MEMORANDUM

To: Consolidated Edison EM&V Team

From: Cadmus Evaluation Team

Subject: Recommended Gross Savings Values for Refrigerator Recycling Program

Date: December 17, 2015

Cadmus analyzed recent program data and four savings estimation methods to determine appropriate unit energy savings (UES) values for Con Edison's Refrigerator Recycling program. We recommend Con Edison adopt the savings values we estimated using a regression model that combines data from Con Edison's Energy Efficiency Portfolio Standard Cycle I (EEPS 1) impact evaluation and the Uniform Methods Project (UMP) protocols for refrigerator replacement measures.[1] To determine gross savings estimates we applied removed units' characteristics from Con Edison's 2014-2015 program to this combined regression model.

Table 1 shows the savings values from four estimation methods, including the New York Technical Resource Manual (TRM Version 3) and three regression-based estimation methods. The gross savings values include a part-use factor for the secondary units, and the net savings values include the estimated free-ridership rate for both primary and secondary units.

Table 1. Summary of Gross and Net Savings Estimates by Method

Estimation Method	Gross Savings (kWh) [A]		FR [C]	Net Savings (kWh) [B]	
	Primary	Secondary		Primary	Secondary
Method 1: Values specified in TRM Version 3	670	822	10%	603	740
Method 2: EEPS II program data applied to EEPS I Impact Regression Model	1,086	916	54%	500	421
Method 3: EEPS II program data applied to UMP Regression Model	1,266	792	54%	582	364
Method 4 (Recommended): EEPS II program data applied to Combined Regression Model	1,218	794	54%	560	365

[A] Gross savings values for secondary units include a part-use factor.

[B] FR = Freeridership Rate; Net Savings = Gross Savings x (1 – FR)

[C] 10% value from TRM; 54% value from Con Edison EEPS 1 Residential Appliance Recycling Impact Evaluation

This memorandum describes each savings estimation method and our reasons for recommending using savings values based on the combined regression model (Method 4).

[1] http://energy.gov/sites/prod/files/2013/11/f5/53827-7.pdf

Methods

Cadmus obtained gross unit energy savings for primary and secondary refrigerators using the following methods and sources:

1. Deemed savings values from the New York TRM Version 3.
2. Current program tracking applied to the regression models developed in the Con Edison EEPS I impact evaluation.[2]
3. Current program tracking data applied to the regression models provided in the UMP Refrigerator Recycling Evaluation Protocol.
4. Current program tracking data applied to a combined-regression model that uses data from both the EEPS I impact evaluation and the UMP protocol.

To produce separate gross savings estimates using regression models, Cadmus calculated average appliance characteristics for primary and secondary refrigerators and applied these average characteristics into the regression equations. To account for secondary units that do not operate throughout the year, Cadmus applied the part use factor specified in the EEPS I impact evaluation (0.87).

Program Tracking Data

Cadmus collected program tracking data from January 2014 through July 2015. This program population had 27.5% primary and 72.5% secondary refrigerators. Table 2 shows the summarized appliance characteristics for primary and secondary refrigerators.

Table 2. Program Appliance Characteristics Applied to Regression Modeling (1/2014 – 7/2015)

Appliance Characteristic	Primary	Secondary
Age (years)	21.03	21.50
Dummy: Pre-1990	0.25	0.31
Appliance Size (cu.ft.)	18.56	17.95
Single Door Configuration	0.01	0.05
Side-by-Side Configuration	0.22	0.18

Part Use Adjustments

The part-use factor represents the percentage of a year that the appliance is used. Primary units are typically assumed to operation all the time, so the part-use factor for primary units is 1.0. This assumption is also explicitly stated in the UMP. The EEPS I impact evaluation report estimated a part-use factor of 0.87 for secondary units.

The TRM deemed savings estimates include the part-use adjustment. To estimate final gross savings values for the regression-based methods, Cadmus applied part-use factors—1.0 for primary units and 0.87 for secondary units—to the savings values produced by the regression models.

[2] Energy & Resource Solutions. "Con Edison EEPS Programs – Impact Evaluation of Residential Appliance Bounty Program." May 4, 2015.

Method 1: NY TRM Version 3 (Link)

NY TRM Version 3 provides deemed savings estimates for primary and secondary refrigerators. Although the value for secondary units is based on a previous Con Edison impact evaluation, neither the primary nor secondary values presented in the TRM are appropriate for Con Edison's current program.

The TRM savings value for primary refrigerators (670 kWh) is based on an Ameren Illinois memo prepared by Cadmus.[3] In the Ameren study, Cadmus conducted a sensitivity analysis to provide a range of savings scenarios for primary units to help Ameren determine which units should be eligible for the program. The NY TRM selected the *lowest* value in this analysis (i.e., the worst-case scenario).

