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ComEd Home Energy Report Combined Evaluation Report

Energy Efficiency / Demand Response Plan: Plan Year 9 (PY9)

Presented to
ComEd

February 6, 2019

Prepared by:

Navigant

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ComEd Home Energy Report Combined Evaluation Report

Submitted to:

ComEd
Three Lincoln Centre
Oakbrook Terrace, IL 60181

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1. INTRODUCTION

This report combines the key deliverables from the evaluation of the Home Energy Report Program for PY9. Each of these deliverables were drafted, reviewed and finalized during the course of the PY9 evaluation.

APPENDIX A. COMED HER YEAR THREE PERSISTENCE AND DECAY STUDY 2017-11-14

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ComEd Home Energy Report Program Decay Rate and Persistence Study – Year Three

FINAL

Presented to

Commonwealth Edison Company

November 14, 2017

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ComEd Home Energy Report Program Decay Rate and Persistence Study – Year Three

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E. EXECUTIVE SUMMARY

This report presents Navigant's persistence and decay rate analysis for the third year after groups of Commonwealth Edison Company (ComEd) customers stopped receiving Home Energy Reports (HER). Navigant's third-year assessment evaluates savings between November 1, 2015 and October 31, 2016. Its primary objective is to identify the extent to which household energy savings persisted or decayed once customers no longer received HERs, extending earlier research which evaluated savings rates after one-year and two-year HER termination periods.[1,2]

Over the past several years, regulators have expressed a growing interest in the persistence of HER programs savings after customers stopped receiving reports. This persistence has important implications for lifetime measure savings and cost-effectiveness of HER programs. The current rule of thumb for electric programs is that savings decay approximately 20 percent each year after reports stop.[3] Navigant's study of the two years after customers no longer received reports found savings persisted in each wave. Moreover, persistence was positively correlated with the length of time ComEd customers received HERs. Continuing this analysis for a third year provides the opportunity to understand the rate of decay over time.

By continuing this analysis for a third year, stakeholders can better identify the rate at which savings diminish following report termination, as this decay is not necessarily constant over time. These results can be used as one data point to determine the persistence factors and measure life for HER programs in the Illinois Technical Reference Manual (IL TRM).[4]

The HER program achieves energy savings by providing residential customers with information about energy use and conservation. Program participants received this information in the form of regularly-mailed HERs that gave customers insight into their energy use, including:

- An assessment of how the customer's recent energy use compared to past energy use.
- Tips on how to reduce energy consumption, some of which were tailored to the customer's unique circumstances.
- Information on how their energy use compared to that of neighbors with similar homes.

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[1] Navigant. 2016a. *Home Energy Report Opower Program Decay Rate and Persistence Study*. Presented to Commonwealth Edison Company. < http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY7_Evaluation_Reports/ComEd_HER_Opower_Persistence_and_Decay_Study_2016-01-29_Final.pdf>

[2] Navigant. 2016b. *Home Energy Report Opower Program Decay Rate and Persistence Study – Year Two*. Presented to Commonwealth Edison Company. < https://library.cee1.org/system/files/private/library/13218/ComEd_HER_Year_Two_Persistence_and_Decay_Study_2016_07_20.pdf>

[3] Cadmus. 2014. *Long-Run Savings and Cost-Effectiveness of Home Energy Report Programs.* Page 7 <http://www.cadmusgroup.com/wp-content/uploads/2014/11/Cadmus_Home_Energy_Reports_Winter2014.pdf>

[4] The relevant measure is "Adjustments to Behavior Savings to Account for Persistence" which is measure 6.1.1 in Volume 4 of Version 6 of the IL TRM. < http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_4_X-Cutting_Measures_and_Attach_020817_Final.pdf >

ComEd discontinued the HER program for three sets of participants in October 2013, identified in Table E-1 via shaded rows. Navigant's third-year assessment evaluates savings between November 1, 2015 and October 31, 2016. Customers in the Wave 1 terminated report (TR) group received reports for just over four years before they were discontinued, Wave 3 TR customers for two and a half years, and Wave 5 TR customers for just over one year.

Table E-1. Summary of HER Waves

Wave	Start Date	Stop Date	Restart Date	Length of Treatment Before Termination
Wave 1 CR	July 2009	-	-	-
Wave 1 LR	July 2009	October 2012	August 2013	-
Wave 1 TR	July 2009	October 2013	-	52 months
Wave 2	September 2010	-	-	-
Wave 3 CR	May 2011	-	-	-
Wave 3 LR	May 2011	October 2012	August 2013	-
Wave 3 TR	May 2011	October 2013	-	30 months
Wave 4	January 2012	-	-	-
Wave 5 CR	July 2012	-	-	-
Wave 5 TR	July 2012	October 2013	-	16 months
Wave 6	June 2013	-	-	-
Wave 7 Low	June 2014	-	-	-
Wave 7 High	June 2014	-	-	-
New Mover	Rolling starting September 2014	-	-	-
Wave 8	July 2015	-	-	-
Wave 9	September 2016	-	-	-

Source: Implementation contractor data
Note: CR refers to continued report, LR to lapsed report, and TR to terminated report.

Annual Savings Decay Rate

Table E-2 and Table E-3 present annual decay rates and persistence factors for the three TR groups in the first, second, and third years after customers stopped receiving reports.[5] Navigant calculated persistence for each wave by comparing savings rates of the TR group to those of the continued report (CR) group. The first two years after customers stopped receiving reports, decay rates increased for all three waves, while the third year showed mixed results with rates increasing for Wave 1, remaining roughly flat for Wave 3, and decreasing for Wave 5. On average, decay rates did not increase as much from the second to third year as in the first to second year after report termination.

[5] These estimates assume a resident move-out-rate of six percent, which was calculated based on historical ComEd HER program data.

Table E-2. HER Decay Rates

	Wave 1	Wave 3	Wave 5	Average
Year 1 (Nov 2013 - Oct 2014)	4%	2%	22%	9%
Year 2 (Nov 2014 - Oct 2015)	15%	17%	60%	31%
Year 3 (Nov 2015 - Oct 2016)	39%	18%	47%[6]	35%
Year 3 Standard Error	*16%*	*13%*	*30%*	-

Source: Navigant analysis

Table E-3. HER Persistence Factors

	Wave 1	Wave 3	Wave 5	Average
Year 1 (Nov 2013 - Oct 2014)	96%	98%	78%	90%
Year 2 (Nov 2014 - Oct 2015)	85%	83%	40%	69%
Year 3 (Nov 2015 - Oct 2016)	61%	82%	53%	65%

Source: Navigant analysis
Note: The persistence factor is equal to one minus the decay rate.

Table E-4 presents a summary of lifetime persistence savings and measure life using results from the three years after report termination.[7] Readers should not compare lifetime persistence savings across waves due to variation in the number of participants, and therefore total savings. For example, because Wave 1 had 11 percent more customers than Wave 5, it will likely have a higher savings figure, regardless of its persistence factor. Wave measure life, however, can be directly compared. To calculate measure life, Navigant took decay figures from the first three years, and projected savings would continue to decay at the rate observed in the third year.[8] Of the three waves, Wave 3 had the longest measure life and Wave 5 had the shortest.

Table E-4. HER Persistence Savings and Measure Life

	Wave 1	Wave 3	Wave 5	Average
Lifetime Persistence Savings	8,083	19,027	5,141	-
Measure Life	3.18	4.95	2.21	3.44
Year 3 Standard Error	*0.38*	*0.53*	*0.57*	-

Source: Navigant analysis

Study Savings: November 2015 – October 2016

Table E-5 summarizes wave results for November 2015 - October 2016 (also referred to as the third year after report termination). In this table, the number of participants, in the first row, represents the number of customers with an active ComEd account as of November 2015; whereas the sample sizes, in the second

[6] The decrease in decay rate for Wave 5 from year 2 to year 3 was due to a higher proportional increase in the TR customer savings rate from 0.58% to 0.89%, while the CR customer savings rates only went up from 1.47% to 1.66%.
[7] See Section 2.6 for a more detailed examination of how these calculations were conducted.
[8] Future analysis will provide additional decay rate estimates and suggest the point in time at which savings diminish to zero.

and third rows, indicate the number of customers with sufficient data for inclusion in the regression analysis. Results are separated by CR and TR customers to identify the number of participants and savings related to each group. Because the analysis period does not match up with a typical ComEd program year, this study did not estimate legacy uplift savings, although it did include uplift savings for the analysis period.[9]

Table E-5. HER Results from November 2015 – October 2016

Savings Category	Wave 1 CR	Wave 1 TR	Wave 3 CR	Wave 3 TR	Wave 5 CR	Wave 5 TR
Number of Participants	20,411	6,270	140,368	7,603	5,668	5,605
Sample Size - Treatment	17,641	5,420	121,570	6,583	4,289	4,193
Sample Size - Control	26,637		33,235		5,438	
Percentage Savings	2.79%	1.70%	2.53%	2.07%	1.67%	0.89%
Standard Error	0.29%	0.47%	0.17%	0.35%	0.57%	0.57%
Verified Net Savings, Prior to Uplift Adjustment, MWh†	8,152	1,521	62,939	2,786	1,951	1,038
Standard Error	837	417	4,164	470	669	662
Savings Uplift in Other EE Programs in Analysis Period, MWh‡	24	17	68	6	19	23
Verified Net Savings, MWh†‡	8,128	1,504	62,871	2,780	1,932	1,015

Source: Navigant analysis
†Total savings are pro-rated for participants that closed their accounts during the analysis period.
‡Negative double counted savings indicate that the participation rate in the EE program is higher for the control group than the treatment group. This results in a lower baseline and underestimates HER program savings.
†‡ Gross savings adjusted for savings uplift are equal to gross savings less the uplift of savings in other EE programs.

Findings and Recommendations

The following section includes key findings and recommendations.

Finding 1. Wave decay rates diverged in the third year of the ComEd persistence study. For Wave 1, it more than doubled from 15 percent to 39 percent, while Wave 3 stayed basically the same at 18 percent, and the Wave 5 decay rate decreased from 60 percent to 47 percent. The combined average decay rate increased in absolute terms from 31 percent to 35 percent, but the rate of increase slowed markedly.

[9] In program year reports, Navigant conducts both legacy uplift and analysis period uplift. Legacy uplift captures the portion of savings due to uplift in each year from measures installed in a previous year (through that measure's effective useful life). Analysis period uplift captures uplift for measures installed during the analysis, or evaluation, period. This report calculated analysis period uplift, but not legacy uplift. Navigant tested estimating legacy uplift in the first-year persistence study, but since the difference in total savings made a negligible impact on the decay rate and measure life the legacy adjustment was not included in the analysis.

Finding 2. Assuming savings decayed as observed in the first three years and continue to decay at the rate observed in year three[10], the implied measure life is three years for Wave 1, five years for Wave 3, and two years for Wave 5. Across the three waves, the average measure life was 3.44 years. This finding provides ComEd an indication of measure lives for the three persistence waves in this study, and is not a recommendation to update the measure life in the IL TRM.

Recommendation 1. Navigant recommends that the IL TRM combine this analysis with other relevant studies[11] to update the persistence factors the next time this measure is updated. The IL TRM[12] currently includes HER energy savings persistence values based on existing research and extrapolation of those findings. Table E-6 shows those figures relative to Navigant's research using ComEd data. The year column identifies the temporal relationship of the data to report termination. For example, Persistence Factor Electric 1 (PFE_1) is one year after customers no longer received HERs.

Table E-6. Existing and Recommended TRM Persistence Factors

Year	TRM Persistence Factors	Navigant Analysis Persistence Factors
	100%	100%
PFE_1	80%	90%
PFE_2	54%	69%
PFE_3	31%	65%
PFE_4	15%	-

Source: Navigant analysis

Recommendation 2. ComEd should continue this study and look at savings in the fourth year after reports are stopped, from November 2016 to October 2017. The continued study would estimate the decay rate in the fourth year after reports are stopped. A year four report would add to research on how decay rates evolve over time. The results could be used, along with other relevant studies, to inform fourth year persistence factors in the IL TRM.

[10] An assumption of a constant decay rate from year 3 forward is necessary to calculate a measure life as discussed with the calculations in Section 2.6.

[11] For example, this study for Puget Sound Energy: http://www.oracle.com/us/industries/utilities/herp-puget-sound-energy-3628986.pdf

[12] Version 6.0, Volume 4, Measure 6.1.1

1. INTRODUCTION

1.1 Program Description

This report presents Navigant's persistence and decay rate analysis for the third year after groups of Commonwealth Edison Company (ComEd) customers stopped receiving Home Energy Reports (HER). Its primary objective is to identify the extent to which household energy savings persisted or decayed once customers no longer received HERs, extending earlier research which evaluated savings rates after one-year and two-year HER termination periods.[13,14] By continuing this analysis for a third year, Navigant can better identify the rate at which savings diminish following report termination, as this decay is not necessarily constant over time. These results can be used as one data point to determine the persistence factors and measure life for HER programs in the Illinois Technical Reference Manual (IL TRM).[15]

ComEd designed the HER program to generate energy savings by providing residential customers with information about energy use and conservation. Program participants received this information in the form of regularly-mailed HERs that gave customers insight into their energy use, including:

- An assessment of how the customer's recent energy use compared to past energy use.
- Tips on how to reduce energy consumption, some of which were tailored to the customer's unique circumstances.
- Information on how their energy use compared to that of neighbors with similar homes.

ComEd discontinued the HER program for three sets of participants in October 2013, identified in Table 1-1 via shaded rows. Navigant's third-year assessment evaluates savings between November 1, 2015 and October 31, 2016. Customers in the Wave 1 terminated report (TR) group received reports for just over four years before they were discontinued, Wave 3 TR customers for two and a half years, and Wave 5 TR customers for just over one year.

