RESIDENTIAL BEHAVIORAL PROGRAM PERSISTENCE STUDY

Prepared on Behalf of:

PENNSYLVANIA PUBLIC UTILITY COMMISSION

Final Report

December 15, 2015

Prepared by:

Statewide Evaluation Team

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research into action
APEX ANALYTICS, LLC

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LIST OF ACRONYMS

CR	Customer Rotation
Duquesne	Duquesne Light Company
EDC	Electric Distribution Company
EE&C	Energy Efficiency & Conservation
EM&V	Evaluation, Measurement, and Verification
HER	Home Energy Report
EUL	Effective Useful Life
LFER	Linear Fixed Effects Regression Model
PPL	PPL Electric Utilities Corporation
PUC	Public Utility Commission
PY	Program Year
REEP	Residential Energy Efficiency Program
SC	Single Cohort
TRC	Total Resource Cost Test
TRM	Technical Reference Manual

1 INTRODUCTION

Home energy report (HER) programs are residential behavioral energy efficiency programs that provide information to homeowners about energy usage and suggest adjustments to behavior consumers can make in order to reduce electricity consumption. Of interest is whether the effects of such a program persist after this information reporting has ended and, if so, for how long. In 2014, the Cadmus Group released a white paper in which they evaluated the persistence issue.[1] As part of their study, Cadmus performed a meta-analysis of four other post-treatment studies conducted by various researchers. They estimated an average annual energy savings decay rate of 20% after two years of treatment.

Two electric distribution companies (EDCs) subject to Pennsylvania Act 129, PPL Electric Utilities Corporation (PPL) and Duquesne Light Company (Duquesne), ran HER programs in Program Year (PY) 4 but then discontinued the programs in PY5. PY4 was the last year of Phase I and the HER program was assumed to have a one-year useful life. Additionally, Phase I and Phase II accounting required that a measure still be within its useful life at the end of the phase to count towards compliance savings. The HER programs were then discontinued in PY5 because any savings generated in PY5 would not count toward Phase II goals. Both EDCs restarted their program later in Phase II, but the stoppage provides the Pennsylvania Statewide Evaluator (SWE) with Pennsylvania-specific data that can be used to evaluate the persistence of HER impacts after the information reporting has ceased. Both EDCs contracted with Opower to administer and execute the behavioral program.

1.1 AUTHORIZATION OF STUDY

In the *2016 TRM Update Final Order*, the Pennsylvania Public Utility Commission (PUC) ordered the SWE to conduct an analysis of the HER persistence. The following excerpts from the order provide further background about the issue:

> *As noted by OPower, recent evaluation findings across North America suggest that the persistence of the HER program effect is longer than the one year. Research also indicates that both the magnitude of savings and the persistence of savings can vary depending on the duration of HER exposure. The Commission believes that the concept of measure life must be adjusted slightly in the context of HERs. Unlike an equipment measure which generates full savings for a number of years and then reaches the end of its mechanical life, the effect of HER exposure appears, based on the findings in the studies referenced by OPower, to deteriorate gradually once homes no longer participate in HERs.*
>
> *The Commission believes that this is an important issue for Phase III of Act 129 and prefers that the decay rate assumption be based on Pennsylvania-specific data. We also believe that the deployment and subsequent cessation of HERs by PPL and Duquesne in Phases I and II creates the ideal experimental framework for assessing the HER decay rate in the Commonwealth. Because homes participated in HERs programs in Program Years Three and Four and then ceased participation in Program Years Five and Six, there is data available to estimate the rate at which the electric consumption of homes in the treatment group returns to the level observed in control group homes. Accordingly, the Commission directs the SWE to conduct an*

[1] Khawaja, M. Sami, Ph.D. and James Stewart, Ph.D. *Long-Run Savings and Cost-Effectiveness of Home Energy Report Programs*. Cadmus Group, Inc. November 2014.

> *independent assessment of the HER's program decay by analyzing billing data provided by PPL, Duquesne and any other EDC that withdrew HER application during Phase II. We direct the EDCs to work in cooperation with the SWE to provide this data. The SWE's findings will be used to update the existing custom measure protocol for the HERs program. An update to a custom measure protocol does not require an update to the TRM for it to be available for EDC use. However, we can again consider the appropriateness of including the HER protocol in the TRM during a future TRM update.*

This report presents the analysis completed by the SWE in response to the order to evaluate the persistence in energy savings achieved by the Opower HER programs run by PPL and Duquesne.

1.2 STUDY OBJECTIVES

The objectives of the study are threefold and focus exclusively on energy savings of the Pennsylvania HER programs after regular reporting has been discontinued. This study does not evaluate or comment on savings achieved during PY4 when the program was active. However, as part of the SWE analysis, we estimated program impacts during PY4 and got results consistent with the savings claimed by the EDCs. The three objectives of the study can be summarized as follows:

- Determine whether energy savings from an HER program persists after reporting is discontinued
- If there is decay of savings evident, measure the rate of savings decay
- Determine if a one-year effective useful life (EUL) assumption for HER programs for energy efficiency potential analysis is appropriate

2 SUMMARY OF PPL AND DUQUESNE HER PROGRAMS

This chapter provides a brief summary of the PPL and Duquesne HER programs. These programs provide the source data used by the SWE to evaluate persistence characteristics of HER programs in Pennsylvania.

2.1 PPL PROGRAM

During PY4, PPL had two separate groups of residences on its Energy Efficiency Behavior and Education Program, administered by Opower. The first group, called the Legacy group, consisted of homes that began the program in May 2010. Another group, called the Expansion group, began the program about a year after the Legacy group. The groups are independent, with no home participating in both programs. Both groups were designed as a randomized control trial, with randomly selected treatment and control customers. For each cohort, the control group consisted of a number of customers equal to the size of the treatment group and with equivalent pre-program energy usage.