The TRM savings value for secondary refrigerators (822 kWh) is based on the results of Con Edison's EEPS I impact evaluation.[4] Although the results use Con Edison program data, the values are based on data from the 2013 program year. Because appliance characteristics evolve over time, savings values should be based on the most recent program year.

Method 2: Con Edison EEPS I Impact Evaluation Model

For Con Edison's EEPS I impact evaluation, the evaluator developed a regression model of annual energy savings using metered power data from 69 refrigerators in Con Edison territory. Since the evaluator conducted the metering in 2013 before primary appliances were eligible for Con Edison's program, this EEPS 1 regression model is based on secondary unit data only.

The model is consistent with UMP protocols and uses the following explanatory variables:

- Age
- Dummy variable indicating if the unit was manufactured pre-1993
- Appliance size
- Proportion of single door/side-by-side configurations
- Unconditioned spaces x Heating Degree Days (HDD)

Using the EEPS I program data, the evaluator compared savings estimates from this EEPS I regression model (using EEPS I program data) to estimates from the UMP regression model (also using EEPS I program data). Evaluators selected the EEPS I model due to higher precision values around the estimates and use of Con Edison program data.

Cadmus recalculated savings by applying the updated program data (from program years 2014 and 2015) to the EEPS I regression model. As no primary units were used to develop the model, there is no explicit difference between primary and secondary units. However, as the model does include differences in ages, size, and configurations, it could still be used to produce estimates for both types of

[3] Primary Refrigerators: An Examination of Appliance Recycling Program Design; Kate Bushman and Joshua Keeling – Cadmus Group, Inc. and Karen Kansfield, Ameren, Illinois, April 2013

[4] Refrigerators: Gross Unit Use (948 kWh) x Part Use Factor (0.867) = 822 kWh [based on Con Edison EEPS 1 data]. Published January 12, 2015.

refrigerator use. As listed in Table 1, these calculations produced savings values of 1,086 kWh for primary and 916 kWh for secondary refrigerators.

Cadmus does not recommend using these savings estimates because the EEPS I regression is based on 2013 program data for secondary units only.

Method 3: Uniform Methods Project Regression Model

UMP developed a protocol for estimating savings from appliance recycling measures. The protocol team reviewed the set of metered data for 527 refrigerators collected from existing evaluation studies across the country, and used these data to develop the UMP regression model. The UMP model uses the following inputs:

- Age
- Dummy variable indicating if the unit was manufactured pre-1990
- Appliance size
- Proportion of single door/side-by-side configurations
- Proportion of primary refrigerators
- Proportion of appliances in unconditioned spaces x daily HDD and Cooling Degree Day (CDD)

Analysis of the metered data in the UMP dataset indicated a significant difference in consumption between primary and secondary units. This difference (higher energy consumption from primary units) is likely a result of heavier use for primary compared to secondary units. With each door opening, cold air escapes the interior, heat-producing lights come on, and the refrigerator has to work harder to maintain temperature.

To estimate updated savings results for both primary and secondary units in Con Edison's program, Cadmus applied the 2014/15 program data to the UMP regression models. Table 3 shows the UMP regression coefficients for each independent variable, the primary and secondary input data, and the estimated UES results.

Table 3. UMP Estimates – Primary and Secondary Refrigerators

Independent Variable	Estimate Coefficient (Daily kWh)	Primary Unit Inputs	Secondary Unit Inputs
Intercept	0.58	1.00	1.00
Appliance Age (years)	0.03	21.03	21.50
Dummy: Pre-1990	1.06	0.25	0.31
Appliance Size (cu.ft.)	0.07	18.56	17.95
Single Door Configuration	-1.98	0.01	0.05
Side-by-Side Configuration	1.07	0.22	0.18
Primary Usage	0.61	1.00	0.00
Unconditioned x CDD	0.02	0.00	1.21
Unconditioned x HDD	-0.05	0.00	6.91
UES (kWh)	**n/a**	**1,266**	**911**
UES w/ part-use adjustment (kWh)	**n/a**	**1,266**	**792**

The UMP models produced a savings estimate of 1,266 kWh for primary units and 792 kWh for secondary units. The difference between primary and secondary refrigerators is driven by three factors:

- Fewer primary units with a single-door configuration,
- Weather impacts for secondary units kept in unconditioned spaces, and
- Higher usage intensity (e.g., more frequent door openings) for primary units.

Method 4: Combined Regression Model

Cadmus combined the metering data from the EEPS I impact evaluation report (n=69) with those used to develop the UMP model (n=527). Table 4 shows the combined model coefficients for each independent variable, the primary and secondary input data, and the estimated UES results.