[13] Navigant. 2016a. *Home Energy Report Opower Program Decay Rate and Persistence Study*. Presented to Commonwealth Edison Company. < http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY7_Evaluation_Reports/ComEd_HER_Opower_Persistence_and_Decay_Study_2016-01-29_Final.pdf>

[14] Navigant. 2016b. *Home Energy Report Opower Program Decay Rate and Persistence Study – Year Two*. Presented to Commonwealth Edison Company. < https://library.cee1.org/system/files/private/library/13218/ComEd_HER_Year_Two_Persistence_and_Decay_Study_2016_07_20.pdf>

[15] The relevant measure is "Adjustments to Behavior Savings to Account for Persistence" which is measure 6.1.1 in Volume 4 of Version 6 of the IL TRM. < http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_4_X-Cutting_Measures_and_Attach_020817_Final.pdf >

Table 1-1. Summary of HER Waves

Wave	Start Date	Stop Date	Restart Date	Length of Treatment Before Termination
Wave 1 CR	July 2009	-	-	-
Wave 1 LR	July 2009	October 2012	August 2013	-
Wave 1 TR	July 2009	October 2013	-	52 months
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Wave 5 CR	July 2012	-	-	-
Wave 5 TR	July 2012	October 2013	-	16 months
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Wave 7 High	June 2014	-	-	-
New Mover	Rolling starting September 2014	-	-	-
Wave 8	July 2015	-	-	-
Wave 9	September 2016	-	-	-

Source: Implementation contractor data
Note: CR refers to continued report, LR to lapsed report, and TR to terminated report.

Over the past several years, regulators have expressed a growing interest in the persistence of HER programs savings after customers stopped receiving reports. This persistence has important implications for lifetime measure savings and cost-effectiveness of HER programs. The current rule of thumb for electric programs is that savings decay approximately 20 percent each year after reports stop.[16] Navigant's study of the two years after customers no longer received reports found savings persisted in each wave. Moreover, persistence was positively correlated with the length of time ComEd customers received HERs. Continuing this analysis for a third year provides the opportunity to understand how the rate of decay changes over time.

1.2 Evaluation Objectives

The primary objective of this study is to estimate savings decay rates and associated measure lives for Wave 1, Wave 3, and Wave 5 TR customer groups. In this evaluation, savings decay is defined as the reduction in savings after customers stopped receiving HERs plus any missed incremental savings. A secondary objective is to determine the shape of the decay rate over time following HER termination. This research will help to inform future iterations of the IL TRM persistence factors.

[16] Cadmus. 2014. *Long-Run Savings and Cost-Effectiveness of Home Energy Report Programs*. Page 7.
< http://www.cadmusgroup.com/wp-content/uploads/2014/11/Cadmus_Home_Energy_Reports_Winter2014.pdf>

2. STUDY APPROACH

Navigant used statistical analysis appropriate for a RCT to calculate HER program persistence savings, which is consistent with annual program year evaluations.[17] This approach estimated program impacts using two methods: a lagged dependent variable (LDV)[18] regression and a linear fixed-effects regression (LFER) applied to monthly billing data. Navigant calculated persistence, decay, and measure life by comparing the TR group to the continued report (CR) group for each wave.

2.1 Overview of Data Collection Activities

Navigant used tracking data and monthly billing data for all program participants and control customers from September 2008 through October 2016 from Oracle, the program implementation contractor (see Table 2-1).

Table 2-1. Primary Data Collection Activities

Collection Method	Subject Data	Quantity	Net Impact	Process
Billing Data	Program participants and controls	All	X	N/A
Tracking Data	Program participants and controls	All	X	N/A
Tracking Data for Other Programs	Participants in other programs	All	X	N/A

Source: Navigant analysis

2.2 Sampling Plan

Oracle implemented the HER program as a RCT, in which they randomly assigned individuals to either treatment (participant) group or control (non-participant) groups.[19] To calculate persistence, Oracle randomly designated customers to no longer receive HERs, creating TR subgroups in relevant waves.

2.3 Data Used in Impact Analysis

In preparation for the impact analysis, Navigant combined and cleaned the data provided by the implementer. The dataset included 185,925 treatment customers and 65,310 controls over the twelve-month pre-period (November 2012 to October 2013) and analysis period (November 2015 to October 2016).

[17] See for example: Navigant Consulting Inc. 2016. "Home Energy Report Opower Program PY8 Evaluation Report." Presented to Commonwealth Edison Company. < http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY8_Evaluation_Reports_Final/ComEd_Home_Energy_Report_Opower_PY8_Evaluation_Report_2016-12-22_Final.pdf>

[18] The model is identical to the post-program regression (PPR) model used in previous evaluations. We have changed the nomenclature to better align with academic research and because LDV is more descriptive of the model structure than PPR.

[19] In this design, treatment customers receive HERs, while control customers do not.

Navigant removed the following customers and data points from the analysis:

- Lapsed Report (LR) customers[20]
- Records with a bill duration of 0
- Subset to the one year pre-program period and the one year analysis period
- Bill Flattening - Aggregating records that ended in the same month[21]
- Observations with missing usage
- Observations with negative usage
- Customers with an active account and fewer than 11 bills or any customer with more than 13 bills in either the analysis period or pre-period
- Observations with fewer than 20 or more than 40 days in the billing cycle
- Outliers, defined as observations with average daily usage more than one order of magnitude from the median usage.[22]

Detailed counts of the customers and observations removed by wave are included in Section 5.1 of the appendix.

2.4 Statistical Models Used in the Impact Evaluation

Navigant used the LDV results to calculate decay and measure life, but also ran the LFER models as a robustness check.[23] Although the two models are structurally very different, assuming the RCT is well-balanced with respect to the drivers of energy use, in a single sample the two models generate comparable program savings estimates.

The LDV model combines both cross-sectional and time-series data in a panel format. It uses post-program data as the dependent variable, with lagged energy use from the same calendar month of the pre-program period serving as a control for small, systematic differences between treatment and control customers.

As with the LDV model, the LFER model combines cross-sectional and time-series data in a panel format. The regression compares pre- and post-program billing data for participants and controls to identify the program's effect. The customer-specific fixed effect is a key feature of the LFER analysis, and captures

[20] To examine the persistence of savings, reports for 10,000 customers within both Waves 1 and 3 were terminated beginning in October 2012 and restarted in August 2013; these customers are referred to as the Waves 1 and 3 lapsed report (LR) subgroups. Since reports were restarted for these customers they are not a part of this research.
[21] This does not remove any records but rather redistributes records for analysis purposes.
[22] Median usage was calculated by wave. Chronologically, the medians were 35, 46, and 53 kilowatt-hours (kWh) per day.
[23] Navigant prefers to report out the LDV model for two reasons. One, the implementer is also using a post-only model for evaluation. Two, although both the LFER and LDV models generate unbiased estimates of program savings, as an empirical matter—based on our past analyses and those in the academic literature—estimated savings from the LDV model tend to have lower standard errors than those from the LFER model, though the differences are usually very small.

customer-specific factors affecting electricity usage that do not change over time, including those unobservable to the researcher. Examples include the square footage of a residence or the number of occupants in a household. The fixed effect represents an attempt to control for systematic differences between the treatment and control customers that might occur due to chance, like the LDV's lagged energy use term.

Section 5.2 presents the LDV and LFER models used in this analysis.

2.5 Accounting for Uplift in Other Energy Efficiency Programs

2.5.1 Accounting for Uplift in the Analysis Period

The reports sent to participating households included energy-saving tips, some of which encouraged participants to enroll in other ComEd energy efficiency (EE) programs. If participation rates in other EE programs are the same for the HER participant and control groups, the savings estimates from the regression analyses are already "net" of savings from the other programs, as this indicates the HER program did not increase or decrease participation in the other EE programs. However, if the HER program affects participation rates in other EE programs, then savings across all programs are lower than indicated by the simple summation of savings in the HER and EE programs. For instance, if the HER program increases participation in other EE programs, the increase in savings may be allocated to either the HER program or the EE program, but cannot be allocated to both programs simultaneously.[24]

Navigant used a difference-in-difference (DID) statistic to estimate uplift in other EE programs between November 2015 and October 2016. To calculate the DID statistic, Navigant subtracted the change in the participation rate in another EE program between the analysis period and the pre-program year for the control group from the same change for the treatment group. For instance, if the rate of participation in an EE program during the analysis period is five percent for the treatment group and three percent for the control group, and the rate of participation during the year before the start of the HER program is two percent for the treatment group and one percent for the control group, then the rate of uplift due to the HER program is one percent, as reflected in Equation 2-1.

Equation 2-1. DID Statistic Calculation

$$(analysis\ period\ treatment\ group\ participation - prePY\ treatment\ group\ participation) - (analysis\ period\ control\ group\ participation - prePY\ control\ group\ participation) = DID\ statistic$$

$$(5\% - 2\%) - (3\% - 1\%) = 1\%$$

The DID statistic generates an unbiased estimate of uplift when the baseline average rate of participation is the same for the treatment and control groups, or when they are different due only to differences between the two groups in time-invariant factors, such as residency square footage.

A simple difference in participation rates during the analysis period provides an alternative unbiased estimate of uplift when the baseline average rate of participation in the EE program is the same for the

[24] It is not possible to avoid double counting of savings generated by programs for which tracking data are not available, such as upstream compact fluorescent lamp (CFL) programs.

treatment and control groups. Navigant used this alternative statistic –the "post-only difference" (POD) statistic –in cases where the EE program did not exist for the entire pre-program year.

Navigant examined uplift associated with four EE programs in the third year following report termination: the Fridge and Freezer Recycling (FFR) program, the Home Energy Assessment (HEA) program, the Home Energy Rebates (Rebate) program, and the Multi-family Energy Savings Program (MESP).[25]

2.5.2 Accounting for Legacy Uplift

The uplift adjustment methodology described in Section 2.5.1 only accounts for uplift which occurs in the current year because EE program tracking files in any given program year only capture new measures installed in that year, regardless of expected measure lives.[26] However, for other EE programs with multi-year measure lives, HER program savings capture the portion of their savings due to uplift in each year of that program's measure life. For instance, a measure with a ten-year measure life that was installed in PY2 would generate savings captured in the HER program savings not just in PY2, but in PY3 through PY11 as well.

Since the analysis period for this study is off from a regular program year Navigant was unable to accurately estimate legacy uplift for this analysis period. Navigant did test estimating legacy uplift as the same percentage of current year uplift as was found in the PY8 HER evaluation report.[27] However, the difference in total savings made a negligible impact on the decay rate and measure life estimation that are the focus of this study, so the legacy uplift adjustment was not included in this analysis.

2.6 Estimating Decay of Savings

The annual decay rate for any year *t* is equal to one minus the ratio of the percentage savings for the TR group in the t^{th} year after the reports were discontinued to percentage savings for the CR group in that same year. Equation 2-2 shows this calculation, where δ_t is the decay rate for the t^{th} year after reports were discontinued.

Equation 2-2. Year t Decay Rate

$$\delta_t = 1 - \frac{\%\ Savings\ for\ TR\ in\ t^{th}\ year\ after\ reports\ stop}{\%\ Savings\ for\ CR\ in\ t^{th}\ year\ after\ reports\ stop\ for\ TR}$$

Both decay rate and lifetime persistence savings are used to estimate measure life, which represents the time that an HER program is expected to continue producing energy savings. Lifetime persistence savings is the total savings attributable to the program after reports stop. The lifetime persistence savings are calculated via an infinite series which converges to Equation 2-3,[28] where α is the annual attrition due

[25] These are the names used for these programs in PY8.
[26] Tracking data files are set-up this way because, in conformity the Illinois Technical Reference Manual Section 3.2, savings are first-year savings, not lifetime savings.
[27] Navigant Consulting Inc. 2016. "Home Energy Report Opower Program PY8 Evaluation Report." Presented to Commonwealth Edison Company.
[28] The Cadmus Group, Inc. 2014. "Long-Run Savings and Cost-Effectiveness of Home Energy Report Programs." Prepared by M. Sami Khawaja, PhD. And James Stewart, PhD.

to residence changes,[29] and δ_t is the decay rate for the t^{th} year after reports were discontinued. Most importantly, the lifetime persistence savings measure assumes that savings in the *t*th year following the termination of reports will remain constant for year *t+1* onward.

Equation 2-3. Lifetime Persistence Savings

$$Lifetime\ Persistence\ Savings_t = Total\ savings\ for\ TR\ up\ to\ t^{th}\ year\ after\ reports\ stop\ for\ TR + \frac{Total\ Savings\ for\ TR\ in\ t^{th}\ year\ after\ reports\ stop\ for\ TR}{\delta_t + \alpha - (\delta_t * \alpha)}$$

Measure life in Equation 2-4 represents the time that an HER program is expected to remain useful following termination considering (1) lifetime persistence savings, measured in year *t* since HER termination, and (2) total savings in the first year after HER termination. Due to the savings term in the denominator, measure life can be expressed in first-year savings equivalents, allowing its interpretation as a duration of savings directly following HER termination.

Equation 2-4. Measure Life

$$Meas\ Life_t = \frac{Lifetime\ Persistence\ Savings_t}{Total\ Savings\ for\ TR\ in\ 1st\ year\ after\ reports\ stop\ for\ TR}$$

[29] The convergence assumes that savings decay infinitely at a constant annual rate of *(1-δ)(1-α)*.

3. GROSS IMPACT EVALUATION

Table 3-1 summarizes wave results for the third year after report termination. Results are separated by CR and TR customers to identify the number of participants and savings related to each group. Because the analysis period does not match up with a typical ComEd program year, this study did not estimate legacy uplift savings.[30]

Table 3-1. HER Total Savings from November 2015 – October 2016

Savings Category	Wave 1 CR	Wave 1 TR	Wave 3 CR	Wave 3 TR	Wave 5 CR	Wave 5 TR
Number of Participants	20,411	6,270	140,368	7,603	5,668	5,605
Sample Size - Treatment	17,641	5,420	121,570	6,583	4,289	4,193
Sample Size - Control	26,637		33,235		5,438	
Percentage Savings	2.79%	1.69%	2.53%	2.07%	1.67%	0.89%
Standard Error	0.29%	0.47%	0.17%	0.35%	0.57%	0.57%
Verified Net Savings, Prior to Uplift Adjustment, MWh†	8,152	1,521	62,939	2,786	1,951	1,038
Standard Error	837	417	4,164	470	669	662
Savings Uplift in Other EE Programs in Current Year, MWh‡	24	17	68	6	19	23
Verified Net Savings, MWh†‡	8,128	1,504	62,871	2,780	1,932	1,015

Source: Navigant analysis

†Total savings are pro-rated for participants that closed their accounts during the analysis period.

‡Negative double counted savings indicate that the participation rate in the EE program is higher for the control group than the treatment group. This lowers the baseline and underestimates HER program savings.

†‡ Gross savings adjusted for savings uplift are equal to gross savings less the uplift of savings in other EE programs.

