Primary Refrigerators: An Examination of Appliance Recycling Program Design

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ABSTRACT

Many utilities recognize residential appliance recycling programs (ARPs) as a cost-effective and customer-friendly demand-side management resource. Decades ago, utilities began sponsoring refrigerator recycling programs, and, in recent years, their popularity has expanded. The U.S. Environmental Protection Agency has demonstrated its support of these programs through its Responsible Appliance Disposal Program, which includes roughly 30 utility partners. Impact evaluations of ARPs have uncovered the nuances involved in estimating savings and net-to-gross ratios, one being the distinction between primary refrigerators (typically located in kitchens and operating year-round) and secondary refrigerators (often stored in garages or basements, and, in some cases, operated only part of the year).

While most programs allow both primary and secondary units to be recycled, some limit participation to secondary units, assuming this will result in greater cost-effectiveness. This paper summarizes our research and analysis investigating the hypothetical incremental impacts of allowing primary refrigerators to be included in programs historically limited to secondary units. Study results indicate that such inclusions may prove beneficial in terms of total net kWh savings and cost-effectiveness.

These findings can serve to inform utility program design and marketing efforts, while shedding light on the program maturation process. As widespread implementation of ARPs continues, an enhanced understanding of the factors that influence their evaluation will allow program administrators to make strategic decisions for achieving optimal results.

Introduction

The Cadmus Group, Inc. (Cadmus) and Ameren Illinois conducted research and analysis to estimate impacts from expanding the Ameren Illinois' Residential Appliance Recycling Program (ARP) to allow participation by consumers seeking to recycle their primary refrigerators. Study results, summarized in this paper, show that including primary refrigerators in the program would prove beneficial in terms of net kWh savings and cost-effectiveness. These findings supported Ameren Illinois' decision to include primary units in the program's third year of implementation, beginning in January 2011.

Approach and Methods

In investigating impacts from including primary units in its ARP, Ameren Illinois and Cadmus identified publicly available studies of other utility ARPs (such as reports included in online databases and utility and commission Websites). Cadmus further researched other utility ARPs through prior evaluation contacts and clients.

After identifying the other studies, Cadmus compared Ameren Illinois' program results to those of programs allowing primary units. This comparison sought to answer the following questions:

- In similar programs allowing primary units, what portion of participating units were primary?
- In studies where net-to-gross (NTG) was calculated for primary and secondary units using the same method used for Ameren, did NTG differ between primary and secondary units?
- How did appliance characteristics differ between primary and secondary units, and what effect would these likely have on average gross savings?

Our research included comparisons of the following technical specifications of participating primary and secondary units from the other programs:

- Configuration
- Average age
- Defrost type
- Average size

These characteristics represented important factors in estimating gross and net savings. Under the evaluation methodology Cadmus used for Ameren Illinois' program, changes in any of these specifications could alter the program's attributable savings and cost-effectiveness.

In the final analysis step, the research team created a baseline total resource cost (TRC) cost-effectiveness test, using results from 2010, Ameren Illinois' second Program Year (PY2). We then analyzed a scenario where primary units would be allowed, using assumptions for participating rates, savings, and NTG results based on our secondary research.

Findings

Cadmus has evaluated ARP programs for numerous North American utilities. Some of these clients have published their data; others have chosen to keep detailed program information confidential. Two large, publicly available studies provided the basis for much of our analysis: Cadmus' study for the California Public Utilities Commission (CPUC), evaluating programs at three utilities from 2006–2008 (Cadmus, 2010a); and Cadmus' study for the Ontario Power Authority (OPA), which evaluated that utility's 2008 and 2009 program years (Cadmus, 2010b).

Additionally, Cadmus gathered information on participant units from two other publicly available reports: appliance recycling evaluations from OPA's 2007 ARP program (Quantec, 2008); and PacifiCorp's Utah 2004–2005 ARP program (Quantec, 2005). We also included one data point (the percentage of refrigerators that were primary units) from Com Ed's recent evaluation of its PY2 program (Navigant, 2010).

