdown of CA Ads Analyzed		
CA Ads by Dealers	27,500	32%
CA Ads by Individuals, unique	58,300	68%
Ads by Individuals in IOU Territories, annually		
Unique Ads Posted Annually	215,893	-

Table 60 shows the estimated population for the entire peer-to-peer channel. This was derived using responses from the non-participant acquirers coupled with the estimated Craigslist population above. Proportions from the non-participant acquirers' survey were used to calculate the volume in each response category.

Table 60. Estimate of Peer-to-Peer Market Volume in IOU Territories

Second-hand Unit Sources Reported by Acquirers	Response Proportions	Estimated Annual Volume
From Craigslist Transfers (n= 92)	22.16%	215,893
From a person they knew, e.g. family, friend or neighbor (n= 245)	65.50%	478,598
Already in residence, e.g. moved into a new location with unit present (n= 46)	12.34%	90,166
Total Peer-to-Peer Volume	100.0%	784,657

5.2.2 Characteristics of Units on Peer-to-Peer Channel

The limited budget available for analysis of the data gathered from Craigslist did not allow for a thorough examination of the Craigslist market. However we attempted to estimate a few pertinent characteristics. Using the data gathered from the RSS feeds, we were able to identify the average advertised asking price, across postings by both dealers and individuals, and average unit size as shown in Table 61. Units offered for free were excluded when calculating the average advertised asking price.

Table 61. Characteristics of Units offered for Sale on Craigslist

Characteristics	Mean Value
Advertised Price	$250
Unit Size	19.25 cu. ft.

5.3 Overall Volume in the Secondary Market

Using the results presented from the studies of the retail and peer-to-peer channels of the secondary market and the study of consumer choices using participant and non-participant surveys, we estimated the combined annual volume of units in the second-hand market to be approximately 850,000 as shown in Table 62. Since we expect that not all Craigslist advertisements lead to transfers, the total number of secondary market transfers may be somewhat lower. It is important to bear in mind that these results are for informational purposes, only, and are not used in the impact analysis.

Table 62. Annual Volume of Units Transferred in the Second-hand Market

Disposition path	Proportion of Second-hand Market	Second-hand Market Volume
Peer-to-Peer Transfers	92%	784,657
Retail Channel Transfers to Users	8%	68,703
Total Secondary Market Transfers	**100%**	**853,360**

In a related study, the annual size of the 2012 statewide second-hand market for refrigerators and freezers, combined, appears to have been estimated to be approximately 1,350,000.[6] Further in the report, the number of units discarded in 2012 was approximately 350,000 and 273,000 in SCE and PG&E territories, respectively.[7]

[6] The Cadmus Group, *Appliance Recycling Program Process Evaluation and Market Characterization, Volume 1* (for Southern California Edison and Pacific Gas and Electric, CALMAC Study ID SCE0337.01, 2013), 91-92. See Section 5.1.3.

[7] Ibid., 112 & 114.

6. Overall Program Impacts & Recommendations

6.1 Program Impacts

Table 63 and Table 64 show the final gross and net impacts, NTGR, and realization rate for refrigerators and freezers recycled through the program, by IOU and statewide. These tables combine the per unit savings reported in Table 51 with the verified number of units reported in Table 28.

For refrigerators, *ex post* savings were estimated at about 70% of *ex ante* claims. Most of the difference is driven by lower evaluated gross savings estimates, mostly attributable to the trend of decreasing age of recycled units, with NTGRs from the evaluation being similar or somewhat higher than IOU estimates. The evaluation savings reduction for SDG&E is much larger than for PG&E and SCE, which a combined result of SDG&E's higher unit savings claim and the fact that recycled units in the SDG&E area tend to be much newer units than those recycled by PG&E and SCE.

For freezers, *ex post* savings estimates are about 13% higher than *ex ante* estimates. This increase was mainly due to verification analysis, which found that in some cases recycled freezers were misclassified as refrigerators in the IOU tracking data. The correction caused an upward adjustment in freezer counts and a corresponding downward adjustment in refrigerator counts. *Ex ante* and *ex post* NTGRs were similar.

Table 63: Refrigerator Gross and Net Annual Electric Impacts - kWh

IOU	Evaluation Result	*ex ante* (kWh)	*ex post* (kWh)	Realization Rate	Precision at 90% confidence
PG&E	Gross Savings, kWh	41,137,792	27,877,172	0.68	±26%
	NTGR	0.61	0.67		
	Net Savings, kWh	25,094,053	18,804,152	0.75	±28%
SCE	Gross Savings, kWh	153,059,770	93,620,340	0.61	±25%
	NTGR	0.62	0.68		
	Net Savings, kWh	94,131,759	63,606,906	0.68	±26%
SDG&E	Gross Savings, kWh	39,149,035	14,540,681	0.37	±26%
	NTGR	0.61	0.69		
	Net Savings, kWh	24,037,507	9,966,448	0.41	±28%
Statewide	Gross Savings, kWh	233,346,597	136,038,193	0.58	±25%
	NTGR	0.61	0.68		
	Net Savings, kWh	143,338,807	92,377,506	0.64	±27%