The Legacy treatment group consisted of approximately 48,700 residential accounts with average electricity usage just above 18,000 kWh per year (or 1,500 kWh per month). In PY4, PPL and Cadmus estimated savings of 360 kWh per home for the year from the Legacy program, which equates to 2.0% savings.[2] PPL reported a 95% confidence interval on the savings estimate of 308 to 413 kWh per home, or 1.7% to 2.3%. The total reported energy savings in PY4 equated to 15,072 MWh for the Legacy group.

The Expansion treatment group had 52,900 residential accounts with average electricity usage of over 27,000 kWh per year, or 2,270 kWh per month. As stated earlier, this was an entirely different group of participating homes from the Legacy group. In PY4, the Expansion savings were estimated to be 495 kWh per home for the year, with a confidence interval ranging from 392 to 598 kWh. On a percentage savings basis, the point estimate is 1.7%, with a confidence interval of 1.3% to 2.1%. The total reported savings from the Expansion group in PY4 is 21,399 MWh.

Reporting was discontinued for both the Legacy and Expansion groups after May 2013, coinciding with the end of PY4. PPL resumed the program in October 2014, providing 16 months over which customers who had been receiving reports were no longer receiving reports.

2.2 DUQUESNE PROGRAM

Duquesne incorporated its Opower program as part of its overall Residential Energy Efficiency Program (REEP). There were a total of 52,200 treatment group accounts in the program in PY4 with average usage of 13,500 kWh per year, or 1,125 kW per month. The control group was similar in size and usage characteristics. In PY4, Duquesne reported 4,791 MWh of energy savings from the program[3], or roughly a 1.0% reduction. Duquesne discontinued reporting after the end of PY4 (May 2013) and resumed the program in March 2015.

[2] See PPL's *Program Year 4 Final Annual Report*, Appendix E.

[3] See Duquesne's *Program Year 4 Final Annual Report*, Table 2-4.

3 STUDY METHODOLOGY

In order to determine program impacts during PY4, both PPL and Duquesne and their evaluation contractors used a linear fixed effects regression (LFER) approach. The analysis involves comparing consumption of the treatment group with a control group in both pre- and post-treatment periods. The SWE used the same approach to further analyze the differences in consumption between the treatment and control groups for the three different groups under study (PPL Legacy, PPL Expansion, and Duquesne).

3.1 DATA REQUIREMENTS AND PREPARATION

The SWE required a significant amount of data from the EDCs in order to complete the study. The primary data requested was monthly billing history for every customer in the treatment and control groups for several years, including the twelve months of consumption history required for program eligibility. For PPL, this represented multiple years of billing history for approximately 200,000 residential accounts. There were just over 100,000 accounts across the Legacy and Expansion treatment groups, and each group had separate unique control groups of the same size. Billing history for over 100,000 accounts was required from Duquesne. The second major piece of information provided by the EDCs was tables providing account-specific information about when HER reports were sent and the start and stop dates of program participation. The SWE used this information to verify the months during which reports were not provided to the treatment group.

The SWE employed SAS[4] software to perform data summarization and statistical analysis for the persistence study. Both PPL and Duquesne provided data in a timely fashion and in formats that were sufficiently structured to allow the SWE to read in the data into SAS without difficulty. Furthermore, the data was "calendarized" and provided in raw formats and with outlier handling already completed. The calendarization process involves spreading usage into the calendar month in which it took place and then computing average daily kWh consumption as opposed to aggregate monthly kWh consumption.

This process is important to the analysis for several reasons.

- Particularly short or long billing periods are expressed into appropriate calendar months
- Control and treatment billing can be appropriately aligned within each month, which eliminates billing cycle mismatches
- With proper control group selection and with calendarized months aligned properly, variations in consumption due to changes in weather are addressed because control and treatment consumption is based on the same days with the same weather.

Opower also handled outliers to trim the data. The following outlier conditions resulted in flagging the data for removal from the analysis. The SWE excluded such outliers from their analysis as well.

- Usage occurring after the customer move out date
- Billing data with duration less than 1 day
- Billing months with read dates that overlapped other billing month read dates
- Negative or very high (>300 kWh per day) daily usage that would indicate errant data

[4] SAS is a brand name and not an acronym.

PPL's evaluation contractor selected a sample of 5,000 control and 5,000 treatment accounts for each of the Legacy and Expansion groups to facilitate estimation of program impacts. They used a simple random sampling approach as described in PPL's PY4 Annual Report. The SWE elected to use all control and treatment customers in the analysis database since the data was available and did not provide significant computational burdens relative to modeling a sample. It is unclear from Duquesne's PY4 Annual Report whether a sample or the total set of customers was used by their evaluation contractor to estimate program impacts. However, as with PPL, the SWE used all control and treatment customers. The SWE computed average daily energy per month in the months prior to the start of the program to evaluate the control group's representativeness. For all three groups, the control and treatment daily average usage values prior to start of the HER program were nearly equivalent, indicating the control group is representative of the treatment group and appropriate for use in measuring impacts of the HER program.

3.2 Determination of Program Impacts

The SWE used a linear fixed effects regression model (LFER) approach, as the EDC evaluation contractors did, to estimate program impacts as the first step in evaluating persistence of savings after discontinuation of the program. The LFER is a panel regression approach in which time series data for each customer is stacked up into one database and a single regression model is structured such that model coefficients represent the difference in consumption between the control and treatment groups. Fixed effects are included to control for consumption differences in each home. The model used by the SWE is depicted in Equation 3-1. A separate model was constructed for each of the three groups under evaluation.

