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

FINAL

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Prepared by:

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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]

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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 >

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.

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

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

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.

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.

[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.

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 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]

[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.

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.

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

[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 >

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 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
Wave 2	September 2010	-	-	-
Wave 3 CR	May 2011	-	-	-
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Wave 5 TR	July 2012	October 2013	-	16 months
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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

[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.

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).

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]

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

[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.

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 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.

[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.

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.

[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.

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 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

[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.

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 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.

[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.

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

Equation 2-4. Measure Life

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

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.

[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.

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.

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.

[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.

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.

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

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

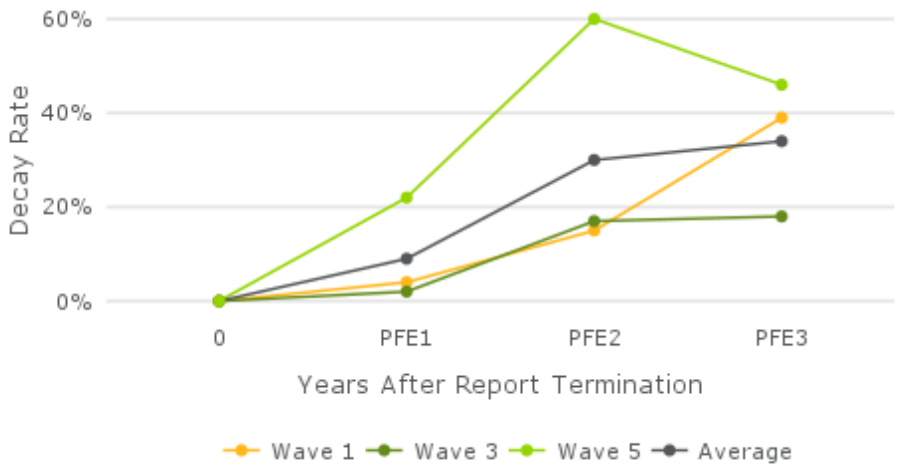
Table 3-3. HER Persistence Factors

	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.

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.

[33] Version 6.0, Volume 4, Measure 6.1.1

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%

[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

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.

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

[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.

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.

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

Data Cleaning Step	Customers		Observations		Customer % Change		Observation % Change	
Wave 1	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	Customers		Observations		Customer % Change		Observation % Change	
Wave 3	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	Customers		Observations		Customer % Change		Observation % Change	
Wave 5	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.

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

[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.

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.