3.1 LDV and LFER Model Parameter Estimates

The LDV and LFER models generate very similar results for program savings estimates for each of the three waves included in this study. Navigant uses LDV results to estimate decay and measure life. Across the two models, the parameter estimates are not statistically different; that is, the estimates for each model are within the 90 percent confidence bounds for the other model. Section 5.3 includes detailed estimate information for each relevant wave and model.

3.2 Uplift of Savings in Other EE Programs

LDV program savings estimates include savings resulting from the uplift in participation in other EE programs caused by the HER program. To avoid double-counting savings, program savings due to this uplift must be counted towards either the HER program or the other EE programs, but not both programs. The uplift of savings in other EE programs was a very small proportion of the total savings for the relevant TR and CR groups: 157 MWh, or 0.20 percent. This estimate includes uplift in the analysis period but not legacy uplift from prior years.

[30] When legacy uplift was included in Navigant's first-year persistence study, the difference in total savings made a negligible impact on the decay rate and measure life, so the legacy adjustment was not included in the analysis.

Table 3-1 above includes a breakdown of the assumed savings from uplift for each wave, and the verified net savings for the HER program obtained by removing these savings from the estimate of verified net program savings prior to uplift adjustment. As previously mentioned, the programs included in the uplift analysis were the FFR program, the HEA program, the Rebate program and the MESP.[31] Where possible, Navigant used a DID statistic to estimate double-counted savings, and otherwise used a simple comparison of the rate of participation in EE programs by treatment and control households in the analysis period – the POD estimate of double-counted savings.

The estimate of double-counted savings is most likely an *overestimate* because it presumes participation in the other EE programs occurs at the very start of the analysis period. Under the more reasonable assumption that participation occurs at a uniform rate throughout the year, the estimate of double-counted savings would be approximately 78.5 MWh, half the estimated value of 157 MWh. The upshot is that double counting of savings with other ComEd EE programs *is not a significant issue* for the HER program.

3.3 Decay Estimates

Table 3-2 and Table 3-3 present annual decay rates and persistence factors for the three TR groups in the first, second, and third years after customers stopped receiving reports.[32] Navigant calculated persistence for each wave by comparing savings rates of the TR group to those of the CR group over the same time period.

An alternate analytical approach could compare TR group savings in years after reports stopped to the same group's savings in the final year it received reports. The benefit of this approach is that program design changes such as altering report cycles would not bias estimates. However, this method does not allow for naturally occurring dynamics including program ramp-up to be incorporated into the counter-factual. On balance, Navigant chose an in-year comparison between CR and TR groups because we believe this approach more accurately captures the TRM's goal to determine what saving would have been if reports had stopped relative to continuing.

The first two years after customers stopped receiving reports, decay rates increased for all three waves, while the third year showed mixed results with rates increasing for Wave 1, remaining roughly flat for Wave 3, and decreasing for Wave 5. On average, decay rates did not increase as much from the second to third year as in the first to second year after report termination. For the first two years, there was a negative correlation between length of treatment before termination and decay rates (i.e., Wave 1 with the longest treatment period had the lowest decay rate). However, that trend diverged in the third year with Wave 5 still having the highest decay rate, but Wave 3 having a lower decay rate than Wave 1.

[31] ComEd has other residential programs that were not included in the analysis. The Residential Lighting and Elementary Education programs do not track participation at the customer level, and so do not have the data necessary for the uplift analysis. Double counting between the Residential New Construction and HER programs is not possible due to the requirement that HER participants have sufficient historical usage data.

[32] These estimates assume a resident move-out-rate of six percent, which was calculated based on historical ComEd HER program data.

Table 3-2. HER Decay Rates

	Wave 1	Wave 3	Wave 5	Average
Year 1 (Nov 2013 - Oct 2014)	4%	2%	22%	9%
Year 2 (Nov 2014 - Oct 2015)	15%	17%	60%	31%
Year 3 (Nov 2015 - Oct 2016)	39%	18%	47%	35%
Year 3 Standard Error	*16%*	*13%*	*30%*	-

Source: Navigant analysis

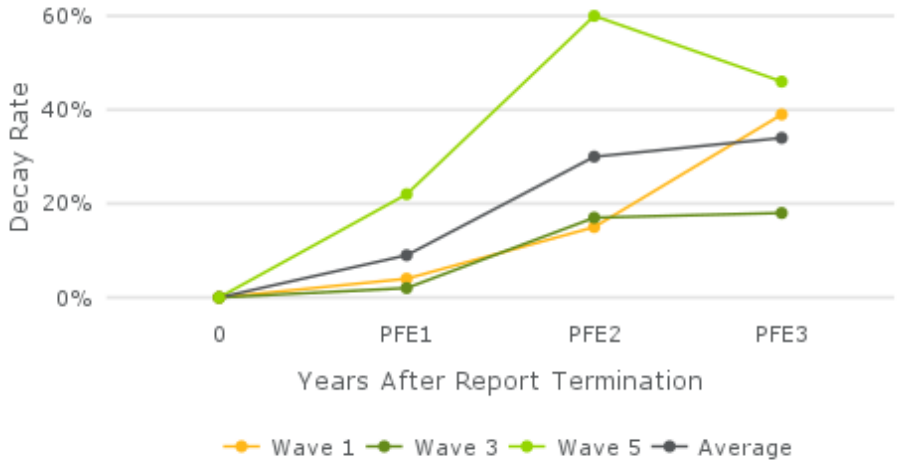
Table 3-3. HER Persistence Factors

	Wave 1	Wave 3	Wave 5	Average
Year 1 (Nov 2013 - Oct 2014)	96%	98%	78%	90%
Year 2 (Nov 2014 - Oct 2015)	85%	83%	40%	69%
Year 3 (Nov 2015 - Oct 2016)	61%	82%	53%	65%

Source: Navigant analysis
Note: The persistence factor is equal to one minus the decay rate.

The growth in the year-over-year decay rate can be more clearly seen in Figure 3-1. As opposed to a steady linear pattern, the decay rates vary across wave groups. For example, Wave 1's decay rate is exponential, while Wave 3 and Wave 5 show diminishing growth and a decrease in growth respectively. However, the average of these decay rates is a relatively linear pattern of 12 percent per year.

Figure 3-1. Annual Decay Rate



Source: Navigant analysis

The IL TRM[33] provides HER energy savings persistence values based on existing research and extrapolation of those findings.

[33] Version 6.0, Volume 4, Measure 6.1.1

Table 3-4 shows those figures relative to Navigant's research using ComEd data. The year column identifies the temporal relationship of the data to report termination. For example, Persistence Factor Electric 1 (PFE_1) is one year after customers no longer received HERs.

Table 3-4. Existing and Recommended TRM Persistence Factors

Year	TRM Persistence Factors	Navigant - Analysis Persistence Factors
	100%	100%
PFE_1	80%	90%
PFE_2	54%	69%
PFE_3	31%	65%
PFE_4	15%	-

Source: Navigant analysis

Table 3-5 presents a summary of lifetime persistence savings and measure life using results from the three years after report termination.[34] Readers should not compare lifetime persistence savings across waves due to of variation in the number of participants, and therefore total savings. For example, because Wave 1 had more customers than Wave 5, it will likely have a higher savings figure, regardless of its persistence factor. Wave measure life, however, can be directly compared. To calculate measure life, Navigant took decay figures from the first three years, and projected savings would continue to decay at the rate observed in the third year. Table 3-2 shows lower decay rates associated with TR customers who received HERs for a longer period.

Table 3-5. HER Persistence Savings and Measure Life for November 2015 – October 2016

	Wave 1	Wave 3	Wave 5	Average
Lifetime Persistence Savings	8,083	19,027	5141	-
Measure Life	3.18	4.95	2.21	3.44
Year 3 Standard Error	*0.38*	*0.53*	*0.57*	*-*

Source: Navigant analysis

[34] See Section 2.6 for a more detailed examination of how these calculations were conducted.

4. FINDINGS AND RECOMMENDATIONS

The following section includes key findings and recommendations.

Finding 1. Wave decay rates diverged in the third year of the ComEd persistence study. For Wave 1, it more than doubled from 15 percent to 39 percent, while Wave 3 stayed basically the same at 18 percent, and the Wave 5 decay rate decreased from 60 percent to 47 percent. The combined average decay rate increased in absolute terms from 31 percent to 35 percent, but the rate of increase slowed markedly.

Finding 2. Assuming savings decayed as observed in the first three years and continue to decay at the rate observed in year three[35], the implied measure life is three years for Wave 1, five years for Wave 3, and two years for Wave 5. Across the three waves, the average measure life was 3.44 years. This finding provides ComEd an indication of measure lives for the three persistence waves in this study, and is not a recommendation to update the measure life in the IL TRM.

Recommendation 1. Navigant recommends that the IL TRM combine this analysis with other relevant studies[36] to update the persistence factors the next time the measure is updated. The IL TRM[37] currently includes HER energy savings persistence values based on existing research and extrapolation of those findings. Table 4-1 shows those figures relative to Navigant's research using ComEd data. The year column identifies the temporal relationship of the data to report termination. For example, Persistence Factor Electric 1 (PFE_1) is one year after customers no longer received HERs.

Table 4-1. Existing and Recommended TRM Persistence Factors

Year	TRM Persistence Factors	Navigant - Analysis Persistence Factors
	100%	100%
PFE_1	80%	90%
PFE_2	54%	69%
PFE_3	31%	65%
PFE_4	15%	-

Source: Navigant analysis

Recommendation 2. ComEd should continue this study and look at savings in the fourth year after reports are stopped, from November 2016 to October 2017. The continued study would estimate the decay rate in the fourth year after reports are stopped. A year four report would add to research on how decay rates evolve over time. The results could be used, along with other relevant studies, to inform fourth year persistence factors in the IL TRM.

[35] An assumption of a constant decay rate from year 3 forward is necessary to calculate a measure life as discussed with the calculations in Section 2.6.

[36] For example, this study for Puget Sound Energy: http://www.oracle.com/us/industries/utilities/herp-puget-sound-energy-3628986.pdf

[37] Version 6.0, Volume 4, Measure 6.1.1

5. APPENDIX

5.1 Detailed Data Cleaning

In preparation for the impact analysis, Navigant combined and cleaned the data provided by the implementer. The dataset included 185,925 treatment customers and 65,310 controls. Data during the twelve-month pre-period for each wave and the twelve-month analysis period from November 2015 to October 2016 were used in the regression analysis for each of the two models described in Section 2.4.

Table 5-1 provides a detailed account of the data cleaning done for this analysis. Navigant removed the following customers and data points from the analysis:

- Lapsed Report (LR) customers[38]
- Records with a bill duration of 0
- Subset to the one year pre-program period and the one year analysis period
- Bill Flattening - Aggregating records that ended in the same month[39]
- Observations with missing usage
- Observations with negative usage
- Customers with an active account and fewer than 11 bills or any customer with more than 13 bills in either the analysis period or pre-period
- Observations with fewer than 20 or more than 40 days in the billing cycle
- Outliers, defined as observations with average daily usage more than one order of magnitude from the median usage.[40]

Table 5-1 through Table 5-3 give counts and percentages of customers and observations removed for the data cleaning steps identified above. The table also provides the percentage of customers or observations removed. It is evident from the table that the percentage of customers or observations removed was very similar across the treatment and control groups for each wave. This suggests that non-random biases were not introduced into the data by our cleaning. Across the three waves, the sample size used in our LDV regression analysis represents approximately 81 percent of the original data received.

[38] To examine the persistence of savings, reports for 10,000 customers within both Waves 1 and 3 were terminated beginning in October 2012 and restarted in August 2013; these customers are referred to as the Waves 1 and 3 lapsed report (LR) subgroups. Since reports were restarted for these customers they are not a part of this research.
[39] This does not remove any records but rather redistributes records for analysis purposes.
[40] Median usage was calculated by wave. Chronologically, the medians were 35, 46, and 53 kilowatt-hours (kWh) per day.

Table 5-1. Customers/Observations Removed by Data Cleaning Step (Wave 1)

Data Cleaning Step Wave 1	Customers		Observations		Customer % Change		Observation % Change	
	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
Raw Data	32,954	30,965	3,522,757	3,310,906	-	-	-	-
LR Customer Removal	26,681	30,965	2,852,326	3,310,906	19%	0%	19%	0%
Bill duration does not equal 0	26,681	30,965	2,852,326	3,310,906	0%	0%	0%	0%
Subset to pre/post periods	26,681	30,965	630,158	731,362	0%	0%	78%	78%
Bill Flattening	26,681	30,965	616,432	715,069	0%	0%	2%	2%
Exclude observations missing usage	26,681	30,965	616,432	715,069	0%	0%	0%	0%
Remove observations with negative usage	26,681	30,965	616,432	715,069	0%	0%	0%	0%
Remove customers with too many/few bills	23,130	26,733	541,672	625,888	13%	14%	12%	12%
Exclude bills with long or short durations	23,130	26,733	540,951	625,061	0%	0%	0%	0%
Exclude outliers	23,128	26,730	539,513	623,307	0%	0%	0%	0%
Remove pre-period data (for PPR analysis)	23,073	26,646	267,243	308,733	0%	0%	50%	50%
Remove observations without a monthly pre-use value (for PPR analysis)	23,061	26,637	262,549	303,258	0%	0%	2%	2%

Source: Navigant analysis

Table 5-2. Customers/Observations Removed by Data Cleaning Step (Wave 3)

Data Cleaning Step Wave 3	Customers		Observations		Customer % Change		Observation % Change	
	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
Raw Data	155,594	38,470	13,472,342	3,332,175				
LR Customer Removal	147,971	38,470	12,812,390	3,332,175	5%	0%	5%	0%
Bill duration does not equal 0	147,971	38,470	12,812,390	3,332,175	0%	0%	0%	0%
Subset to pre/post periods	147,966	38,466	3,489,339	907,387	0%	0%	73%	73%
Bill Flattening	147,966	38,466	3,405,108	885,271	0%	0%	2%	2%
Exclude observations missing usage	147,966	38,466	3,405,108	885,271	0%	0%	0%	0%
Remove observations with negative usage	147,966	38,466	3,405,099	885,268	0%	0%	0%	0%
Remove customers with too many/few bills	128,625	33,346	3,007,256	779,892	13%	13%	12%	12%
Exclude bills with long or short durations	128,625	33,346	2,997,861	777,445	0%	0%	0%	0%
Exclude outliers	128,625	33,346	2,986,796	774,807	0%	0%	0%	0%
Remove pre-period data (for PPR analysis)	128,176	33,240	1,479,247	383,937	0%	0%	50%	50%
Remove observations without a monthly pre-use value (for PPR analysis)	128,153	33,235	1,448,793	376,045	0%	0%	2%	2%

Source: Navigant analysis

Table 5-3. Customers/Observations Removed by Data Cleaning Step (Wave 5)

Data Cleaning Step Wave 5	Customers		Observations		Customer % Change		Observation % Change	
	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
Raw Data	11,273	7,253	779,800	501,453				
LR Customer Removal	11,273	7,253	779,800	501,453	0%	0%	0%	0%
Bill duration does not equal 0	11,273	7,253	779,800	501,453	0%	0%	0%	0%
Subset to pre/post periods	11,243	7,230	255,685	164,320	0%	0%	67%	67%
Bill Flattening	11,243	7,230	249,988	160,562	0%	0%	2%	2%
Exclude observations missing usage	11,243	7,230	249,988	160,562	0%	0%	0%	0%
Remove observations with negative usage	11,243	7,230	249,984	160,562	0%	0%	0%	0%
Remove customers with too many/few bills	8,548	5,468	198,918	127,354	24%	24%	20%	21%
Exclude bills with long or short durations	8,548	5,468	198,211	126,925	0%	0%	0%	0%
Exclude outliers	8,545	5,467	196,950	126,115	0%	0%	1%	1%
Remove pre-period data (for PPR analysis)	8,489	5,441	96,549	61,904	1%	0%	51%	51%
Remove observations without a monthly pre-use value (for PPR analysis)	8,482	5,438	94,840	60,779	0%	0%	2%	2%

Source: Navigant analysis

5.2 Detailed Impact Methodology

Navigant used two regression models to estimate impacts: an LDV model and an LFER model. The following sections present each model.