Equation 3-1: Linear Fixed Effects Regression Model Specification

$$DailyUse_{i,m} = \beta_0 + \beta_1 Post_m + \sum_i \gamma_i Acct_i + \sum_m \propto_m D_m + \sum_m \theta_m Treatment_i Post_m$$

Where:

i	=	index to represent each residential account
m	=	index to represent each month of each year of the analysis period
$DailyUse_{i,m}$	=	average daily usage in month m for customer i
Post	=	indicator variable to represent months after the start of the program
β_0, β_1	=	model coefficients
$Acct_i$	=	indicator variable for each account in the database
γ_I	=	fixed effects coefficient for account i
D_m	=	indicator variable for each month/year of the analysis period
α_m	=	coefficients for each month
Treatment	=	indicator representing a customer in a treatment group
θ_m	=	coefficient representing average daily energy savings in month m

The θ coefficients represent the savings, in kWh per day, of the program in each month. Taking this estimate and dividing it by the control group average usage in the month provides the percentage reduction achieved by the program in each month, providing a helpful time series since impacts are seasonal. The SWE models, using all treatment and control data, achieve PY4 savings estimates consistent with those reported by the EDCs in their PY4 Annual Reports. The figures below show the estimated energy savings as a percentage in each month for each of the three groups. The blue lines represent savings when programs were active and reports were being sent to customers. The orange line represents months in which reports were not being sent to customers. As can be seen from the figures, savings did not rapidly decay and some level did persist for 16-21 months after the program was discontinued. For example, in Figure 3-1, had the savings decayed within a year after cessation of reporting, the orange line would have reached 0.0% within 12 months.

Figure 3-1: Estimated Program Impacts During and After Program Reporting – PPL Legacy

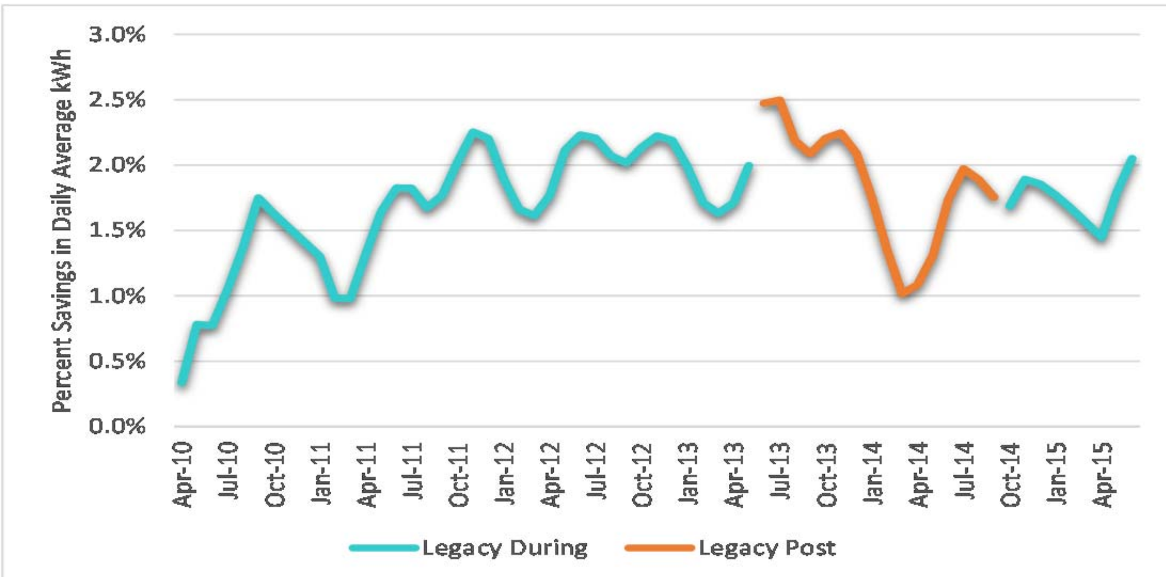


Figure 3-2: Estimated Program Impacts During and After Program Reporting – PPL Expansion