Table 4. Combined Model Estimates – Primary and Secondary Refrigerators

Independent Variable	Estimate Coefficient (Daily kWh)	Primary Unit Inputs	Secondary Unit Inputs
Intercept	0.93	1.00	1.00
Appliance Age (years)	0.02	21.03	21.50
Dummy: Pre-1990	0.97	0.25	0.31
Appliance Size (cu.ft.)	0.05	18.56	17.95
Single Door Configuration	-1.68	0.01	0.05
Side-by-Side Configuration	1.21	0.22	0.18
Primary Usage	0.47	1.00	0.00
Unconditioned X CDD	0.02	0.00	1.21
Unconditioned X HDD	-0.05	0.00	6.91
UES (kWh)	**n/a**	**1,218**	**912**
UES w/part-use adjustment (kWh)	**n/a**	**1,218**	**794**

Including the part-use adjustment, the combined model produced a savings estimate of 1,218 kWh for primary units and 794 kWh for secondary units. These results are similar to the UMP model savings in Table 3 and also show higher savings for primary compared to secondary units.

Summary of Gross Savings

Table 5 shows the gross savings values, including the part-use factor, for each estimation method.

Table 5. Summary of Gross Savings Estimates by Method

Estimation Method	Gross Savings (kWh) [A]		
	Primary	Secondary	Weighted Average [B]
Method 1: Values specified in TRM Version 3[C]	670	822	780
Method 2: EEPS II program data applied to EEPS I Impact Regression Model	1,086	916	963
Method 3: EEPS II program data applied to UMP Regression Model	1,266	792	923
Method 4 (Recommended): EEPS II program data applied to Combined Regression Model	1,218	794	910

[A] Gross savings values for secondary units include a part-use factor.

[B] Weighted based on the percentage of primary (27.5%) and secondary (72.5%) units in 2014/15 program data.

[C] Deemed values based on Ameren IL study (primary units) and Con Edison EEPS I impact evaluation (secondary units)

The gross savings values for Methods 3 and 4 are similar, but very different compared to the gross values currently proposed in TRM Version 3. The recommended combined-regression method provides a gross savings value of 1,218 kWh/year (compared to the TRM value of 670 kWh/year) and a gross savings value of 794 kWh/year for secondary refrigerators (compared to 822 kWh/year).

Freeridership Estimation

The NTG calculation methods in Con Edison's EEPS I impact evaluation are partly in line with UMP. The evaluator used participant surveys with questions to verify the plausibility of responses. The evaluation report stated the participant surveys were used to estimate the proportion of units that were likely to enter the secondary market (i.e., transferred to a new household rather than kept or destroyed); however, the evaluator did not adjust freeridership estimates based on that research.

Also, the evaluator did not conduct non-participant surveys to mitigate potential self-reporting errors. According to UMP, non-participant surveys are important to:

> *"… provide information from other utility customers regarding how they actually discarded their refrigerator independent of the program. Evaluators can also use this information to estimate the proportion of discarded units that are transferred versus destroyed. Specifically, evaluators should calculate the distribution of the ratio of likely discard scenarios as a weighted average from both participants and nonparticipants (when nonparticipant surveys are possible). The averaging of participant and nonparticipant values mitigates potential biases in the responses of each group."*

Table 5 shows freeridership values from evaluations conducted using nonparticipant surveys. Adding nonparticipant surveys can decrease the NTG ratio slightly. As such, we do not recommend changing the current freeridership estimation approach.

Table 6. Comparison of Freeridership Results with Nonparticipant Surveys

Utility	Participant surveys only	Participant and nonparticipant surveys	Change
Mid-Atlantic (2012)	50%	40%	-10%
Northwest (2012)	43%	42%	-1%
Southeast (2012)	34%	32%	-2%
Southwest (2013)	29%	26%	-3%

Recommendation

The combined-regression *gross* savings estimates —1,218 kWh/year for primary units and 794 kWh/year for secondary units—are the most appropriate values for Con Edison's Residential Refrigerator Recycling program. These estimates follow the appropriate UMP protocols, are based on appliance characteristics from the latest set of available program tracking data, and combine meter data from Con Edison territory with data provided by UMP.

Based on the existing free-ridership value (54%) estimated in Con Edison's EEPS I impact evaluation, the recommended unit *net* savings are 560 kWh/year (compared to 670 in the TRM) for primary units and 363 kWh/year (compared to 740) for secondary units.

Con Edison should update savings estimates annually, using the model coefficients displayed in Table 2 above and the most recent year of program participation data.