5.2.1 Lagged Dependent Variable Model

The LDV model controls for non-treatment differences in energy use between treatment and control customers using lagged energy use as an explanatory variable. The model frames energy use in calendar month *t* of the post-program period as a function of both the treatment variable and energy use in the same calendar month of the pre-program period. The underlying logic is that systematic differences between control and treatment customers will be reflected in differences in their past energy use, which is highly correlated with their current energy use. Formally, the model is shown in Equation 5-1.

Equation 5-1. Post Program Regression Model

$$ADU_{kt} = \beta_1 Treatment_k \cdot TR_k + \beta_2 Treatment_k \cdot CR_k + \sum_J \beta_{3j} Month_{jt} + \sum_J \beta_{4j} Month_{jt} \cdot ADUlag_{kt} + \varepsilon_{kt}$$

Where,

ADU_{kt}	is average daily consumption of kWh by household *k* in bill period *t*
$Treatment_k$	is a binary variable taking a value of 0 if household *k* is assigned to the control group, and 1 if assigned to the treatment group
TR_k	is a binary variable taking a value of 1 if household *k* is assigned to the terminated report group
CR_k	is a binary variable taking a value of 1 if household *k* is assigned to the continued report group
$ADUlag_{kt}$	is household *k*'s energy use in the same calendar month of the pre-program year as the calendar month of month *t*
$Month_{jt}$	is a binary variable taking a value of 1 when *j* = *t* and 0 otherwise[41]
e_{kt}	is the cluster-robust error term for household *k* during billing cycle *t;* cluster-robust errors account for heteroskedasticity and autocorrelation at the household level.[42]

The coefficients β_1 and β_2 are the estimates of average daily kWh energy savings due to the program in the second year after reports were terminated for the TR and CR groups, respectively.

5.2.2 Linear Fixed Effects Regression Model

The version of the LFER model used by Navigant is one in which average daily consumption of kWh by household *k* in bill period *t*, denoted by ADU_{kt}, is a function of the following three terms:

1. The binary variable $Treatment_k$
2. The binary variable $Post_t$, taking a value of 0 if month *t* is in the pre-treatment period, and 1 if in the post-treatment period
3. The interaction between these variables, $Treatment_k \cdot Post_t$, taking the value of 1 at time t for household k if a treatment household is operating in the post-treatment period

Formally, the LFER model is showing in as shown in Equation 5-2.

[41] In other words, if there are *T* post-program months, there are *T* monthly dummy variables in the model, with the dummy variable $Month_t$ to take a value of 1 at time t. These are, in other words, monthly fixed effects.

[42] Ordinary Least Squares (OLS) regression models assume that the data are homoscedastic and not autocorrelated. If either of these assumptions are violated, the resulting standard errors of the parameter estimates are incorrect (usually downward biased). A random variable is heteroscedastic when its variance is not constant over the variable's entire distribution. A random variable exhibits autocorrelation when its error term in one period is correlated with the error terms in at least some of the previous periods.

Equation 5-2. Linear Fixed Effects Regression Model

$$ADU_{kt} = \alpha_{0k} + \alpha_1 Post_t + \alpha_2 Treatment_k \cdot TR_k \cdot Post_t + \alpha_3 Treatment_k \cdot CR_k \cdot Post_t + \varepsilon_{kt}$$

Three observations about this specification deserve comment. First, the coefficient α_{0k} captures all household-specific effects on energy use that do not change over time, including those that are unobservable to the researcher. Second, α_1 captures the average effect across all households of being in the post-treatment period. Third, the effect of being both in the treatment group and in the post period – the effect directly attributable to the program – is captured by the coefficient α_2 for the TR group and α_3 for the CR group. In other words, whereas the coefficient α_1 captures the change in average daily kWh use between the pre- and post-treatment time periods for both the treatment and the control group, the sums $\alpha_1 + \alpha_2$ and $\alpha_1 + \alpha_3$ capture this change exclusively for the TR treatment group and CR treatment group, and so α_2 and α_3 are the estimates of average daily kWh energy savings due to the program in the second year after reports were terminated for the TR and CR groups, respectively.

5.3 Detailed Impact Results: Parameter Estimates

Wave LDV and LFER model results are available in the associated excel file. Across the two models, the parameter estimates are not statistically different; that is, the estimates for each model are within the 90 percent confidence bounds for the other model. Furthermore, the pattern across the different program waves between the two models is very similar.

APPENDIX B. ILLINOIS HER WEATHER NORMALIZATION RESULTS MEMO 2017-12-13

Memorandum

To: Ameren Illinois Company, Commonwealth Edison, ICC Staff
From: Opinion Dynamics and Navigant
Date: December 13, 2017
Re: Home Energy Report Weather Normalization Study – DRAFT Analysis Results

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This memo provides results from an analysis of Commonwealth Edison's (ComEd) Home Energy Report (HER) Program and Ameren Illinois Company's (AIC) Behavior Modification (BM) Program related to weather normalization methods. This research has two objectives:

1. Determine to what extent gas and electric savings from the programs are sensitive to weather conditions.
2. Determine the reliability and accuracy of the weather normalization method outlined in the Illinois Technical Reference Manual (IL-TRM) [1]

The findings presented within this memo are a compilation of electric results from research conducted by Navigant for ComEd and gas results from research conducted by Opinion Dynamics for AIC.

Overall, we found that both gas and electric savings are sensitive to weather conditions, but that the sensitivity is quite low. The evaluation teams recommend using a weather normalization method when accounting for persistence with cooling degree day (CDD) and heating degree day (HDD) interaction terms in the regression model (see Equation 1 below) to weather normalize. The evaluation teams recommend keeping the current IL-TRM references to weather normalization as a part of the custom savings calculation included in Version 6. The current language is weather normalization method agnostic and the research teams would prefer to keep it this way to be consistent with the measure's references to other portions of the custom savings analysis. Additional discussion is included below.

Study Overview and Overall Findings

ComEd's and AIC's programs are implemented as randomized controlled trials (RCTs) where customers selected for inclusion in the program are randomly allocated between a treatment group (who receive the HER) and a control group (who do not). We evaluate these programs using regression models to determine the savings of the treatment group relative to the control group. Because the treatment and control group, on average, experience the exact same weather conditions in a given year, the RCT design means that there is no need to control for weather in the regression models to produce an accurate estimate of program savings for one year.

However, the behavioral persistence measure in the IL-TRM V6.0 compares savings from the programs across multiple years to account for the persistence of savings from one year to the next. As a result, if program

[1] "Adjustments to Behavior Savings to Account for Persistence" is measure 6.1.1 in Version 6.0 Volume 4 of the TRM.

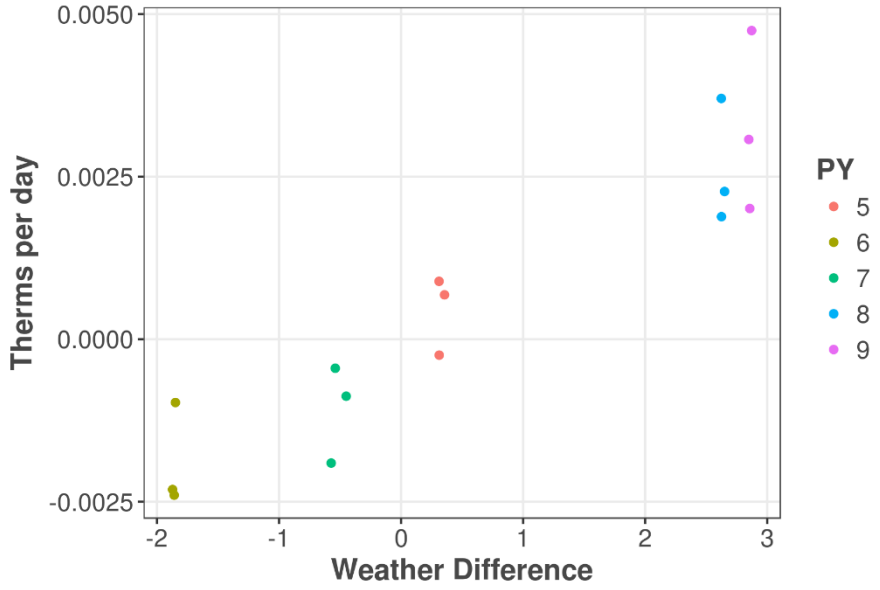
savings are weather sensitive, then comparing actual, non-weather normalized savings across years will not correct for the weather sensitivity of savings. In this case, for comparison across years, the evaluation teams would need to weather normalize the savings across different years.

Research Objective 1: Determine Sensitivity to Weather Conditions

Overall, we found that both gas and electric savings are sensitive to weather conditions, but that the sensitivity is quite low.

For gas savings, changing from actual weather to typical meteorological year (TMY) weather[2] changes savings by approximately 0.005 therms per day.[3] Figure 1 shows the relationship for the three modeled cohorts for PY5 through PY9. [4] The x-axis plots the weather difference in HDD between actual weather and TMY, and the y-axis plots the difference in average daily savings. This plot shows that gas savings are sensitive to HDD; CDD are not shown because the results show that gas savings are not sensitive to CDD.

Figure 1. Plot of Gas Savings Difference by Weather Difference



Source: Opinion Dynamics analysis of AIC data

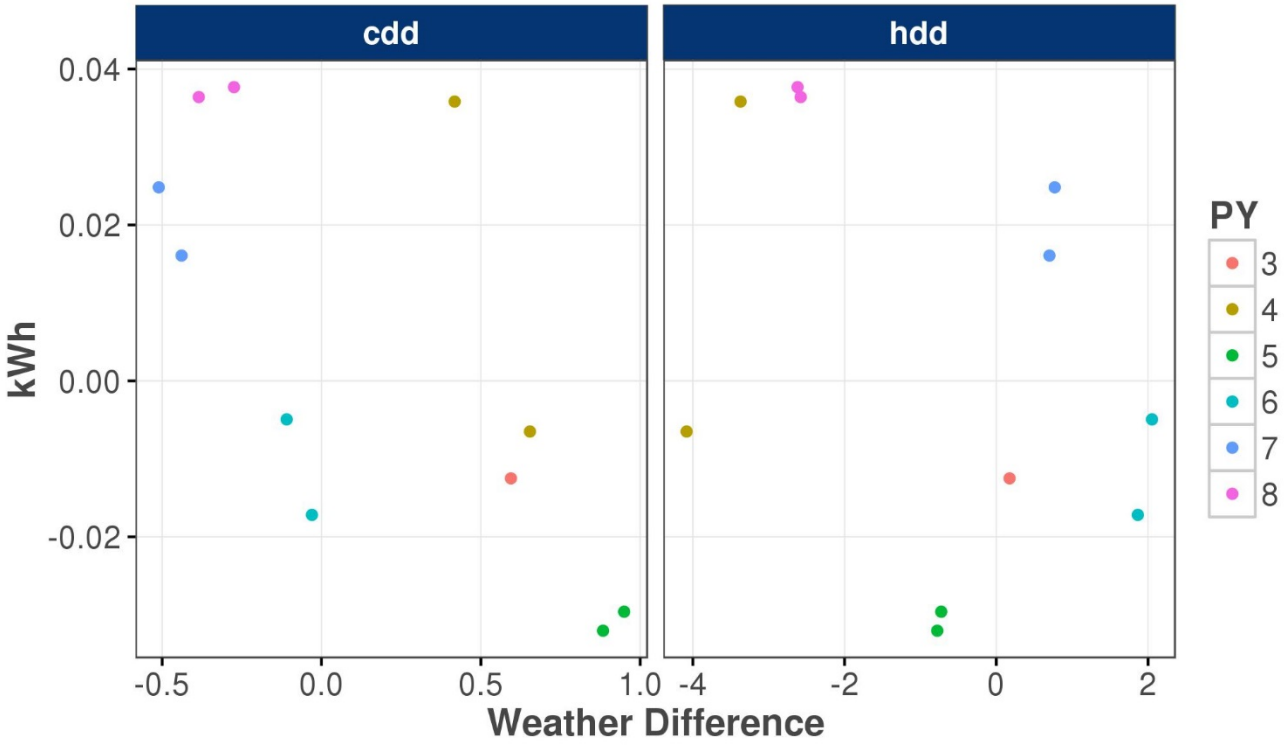
[2] For this work, we incorporated the latest TMY3 dataset derived from 1991-2005 weather from NREL, the official source.

[3] Assuming a cohort with 100,000 customers who were all in the Program for the entire year, this would change total savings by 182,500 therms (0.005 therms/customer/day * 365 days * 100,000 customers).