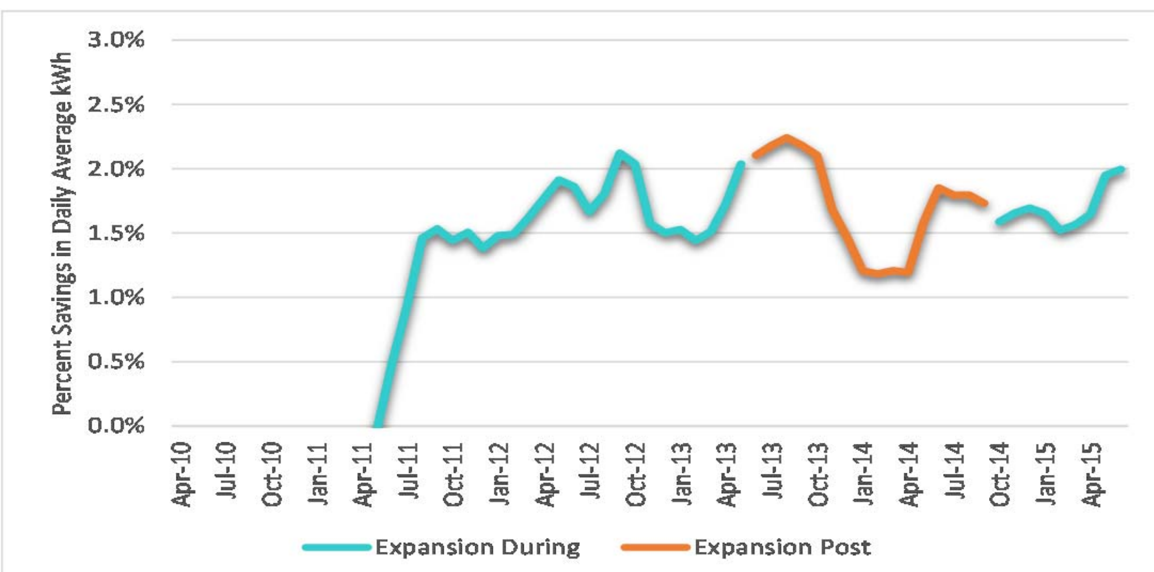
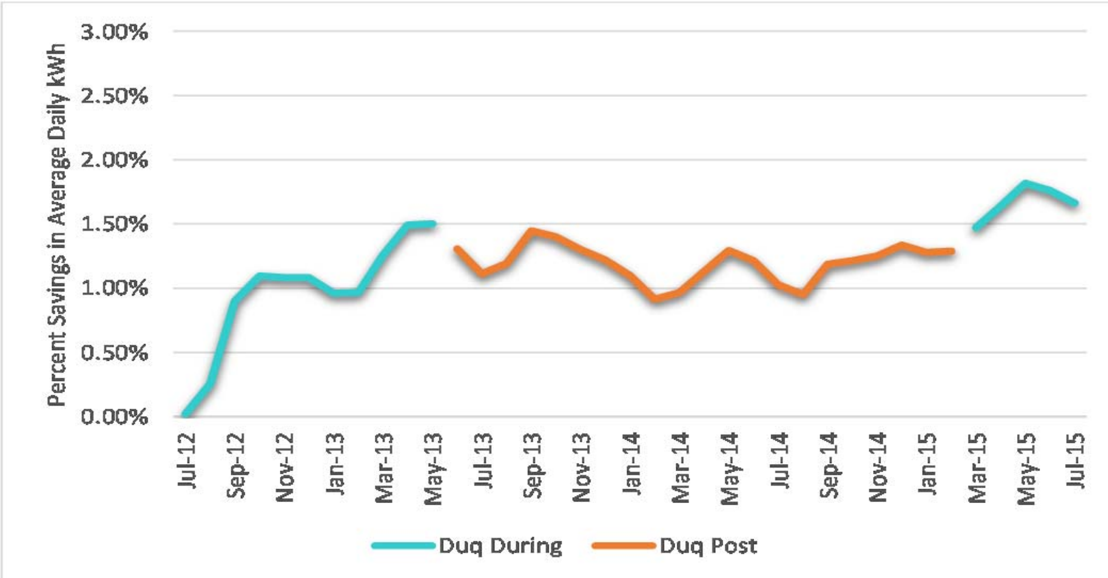


Figure 3-3: Estimated Program Impacts During and After Program Reporting – Duquesne



3.3 MEASUREMENT OF RATE OF SAVINGS DECAY

It was obvious that HER energy benefits persisted at some level for up to 16 months after the program was ended for all three Pennsylvania groups under analysis. The next task became estimating the rate of decay of impacts over time. There are some challenges to estimating the rate of decay, which are discussed in more detail below.

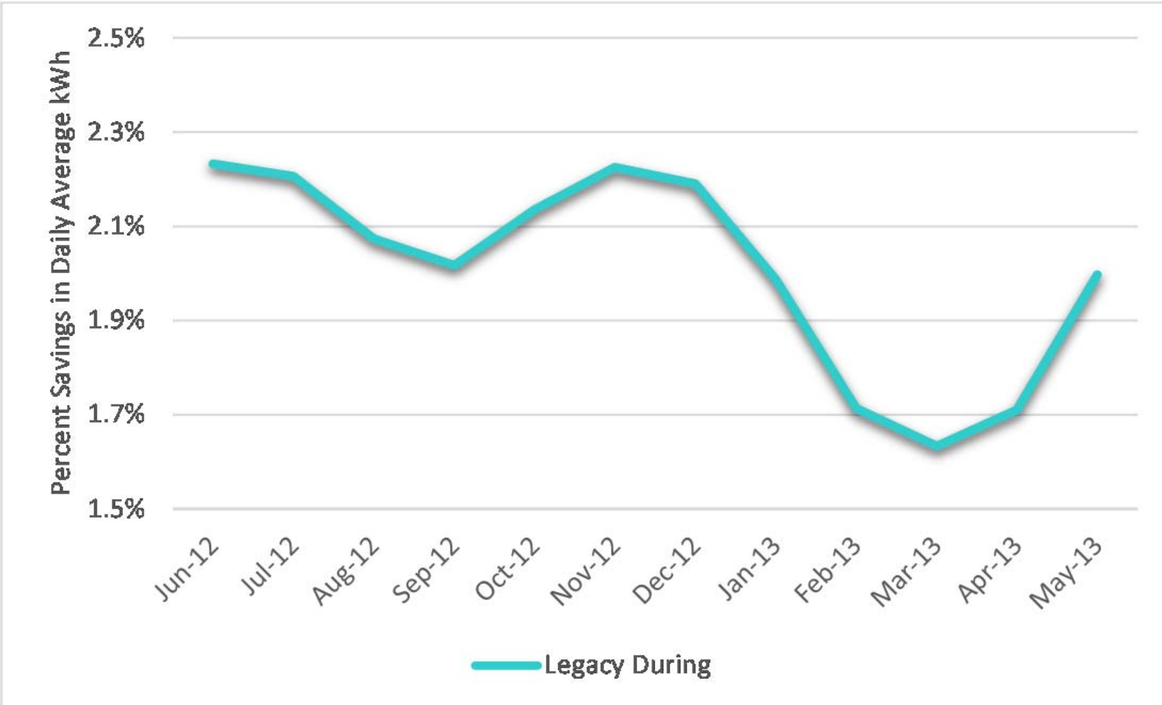
3.3.1 Limited Time Series Data Available

Since both PPL and Duquesne restarted their HER programs, the number of months available to analyze decay of energy savings has been limited. PPL had 16 months between stopping and restarting the program and Duquesne had 21 months. With less than two years available for analysis, a detailed study of the full decay patterns could not be conducted. Therefore, the SWE focused on calculating an average decay rate in the near term, across the months available. Conclusions drawn about how impacts may decay in the longer term (after one or two years have passed) cannot be supported by the analysis conducted herein.