Table 64: Freezer Gross and Net Annual Electric Impacts - kWh

IOU	Evaluation Result	*ex ante* (kWh)	*ex post* (kWh)	Realization Rate	Precision at 90% confidence
Statewide	Gross Savings, kWh	22,193,427	21,438,815	0.97	±18%
	NTGR	0.7	0.75		
	Net Savings, kWh	15,535,399	16,037,661	1.21	±21%

Overall, at the program level the evaluation team found that approximately 32% of the refrigerators and 25% of the freezers would have been destroyed in the absence of the program, leading to net-to-gross ratios (NTGRs) of approximately 68% and 75%, respectively. In PG&E territory, a higher proportion of discarder survey respondents reported discarding refrigerators onto the second-hand retail market or destroying them directly. It is believed that some of this difference is driven by the older age of the units being recycled by PG&E program participants.

This resulted in a larger proportion of PG&E units ending up in the "Destroyed" disposition paths, thereby driving down NTGR for PG&E, somewhat compared to the other IOUs.

Table 65 and Table 66 combine the verification results with the per unit gross and net peak demand savings estimates to produce program-level estimates of gross and net demand savings. These savings estimate are compared to the *ex ante* gross and net demand savings. The realization rate, comparing *ex post* gross peak demand savings to *ex ante* gross peak demand savings, is also provided.

Table 65: Refrigerator Gross and Net Peak Demand Impacts - kW

IOU	Evaluation Result	*ex ante* (kW)	*ex post,* (kW)	Realization Rate	Precision at 90% confidence
PG&E	Gross Savings, kW	9,141	6,194	0.68	±26%
	NTGR	0.61	0.67		
	Net Savings, kW	5,576	4,178	0.75	±28%
SCE	Gross Savings, kW	29,641	18,130	0.61	±25%
	NTGR	0.62	0.68		
	Net Savings, kW	18,229	12,318	0.68	±26%
SDG&E	Gross Savings, kW	6,090	2,262	0.37	±26%
	NTGR	0.614	0.69		
	Net Savings, kW	3,739	1,550	0.41	±28%
Statewide	Gross Savings, kW	44,872	26,587	0.59	±25%
	NTGR	0.61	0.68		
	Net Savings, kW	27,544	18,047	0.66	±27%

Table 66: Freezer Gross and Net Peak Demand Impacts - kW

IOU	Evaluation Result	*ex ante* (kW)	*ex post* (kW)	Realization Rate	Precision at 90% confidence
Statewide	Gross Savings	4,395	4,305	0.98	±18%
	NTGR	0.70	0.75		
	Net Savings	3,077	3,221	1.05	±21%

Table 67 and Table 68 repeat this comparison of *ex ante* to *ex post* values for the interactive effects for refrigerators and freezers.

Table 67: Refrigerator Gross and Net Interactive Effects - therm

IOU	Evaluation Result	*ex ante* (therms)	*ex post* (therms)	Realization Rate	Precision at 90% confidence
PG&E	Gross Effects, therm	-414,597	-280,953	0.68	±26%
	NTGR	0.61	0.67		
	Net Effects, therm	-252,904	-189,513	0.75	±28%
SCE	Gross Effects, therm	-3,214,568	-1,966,212	0.61	±25%
	NTGR	0.62	0.68		
	Net Effects, therm	-1,976,959	-1,335,870	0.68	±26%
SDG&E	Gross Effects, therm	-386,649	-143,609	0.37	±26%
	NTGR	0.61	0.69		
	Net Effects, therm	-237,402	-98,432	0.41	±28%
Statewide	Gross Effects, therm	-4,015,814	-2,390,773	0.60	±25%
	NTGR	0.61	0.68		
	Net Effects, therm	-2,467,266	-1,623,815	0.66	±27%

Table 68: Freezer Gross and Net Interactive Effects - therm

IOU	Evaluation Result	*ex ante* (therms)	*ex post* (therms)	Realization Rate	Precision at 90% confidence
Statewide	Gross Effects, therms	-346,086	-300,264	0.87	±18%
	NTGR	0.70	0.75		
	Net Effects, therms	-242,260	-224,618	0.93	±21%

6.1.1 Comparison of Per-unit Gross Energy Savings

For the past several evaluation cycles, a downward trend in energy savings from recycled units has been seen. The 2006-2008 evaluation found that a substantial change in the population of recycled units had taken place, where for the first time a significant portion of the eligible appliances were manufactured after the DOE's first appliance efficiency standard became effective (1993). This evaluation found that this trend is continuing, driving the average energy use of recycled units even lower as greater proportions are manufactured subsequent to the appliance standard.

