Gross savings results of the models tested are fairly consistent across program years for each model, though there is some variation across models. All estimates from *in situ* models are lower than estimates reported in PY1-PY3 (first row).

Table 11. Average Annual UEC Using California Lab-Based Metering Coefficients vs. ComEd *in situ* Metering Coefficients (for same specification)

	PY1	PY2	PY3
Original California Lab-Based Model *(Reported)*			
Weighted Average Annual kWh[22]	1,929	2,003	1,864
Re-Estimation of California Lab-Based Model			
Weighted Average Annual kWh	945	902	956
Relative Precision	14.9%	15.0%	14.9%
Model A			
Weighted Average Annual kWh	1,038	1,033	1,088
Relative Precision	8.0%	7.3%	7.3%
Model B (1990 dummy)			
Weighted Average Annual kWh	953	933	997
Relative Precision	8.1%	7.5%	7.5%
Model C (1993 dummy)			
Weighted Average Annual kWh	930	911	980
Relative Precision	7.9%	7.4%	7.4%
Model B.1			
Weighted Average Annual kWh	1,063	1,061	1,127
Relative Precision	10.0%	9.0%	9.6%

Next, we compared estimates of savings for different appliance configurations using PY3 summary statistics for each configuration.[23] We compared model estimates of PY3 savings for each configuration to observed and predicted UEC (from Stage 1 models) from the metering sample. We also entered the same ComEd PY3 summary statistics for each configuration into two models recently developed from *in situ* metering as part of other program evaluations, so that we could make a fair comparison between what the coefficients of *in situ* models in other jurisdictions would have predicted for ComEd's PY3 population (Table 12).

[22] UEC values reported in PY1-PY3, weighted by the proportion of refrigerators and freezers in each year.

[23] For simplicity of this memo, we compare only estimates based on PY3 characteristics. PY3 characteristics were selected because they are expected to be more similar to future program years and are more similar to the metering sample than PY1-PY2 characteristics.

Table 12. Comparison of Average UEC across Metering Studies using ComEd PY3 Participant Characteristics

Study & Model	Appliance Type		Configuration					
	All Fridge	All Freezer	Top Freezer	Bottom Freezer	Side-by-Side	Single Door	Chest	Upright
Metering Study Sample Observations								
Observed kWh (annualized estimate)	908	1,134	787	822	1,291	323	1,097	1,162
Sq Ft observed	*19.6*	*16.0*	*18.7*	*18.4*	*22.8*	*9.0*	*15.6*	*16.4*
Energy Intensity (from Observed)	*46*	*71*	*42*	*45*	*57*	*36*	*70*	*71*
Metering Study Sample UEC								
Predicted UEC (from Stage 1 models)	937	1,091	802	937	1,337	361	1,005	1,156
Energy Intensity (from Predicted)	*48*	*68*	*43*	*51*	*59*	*40*	*64*	*71*
ComEd *In situ* Metering Study Models								
CA Lab-Based Metering Re-Estimation	898	1,220	902	638	1,591	428	1,279	1,241
Model A Estimates	1,037	1,344	1,042	754	1,684	655	1,153	1,483
Model B Estimates	956	1,232	962	742	1,584	266	963	1,377
Model C Estimates	937	1,220	945	720	1,584	272	948	1,374
Model B.1 Estimates	1,081	1,340	1,082	810	1,723	446	1,088	1,475
Other *In situ* Metering Studies[24]								
Consumers Energy (2010)	995	1,025	870	871	1,749	343	1,087	1,040
Ontario Power Authority (2010)	998	1,173	885	1,525	1,177	684	1,156	1,262
Lab-Based Metering Studies								
Ameren PY2 (2010)[25]	1,139	1,180	1,143	1,131	1,475	1,389	1,267	1,139
California 2004-2005	1,983	1,966	2,015	2,313	1,573	1,430	1,984	1,939

[24] References for *in situ* and lab-based metering studies provided in Appendix

[25] The Ameren PY2 evaluation models are based on a database maintained by the California Energy Commission (CEC) that contains lab-based metering results of unit energy consumption at the time of manufacture, for 61,000 makes and models manufactured between 1978 and 2008. These models require the application of a degradation factor of 1.5% to account for the fact that the model estimates energy consumption of units at the time of manufacture, not at time of retirement. This degradation factor was applied to the estimates obtained by entering ComEd PY3 characteristics into the equations.