3.3.2 Seasonality of the Savings

The savings attributed to the program seem to have seasonality to them, with greater savings in months with hotter or colder weather. This makes sense, as a single large source of behavioral impacts can be adjusting thermostat settings to reduce electric heating and air conditioning requirements. The seasonality means that it is tricky to determine exactly when effects have completely eroded, since valley months will reach 0% faster than heating or cooling months.

Figure 3-4: Demonstration of Seasonality of Impacts, PPL Legacy Impacts During PY4



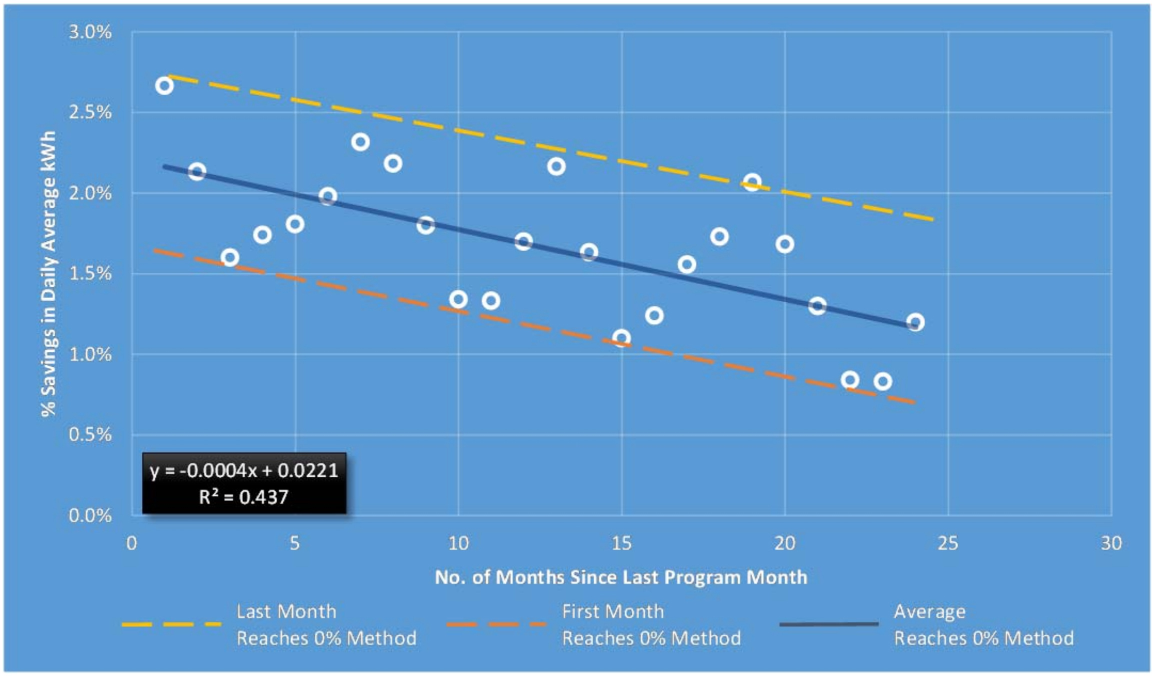
There are three relatively straightforward options for determining how long impacts have persisted before they are considered completely decayed.

When the first month reaches 0% impact | This approach is demonstrated in the orange dashed line in **Figure** 3-5 below. This approach would lead to the fastest rate of decay, but would consider impacts fully decayed when all other months still indicate some savings persisting relative to the control group.

When the last month reaches 0% impact | This approach requires every month to reach 0%, as indicated by the yellow dashed line in **Figure** 3-5. This would produce the slowest rate of decay estimate, but might present a problem if slight variations in the control and treatment groups several years out lead to natural differences in the two populations (such as changes in number of persons in the household, appliance mix, amount of conditioned space, or turnover in homeownership). As the analysis horizon pushes further into the future, the likelihood of divergence between control and treatment homes increases.

When the average impact reaches 0% | This approach involves using a trend line to project when the trend would reach 0% (blue line in **Figure** 3-5). This approach is the middle ground between the other two approaches and has the additional benefit of ease of computation. To determine the decay rate, a simple trend regression can be calculated in which the number of months since the last report is the independent variable. Then, the resultant linear equation can be solved for when the savings equals 0%. That indicates how many months elapse before the average impact fully decays. This is the approach used by the SWE to determine the long-term average rate of decay.

Figure 3-5: Demonstration of Approaches to Determining when Impacts Have Fully Decayed (Example data for demonstration purposes, not based on actual program data)



In the example above, the trend line regression for the blue line is:

$$\% \; Impact = -0.000433 \; x \; No. \; Months \; Since \; Program \; Ended + 0.02206$$

Solving this equation for 0% impact yields 51 months, indicating average impacts will decay within 51 months *assuming a linear rate of decay over time*. That equates to 4.25 years for the decay, or an average annual rate of 23.5% for decay. This is the approach used by the SWE to estimate the annual rate of decay for PPL and Duquesne programs. It is important to note that this approach assumes the rate of decay is linear over time.