For all three IOUs, the mean manufacturing year of recycled units is less than the span since the implementation of the appliance standard. For SGE&E, this was especially noticeable, where the mean age reported for recycled units was only 13.5 years, compared to 18.1 years for SCE and 21.5 years for PG&E. Although the claimed energy savings for all three IOUs were lower than in previous program cycles, the per unit energy savings for all three IOUs still failed to keep pace with the efficiency improvements in recycled stock due to this change in the proportion of post-standard units. For SDG&E particularly, the discrepancy between high claims and low *ex post* savings was quite high. Table 69 shows the difference between the *ex ante* and *ex post* gross and net savings for each IOU.

Table 69: Comparison of *Ex Ante* and *Ex Post* per Unit Gross and Net Savings

IOU	*Ex Ante* Gross Unit Savings	*Ex Post* Gross Unit Savings	*Ex Ante* Net Unit Savings	*Ex Post* Net Unit Savings
Refrigerators				
PG&E	738	510	450	344
SCE	835	519	514	352
SDG&E	957	360	588	247
Freezers				
PG&E	565	771	395	577
SCE	963		674	
SDG&E	720		504	

6.2 Recommendations

6.2.1 In Situ Metering

Like the 2006-2008 evaluation, this evaluation team recommends continuing the use of in situ metering to evaluate the energy savings from appliance recycling in lieu of laboratory metering. Unlike laboratory metering, where the metering conditions are highly artificial, in situ metering is better suited to capture the real world conditions and the impact on energy consumption to provide a more accurate representation of the actual energy savings achieved by the appliance recycling program. Additionally, the potential uncertainty introduced through transport of older appliances to the testing location, makes the value of laboratory metered consumptions more suspect. Laboratory metering is a much more expensive metering option and drives up evaluation costs without improving accuracy. Reallocating evaluation dollars to increase the scope of in situ metering would be beneficial to future evaluation efforts.

6.2.2 Improve the Quality of Tracking Data

The data collected for recycled appliances should be improved. Accurate data about unit characteristics such as configuration, age, size and model number is critically important in estimating gross savings. Not all data was recorded for each appliance, and in addition, there

were differences by IOU in the data collected that made meaningful comparisons more difficult. For example, age of the recycled unit was collected as "years old" by one IOU, as a manufacturing year bin (recorded as a single manufacturing age, but review of program tracking data showed that all units were manufactured in exactly four evenly spaced years), or as a real manufacturing year, that varied individually for each appliance recycled. In addition, data collected by the implementers did not contain a unique identifying key connected to program tracking data. The evaluation team strongly recommends that the utilities work with the implementing subcontractors to ensure that accurate and specific data is collected about each recycled appliance, and that this data is linked to the final program tracking data with a unique key present in both data sets.

6.2.3 Include Environmental Benefits in Program Cost-effectiveness

Quantify the environmental benefits from avoided greenhouse gas emission, such as captured CFCs from insulation and refrigerant through the recycling process, and reuse/resale of materials, such as scrap metal, and include these benefits in the cost-effectiveness calculations for appliance recycling. Energy Division guidelines for the Appliance Recycling program should be revised to allow IOUs to include these benefits.

6.2.4 Role of Auction Houses in the Secondary Market

Study the role of auction houses and liquidators more closely and determine whether there is an opportunity for the program to play a role in removing these units from resale on the retail market. This evaluation found that nearly 40% of the units sold back onto the grid passed through auction houses. By targeting this market actor, groups of units could be efficiently removed from the grid.

6.2.5 Further Study the Peer-to-Peer Market

The magnitude of the peer-to-peer market channel dwarfs other market forces in the second-hand market. Unfortunately this market segment is very difficult to study, and traditionally research into the second-hand market focuses on the retail channel, which can be more easily located. The original research plan for this evaluation did not include a peer-to-peer component, however as the magnitude of the sector became apparent, attempts were made to include and explore it. Analysis funds were not sufficient to fully study the data collected, and additional data could be easily gathered using the methodology developed in the course of this evaluation.

6.2.6 Revise Program Criteria to Limit Program Eligibility

The base efficiency of refrigerators and freezers has increased significantly since the program was first designed. As the proportion of refrigerators and freezers manufactured since the

appliance standards were enacted increases, the program savings declines. The most recent appliance standard was implemented in 2001, restricting program eligibility to units manufactured close to this year will help slow this trend of declining savings.

6.2.7 Explore the Use of AMI Data to Target Program Activities

As the availability of AMI meter data and equipment disaggregation models become more sophisticated, consider revising program design to identify and target program actions. Meter data could be used to identify households with high consuming appliances and target marketing efforts and potentially bundled services such as combined recycling and rebates for efficient appliances.

6.2.8 Confirm and Expand Program Bundling

Where applicable and not already present, make sure that programs promoting purchase of efficient appliances contain information about appliance recycling to help increase customer awareness of the program and promote bundling of program services.

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