Based on a comparison of potential models, Models B and C are preferable to other models for the following reasons:

- Relative precision around PY1-PY3 estimates is relatively strong (especially compared with relative precision using a re-estimation of the California lab-based metering model)
- Point estimates are in line with UEC observed within the metering sample
- The inclusion of dummy variables for manufacturing year before NAECA standards provides for a cohort effect that is supported by theory and the metering sample

UEC estimates from Models B and C are similar across years and configurations. Because LBNL research on the relationship between year of manufacture and UEC suggests that a more pronounced change in the relationship between year of manufacture and UEC occurred after the first NAECA update (1993) compared with 1990, Model C is preferable to B. Additionally, as the program matures, more units may be manufactured around the time of this change in standards (if not later), making the 1993 change in standard a potentially more relevant indicator of a cohort effect than the earlier standard.

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APPENDIX A. SUPPLEMENTAL INFORMATION

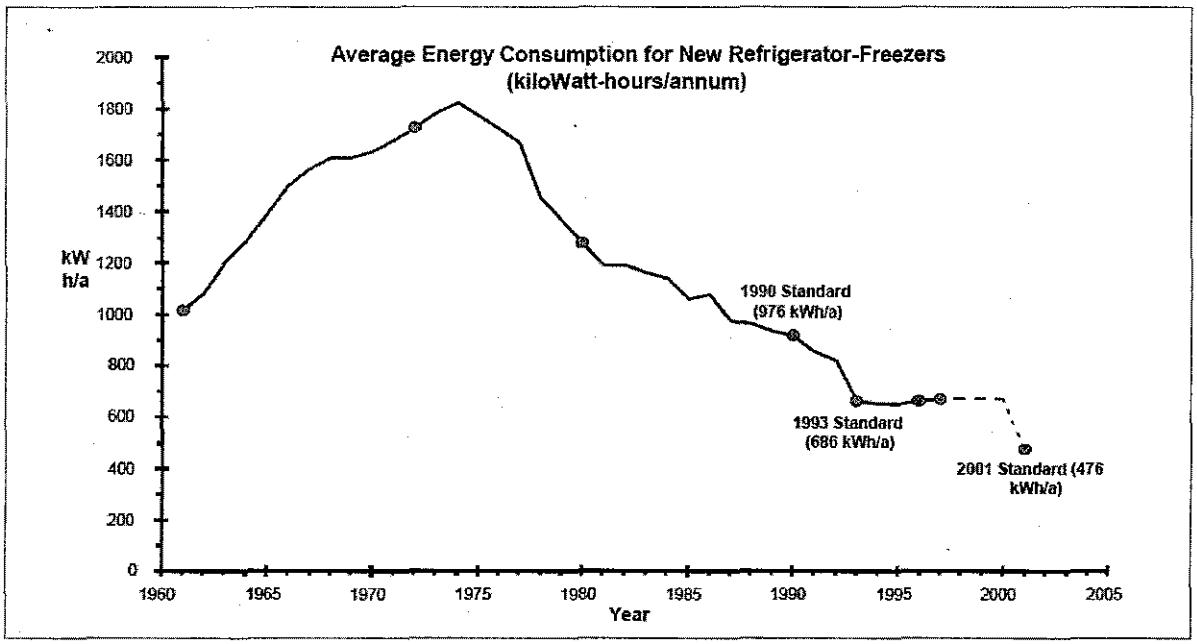
Table 13. Data Collected During Appliance Recycling Metering Study

