ARPs are RAD: How to Incorporate Environmental Benefits from Appliance Recycling Programs into Cost-Effectiveness Calculations

Josh Keeling, Cadmus, Portland, OR
Arnab Pal, Cadmus, Portland, OR
Caroline Chen, StatWizards LLC, Rosemead, CA

ABSTRACT

Utility-sponsored appliance recycling programs (ARPs) serve as a critical part of residential energy-efficiency programs across the country. These programs have proven reasonably cost-effective, given their high savings rates and their low implementation costs. Still, as programs mature—and as an increasing proportion of the participating appliances have been manufactured after the National Appliance Energy Conservation Act standards—reductions in energy benefits result in decreased benefit-cost ratios. Even though non-energy benefits often can be factored into Total Resource Cost and Societal Cost tests, typically they are not included for most programs. Environmental benefits in particular—a major non-energy ARP impact—have largely been ignored in cost-effectiveness calculations.

This paper provides program administrators and evaluators with a methodology that easily can be incorporated into a typical appliance program evaluation at little additional cost. A case study, drawn from work recently conducted for Southern California Edison, showcases this approach and its potential benefits.

Introduction

Utility-sponsored appliance recycling programs (ARPs) serve as a critical part of residential energy-efficiency programs across the country. In the past, these programs have been reasonably cost-effective, due to their high savings rates and their low implementation costs. Still, as programs have matured—and as an increasing proportion of participating appliances have been manufactured after the National Appliance Energy Conservation Act standards—reductions in energy benefits have resulted in decreased benefit-cost ratios. However, cost-effectiveness tests typically fail to account for all non-energy benefits (NEBs) associated with ARPs, even though these benefits often can be incorporated into Total Resource Cost (TRC) and Societal Cost tests. In particular, cost-effectiveness calculations generally have not included environmental benefits—a major non-energy impact resulting from ARPs.

Typical ARPs recycle 95% of materials in a responsible manner. The appliance recycling process includes the following:

- Recycling metals (steel, aluminum, and copper), for industrial uses;
- Recycling glass for alternative purposes;
- Recycling plastic; and
- Recycling or responsibly disposing of hazardous materials.

In accordance with the U.S. Environmental Protection Agency's (EPA) Responsible Appliance Disposal (RAD) protocol, recycling decommissions refrigerant from appliances in an environmentally safe manner, avoiding greenhouse gas (GHG) emissions. In 2006, EPA developed the RAD protocol as voluntary guidelines, designed to encourage market actors to adopt more environmentally responsible disposal practices. The program also meant to boost perceived low compliance rates with existing state and local regulations for the disposal of ozone-depleting substances and other toxic substances. As of 2012, the RAD program had acquired 50 partners throughout the United States.

Many utility programs exceed RAD requirements by sequestering the blow-in foam insulating appliances; this further reduces GHG emissions. Notably, in light of growing carbon markets in Europe, Canada, and California, potential carbon offsets may result from a program's ability to reduce total energy consumption on the grid.

However, attribution complicates incorporating NEBs into an ARP evaluation, in that the methodology for assessing net environmental benefits differs from that used to calculate net-to-gross (NTG). For example, customers taking their appliances to a dump in the absence of an ARP program may be considered energy-benefit freeriders, but not environmental-benefit freeriders .

This paper provides program administrators and evaluators with a methodology that, at little additional cost, can easily be incorporated into a typical appliance program evaluation to capture the complexity of the attribution problem. Specifically, this paper:

- Presents a clear framework for evaluating and quantifying aggregate environmental impacts.
- Highlights a variety of sources and monetary values for each major material recycled through these programs.
- Describes an approach for environmental attribution, using the same survey data used in calculating NTG, as part of a standard impact evaluation.
- Uses a case study, drawn from our evaluation of Southern California Edison's (SCE) program, which provides concrete examples of this approach's feasibility, and of preliminary values that might be produced through an ARP program's environmental benefits.[1]

Methodology

For our analysis, we developed a spreadsheet model to assess the ARP's net environmental impacts. This model accounts for and monetizes[2] (where possible) all gross and net environmental benefits associated with decommissioning an appliance, including:

- Energy reductions;
- Benefits from reclaimed materials;
- Landfill offsets for recycled materials (e.g., metal and plastic); and
- Avoided water contamination (e.g., resulting from proper disposal of mercury-containing components).