The SWE considered use of a regression or univariate model that would take seasonality into account to determine when the underlying trend would reach 0%. However, with so few degrees of freedom available for such modeling and with the underlying trend really being the variable of interest, we felt such an approach would not provide greater accuracy than a linear trend approach. Given the lack of controlling for seasonality, the SWE expects R^2 statistics for the linear trend to be below 0.5.

3.3.3 Time Delay in Reporting and Effects

Intuitively, there is likely a delay between EDC mailing and customer receipt of HERs and observation of load impacts at the meter. Several factors contribute to the likelihood. First, Opower must receive the billing data and perform its analyses and processes necessary to produce an energy report for a month. Then the report must be mailed to the homeowners. Finally, the homeowners must read the report and take the time necessary to make the behavioral changes to respond. Such a process could easily take up to eight to ten weeks before impacts are noticeable. Therefore, it might make sense to exclude one-to-two months of data after the reporting stopped and include one-to-two months of data after the program was resumed to assess decay of impacts during non-program months. However, with no quantitative analysis of how long such lags may be, the SWE has elected to specifically use the months in which reports were not sent as the data series under analysis.

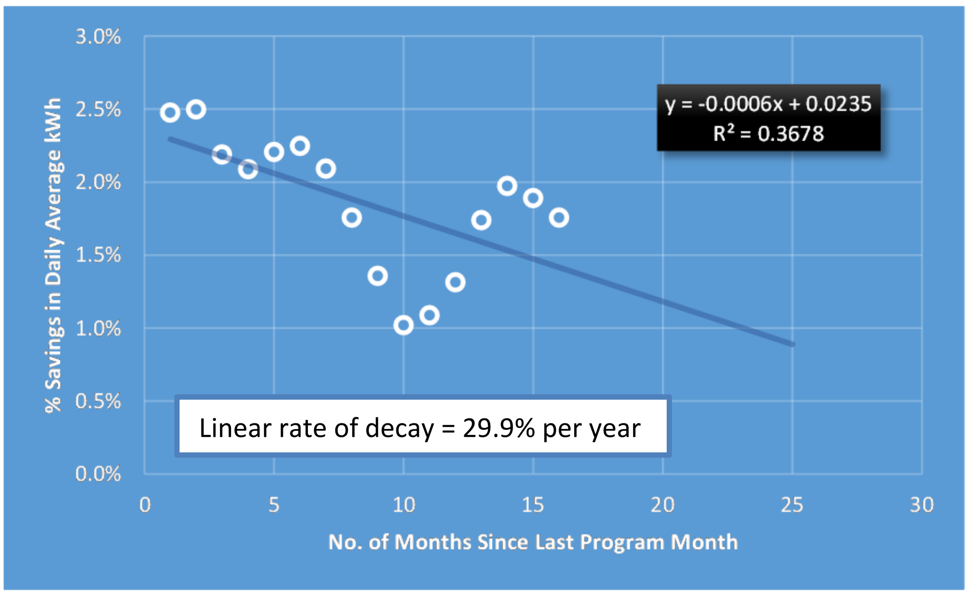
4 STUDY RESULTS

As can be seen in Figure 3-1, Figure 3-2 and Figure 3-3, HER impacts persisted for all three EDC groups analyzed by the SWE. Both PPL programs indicate some decay occurring prior to program restart, however significant savings of more than 1% still persisted 16 months after the end of the program. The Duquesne program shows little decay over 21 months, indicating strong persistence for that program.

4.1 PPL LEGACY PROGRAM

Isolating the months in which no program was in place and performing a trend analysis indicates that impacts from the HER program would decay in just over 3 years assuming linear decay consistent with that seen in the first 16 months after the program was discontinued. This equates to a linear decay rate of 29.9% per year. Figure 4-1 presents the trend line used to estimate the rate of decay for the PPL Legacy program. The t-statistic on the slope parameter is 2.85 (p-value = 0.01), indicating statistical significance above 95% confidence.

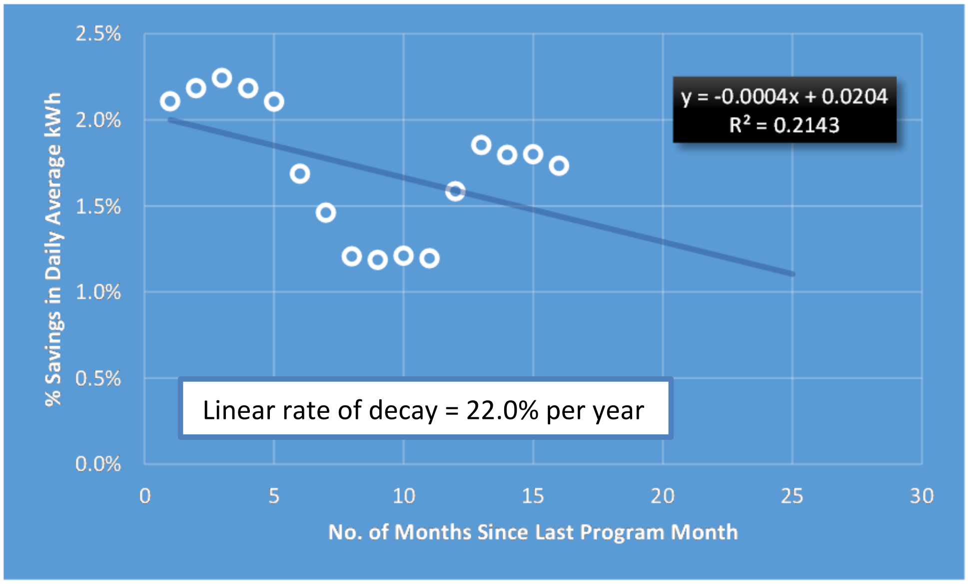
Figure 4-1: Decay Rate Analysis of PPL Legacy Program