Data Point	Application	Data collection method
Power (5 minute interval)	Energy usage and demand	Meters
Internal temperature (5 minute interval)	QA/QC power data (e.g., start and end dates/time of unit usage)	Meters
Light usage (on/off)	QA/QC power data (e.g., determine that unit was used during metering period)	Meters
Metering start and end dates & times	Clean power data and append weather	Technician report
Participant address and ZIP	Look up local weather data	Participant self-report and technician verification
Unit configuration	Potential association with energy consumption	Participant self-report and technician verification
Frost-free/manual defrost	Potential association with energy consumption	Participant self-report and technician verification
Through-door features	Potential association with energy consumption	Participant self-report and technician verification
Estimated Age	Potential association with energy consumption	Participant self-report and technician verification
Estimated Internal Capacity (size)	Potential association with energy consumption	Participant self-report and technician verification
Nameplate information	Look up additional information, if needed	Technician report
Primary/secondary unit	Study qualification; Potential association with energy consumption	Participant self-report
Location in home	Potential association with energy consumption	Participant self-report and technician verification
Air conditioned space (in summer)	Potential association with energy consumption	Participant self-report and technician verification
Heated space (in winter)	Potential association with energy consumption	Participant self-report and technician verification
Household occupants (#)	Potential association with energy consumption	Participant self-report
Occupants by age group	Potential association with energy consumption	Participant self-report
Part-Use Factors	Energy use and demand calculations	Participant Surveys
Hourly temperature and relative humidity data to calculate WTHI using PJM guidelines	Potential association with energy consumption	Rockford and O'Hare airports weather stations

Table 14. Refrigerator and Freezer Unit Characteristics

	PY1	PY2	PY3	PY1-PY2 Pooled	PY1-PY3 Pooled	Metering Sample
Ex Post Count	11,513	25,011	39,983	36,524	76,507	130
% Refrigerator	73.3%	80.2%	84.9%	78.0%	81.6%	78.5%
% Freezer	26.7%	19.8%	15.1%	22.0%	18.4%	21.5%
Refrigerator Configuration						
% Top Freezer	10.3%	46.0%	49.1%	34.7%	42.2%	52.3%
% Bottom Freezer	0.7%	2.6%	9.6%	2.0%	6.0%	4.6%
% Side-by-Side	3.1%	13.3%	14.7%	10.1%	12.5%	20.0%
% Single Door	1.7%	6.8%	6.7%	5.2%	6.0%	1.5%
% Unknown	57.5%	11.6%	4.8%	26.1%	15.0%	0.0%
Freezer Configuration						
% Chest	1.6%	5.8%	3.9%	4.5%	4.2%	9.2%
% Upright	2.4%	12.7%	8.8%	9.4%	9.1%	12.3%
% Unknown	22.7%	1.3%	2.4%	8.0%	5.1%	0.0%
Defrost Type						
% Manual	51.3%	38.6%	14.4%	42.6%	27.8%	28.4%
% Frost Free / Auto	44.5%	48.1%	83.4%	47.0%	66.0%	71.7%
% Part Frost Free	0.1%	2.1%	0.7%	1.5%	1.1%	0.0%
% Unknown	4.1%	11.2%	1.5%	9.0%	5.1%	0.0%
Through Door Features						
% with Water/Ice	17.6%	23.0%	25.6%	21.3%	23.5%	19.7%
Age						
Average age	27.0	25.7	24.9	26.1	25.5	23.9
% Age 15 years or higher	89.6%	86.0%	70.5%	87.1%	78.4%	84.6%
Mfg. year before 1990	73.4%	66.5%	63.1%	68.7%	65.8%	49.2%
Mfg. year before 1993	83.4%	76.8%	74.0%	78.9%	76.3%	65.4%
Size & Amps						
Average size (cubic feet)	16.8	17.6	18.0	17.4	17.7	18.8
Average label amps	4.8	5.5	5.9	5.3	5.6	7.0
Location						
% Garage	45.9%	47.85%	45.3%	47.2%	46.2%	56.2%
% Basement	37.1%	23.8%	21.0%	28.0%	24.3%	28.5%
% Kitchen / Non-basement inside	10.9%	14.1%	12.5%	13.1%	12.8%	13.1%
% Porch / Patio	0.6%	2.0%	3.5%	1.6%	2.6%	1.5%
% Other or Unknown	5.6%	12.2%	17.8%	10.1%	14.1%	0.8%

Figure 1. Average Annual Energy Consumption for New Refrigerators and Freezers by Year



Source: McMahon, Chan, and Chaitkin (2000).