Comparative Analysis of ARPs

For each of the major research questions examined in this study, we used data from the CPUC and OPA. Given their divergent characteristics, these programs provided appropriate and useful comparison points. While both programs allow recycling of primary refrigerators along with secondary refrigerators and freezers, the California utility programs (implemented by Southern California Edison, Pacific Gas & Electric, and San Diego Gas & Electric) have operated for over a decade in a state where energy-efficiency standards have been in place much longer. By contrast, the OPA program was in its second year when evaluated by Cadmus, operating in a service territory similar to that of Ameren Illinois.

Participating Primary Units. Typically, we assume that, as a program matures, it removes increasing numbers of primary participant units, given existing secondary unit stocks correspondingly (and desirably) decrease as a program facilitates their removal from a service territory. We have observed this trend in all ARP programs evaluated. Cadmus compared the percentage of primary participant units across seven utility programs in various stages of program maturity. As depicted in Table 1, newer programs, evaluated within two years of program launch, showed a low percentage of primary refrigerators, while mature programs showed over half their participant refrigerators were primary units.

Table 1. Participating Refrigerators in ARPs: Percent Primary

	New Programs		Maturing Programs		Mature Programs		
	Com Ed 2009	OPA 2007	PacifiCorp Utah 2004–2005	OPA 2008–2009	CPUC 2006–2008		
					PGE	SCE	SDGE
Primary Refrigerators	14%	20%	39%	35%	62%	69%	62%

Net-To-Gross Ratio. As in the Ameren evaluation, programs researched for this study used a similar participant self-reporting method to estimate NTG ratios. Though the precise wording and order of questions may have differed slightly, all these methods followed the same underlying logic and were sufficiently similar for comparison purposes.

NTG ratio comparisons revealed, in most cases, higher freeridership for primary units. As we expected, participants purchasing a replacement unit were more likely to have been planning appliance disposal prior to learning of the program. Table 2 summarizes NTG differences between programs.

Table 2. Comparison of NTG Ratios

Utility	NTG		% Difference
	Primary	Secondary	
PG&E 06-08	0.49	0.61	-20%
SCE 06-08	0.52	0.72	-28%
SDG&E 06-08	0.55	0.71	-22%
OPA 08-09	0.54	0.54	0%
Average	**0.52**	**0.64**	**-18%**

Appliance Characteristics. Appliance characteristics between primary and secondary units also differed predictably. We expected primary units, overall, would be newer, larger units, with a higher incidence of more modern characteristics, such as automatic defrost.

We anticipated appliance age and size would show the greatest difference between primary and secondary refrigerators. However, though we found significant appliance age differences for most programs (on average, primary units were 18% younger), average size differences were not nearly as striking (primary units were 5% larger).

Table 3. Comparison of Average Unit Age

Utility	Average Age		% Difference
	Primary	Secondary	
PG&E	15.0	25.4	-41%
SCE	13.8	18.4	-25%
SDG&E	16.0	16.6	-4%
OPA	25.3	25.1	1%
Average	**17.5**	**21.4**	**-18%**

Table 4. Comparison of Average Unit Size

Utility	Average Size		% Difference
	Primary	Secondary	
PG&E	18.6	18.5	1%
SCE	21.4	19.0	12%
SDG&E	20.5	18.4	12%
OPA	17.2	18.4	-7%
Average	**19.4**	**18.6**	**5%**

Though unit configurations did not show unusually large differences, they matched our expectations. For example, fewer primary units had single doors than side-by-side doors, which follows logically, given side-by-side refrigerators tend to be relatively newer models.

Table 1. Comparison of Unit Configurations

Utility	Single Door			Side-by-Side		
	Primary	Secondary	Difference	Primary	Secondary	Difference
PG&E	0%	4%	-4%	22%	32%	-10%
SCE	0%	9%	-9%	41%	29%	12%
SDG&E	0%	6%	-6%	39%	33%	6%
OPA	0%	5%	-5%	19%	4%	15%
Average	**0%**	**6%**	**-6%**	**31%**	**25%**	**6%**

Similarly, as shown in Table 6, more primary units had automatic defrost features than did secondary units. As this feature has become more common over time, the findings match expectations.