4.2 PPL EXPANSION PROGRAM

The PPL Expansion program also shows a statistically significant rate of decay over the 16 months the HER program was discontinued. However, the measured rate of decay is lower at 22.0% per year. The linear trend equation indicates linear decay consistent with the 16 months evaluated would result in the program fully decaying within 4.6 years. Figure 4-2 presents the trend line used to estimate the rate of decay for the PPL Expansion program. The t-statistic on the slope parameter is 1.95 (p-value = 0.07), indicating statistical significance at just outside of 95% confidence.

Figure 4-2: Decay Rate Analysis of PPL Expansion Program

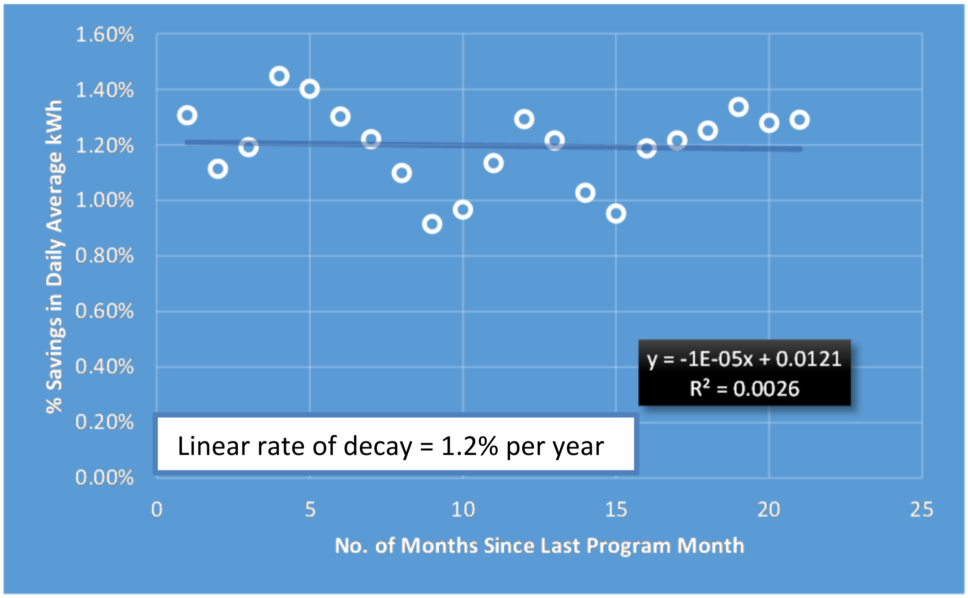


4.3 DUQUESNE PROGRAM

The Duquesne program demonstrates persistence of effects unlike the PPL programs, with a statistically insignificant upward trend from which to estimate the rate of decay. Using the trend line shown in Figure 4-3 produces an estimated rate of decay of 1.2% per year, a rate that would require nearly 85 years for full erosion of impacts. The t-statistic on the slope of the trend line is only 0.22 and the associated p-value is 0.83. This implies that we cannot be confident that the slope is statistically different from 0 and that there is a rate of decay at all.

This rate of decay is much lower than either of the PPL estimates or of any of the programs analyzed by Cadmus in their meta-analysis (the slowest rate of decay in that study was 11% per year). The SWE does not have sufficient data or time to fully analyze potential root causes for this result. However, we do observe that the Duquesne impacts, even during program implementation, were half that of PPL and lower than is typically cited by Opower. This seems to indicate that customers took less drastic measures to save energy during the program and therefore it is less likely they will abandon those measures once they stop receiving energy reports. However, this is conjecture and has not been verified with customer surveys or other research initiatives.

Figure 4-3: Decay Rate Analysis of Duquesne Program



5 OBSERVATIONS

PERSISTENCE OF EFFECTS

HER program effects certainly persisted in Pennsylvania according to the SWE's analysis, as shown in Figure 5-1, in which the orange line represents energy savings of the treatment groups relative to the control group for months after the HER program was discontinued.

Figure 5-1: HER Program Impacts During and After Program Implementation

5.1 INITIAL DECAY OF EFFECTS

Over a 16 month period, the PPL Legacy group has an estimated rate of decay of impacts of 29.9% per year, higher than the average of the Cadmus study, but within the range of studies evaluated by Cadmus. Interestingly, and perhaps counterintuitively, the Legacy group had the longest exposure to HERs but also had the fastest rate of decay. The PPL Expansion group has an estimated rate of decay of 22.0% per year as measured over the 16 month period available to the SWE for analysis. This is in line with the Cadmus estimate. Finally, the Duquesne analysis indicates little if any decay over a 21 month period. The estimated rate of decay is 1.2% per year, significantly lower than even the lowest rate in studies reviewed by Cadmus.