The basic analytic framework took the following steps (described in greater detail below):

1. Construct a list of all recycled materials recycled or destroyed by the program.
2. Calculate the average weight or counts of each raw material, per appliance.
3. Inventory all quantifiable benefits for each raw material, and estimate conversion values.
4. Estimate the monetary value of each benefit (often expressed in low, medium, and high valuation scenarios).
5. Develop "discard scenarios," with each scenario representing a different combination of material-specific disposal methods.
6. Estimate the likely distribution of units across the non-program discard scenarios (i.e., in the program's absence).
7. Estimate gross environmental benefits as the sum of all benefits realized under the program scenario.
8. Estimate net environmental benefits as the difference between gross benefits and average benefits realized in the program's absence.

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[1] This report presents preliminary numbers; final numbers will be presented in the *2011–2012 SCE/PG&E Appliance Recycling Process Evaluation*, which should become publicly available in late 2013.

[2] We monetized several benefits by converting to GHG offset equivalents.

While, the research described below used data from Cadmus' 2010–2012 SCE ARP Process Evaluation, the results are intended to provide a more general framework, and many of the input values could be applied to other programs.

Having operated since 1994, SCE's program serves as the longest, continually running ARP in the country. The program currently accepts refrigerators and freezers, providing rebates of $35 per unit. JACO Environmental (JACO) and the Appliance Recyclers of America (ARCA)—the two major implementers of such programs nationally—execute the program for SCE. The program's location in California also presents unique idiosyncrasies, most notably the recent development of a market for GHG offsets.

Our analysis began with taking a full inventory of all materials recycled, reclaimed, or destroyed under a typical ARP. Interviews with senior staff from JACO and ARCA, as well as visits to their decommissioning facilities, informed the construction of this list. We also interviewed and obtained documentation from EPA staff overseeing the RAD programs nationally; this provided a perspective outside the program regarding materials typically recycled by these programs and materials such programs could potentially recycle in the future.

After developing our list of materials, we calculated average values for each type of material recycled, reclaimed, or destroyed by the program, drawing upon reviews of JACO's and ARCA's comprehensive tracking databases and upon the RAD reports they produce for EPA. We bridged data gaps through discussions with program implementers.

Once we calculated average values per appliance for each implementer, we mapped materials and their disposal methods to specific benefits (e.g., GHG reduction, landfill reduction), and converted raw materials to benefit amounts using conversion factors collected through secondary research. Where possible, we also converted benefits to dollar values, based on market valuations (as with GHG offsets and reclaimed materials) or avoided cleanup costs (as with responsible disposal of mercury). In most cases, we assigned high, medium, and low monetary values to reflect market volatilities or uncertainties in input estimates.

Our analysis assessed five possible discard scenarios, representing varying levels of recycling and EPA compliance. The lowest level represented no recycling and/or compliance; the highest level represented the program. Each scenario addressed a different set of materials recycled or destroyed to reap the resulting benefits. To ascertain the program's net environmental impact, we used participant survey data to estimate the likely distribution of scenarios in the program's absence. The difference between the weighted average benefits, drawn from alternative scenarios, and the program scenario represented net environmental benefits attributable to the program.

Conceptually, this is similar to traditional NTG. Naturally, freeridership with respect to energy differs from environmental benefits—an individual throwing a refrigerator into a river would be considered both an energy freerider and a quintessential environmental non-freerider.

Thus, we defined gross environmental benefits as the total realized benefits for a given program, after converting all raw materials into their respective benefits and monetary values. Net benefits derive from the difference between the program scenario and the baseline (the weighted average of the likely scenarios in the program's absence). In this analysis, we estimated total gross and net environmental benefits (in dollars and raw benefits) for high, medium, and low valuation cases. These estimates represented possible values for incorporation in an enhanced TRC or societal benefit-cost ratio.