[4] The PY5 program year began June 1, 2012 and ended May 31, 2013. The PY9 program year began June 1, 2016 and ends December 31, 2017; this research represents results through May 31, 2017 for PY9.

For electric savings, changing from actual weather to TMY weather changes savings by approximately 0.02 kWh per day.[5] Figure 2 shows the relationship between kWh savings and HDD and CDD for the two modeled ComEd electric waves for PY3 through PY8.[6]

Figure 2. Plot of Electric Savings Difference by Weather Difference



Source: Navigant analysis of ComEd data

To determine the extent to which program savings are sensitive to weather conditions, the evaluation teams estimated a model with interactions between a treatment indicator and CDD/HDD for several program years and program waves, as shown in Equation 1 below. This model is consistent across the AIC and ComEd analyses.

[5] Assuming a wave with 100,000 customers who were all in the Program for the entire year, this would change total savings by 730 MWh $\left(\frac{0.02\ \text{kWh/customer/day} * 365\ \text{days} * 100{,}000\ \text{customers}}{1{,}000}\right)$.

[6] The PY3 program year began June 1, 2010 and ended May 31, 2011. The PY8 program year began June 1, 2015 and ended May 31, 2016.

Equation 1

$$ADU_{kt} = \beta_1 Treatment_k + \beta_2 Treatment_k \cdot CDD_{kt} + \beta_3 Treatment_k \cdot HDD_{kt} + \beta_4 CDD_{kt} + \beta_5 HDD_{kt} + \sum_J \beta_{6j} Month_{jt} + \sum_J \beta_{7j} Month_{jt} \cdot ADUlag_{kt} + \varepsilon_{kt}$$

Where

ADU_{kt}	is average daily energy usage (gas or electric) by household *k* in bill period *t*.
$Treatment_k$	is a binary variable taking a value of 0 if household k is assigned to the control group, and 1 if assigned to the treatment group.
CDD_{kt}	is the CDD experienced by household *k* in bill period *t*.
HDD_{kt}	is the HDD experienced by household *k* in bill period *t*.
$Month_{jt}$	is a binary variable taking a value of 1 when j = t and 0 otherwise.[7]
$ADUlag_{kt}$	is household *k*'s energy use in the same calendar month of the pre-program year as the calendar month of month *t*.
ε_{kt}	is the cluster-robust error term for household *k* during billing cycle *t*.[8]

In Equation 1, β_1 captures the treatment effect when CDD and HDD are zero, β_2 captures the impact of CDD on the treatment effect, and β_3 captures the impact of HDD on the treatment effect. The treatment effect under any specified weather conditions is captured by $\beta_1 + \beta_2$*CDD + β_3*HDD; for example, the average treatment effect in program year t is captured by $\beta_1 + \beta_2$*mean(CDD_{kt}) + β_3*mean(HDD_{kt}). This average treatment effect is similar to the savings estimated using a model without weather terms. If β_2 and β_3 are large compared to β_1, it would suggest that the program savings are weather sensitive. The weather normalized treatment effect is captured by replacing the program year CDD and HDD values with TMY values, i.e., $\beta_1 + \beta_2$*mean(CDD_{kTMY3}) + β_3*mean(HDD_{kTMY3}).

Table 1 and Table 2 provide gas and electric savings using actual and TMY weather.

[7] In other words, if there are *T* post-program months, there are *T* monthly dummy variables in the model, with the dummy variable $Month_{tt}$ the only one to take a value of 1 at time t. These are, in other words, monthly fixed effects.

[8] Cluster-robust errors account for heteroskedasticity and autocorrelation at the household level.

Table 1. Gas Savings with Actual Weather and with TMY Weather

AIC Behavioral Modification Cohort	PY	Actual Weather Average Daily Savings	TMY Weather Average Daily Savings
Original	5	0.021	0.022
	6	0.027	0.024
	7	0.021	0.020
	8	0.020	0.022
	9	0.019	0.022
Expansion 1	5	0.031	0.032
	6	0.034	0.032
	7	0.027	0.025
	8	0.029	0.033
	9	0.031	0.036
Expansion 2	5	0.009	0.009
	6	0.014	0.013
	7	0.012	0.012
	8	0.013	0.015
	9	0.013	0.015

Source: Opinion Dynamics analysis of AIC data

Table 2. Electric Savings with Actual Weather and with TMY Weather

ComEd HER Wave	PY	Actual Weather Average Daily Savings	TMY Weather Average Daily Savings
Wave 1	3	0.91	0.90
	4	0.99	0.98
	5	1.05	1.02
	6	1.11	1.09
	7	1.01	1.02
	8	1.09	1.13
Wave 3	4	0.73	0.76
	5	1.19	1.16
	6	1.27	1.26
	7	1.36	1.38
	8	1.24	1.28

Source: Navigant analysis of ComEd data
Note: Wave 3 did not begin until PY4.

Research Objective 2: Determine the Accuracy of the IL-TRM Weather Normalization Method

The evaluation teams verified that the CDD/HDD interaction method shown in Equation 1 is accurate by checking that entering the actual weather CDD/HDD values into the model returned the same treatment effect as a model with weather included. Based on this analysis, the evaluation teams recommend that the TRM keep the current references to weather normalization as a part of the custom savings calculation currently included in Version 6. The current language is weather normalization method agnostic and the research teams would prefer to keep it this way to be consistent with the measure's references to other portions of the custom savings analysis. Currently, Opinion Dynamics and Navigant each plan to use the weather normalization method described in the previous section but reserve the right to use a different method if they believe it is appropriate in the future.

Appendix A. Detailed Methodology and Results

Program Information

AIC

Approximately 302,500 customers participated in the AIC Behavioral Modification Program in PY9, representing roughly one-third of AIC's residential customers. In 2010, the program began as a pilot by targeting dual-fuel customers with higher-than-average energy consumption. Oracle, the program implementer, developed each expansion cohort based on several characteristics: energy usage tier, residential customer, and available energy use history. Original Cohort customers are now in their seventh year with the program. Over the following 6 years, seven additional cohorts were added to the program. All cohorts were dual-fuel customers, except for Expansion Cohort 3, which is gas only. The most recent cohort, Expansion Cohort 7, began receiving reports late in PY9, making PY9 this group's first full year in the program. Table 3 provides a breakdown by cohort of all treatment customers who received reports for at least 1 month in PY9.

For this analysis, we selected just the first three cohorts, the Original cohort and Expansion Cohorts 1 and 2. We selected these cohorts because they have many years of participation data and are among the largest.

Table 3. AIC Behavioral Modification Program Participation in PY9

Cohort Name	Fuel Type	Number of Treated Customers in PY9	Start Date	Program Year
Original Cohort	Dual-Fuel	32,519	August 2010	7th year in the program
Expansion Cohort 1	Dual-Fuel	49,057	April 2011	6th year in the program
Expansion Cohort 2	Dual-Fuel	72,536	November 2011	6th year in the program
Expansion Cohort 3	Gas-Only	11,732	November 2011	6th year in the program
Expansion Cohort 4	Dual-Fuel	20,146	June 2013	4th year in the program
Expansion Cohort 5	Dual-Fuel	45,191	September 2014	3rd year in the program
Expansion Cohort 6	Dual-Fuel	27,647	April 2015	3rd year in the program
Expansion Cohort 7	Dual-Fuel	43,692	September 2016	1st year in the program
	Total	302,520		

ComEd

ComEd's HER program included almost 2 million electric customers in PY9. Customers in Wave 1 and Wave 3 were used in this analysis; these waves were chosen because they are two of the largest and longest running waves in the program.

The program was rolled out in nine different waves:

1. A pilot program targeting 50,000 residential customers kicked off in July 2009 (Wave 1).
2. A wave of about 3,000 customers (Wave 2) targeted for program enrollment started in September 2010 to "fill-in" for Wave 1 dropouts.

3. A major expansion targeting 200,000 customers began in May 2011 (Wave 3).
4. Another fill-in wave of 20,000 customers started in January 2012 (Wave 4).
5. A third fill-in wave of 20,000 customers introduced in July 2012 (Wave 5).[9]
6. A fourth fill-in of 10,000 customers and a major expansion targeting 90,000 customers began in June 2013 (Wave 6).
7. A "tsunami" wave of 1.2 million customers began in June 2014; this wave was split into two groups based on usage (Wave 7 Low and Wave 7 High).
8. A wave targeting customers who had just moved into a new home, this wave first started in September 2014 and was evaluated for the first time in PY8 (New Mover Wave).[10]
9. An expansion of 81,679 customers added to the program in July 2016 (Wave 8).

Data Cleaning Approach

AIC

The data used in the billing analysis came from three primary sources:

- Monthly billing data from July 2009 to May 2017, from AIC
- Program launch date specific to each customer (treatment and control), from Oracle
- Weather data (HDD and CDD), from NOAA (the data came from 46 weather stations across the state and are appended at the zip code level)

To develop the dataset used for the statistical analysis, the evaluation team conducted the following data processing steps:

- Cleaned billing data
  - Removed exact duplicates
  - Dropped billing periods in excess of 90 days
  - Dropped first and last billing periods with more than 60 days
  - Dropped first and last billing periods with less than 10 days
  - Combined overlapping billing periods
  - Combined estimated bills with actual bills to correct for bill estimation
- Removed observations and customers within each cohort based on the following criteria:

[9] This wave has been referred to as Wave 5 Non-AMI in previous reports, but as Wave 5 AMI has been dropped from the program this distinction is no longer necessary.

[10] The New Mover Wave is made up of 21 groups of customers who received their first report in the same month (for example, customers who received their first report in September 2014 were one group, and customers who received their first report in March 2015 were another). Navigant estimated the impact for the New Mover Wave in two parts: for customers who started before PY8 and for customers who started during PY8.

- No first report dates
- First report date occurring after inactive date
- Out-of-range usage data
- Very low usage data
- No post-participation period data

- Determined the monthly usage for each customer based on his/her read cycle (each usage record has a start date and a duration; based on these two variables, the team identified the appropriate month for each read cycle)
- Matched weather data by customer to the geographically closest weather station

Depending on the cohort, data cleaning removed between <1% to 19% of customers in the gas analysis. The majority of these drops are due to insufficient pre-participation period billing data.

ComEd

The data used in the billing analysis came from two primary sources:

- Monthly billing data from July 2008 to May 2016, from Oracle
- Program launch date specific to each customer (treatment and control), from Oracle
- Weather data (HDD and CDD), from NOAA (the data came from 5 weather stations across the state and are appended at the zip code level)

To develop the dataset used for the statistical analysis, the evaluation team conducted the following data processing steps:

- Subset to the one year pre-program period and the one year analysis period for each regression
- Records with a bill duration of 0
- Bill Flattening - Aggregating records that ended in the same month[11]
- Observations with missing usage
- Observations with negative usage
- Customers with an active account and fewer than 11 bills or any customer with more than 13 bills in either the analysis period or pre-period
- Observations with fewer than 20 or more than 40 days in the billing cycle

[11] This does not remove any records but rather redistributes records for analysis purposes.

- Outliers, defined as observations with average daily usage more than one order of magnitude from the median usage.

Model Coefficients

Table 4 provides model coefficients for each selected gas cohort for PY5 through PY9 and Table 5 shows the same for each selected electric wave for PY3 through PY8.

Table 4. Gas Billing Analysis Model Coefficients

AIC Behavioral Modification Cohort	PY	Variable	Coefficient	Standard Error
Original	5	Treatment	-0.00747	0.00414
		Treatment:CDD	0.00002	0.00003
		Treatment:HDD	-0.00003	0.00001
	6	Treatment	-0.00886	0.00526
		Treatment:CDD	0.00007	0.00007
		Treatment:HDD	-0.00004	0.00001
	7	Treatment	-0.01060	0.00530
		Treatment:CDD	0.00007	0.00008
		Treatment:HDD	-0.00002	0.00001
	8	Treatment	-0.00925	0.00455
		Treatment:CDD	0.00005	0.00006
		Treatment:HDD	-0.00003	0.00001
	9	Treatment	-0.00827	0.00447
		Treatment:CDD	0.00006	0.00005
		Treatment:HDD	-0.00003	0.00001
Expansion 1	5	Treatment	-0.01158	0.00548
		Treatment:CDD	0.00003	0.00004
		Treatment:HDD	-0.00005	0.00001
	6	Treatment	-0.01726	0.00709
		Treatment:CDD	0.00010	0.00009
		Treatment:HDD	-0.00004	0.00001
	7	Treatment	-0.02185	0.00723
		Treatment:CDD	0.00020	0.00011
		Treatment:HDD	-0.00002	0.00001
	8	Treatment	-0.01109	0.00618

		Treatment:CDD	0.00008	0.00009
		Treatment:HDD	-0.00005	0.00001
	9	Treatment	-0.01592	0.00588
		Treatment:CDD	0.00010	0.00007
		Treatment:HDD	-0.00005	0.00001
Expansion 2	5	Treatment	0.00074	0.00350
		Treatment:CDD	-0.00002	0.00002
		Treatment:HDD	-0.00002	0.00000
	6	Treatment	-0.00701	0.00468
		Treatment:CDD	0.00004	0.00006
		Treatment:HDD	-0.00002	0.00001
	7	Treatment	-0.00340	0.00479
		Treatment:CDD	0.00002	0.00008
		Treatment:HDD	-0.00002	0.00001
	8	Treatment	-0.00374	0.00417
		Treatment:CDD	0.00001	0.00006
		Treatment:HDD	-0.00002	0.00001
	9	Treatment	-0.00421	0.00397
		Treatment:CDD	0.00001	0.00004
		Treatment:HDD	-0.00002	0.00001

Source: Opinion Dynamics analysis of AIC data

Table 5. Electric Billing Analysis Model Coefficients

ComEd HER Wave	PY	Variable	Coefficient	Standard Error
Wave 1	3	Treatment	-0.81866	0.10846
		Treatment:CDD	-0.02046	0.01497
		Treatment:HDD	-0.00192	0.00372
	4	Treatment	-0.80198	0.10073
		Treatment:CDD	-0.03943	0.01215
		Treatment:HDD	-0.00473	0.00400
	5	Treatment	-0.77704	0.11243
		Treatment:CDD	-0.03794	0.01185
		Treatment:HDD	-0.00885	0.00401
	6	Treatment	-0.81851	0.11820
		Treatment:CDD	-0.04150	0.01868

ComEd HER Wave	PY	Variable	Coefficient	Standard Error
		Treatment:HDD	-0.00988	0.00367
	7	Treatment	-0.82512	0.12266
		Treatment:CDD	-0.04478	0.01981
		Treatment:HDD	-0.00512	0.00385
	8	Treatment	-0.84117	0.12438
		Treatment:CDD	-0.06177	0.02120
		Treatment:HDD	-0.00791	0.00473
Wave 3	4	Treatment	-0.59805	0.07416
		Treatment:CDD	0.00408	0.00877
		Treatment:HDD	-0.01012	0.00321
	5	Treatment	-0.92094	0.08653
		Treatment:CDD	-0.04285	0.00904
		Treatment:HDD	-0.00747	0.00332
	6	Treatment	-1.01961	0.09475
		Treatment:CDD	-0.05900	0.01542
		Treatment:HDD	-0.00555	0.00325
	7	Treatment	-1.18735	0.09538
		Treatment:CDD	-0.05413	0.01673
		Treatment:HDD	-0.00364	0.00327
	8	Treatment	-1.03847	0.09816
		Treatment:CDD	-0.06088	0.01719
		Treatment:HDD	-0.00503	0.00389

Source: Navigant analysis of ComEd data
Note: Wave 3 did not begin until PY4.