Table 6. Comparison of Defrost Type

Utility	% Automatic Defrost		% Difference
	Primary	Secondary	
PG&E	100%	96%	4%
SCE	86%	82%	5%
SDG&E	100%	94%	6%
OPA	95%	90%	6%
Average	**95%**	**91%**	**5%**

Savings Scenario Analysis. Using the above differences in freeridership and appliance characteristics, Cadmus conducted a hypothetical impact analysis for three separate scenarios.

In the best-case scenario, using selected differences in characteristics leading to the highest savings from each table, we adjusted characteristics from Ameren's PY2 evaluation. Applying the selected numbers to the same calculations used for Ameren's evaluation allowed determination of best-case primary unit gross and net savings numbers. Estimating a worst-case scenario followed a similar process, using the least ideal numbers for each aspect. Analysis using the average differences across programs produced a more likely result between the two extreme estimates.

The analysis then determined gross savings for each scenario by deriving adjusted appliance characteristics for each scenario from the CPUC and OPA data. These characteristics, shown in Table 7, were entered into the same regression equation used in Cadmus' PY2 ARP evaluation (the coefficients of which are also shown in Table 7).[1]

Table 2. Comparison of Gross Unit Savings Estimates

Independent Variable	Coefficient	PY2 Secondary Value	Average Primary Value	Best Case Primary Value	Worst Case Primary Value
Intercept	-1,166.60	1	1	1	1
Age (years)	47.8	27.2	22.3	27.4	16.0
Volume (CuFt)	37.3	16.91	17.7	19.0	15.8
Dummy: Side-by-Side	227.5	0.12	0.13	0.14	0.11
Dummy: Bottom Freezer	211.4	0.04	0.04	0.04	0.04
Dummy: Automatic Defrost	429.5	0.70	0.74	0.74	0.73
Estimated Annual UEC		**1,650**	**1,268**	**1,815**	**678**

Considerable variation resulted between the various scenarios. In fact, for the best-case scenario, savings were actually higher for primary units. Though this is a possible result, the introduction of primary units would more likely produce lower unit energy consumption (UEC), as seen in the other two scenarios.

UECs were adjusted using both a part-use factor (to account for units used only part of the year) and an NTG ratio. As primary units were, by definition, always in use, they were assigned a part-use factor of 1.

[1] The regression model was based on the California Energy Commission's energy consumption database of over 61,000 specific refrigerator and freezer makes and models, manufactured between 1978 and 2008 (CEC, 2009). This database provides UEC values for each appliance, as reported by manufacturers, and energy consumption, determined using U.S. Department of Energy appliance-testing protocols. The regression model employed the Department of Energy-based UEC as the dependent variable, and various characteristics (e.g., configuration, age, size) of tested refrigerators or freezers as independent variables.

NTG was determined, following the same three scenarios used for calculating gross savings, by adjusting Ameren Illinois' PY2 NTG according to best-, average-, and worst-case comparison values. These calculations, presented in **Table**Table 8 and Table 9, produced overall ranges of net unit savings possible for primary units.

Table 8. Comparison of Gross Per-Unit Savings Estimates

Type	Annual UEC	Part-Use Factor	Gross Per-Unit Savings
Secondary (Actual)	1,650	0.88	1,452
Best Case Primary	1,815	1.00	1,815
Average Primary	1,268	1.00	1,268
Worst Case Primary	678	1.00	678

Table 9. Comparison of Gross and Net Per-Unit Savings Estimates

Type	Gross Per-Unit Savings	NTG	Net Per-Unit Savings
Secondary (Actual)	1,452	0.79	1,147
Best Case Primary	1,815	0.79	1,440
Average Primary	1,268	0.64	817
Worst Case Primary	678	0.57	386

Cost-Effectiveness Analysis

Using Cadmus' DSM PortfolioPro tool and the underlying assumptions from the Program Year 1 (PY1) evaluation of the Ameren Illinois program, we conducted a base-case analysis of cost-effectiveness for Ameren Illinois' actual PY2 evaluated program results, and compared these to worst-case and likely scenarios, based on the preceding savings and participation data. Table 10 shows assumptions and inputs for each scenario.[2]