Collection of Materials Data and Benefits Monetization

We began the data collection process by obtaining information from implementers' tracking databases, dating from the program period, in regard to the following materials: used oil; refrigerant (CFC 12 and HFC 134A); ferrous metal; non-ferrous metal; plastic; glass; capacitors; rubber; foam;

foam-blowing agent; fiberglass; compressors; electrical cords, wires, and other scraps; and switches containing mercury.

The analysis first calculated average weights/quantities of different disposal method-material combinations (e.g., ferrous metal recycled; CFC-11 destroyed vs. recycled). We determined these values by reviewing: information collected during facility visits; RAD reports filed for the programs; and the implementer tracking databases. Based on information gleaned from facility visits and implementer staff interviews, we allocated a portion of the total quantity of each material (expressed as weight, volume, or emissions) to one of three disposal methods: destroyed on site; recycled; or sent to a landfill.[3]

ARCA's and JACO's databases contain information about the materials remaining after appliance decommissioning and dismantling (hereafter called "raw materials"). Database information includes material volumes, weights, and/or quantities. To calculate NEBs, we had to convert material units, using Google's metric conversion tools to convert raw material inputs into normalized values that could be quantified with monetary values.

In addition to metric conversions, we collected specific data regarding material and emissions prices, emissions factors, and contamination costs to determine the benefit values of raw materials preserved or avoided (depending on the material) by SCE's program. Specific collection methodologies for these data points follow below.

Deconstructed Materials and Disposal Methods

Using a number of sources, we determined the deconstructed materials and their respective weights. Table 1 shows the assumed disposal method, units, and weight/count sources, by program implementer. Facility visits determined disposal methods, with further confirmation through reviews of implementers' 2010 and 2011 RAD reports filed for SCE. As the table shows, most weights derived from the unit tracking data (such as those for refrigerants and blowing agents). Others drew upon assumed weights found in the RAD reports (such as those for metal and glass).

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[3] These are the three disposal methods described by the implementers during our facility site visits.

Table 1. Raw Material Disposal Methods and Data Sources

Material	Units	ARCA		JACO	
		Disposal Method	**Weight/Count Source**	**Disposal Method**	**Weight/Count Source**
Used Oil	lbs.	Recycled	ARCA unit tracking data	Recycled	JACO unit tracking data
Refrigerant (CFC 12 and HFC 134A)	lbs.	Destroyed	ARCA unit tracking data	Destroyed	JACO unit tracking data
Ferrous Metal	lbs.	Recycled	Assumption (RAD report)	Recycled	Assumption (RAD report)
Non-Ferrous Metal	lbs.	Recycled	Assumption (RAD report)	Recycled	Assumption (RAD report)
Plastic	lbs.	Recycled	Assumption (RAD report)	Recycled	Assumption (RAD report)
Glass	lbs.	Recycled	Assumption (RAD report)	Recycled	Assumption (RAD report)
Capacitors	Count	Recycled	Assumption (RAD report)	Recycled (PCB capacitors destroyed)	Assumption (RAD report)
Rubber	lbs.	Landfill	N/A	Landfill	N/A
Foam	lbs.	Recycled	N/A*	Destroyed (waste-to-energy)	N/A*
Foam-Blowing Agent	lbs.	Destroyed	ARCA unit tracking data	Destroyed (waste-to-energy)	JACO unit tracking data
Fiberglass	lbs.	Landfill	N/A	Landfill	N/A
Compressors	lbs.	Recycled	N/A	Recycled	N/A
Electrical cords, wires, and other scraps	lbs.	Recycled	N/A	Recycled	N/A
Mercury switches	Count	Recycled	ARCA unit tracking data	Recycled	JACO unit tracking data

*RAD report claims blowing agents comprise 10% of foam, implying ~9 lbs. of solid waste per unit containing foam.

Benefit Conversion and Monetization

We conducted a rigorous online search of recycled goods and emissions markets to determine unitized monetary values for raw materials. The research included examinations of Websites for scrap metal, textile, and recyclable goods, and a review of CalRecycle documentation to ultimately determine monetary unit values for materials with weight and volume (i.e., hazardous and non-hazardous material values). We also researched GHG auction prices for the California GHG market from the Clean Air Interstate Rule market to determine the monetary value for a metric ton of emissions (respective to each gas). High and low scenarios were constructed for each commodity price to reflect the wide degree of variance in these markets.