APPENDIX C. COMED PY9 HER REPORT 2018-08-20

NAVIGANT

ComEd
Home Energy Report Program Evaluation Report

Energy Efficiency / Demand Response Plan:
Plan Year 9 (PY9)

Presented to
Commonwealth Edison Company

FINAL

August 20, 2018

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1. INTRODUCTION

This report presents the results of the impact evaluation of ComEd's PY9 Home Energy Report (HER) Program. It provides a summary of the energy and demand impacts for the program in total and broken out by wave. The appendix presents the impact analysis methodology. PY9 covers June 1, 2016 through December 31, 2017.

2. PROGRAM DESCRIPTION

The HER program is designed to generate energy savings by providing residential customers with information about energy use and conservation. Program participants receive information in the form of regularly mailed and emailed[1] home energy reports that give customers information, including:

- Assessment of how their recent energy use compares to their past energy use
- Tips on how to reduce energy consumption, some of which are tailored to the customer's circumstances
- Information on how their energy use compares to that of neighbors with similar homes

In PY9, the HER program had 1,995,540 participants and 294,295 controls across 11 waves (Wave 7 has two components), as shown in Table 2-1. Participants and controls in Table 2-1 represent active accounts at the beginning of PY9.

Table 2-1. PY9 Volumetric Findings Detail (in thousands)

Participation	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6	Wave 7 Low	Wave 7 High	Wave 8	Wave 9	Wave 10	New Mover
Participants	25.9	2.0	141.5	15.7	5.3	74.7	485.5	509.9	65.1	316.2	161.9	191.5
Controls	30.9	2.1	36.8	15.8	6.8	22.6	40.5	42.6	8.7	19.9	19.9	48.0

Source: ComEd tracking data and Navigant team analysis.

3. PROGRAM SAVINGS

Table 3-1 summarizes the incremental energy savings the HER Program achieved in PY9. This program specifically focused on energy savings, and demand savings were not estimated. In addition, this type of analysis estimates net savings and no further net-to-gross (NTG) adjustment is necessary. Because of this, there is neither an ex ante estimate of gross savings nor a gross realization rate.

[1] The frequency of reports sent through direct mail varied across the waves, where customers identified by the program implementer as having a greater propensity to save received more frequent reports. Additionally, treatment customers with email addresses on file were sent monthly electronic reports.

Table 3-1. PY9 Total Annual Incremental Savings

Savings Category	Energy Savings (kWh)	Demand Savings (kW)	Peak Demand Savings (kW)
Ex Ante Gross Savings	NA	NA	NA
Program Gross Realization Rate	NA	NA	NA
Verified Gross Savings	NA	NA	NA
Program Net-to-Gross Ratio (NTGR)*	NA	NA	NA
Verified Net Savings†	442,029,131	NA	NA

Source: ComEd tracking data and Navigant team analysis.

* This type of analysis estimates net savings, and no further net-to-gross adjustment is necessary.

† This value is after the uplift adjustment.

Table 3-2 shows PY9 HER program savings including values before and after the uplift adjustment. As noted above, these totals do not include gross savings because the analysis estimates net savings.

Table 3-2. PY9 Total Program Net Electric Savings

Savings Category	Energy Savings (kWh)
Ex Ante Net Savings	462,142,000
Verified Net Savings, Prior to Uplift Adjustment	448,085,144
PY9 Uplift Adjustment	2,099,529
Legacy Uplift Adjustment	3,956,484
Final Verified Net Savings	442,029,131
Program Net Realization Rate*	96%

Source: ComEd tracking data and Navigant team analysis.

* This value is after the uplift adjustment.

The program realization rate compared to the savings estimated by the implementer was 96 percent. The uplift adjustment resulted in a one percent change in the net savings which is not accounted for in the implementer's savings estimate. The remaining three percent difference in the realization rate was likely due to small differences in the regression models used by Navigant and the implementer.

4. Program Savings by Measure

The HER program only has a single measure, behavioral savings from the reports. In PY9, the measure life for the reports was one year. Detailed savings by wave are presented in Section 5.

5. Impact Analysis Findings and Recommendations

5.1 Impact Parameter Estimates

The HER program does not have relevant impact parameters.

5.2 Other Impact Findings and Recommendations

Across all waves, Navigant estimated savings for approximately 2 million participants. Total PY9 verified savings were 448,085,144 kWh prior to uplift and 442,029,131 kWh after the uplift adjustment.

Finding 1. From PY8 to PY9, the average program savings rate remained steady (1.45 percent vs 1.44 percent respectively), despite ComEd adding two additional waves with 478,133 new participants. Waves 9 and 10 had low savings (0.34 percent and 0.56 percent) relative to previous waves. Increases in savings for the New Mover wave and Wave 7 made up for the low savings in Wave 9 and 10.

Finding 2. Waves 9 and 10 both had relatively low savings rates with 90 percent confidence bounds that approached zero. The savings rates of these new waves will likely increase in years to come, based on the ramp up of other waves in the past.

Recommendation 1. ComEd should consider the feasibility of adding higher usage customers to the HER program by transferring customers from existing control groups, such as in Waves 1 and 3, into new treatment groups as participants. ComEd and the implementation contractor should work with Navigant to use a power analysis to first review the statistical significance for both the new and old waves prior to transferring customers.

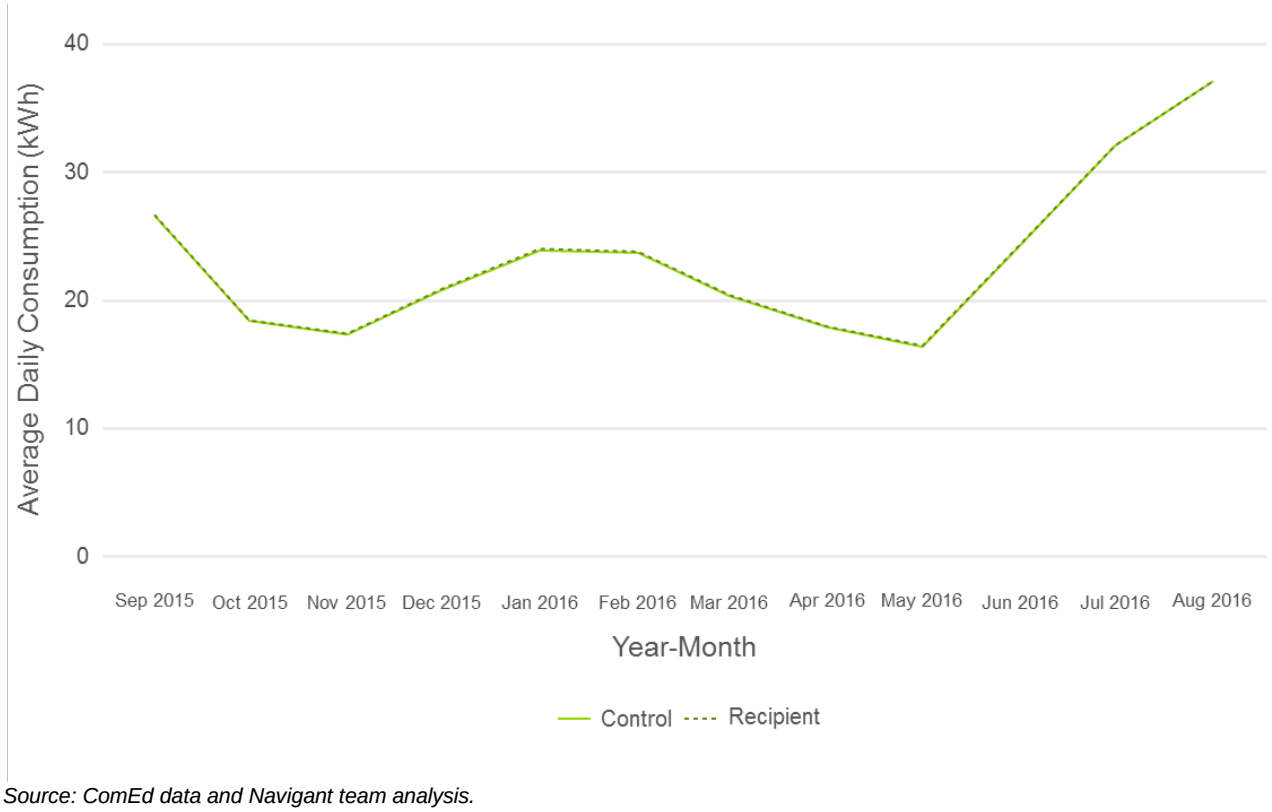
6. Appendix 1. Impact Analysis Methodology

6.1 Graphs for New Wave RCT Checks

To test that the new PY9 waves (Waves 9 and 10) are consistent with an RCT, Navigant compared treatment and control usage for each month during the pre-program period. If the allocation of households across participants and controls is truly random, the two groups should have the same distribution of energy usage during these twelve months. Navigant conducted variance tests and t-tests comparing participant and control usage for each month of the pre-period, and found that mean usage was not statistically different. As an additional check, Navigant performed a regression analysis in which average daily usage in the pre-program period was a function of monthly binary variables and a binary participation variable.

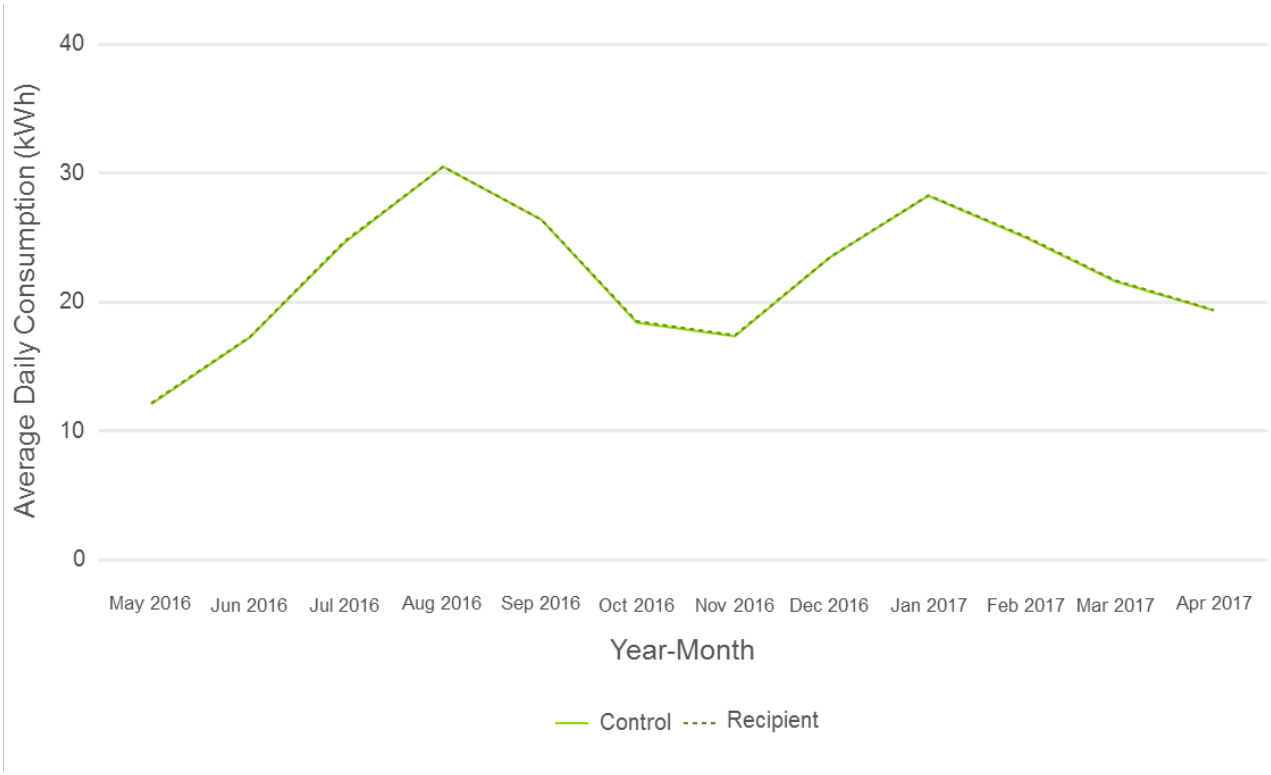
Figure 6-1 and Figure 6-2 illustrate control and participant (treatment recipient) usage during the twelve-month pre-period for Waves 9 and 10 that started during PY9. These graphs illustrate what Navigant's statistical analysis confirmed, namely that the assignment of customers into the treatment and control groups was consistent with randomization.

Figure 6-1. RCT Usage Comparison for Wave 9



Source: ComEd data and Navigant team analysis.

Figure 6-2. RCT Usage Comparison for Wave 10



Source: ComEd data and Navigant team analysis.

6.2 Detailed Data Cleaning

Navigant removed customers and data points from the analysis in several steps:

- Observations outside PY9 and each wave's relevant pre-program year
- Observations with a bill duration of zero days
- Observations missing usage
- Outliers, defined as observations with average daily usage more than one order of magnitude from the median usage

After selecting program and pre-program year data for each wave, cleaning steps removed approximately 3.5% of customers and 7% of observations[2], evenly distributed across participants and controls. This suggests that non-random biases were not introduced into the data by Navigant's cleaning steps.