APPENDIX B. AGE AND VINTAGE SENSITIVITY ANALYSIS

We also tested the sensitivity of our models to how age and vintage were recorded in the metering study compared with program data collection. For the metering study, meter installation technicians either recorded manufacturing year from the label (if available) or estimated age if the year was NOT available. Technicians were able to find manufacturing year for about one-third of units, and estimated age for all but four of the remaining units. Age for these four units was taken from the program database.

On average, age as reported in the program tracking database is about 3.9 years older than ages used in the metering study (average age in the metering study of 24.0 years, vs. 27.9 years for the same units in the tracking database). Similarly, among units for which year was recorded by the metering study, year as reported in the program tracking database reflects an age about 4.8 years older than used in the metering study.

Using the database ages to re-estimate coefficients in Model A, we found the explanatory power of the model to be much lower (an R^2 of 0.18, compared with 0.42 using the metering study age), and the coefficients on age are not individually or jointly significant. Using Model C, the explanatory power of the model is lower, and coefficients on age and vintage are not individually significant (though they are jointly significant at a 90% confidence level). PY3 program savings estimates are actually slightly lower using these models (Table 15 and Table 16).

Next, we compared what estimated savings would be using the metering study coefficients and (a) only metering sample characteristics, or (b) metering sample characteristics, substituting age as recorded by the metering study with age from the program tracking database. For Model A, the metering sample has a predicted average UEC of 1,080 kWh using metering data collection, and 1,230 kWh when year from the program tracking data is used for age (a 14% difference). For Model C, the metering sample has a predicted average UEC of 971 kWh using metering data collection, and 1,115 kWh when year from the program tracking data is used for age and vintage (a 15% difference).

Based on the difference in age and sensitivity of savings estimates to how year or age are collected, we recommend that the program continue to improve data collection QA/QC to ensure that characteristics of future units are reflected accurately in the program tracking database. For example, future evaluation plans could include a process to independently (and routinely) verify appliance characteristics tracked by the program.

Table 15. Comparison of Model A Using Age from the Metering Study vs. Program Tracking Database

	Metering Study Age		Program Age	
Variable Description	Coefficient	Robust t-statistic	Coefficient	Robust t-statistic
Intercept	-695.70	-2.42	34.30	0.08
Freezer dummy (=1 if freezer)	410.79	2.66	468.91	2.71
Side-by-side dummy (= 1 if side-by-side)	655.92	4.35	450.99	2.62
Chest dummy (= 1 if chest freezer)	-399.27	-2.21	-238.42	-1.09
Single door dummy (= 1 if single door)	-567.58	-3.11	-340.86	-2.19
Age	87.55	6.02	23.55	0.82
Age-squared	-0.94	-4.20	-0.18	-0.41
Cubic Feet	7.40	0.72	17.02	1.34
Manual defrost dummy (= 1 if manual defrost)	-350.58	-2.90	-165.85	-1.29
R^2	0.42		0.18	
PY3 Estimate (RP)	1,088 (7.3%)		937 (9.9%)[26]	

Table 16. Comparison of Model C Using Age from the Metering Study vs. Program Tracking Database

	Metering Study Age		Program Age	
Variable Description	Coefficient	Robust t-statistic	Coefficient	Robust t-statistic
Intercept	-103.39	-0.45	129.43	0.45
Freezer dummy (=1 if freezer)	433.40	2.73	477.87	2.72
Side-by-side dummy (= 1 if side-by-side)	614.91	3.96	457.81	2.66
Chest dummy (= 1 if chest freezer)	-490.78	-2.55	-242.84	-1.12
Single door dummy (= 1 if single door)	-797.90	-1.80	-329.78	-2.32
Age	23.93	3.11	7.86	1.08
Pre-1993 dummy (=1 if manufactured pre-1993)	289.82	2.00	214.58	1.24
Cubic Feet	13.52	1.28	17.25	1.42
Manual defrost dummy (= 1 if manual defrost)	-381.23	-3.03	-175.52	-1.39
R^2	0.38		0.19	
PY3 Estimate (RP)	980 (7.4%)		920 (7.6%)[27]	

[26] Estimated using coefficients from the model using age from the program tracking database, and average age of PY3 units from the program tracking database.

[27] Estimated using coefficients from the model using age and year from the program tracking database, and average age and vintage of PY3 units from the program tracking database.