Table 3. Cost-Effectiveness Scenario Inputs

	Base Case (Actual PY2)	Scenario 1 (Low Savings)	Scenario 2 (Likely)
% of Refrigerators Primary	0%	14%	14%
% Secondary	100%	86%	86%
Primary Unit Gross Savings	n/a	678	1,268
Secondary Unit Gross Savings	1,467	1,467	1,467
Primary FR	n/a	0.43	0.36
Secondary FR	0.21	0.21	0.21
Weighted Average Gross Savings	1,467	1,357	1,439
Weighted Average FR	0.21	0.24	0.23

[2] A best-case scenario was not determined for cost-effectiveness analysis, given such a scenario is unlikely. While also unlikely, the low-savings scenario provided a useful indicator of possible negative impacts resulting from changes in program design.

	Base Case (Actual PY2)	Scenario 1 (Low Savings)	Scenario 2 (Likely)
Participation	7,762	9,026	9,026
Additional incentive cost	0	$44,240.00	$44,240.00
Total incentive cost	$391,440.00	$435,680.00	$435,680.00
Additional Implementation Cost	0	$125,765.08	$125,765.08
Total Implementation Cost	$1,394,694.71	$1,520,459.79	$1,520,459.79
Assumed Portfolio Administration	$15,000.00	$15,000.00	$15,000.00

As shown in Table 10, Scenario 1 approximated a low-savings program, with low primary unit savings and high primary freeridership. Though an unlikely scenario for a young program such as Ameren Illinois', it represents savings and NTG characteristics for a mature program. Thus, we included it for comparative purposes. Scenario 2, however, provided both a realistic approximation of Ameren Illinois' PY2 results and primary units qualifying for program participation. Notably, this included a low percentage of primary units (as expected for a newly-launched program), average savings for primary units, a moderate decrease in NTG, and a moderate increase in participation.

Table 11 shows the results of the cost-effectiveness analysis performed on these scenarios. Even under the low-savings scenario, program's net savings increased, although the TRC dropped slightly. All these scenarios assumed Ameren Illinois would not limit participation, allowing primary units and hence increasing potential participation.[3]

Table 11. Cost-Effectiveness Scenario Analysis Results

	TRC Benefits (Net Present Value)	TRC Costs (Net Present Value)	TRC Benefit/Cost Ratio	TRC Cost of Conserved Energy ($/kWh)	Gross Annual Electric Savings (MWh)	Net Annual Electric Savings (MWh)
Base Case (Actual)	$5,340,881	$1,801,135	2.97	$0.022	21,570	17,040
Scenario 1 (Low Savings)	$5,471,941	$1,971,140	2.78	$0.023	23,658	17,959
Scenario 2 (Likely)	$6,999,826	$1,971,140	3.55	$0.018	24,362	18,749

Conclusions

Study results indicate Ameren Illinois' Residential ARP can be expected to remain cost-effective, and would likely increase net savings if allowing primary appliances to participate (provided this participation is not limited). An expected increase in freeridership and a possible reduction in average savings per participant would be offset by a prospective increase in total savings from more participants, while still meeting the TRC. Further, an overall decrease in net savings or the TRC benefit-cost ratio would be very unlikely if all other factors influencing participation remained the same. Such a program design change would more plausibly result in the following:

- An opportunity for increased participation;
- A modest decrease in per-unit savings; and

[3] Preliminary figures from the first quarter of Ameren Illinois' PY3 show that no increase in participation has occurred. We therefore calculated a scenario limiting participation to 7,726 units, using the low-savings estimate for unit savings and freeridership. In this case, the TRC dropped to 1.81, and net savings lowered to 12,534 MWh.

- A modest increase in freeridership.

Changes occurring at the magnitude Cadmus estimated in this study would result in increased program net savings and increased cost-effectiveness. Including primary refrigerators in the program also would increase the program's already robust marketing potential. Customers have expressed high satisfaction with the program, and such changes may introduce more Ameren Illinois customers to demand-side management programs.

In applying these findings to decisions regarding program design, utilities must consider savings targets and program budgets. In some cases, primary units may be excluded due to budget constraints. For example, utilities seeking to maximize per-unit savings to meet high savings targets, despite limited program budgets, may achieve better results by excluding primary units. However, when increased participation proves desirable, study results indicate including primary units will likely produce beneficial results.

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