6.3 Detailed Impact Methodology

The LDV and LFER models generated similar results for program savings estimates. Navigant used the LDV results for reporting PY9 total program savings. Across the two models, the parameter estimates were not statistically different; that is, the estimates for each model are within the 90 percent confidence bounds for the other model. Furthermore, the pattern across the different program waves between the two models is very similar. This supports the methodological approach, and indicates the results are robust. The following sections present the specifications for each model.

[2] Waves 9, 10, and the New Mover Wave dropped more observations than the other waves (19%, 30%, and 48%) because they were more frequently missing pre-period usage.

6.3.1 Lagged Dependent Variable Model[3]

The LDV model controls for non-treatment differences in energy use between treatment and control customers using lagged energy use as an explanatory variable. The model frames energy use in calendar month *t* of the post-program period as a function of both the treatment variable and energy use in the same calendar month of the pre-program period. The underlying logic is that systematic differences between control and treatment customers will be reflected in differences in their past energy use, which is highly correlated with their current energy use. Formally, the model is shown in Equation 1.

Equation 1. Lagged Dependent Variable Regression Model

$$ADU_{kt} = \beta_1 Treatment_k + \sum_J \beta_{2j} Month_{jt} + \sum_J \beta_{4j} Month_{jt} \cdot ADUlag_{kt} + \varepsilon_{kt}$$

Where:

ADU_{kt}	is average daily consumption of kWh by household *k* in bill period *t*
$Treatment_k$	is a binary variable taking a value of 0 if household k is assigned to the control group, and 1 if assigned to the treatment group
$ADUlag_{kt}$	is household *k*'s energy use in the same calendar month of the pre-program year as the calendar month of month *t*
$Month_{jt}$	is a binary variable taking a value of 1 when j = t and 0 otherwise[4]
ε_{kt}	is the cluster-robust error term for household *k* during billing cycle *t;* cluster-robust errors account for heteroskedasticity and autocorrelation at the household level.[5]

The coefficient β_1 is the estimate of average daily kWh energy savings due to the program.

6.3.2 Linear Fixed Effects Regression Model

The LFER model used by Navigant is one in which average daily consumption of kWh by household *k* in bill period *t*, denoted by ADU_{kt}, is a function of the following three terms:

1. The binary variable $Treatment_k$.
2. The binary variable $Post_t$, taking a value of 0 if month *t* is in the pre-treatment period, and 1 if in the post-treatment period.
3. The interaction between these variables, $Treatment_k \cdot Post_t$.

Formally, the LFER model is shown in Equation 2.

Equation 2. Linear Fixed Effects Regression Model

$$ADU_{kt} = \alpha_{0k} + \alpha_1 Post_t + \alpha_2 Treatment_k \cdot Post_t + \varepsilon_{kt}$$

Three observations about this specification deserve comment. First, the coefficient α_{0k} captures all household-specific effects on energy use that do not change over time, including those that are unobservable. Second, α_1 captures the average effect *across all households* of being in the post-

[3] The model is identical to the post-program regression (PPR) model used in previous evaluations (e.g., PY8). We have changed the nomenclature to better align with academic research and because LDV is more descriptive of the model structure than PPR.

[4] In other words, if there are *T* post-program months, there are *T* monthly dummy variables in the model, with the dummy variable $Month_{tt}$ the only one to take a value of 1 at time t. These are, in other words, monthly fixed effects.

[5] Ordinary Least Squares (OLS) regression models assume that the data are homoskedastic and not autocorrelated. If either of these assumptions is violated, the resulting standard errors of the parameter estimates are incorrect (usually underestimated). A random variable is heteroskedastic when the variance is not constant. A random variable is autocorrelated when the error term in one period is correlated with the error terms in at least some of the previous periods.

treatment period. Third, the effect of being both in the treatment group and in the post period, i.e., the effect directly attributable to the program, is captured by the coefficient α_2. In other words, whereas the coefficient α_1 captures the change in average daily kWh use across the pre- and post-treatment for the *control* group, the sum $\alpha_1 + \alpha_2$ captures this change for the treatment group, and so α_2 is the estimate of average daily kWh energy savings due to the program.

6.4 Accounting for Uplift in Other Energy Efficiency Programs

6.4.1 Accounting for Uplift in PY9

The home energy reports sent to participating households include energy-saving tips, some of which encourage participants to enroll in other ComEd energy efficiency (EE) programs. If participation rates in other EE programs are the same for HER treatment and control groups, the savings estimates from the regression analyses are already "net" of savings from other programs as this indicates the HER program does not increase or decrease participation in other EE programs. However, if the HER program affects participation rates in other EE programs, then savings across all programs are lower than indicated by the simple summation of savings in the HER and EE programs. For instance, if the HER program increases participation in other EE programs, the increase in savings may be allocated to either the HER program or the EE program, but cannot be allocated to both programs simultaneously.[6] Note that when the HER program decreases participation in other programs there is no issue of double-counting and thus no adjustment to the savings total is made.

Data permitting, Navigant uses a difference-in-difference (DID) statistic to estimate uplift in other EE programs. To calculate the DID statistic, the change in the participation rate in another EE program between PY9 and the pre-program year for the control group is subtracted from the same change for the treatment group. For instance, if the rate of participation in an EE program during PY9 is five percent for the treatment group and three percent for the control group, and the rate of participation during the year before the start of the HER program is two percent for the treatment group and one percent for the control group, then the rate of uplift due to the HER program is one percent, as reflected in Equation 3.

Equation 3. DID Statistic Calculation

$$\begin{aligned}&(PY8\ treatment\ group\ participation - prePY\ treatment\ group\ participation)\\&\quad - (PY8\ control\ group\ participation - prePY\ control\ group\ participation)\\&\quad = DID\ statistic\\&(5\% - 2\%) - (3\% - 1\%) = 1\%\end{aligned}$$

The DID statistic generates an unbiased estimate of uplift when the baseline average rate of participation is the same for the treatment and control groups, or when they are different due only to differences between the two groups in time-invariant factors, such as the residence's square footage. For PY9 only, an adjustment to the DID statistic was made to account for the differing lengths of the pre and post periods since PY9 was 19 months.

An alternative to the DID statistic is the post-only difference (POD) statistic, which is the simple difference in participation rates between the treatment and control groups during PY9. The POD statistic generates an unbiased estimate of uplift when the baseline average rate of participation in the EE program is the same for the treatment and control groups. Navigant uses this alternative statistic in cases where the EE program did not exist in the pre-program year.

Navigant examined the uplift associated with four EE programs: the Fridge and Freezer Recycling (FFR) program, the Home Energy Assessment (HEA) program, the Home Energy Rebates (Rebate) program,

[6] It is not possible to avoid double counting of savings generated by programs for which tracking data are not available, such as upstream lighting programs.

and the Multi-Family Energy Savings Program (MESP). The FFR program achieves energy savings through retirement and recycling of older, inefficient refrigerators, freezers, and room air conditioners. The HEA program is offered jointly with the local gas utilities and achieves savings by providing direct installation of low-cost efficiency measures for single family homes, such as CFLs and low-flow showerheads. The Rebate program offers weatherization and incentives to residential customers to encourage customer purchases of higher efficiency heating, ventilating, and air-conditioning (HVAC) equipment. The MESP offers direct installation of low-cost efficiency measures, such as water efficiency measures and CFLs at eligible multifamily residences.

For each EE program, double-counted savings were calculated separately for each wave of the HER program and for the LR subgroup in Waves 1 and 3.

6.4.2 Accounting for Legacy Uplift

The uplift adjustment methodology described in Section 6.4.1 only accounts for uplift which occurs in the current program year because EE program tracking files in any given program year only capture the new measures installed in that year, regardless of the expected measure life.[7] However, for other EE programs that include measures with multi-year measure lives, HER program savings capture the portion of their savings due to uplift in each year of that program's measure life. For instance, a measure with a ten-year measure life that was installed in PY2 would generate savings captured in the HER program savings not just in PY2, but in PY3 through PY11 as well.

Consider the following example. A household receiving home energy reports through the HER program enrolls in the FFR program in PY6. The uplift adjustment subtracts FFR PY6 program savings to avoid double counting. In PY7 this household still receives savings from the FFR program because it has an eight-year measure life. However, the PY7 HER uplift adjustment does not remove these savings because the PY7 adjustment only accounts for measures installed in PY7, the initial year that the household entered a program. Thus, when only relying on the uplift adjustment described in Section 6.4.1 FFR second year savings would be included in the PY7 HER program's savings, which is inconsistent with Illinois's practice of only crediting utilities with first-year EE program savings. Legacy uplift removes double counted energy savings from programs that include measures with a multiple-year measure life.

Navigant accounts for legacy uplift by subtracting the double counted savings from previous years, adjusted for the average annual move-out rate, from PY9 HER savings through the measure lives of measures from other EE programs.[8] The legacy uplift adjustment is shown in Equation 4.

Equation 4. Legacy Uplift Calculation

$$\text{HER Savings}_{\text{PY}}^{\text{Adjusted}} = \text{HER Savings}_{\text{PY}}^{\text{Unadjusted}} - \text{Uplift Savings}_{\text{PY}} - \sum_{i=1}^{\text{PY-1}} \text{"Live" Legacy Uplift Savings}_{i} \cdot (1 - \text{MOR})^{\text{PY - i}}$$

Where, "'Live' Legacy Uplift Savings" refers to uplift savings where the other EE programs' measure lives have not yet run out (i.e., where measure life exceeds the difference between *PY* and *i*) and MOR refers to the move out rate.

The legacy uplift adjustment goes back to PY4 when Navigant first considered uplift for the HER program. In PY4, Navigant considered double-counted savings for the Fridge Freezer Recycle Rewards (FFRR), the Central Air Conditioning Efficiency Services (CACES), and the Single-Family Home Performance (SFHP) programs. In PY5, Navigant considered double-counted savings for the FFRR, the CSR, the

[7] Tracking data files are set-up this way because, in conformity the Illinois Technical Reference Manual Section 3.2, savings are first-year savings, not lifetime savings.

[8] Since HER program participants are dropped from that program when they move, other EE programs' savings are no longer captured in the HER program savings from that point forward.

Clothes Washer Rebate (CW), the Multi-Family Home Energy Savings (MF), and the Single-Family Home Energy Savings (SFHES) programs. The same programs were considered in PY6, except for the CW program which was discontinued. In PY7 and PY8 Navigant considered legacy uplift savings for the MESP, HEA, Rebate, and FFR programs.

In PY9, the legacy uplift accounted for the fact that the analysis period is measuring 19 months rather than 12 months of savings.

6.4.3 Uplift Analysis Results

LDV program savings estimates include savings resulting from the uplift in participation in other EE programs caused by the HER program. To avoid double-counting savings, program savings due to this uplift must be counted towards either the HER program or the other EE programs, but not both programs. The uplift of savings in other EE programs was a very small proportion of the total savings: 6,056,013 kWh, or 1.3 percent. The uplift can be broken down into uplift in PY9 and legacy uplift from previous program years. The PY9 uplift was 2,099,529 kWh or 0.5 percent of total program savings and the legacy uplift was 3,956,484 kWh or 0.9 percent of total program savings.

The programs included in the uplift analysis were the FFR program, the HEA program, the Rebate program and the MESP.[9] The estimate of double-counted savings is most likely an *overestimate* because it presumes participation in the other EE programs occurs at the very start of PY9. Under the more reasonable assumption that participation occurs at a uniform rate throughout the year, the estimate of double-counted savings would be approximately 3,028,007 kWh, half the estimated value of 6,056,013 kWh. The upshot is that double counting of savings with other ComEd EE programs does not appear to be a significant issue for the HER program.

7. APPENDIX 2. IMPACT ANALYSIS DETAIL

This section disaggregates program savings according to individual waves and wave subgroups. To examine the persistence of savings, Oracle terminated reports in October 2012 for 10,000 customers in Waves 1 and 3, but accidentally restarted treatment in August 2013. These customers are referred to as the Waves 1 and 3 lapsed report (LR) subgroups. Customers in Waves 1 and 3 who continued to receive reports are referred to as the continued report (CR) subgroup. Wave 7 was divided into low and high users due to its size. Table 7-1 summarizes estimated program savings by participant wave. In PY9, 1,924,384 participants and 280,596 controls had sufficient data for inclusion in our regression. Navigant estimated separate savings for each wave and wave subgroup using regression analysis as described in Section 6.3.

[9] ComEd has other residential programs that were not included in the analysis. The Residential Lighting and Elementary Education programs do not track participation at the customer level, and so do not have the data necessary for the uplift analysis. Double counting between the Residential New Construction and HER programs is not possible due to the requirement that HER participants have sufficient historical usage data.

Table 7-1. PY9 HER Program Results by Wave

Wave	Sample Size - Treatment	Sample Size - Control	Percent Savings	*Percent Savings Std. Err.*	Annualized Customer Savings, kWh*	*Annualized Customer Savings Std. Err.*	Net Savings, Prior to Uplift, kWh	*Net Savings Std. Err.*	PY9 Uplift, kWh†	Legacy Uplift, kWh†	Verified Net Savings, kWh‡
Wave 1 CR	19,841	30,128	2.63%	*0.28%*	382	*40*	11,457,927	*1,208,006*	64,635	238,211	11,155,081
Wave 1 LR	6,087		2.25%	*0.43%*	324	*61*	3,002,726	*568,601*	10,347	228,080	2,764,299
Wave 2	2,047	2,102	2.26%	*0.95%*	308	*130*	958,619	*403,775*	-	10,208	948,410
Wave 3 CR	134,189	36,799	2.60%	*0.17%*	466	*30*	94,714,269	*6,175,498*	332,194	868,727	93,513,347
Wave 3 LR	7,278		3.06%	*0.37%*	549	*66*	6,044,377	*722,872*	24,890	57,564	5,961,923
Wave 4	15,728	15,813	2.44%	*0.28%*	295	*34*	7,016,461	*804,568*	10,270	46,000	6,960,190
Wave 5	5,346	6,841	1.74%	*0.58%*	367	*123*	2,875,193	*964,543*	30,381	70,702	2,774,111
Wave 6	74,264	22,516	2.11%	*0.22%*	337	*35*	37,557,287	*3,909,657*	58,149	213,172	37,285,965
Wave 7 Low	483,582	40,370	1.28%	*0.14%*	86	*9*	153,715,154	*9,609,002*	439,914	1,752,754	151,522,486
Wave 7 High	508,105	42,448	1.95%	*0.12%*	203	*13*	60,941,331	*6,701,528*	22,249	204,551	60,714,531
Wave 8	65,043	8,767	1.60%	*0.33%*	190	*39*	17,008,058	*3,512,573*	118,422	15,027	16,874,608
Wave 9	306,431	19,379	0.34%	*0.17%*	28	*14*	10,768,601	*5,260,956*	598,512	-	10,170,089
Wave 10	147,734	18,212	0.56%	*0.25%*	43	*19*	4,142,679	*1,851,170*	256,623	-	3,886,056
New Mover	148,709	37,221	1.57%	*0.30%*	159	*30*	37,882,464	*7,158,283*	132,942	251,487	37,498,035
Total	1,924,384	280,596	1.44%	-	157	-	448,085,144	-	2,099,529	3,956,484	442,029,131

Source: ComEd data and Navigant team analysis.