The material-to-benefit conversion process involved converting the original units of measurement for raw materials (gases, metals, and toxic substances) into new units of measurement that could be monetarily quantified, based on various market values. Depending on the raw material, we expressed new, converted units of measurement as: avoided emissions, reclaimed material weights, landfill reduction weights, and/or avoided contamination. Though each raw material uniquely converted to a new material metric, which could then be monetized, conversion processes were largely similar within examined raw material subgroups (ozone-depleting substances [ODS], hazardous materials, and non-hazardous materials).

ODS. EPA's RAD program primarily seeks to ensure the proper disposal of ODS, specifically addressing refrigerants, the largest ODS source in appliances. Additionally, ARPs implemented by ARCA and JACO abate ODS present in blowing agents used in older appliances—a step above and beyond the RAD program's requirements.

As the proportion of emissions differ for each GHG involved in the appliance recycling process (CFC-11, CFC-12, HFC-134a, HCFC-22, and HCFC-141b), we researched the global warming potential for each individual gas to normalize emissions as a metric-ton CO_2 equivalence ($MTCO_2E$) emissions factor. These global warming factors have been sourced from the Intergovernmental Panel on Climate Change's (IPCC) Second Assessment Report (SAR) (Hull 2009). Table 2 lists these substances and their GHG equivalences.

Table 2. GHG Emissions Factors for ODSs found in Recycled Appliances

Raw Material*	New Material Metric & Units	100 Yr GWP (SAR)*
CFC-11	$MTCO_2E$ of GHG Emissions	3,800
CFC-12	$MTCO_2E$ of GHG Emissions	8,100
HFC-134a	$MTCO_2E$ of GHG Emissions	1,300
HCFC-22	$MTCO_2E$ of GHG Emissions	1,500
HCFC-141b	$MTCO_2E$ of GHG Emissions	2,250

*(Hull 2009)

The monetary values from these gases derive from their avoided GHG costs. To determine the monetary environmental benefit of GHG avoidance, one converts 1 pound of GHG (e.g., for CFC-11) to metric tons (using standard conversion factors). Multiplying the global warming potential the gas produces by its metric ton weight determines the $MTCO_2E$ for 1 pound of emitted CFC-11. The following equation offers a sample calculation, with conversions noted:[4]

$$\begin{aligned}1\,lbs.\ of\ CFC-12\ Avoided\ Contamination\\ &= (0.000453592\ metric\ ton/\ 1\ lbs.) * 8100\ (100\ Year\ GWP\ SAR)\\ &= 3.674\ MTCO_2\ Eq\ per\ lbs.\ of\ CFC-12\ gas\end{aligned}$$

The emissions factor for each raw material gas converts to $MTCO_2E$; so the per-pounds emissions avoidance can be uniformly monetized.

We determined monetary values for CO_2 using California's Air Resources Board ARB Auction 1 results, held on November 2012. The auction yielded an auction reserve price of $10.09 per metric ton. As this price fluctuates with the market, we added a high-value case of $15.14 (50% above the current price) and a low-value case of $5.05 (50% below the current price). These carbon prices were used throughout this analysis, where other materials were converted to the $MTCO_2E$ (such as in landfill reduction).

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[4] IPCC's SAR provides these global warming potential values.

We multiplied the per-pounds $MTCO_2E$ value by each of the per metric ton emission GHG permit prices listed in our above analysis. This created a monetary range of benefit values resulting from emissions avoidance of these GHGs.

Hazardous Materials. We calculated the monetary benefits for hazardous materials by quantifying the environmental benefits of avoided contamination and the environmental benefits of emissions reductions. As avoided contamination and emissions benefits often differ by material, we individually describe the valuation for each hazardous material (e.g., used oil, mercury, and PCBs). We researched previous studies (e.g., EPA, Sustainablehospitals.org) examining environmental and health costs for hazardous material (e.g., oil, mercury, and PCB) exposure.