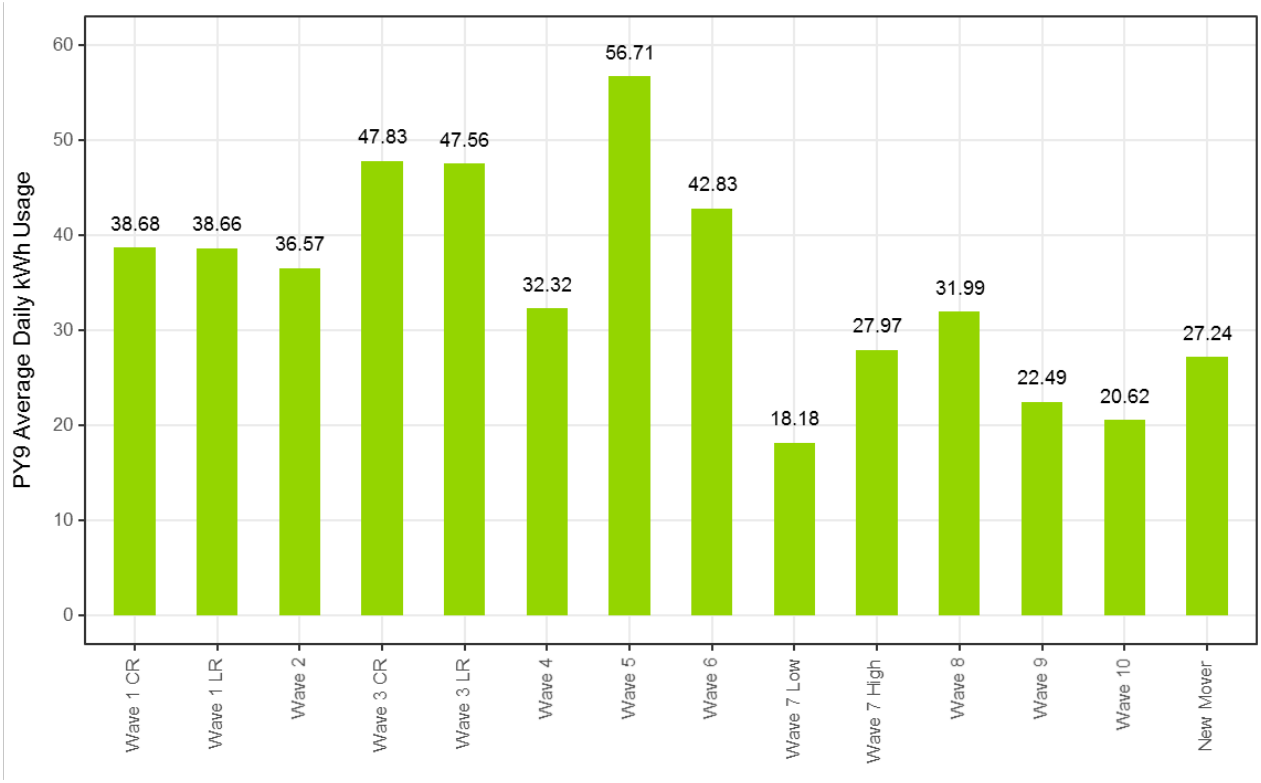
* Total savings are pro-rated for participants that closed their accounts during PY9.

† No adjustment was made to total savings for negative uplift, (i.e. cases where the HER program decreased participation in other programs).

‡ Verified Net Savings are equal to Net Savings, Prior to Uplift less PY9 Uplift and Legacy Uplift.

Daily electricity usage varied widely across waves (see Figure 7-1). Wave 7 Low had the lowest usage at 18 kilowatt-hours (kWh) per day, while Wave 5 had the highest at 57 kWh per day. Previous evaluations[10] have identified that higher usage is often associated with greater HER program savings.

Figure 7-1. PY9 Average Daily Usage by Wave

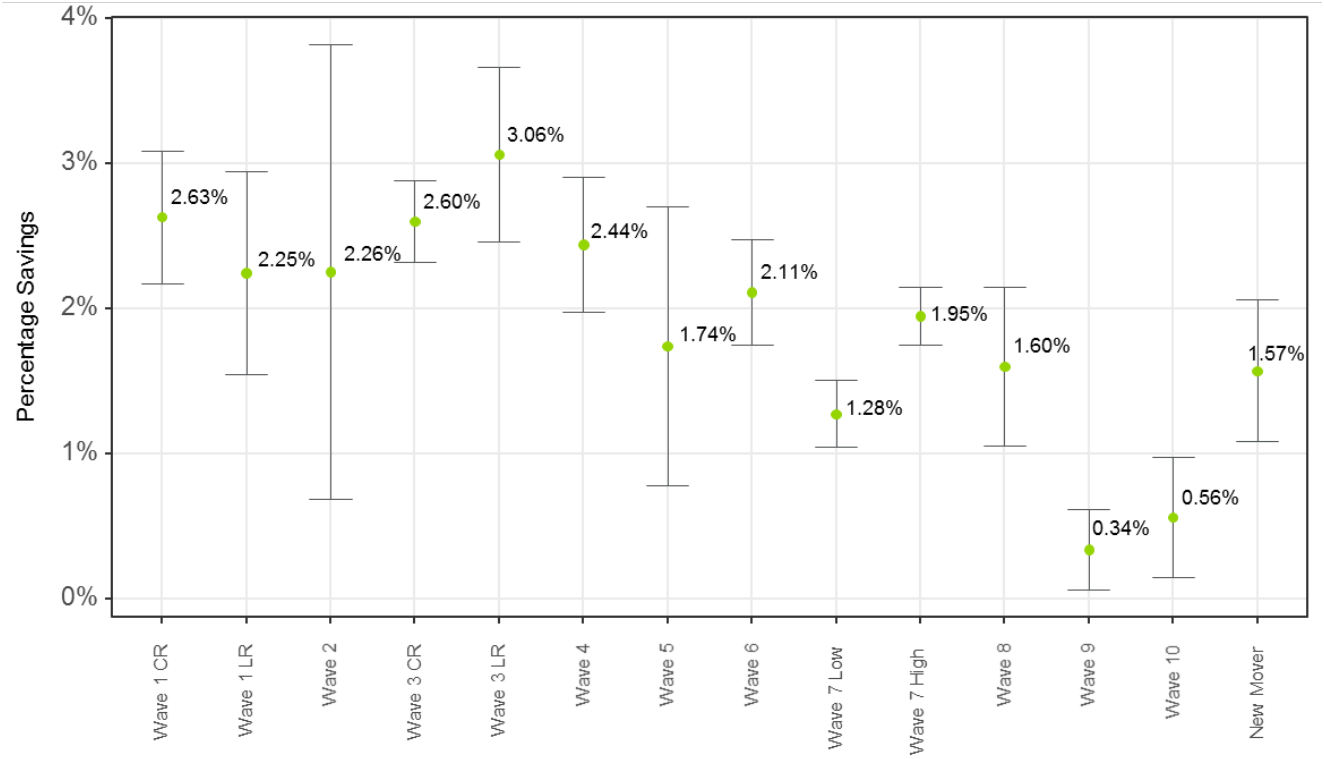


Source: ComEd data and Navigant team analysis.

Figure 7-2 shows energy savings for each wave with 90 percent confidence intervals. Waves with larger confidence bounds generally had smaller sample sizes, which reduced the level of certainty in the regression. For example, Wave 2 had a sample size of 2,047 participants and 2,102 controls and large confidence bounds, while Wave 7 Low had 485,540 participants and 40,370 controls and small confidence bounds.

[10] Navigant. 2016. *ComEd Home Energy Report Program Evaluation Report.* Presented to Commonwealth Edison Company.

Figure 7-2. PY9 Percent Savings and 90 Percent Confidence Interval by Wave

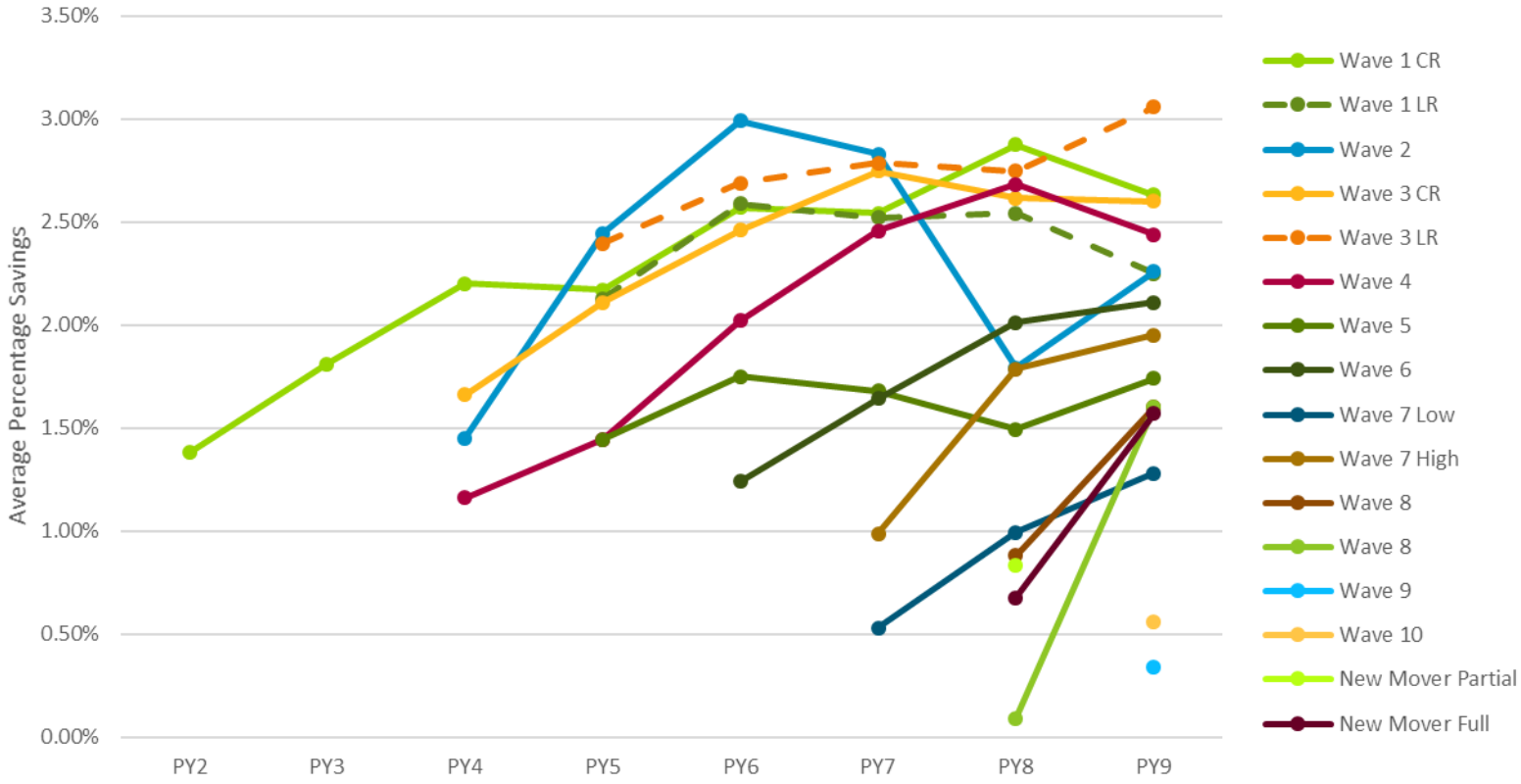


Source: ComEd data and Navigant team analysis.

Figure 7-3 combines PY9 results with those from previous evaluations to show how the estimated percentage savings have changed over program years for each wave. In general, wave savings show a consistent ramp-up from approximately 1 percent to between 2 and 3 percent over three to four years. Wave 7 Low continues to have lower-than-average savings, but that is likely due to its participants' relatively low usage. Based on program performance from the past several years, it is reasonable to expect Waves 9 and 10 to increase their savings rates, but perhaps not to the level of other waves with higher daily usage levels (e.g., Waves 1 and 3).

In PY8, the New Mover Wave was separated according to customers who received HERs for a full or partial year (New Mover Full and New Mover Partial, respectively). In the PY9 evaluation, these two subgroups were combined under the "New Mover Full" heading. As a result, New Mover Partial does not have a savings value for PY9 in Figure 7-3.

Figure 7-3. HER Program Savings over Time by Wave



Source: ComEd data and Navigant team analysis.

Tables with the regression outputs and detailed uplift results by wave are available upon request.

8. APPENDIX 3. TRC DETAIL

Table 8-1 shows the savings detail for the Total Resource Cost (TRC) cost-effectiveness analysis. This TRC variable table only includes cost-effectiveness analysis inputs available at the time of finalizing this PY9 impact report. Additional required cost data (e.g., measure costs, program level incentive and non-incentive costs) are not included in this table and will be provided to evaluation at a later date. Further, detail in this table (e.g., EULs) other than final PY9 savings and program data are subject to change and are not final.

Table 8-1. TRC Detail

End Use Type	Research Category	Units	Quantity (in thousands)	Effective Useful Life	Ex Ante Gross Savings (kWh)	Ex Ante Gross Peak Demand Reduction (kW)	Verified Nat Savings (kWh)	Verified Gross Peak Demand Reduction (kW)
Behavioral	NA	Household	1,995	1	NA	NA	442,029,131	NA

Source: ComEd tracking data and Navigant team analysis.