Used Oil. We calculated emissions reductions for used oil, using the GHG emissions factor for #2 heating oil, which tends to have a similar energy content. To calculate the GHG emissions from 1 gallon of oil, we multiplied the emissions factor by a density factor (to convert the units to pounds), and then multiplied this by another metric conversion factor to determine a value in $MTCO_2E$, as shown in the following equation:

$$(1\, Gallon\ of\ \#2\ heating\ oil) * (22.38\, lb.\ CO2/\,1\, Gallon) * (.000454\, mt\, /\, lb.) = 0.0101\, mt\, CO_2 eq.$$

To determine the monetary benefit from avoided emissions, the number of total gallons disposed of was multiplied as shown in the equation above and converted to $MTCO_2$ eq. We then multiplied this value by the GHG permit price to determine a total monetary value for emissions avoided.

We referenced documentation from the U.S. Department of Transportation's (DOT) Pipeline and Hazardous Materials Safety Administration to determine the per-gallon response cost of an oil spill. One should note the DOT's per-gallon cost calculation included all associated economic, environmental, ecological, and human health damages. As per-gallon costs were not linear with oil spill sizes (or with exposure), DOT presented a range of per-gallon costs by various oil spill sizes (Environmental Protection Agency 2009). We created three cost scenarios, based on the low ($22 per gallon, >10,000 gallon spill), medium ($244 per gallon,> 5 gallon average of all seven scenarios), and high ($723 per gallon, 5–30 gallons) estimates of per-gallon costs. These estimated values (differing based on a spill's size) provided three scenarios for monetary values per unit of avoided oil contamination, achieved by multiplying the number of gallons of oil disposed of and the probability of oil contamination (e.g. a spill), to arrive at a total avoided contamination benefit.

Mercury. As mercury releases do not lead to significant GHG emissions, we did not calculate emissions reduction benefits, nor did we calculate its weight leading to landfill emissions, as appliances contain only trace amounts of mercury.

We noted an appliance with a mercury switch contains approximately 1.5 grams of mercury (Ransom 2001). To determine the benefits of avoided mercury contamination, we identified the estimated costs associated with a mercury spill. As the spill costs are not linear in regard to the amount of mercury spilled, we used a range of cost values to determine the actual benefits of avoided mercury contamination. This non-linear cost curve led to great variations among the three cost scenarios. To calculate the benefits of avoided contamination, we multiplied an estimate of recycled units containing mercury switches by the weight of mercury in each switch. We then multiplied this value by each of the three cost estimates for mercury spills to determine the three different scenarios for avoided contamination benefits.

PCB-Containing Capacitors. PCB-containing capacitors do not directly emit significant amounts of GHGs into the atmosphere. However, emissions associated with the landfill of PCB containing capacitors must be accounted for. To determine these emissions, we referred to values derived directly from the CalRecycle Landfill Avoided Emissions Analysis. CalRecycle used the California Landfill Methane Inventory Model and the 2006 IPCC landfill emissions methodology to conclude the average total avoided landfill methane emissions in California of an estimated 0.53 $MTCO_2E$ per ton of waste. To calculate emissions from landfilled PCB waste, we multiplied the weight of landfilled, PCB-containing capacitors by the $MTCO_2E$ conversion factor, and then multiplied by a pounds/ton conversion factor to determine the result in $MTCO_2E$:

$$(1\ lbs\ PCB\ Capacitors) * \left(0.53\frac{MTCO_2eq}{ton}\right) * \left(0.0005\frac{ton}{lb}\right) = 0.000265\ MTCO_2eq$$

To monetize the benefits on landfill emissions avoidance, we multiplied the total $MTCO_2E$ resulting from the landfill of PCB containing capacitors by the per- $MTCO_2E$ emissions price in California.

We did not specifically calculate environmental and health costs related to PCB contamination. Though these costs exist, credible commissioned studies have not been conducted that examine environmental and health damages arising specifically (and only) from PCB contamination. Other studies that have calculated environmental and health-induced costs from multiple chemicals (including PCB) note that commissioning a study to determine the costs associated only from PCB contamination would prove costly and time consuming (Fox River Watch 2012). Therefore, we chose not to calculate avoided contamination benefits for PCB exposure within this model.

Non-hazardous Materials. As non-hazardous materials do not have contamination costs, one primarily calculates environmental benefits by landfill emissions avoidance and material weights. Just as with PCBs, we calculated landfill emissions benefits for non-hazardous materials using the CalRecycle results for landfill avoided emissions. Many non-hazardous materials also possess value as raw materials. We multiplied the market value (when applicable) for each raw material by its weight (with units for the market price and material weights normalized) to determine the total benefit recovered from the value of the material itself. As material weights were assumed, these overall values varied, based on the scenario used within our model.

Non-hazardous materials produced by the appliance recycling process include: ferrous metal; non-ferrous metal; rubber; plastic; glass; non PCB-containing capacitors; foam; and fiberglass.

Discard Scenarios and Distribution

To ascertain the program's net benefits, we established four disposal scenarios, in addition to the program case. The discard scenarios primarily relied on self-reported disposal methods in the program's absence, from the participant survey fielded as part of the 2010–2012 process evaluation. We supplemented these data with a review of literature addressing white goods laws and compliance in California (Environmental Protection Agency 2012).

We considered the following discard scenarios:

1. **Full Non-Compliance**: Considered the worst-case scenario, no materials would be recycled, and all toxic substances would be disposed of in an EPA-noncompliant manner. Few environmental benefits would be realized under this scenario. Examples of this scenario include dumping appliances in isolated areas.
2. **Modified Non-Compliance**: Under this scenario, the unit would still be disposed of in an environmentally non-compliant manner, but materials with retail values (namely ferrous and non-ferrous metals) would be recycled through secondary means. For this analysis, we assumed 100% of metals would be recycled. An example of Scenario 2 would be abandoning a unit in a public place, such as leaving the appliance on the curb.
3. **Likely Minimum Compliance**: In this case, the unit would be disposed of through minimum formal compliance, though this would not explicitly involve recycling. We assumed a 90% compliance rate under this scenario, meaning 90% of units would have their refrigerant and

compressor oil disposed of in an EPA-compliant manner. We assumed a lower compliance rate for the proper disposal of PCBs and mercury (50%), as compliance has been found to be lower for these rare materials. We assumed 100% of metals and 25% of plastics and glass would be recycled. An example of Scenario 3 would be taking a unit to a dump.

4. **Full Compliance Recycling**: In this case, a unit would be taken to a non-program recycling facility. The scenario assumes all compliance requirements would be met, and much of the unit would be broken down and recycled. We assumed full compliance under this scenario for all toxic substances, save for the blowing agent, which, according to program implementers, non-utility programs do not extract. All metals, plastics, and glass would be assumed recycled. However, we assumed foam and fiberglass would not be recycled under this scenario.
5. **Full Compliance, Utility-Sponsored RAD Program**: This represents the program case, with benefits realized that represented the program's gross environmental benefits.

After establishing the mix of materials recycled or disposed of under each scenario, we determined the likely distribution of units across Scenarios 1 through 4, had the program not existed. In a sense, this can be compared to freeridership analysis for energy-efficiency evaluations, where a baseline level of savings, realized in the program's absence, would be estimated.

We estimated this distribution using data from the participant survey, fielded as part of the 2010–2012 SCE ARP Process Evaluation. This survey asked respondents to report what they would have done with their appliance in the program's absence. Research often uses such questions to assess freeridership with respect to energy savings.

Table 3 shows how we assigned discard scenarios to each survey response. The analysis removed responses likely to result in transferring to another user (indicated in the table with an "N/A"). For some responses, the action prompted by the scenario proved unclear, and the response was divided evenly between scenarios.

Table 3. Assignment of Survey Responses to Discard Scenarios

Response	Proportion (n=188)	Likely Scenario
Sold it to a private individual	16%	N/A
Gave it away for free to a private individual	13%	N/A
Sold it to an appliance dealer	4%	N/A
Given it away to a charity organization	14%	N/A
Gave it away for free to an appliance dealer	3%	2, 3, or 4
Picked up as part of the delivery service with the purchase	3%	2, 3, or 4
Hauled it to the landfill or dump or threw it away yourself	12%	1, 2, or 3
Hauled it to a waste management or recycling center yourself	7%	4
Had someone else pick it up for junking or dumping	11%	3
Left it on the curb for someone to take for free	10%	2
Disposed of it in some other way	1%	1
Kept it	8%	N/A

Mapping these responses provided distributions of likely disposal scenarios, for each utility, in the program's absence.

Table 4. Likely Distributions of Discard Scenarios in Absence of ARPs

Scenario	Proportion (n=86)
1	19%
2	24%
3	37%
4	20%

Findings

Combining the various parameters outlined above, we calculated per-unit and total benefits attributable to the program. We calculated gross benefits as the total monetary value benefits from the recycling process, and calculated net benefits as the difference between gross benefits and the benefits realized in the program's absence (defined as the weighted average of the discard scenarios discussed)[5].

Table 5 shows preliminary gross and net materials attributed to the SCE program (using the medium-case scenario). Much variance occurs in the NTG relationship between materials. For instance, our analysis shows the majority of metal would most likely be recycled in the program's absence; so the net metal recycled remained quite low, relative to gross. Conversely, our research found foam recycling essentially does not occur outside of utility ARPs; therefore, the net and gross savings equal.

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[5] This report presents preliminary numbers; final numbers will be presented in the *2011–2012 SCE/PG&E Appliance Recycling Process Evaluation*, which should become publicly available in late 2013.

Table 5. SCE 2010-2012 Gross and Net Benefits by Material (Medium Case)*

Benefit	Units	Gross		Net		NTG
		Benefit	Monetary Value	Benefit	Monetary Value	
GHG Emissions	$MTCO_2eq$	350,785	$4,910,986	277,644	$3,887,022	0.79
Reclaimed oil	lbs.	99,301	$183,955	44,121	$81,734	0.44
Avoided Oil Contamination	gal.	13,240	$3,230,592	5,883	$1,435,397	0.44
Reclaimed ferrous metal	lbs.	26,864,037	$3,350,968	3,871,582	$482,934	0.14
Reclaimed copper	lbs.	1,355,573	$3,558,378	205,950	$540,618	0.15
Reclaimed aluminum	lbs.	1,343,202	$1,039,614	193,579	$149,827	0.14
Reclaimed plastic	lbs.	2,110,746	$614,755	1,494,077	$435,150	0.71
Reclaimed glass	lbs.	706,140	$967	499,837	$684	0.71
Avoided Mercury Contamination	lbs.	5	$1,270,268	3	$782,086	0.62
Reclaimed foam	lbs.	1,393,338	$271,701	1,393,338	$271,701	1.00
Total Value of Environmental Benefits			**$18,432,184**		**$8,067,152**	**0.44**

*Only materials with monetary values are listed.

Table 6 shows final estimates of per-unit and total gross benefits for SCE's 2010–2012 program, with results presented for each valuation case (high, medium, and low). This program's net benefits ranged from $19 to $79 per unit. For comparison purposes, the SCE program experienced an average implementation cost of $164 per unit.

Table 6. SCE 2010-2012 Gross and Net Environmental Benefits Summary

Case	Gross Benefit		Net Benefit		NTG
	Per-Unit	Total	Per-Unit	Total	
Low	$50	$9,775,199	$19	$3,779,597	0.39
Medium	$94	$14,432,184	$41	$8,067,152	0.53
High	$169	$33,206,920	$79	$15,538,191	0.48

Conclusion

Prior to this study, ARP benefits primarily have been viewed as deriving from resultant energy reductions, with environmental benefits rarely examined. This paper presents a comprehensive review of evaluating environmental benefits from ARPs, using the SCE program as an example. Many parameters in this paper (such as the emissions from ODS abatement) could readily transfer to other utilities. Other parameters, at little additional cost to a utility, could easily be calculated as part of a standard impact evaluation, such as the materials' weights and the distribution of disposal scenarios.

Given many utilities include offset GHG emissions from reduced energy consumption in their avoided cost calculations (as in California's E3 calculator), it should not be too difficult to incorporate the benefits outlined in this paper. Our research shows these benefits potentially could be quite significant, ranging from 12% to 48% of total implementation costs. Such high benefit levels, even under the low-valuation case, should more than justify the cost of additional evaluations, and help buttress these programs' long-term cost-effectiveness as unit energy savings begin to decrease. We hope inclusion of these benefits becomes a standard practice for ARPs moving forward, as it addresses a critical element of their impacts within their service areas.

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