5.2 LONG-TERM DECAY OF EFFECTS

The SWE is unable to draw conclusions about the longer-term decay of effects due to lack of a sufficiently long time series data. Since both PPL and Duquesne restarted their programs, the data available to analyze decay is less than two years. The SWE analysis assumes linear rates of decay. However, we think the rate of decay beyond a year or two is likely to be non-linear. A non-linear rate of decay could produce vastly different results with regards to the amount of time required for impacts to fully erode. Data that includes customers that have been off the program for three to five years could provide a more robust analysis of the functional form of HER program impact erosion. There could also be a correlation between the number of years a home receives HERs and the functional form and rate of decay once reporting is stopped. Also of interest for possible future analysis would be market research to determine how customers modified consumption. Actions that are more behavioral and easy to modify over time (such as grilling outside instead of using an electric stove) might result in more rapid erosion than more permanent responses such as changing equipment, weatherizing the home, or programming thermostats. Such data from a representative sample of program participants (and control group customers) could be invaluable in conducting further research into how different programs achieve different levels of persistence over time.

5.3 Restarting of Programs

Interestingly, it seems as if resumption of the program leads to rapid recovery of the savings that had eroded during the time the program was not active. Both PPL programs, even after a relatively significant level of erosion of impacts over 16 months, had impacts back down to 2.0% within just a few months of restarting their program. Duquesne actually saw increased savings after restarting the program, with energy savings reaching nearly 2% within a few months, achieving savings better than in any month in the first run of the Opower program. Admittedly, this observation is made after only several months of program resumption. A longer time series could be used to further evaluate if this remains to be the case.

6 COST-EFFECTIVENESS CONSIDERATIONS

According to the SWE analysis presented in this report, HER program effects persist in Pennsylvania following the cessation of reports. Based on this finding the SWE conducted a scenario analysis to provide estimates of the benefit/cost implications of changing the assumed measure life of the home energy report measure from one year to five years.[5] We have selected five years as a cutoff because while it is unknown how long savings will persist over the longer term until more research is conducted on the topic, we assume that savings will continue to decay and a five year analysis is useful for providing context within the Phase III timeframe.

This study reviews a total of five scenarios reporting cost-effectiveness of behavioral programs split into two program delivery options. The first delivery option is referred to as "multiple cohort" or "customer rotation." We describe three scenarios which fall into this category. The second delivery option is labeled "single cohort" or "no customer rotation." There are two scenarios which fall into this category. Each scenario considers a five year timeframe. The SWE recognizes that we have not provided an exhaustive consideration of scenarios and that there may be additional valid approaches not included in this review.

The customer rotation category applies to scenarios in which customers receive the HER for one year only and then the EDCs distribute the HER to a new cohort of customers the following year. The single cohort category applies to scenarios in which a single group of customers will receive the HER year after year. This latter arrangement describes how most programs have been implemented in Pennsylvania and other states in recent years. In practice, there often exists some combination of these two categories as the same group of customers receives an HER in the first year of the program and customers are added to the program over time in future years, while some customers may opt out or program administrators may specifically test for persistence by dropping some customers from the program. The SWE has focused on the two exclusive categories of customer rotation and single cohort to simplify the analysis.

6.1 SCENARIO DISCUSSION

SCENARIO 1 (CR1) | Customer Rotation; 1-Year Useful Life

In the first scenario, CR1[6], the SWE assumes that the HER measure has a one-year useful life, produces 400 kWh of annual savings, and costs $27 per participant[7]. Since each customer group will receive the measure for just one year and the measure life is also just one year, there is no persistence of savings beyond the first year.

Table 6-1 below shows the incremental annual savings (shaded green) for HER reports delivered to multiple cohorts across program years 1 through 5 under Scenario 1. The measure life is assumed to be one year, so there is no persistence and the incremental annual savings are equal to the lifetime savings.

[5] For determination of cost-effectiveness considerations, the SWE analysis utilizes a steady decay rate of 20%.

[6] Each scenario is identified by its category (either "CR" for customer rotation or "SC" for single cohort) and its assumption for measure life. For example, CR1 corresponds to customer rotation with a one-year measure life. Scenarios 2 and 3 are only different in terms of the timing of accounting for savings and are identified as CR5A and CR5B to differentiate the scenarios.

[7] The value of 400 kWh of annual savings and $27 cost is approximate data from one of the Pennsylvania EDCs based on activity during Act 129 Phase I PY4.

Table 6-1: Scenario 1 Incremental Annual and Lifetime Savings

		PY1	PY2	PY3	PY4	PY5	Report Year Savings	
Cohort/Report Year #		Energy Savings (kWh)					Incr. Annual	Lifetime
Cohort#1	Year 1	400					400	400
Cohort#2	Year 1		400				400	400
Cohort#3	Year 1			400			400	400
Cohort#4	Year 1				400		400	400
Cohort#5	Year 1					400	400	400
Program Year Savings Total		**400**	**400**	**400**	**400**	**400**		

Table 6-2 below provides the value of the benefits and the costs each year in Scenario 1. The second and third rows show the present value of the benefits and costs in the year in which they are accrued and incurred, respectively. The Total Resource Cost (TRC) ratios in the final row are calculated with the Net Present Value (NPV) benefits and costs figures. The total column at the far right of the table provides the five-year totals for each category.[8] The NPV calculations factor is the discount rate.

Table 6-2: Benefits and Costs Data for Scenario 1

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Scenario TRC Energy Savings (kWh)	400	400	400	400	400	**2,000**
NPV Benefits	$20.0	$18.8	$17.7	$16.7	$15.7	**$88.8**
NPV Costs	$27.0	$25.0	$23.1	$21.4	$19.7	**$116.1**
TRC Ratio	0.74	0.75	0.77	0.78	0.79	**0.76**

SCENARIO 2 (CR5A) | Customer Rotation; 5-Year Useful Life; TRC Based on 5-yr EUL

Consistent with Scenario 1, each cohort in the second scenario (CR5A) receives the HER for a single year. Again, the SWE assumes the HER produces 400 kWh of savings in the first year and costs $27 per participant. However, for this Scenario 2, the SWE also assumed that the HER has a useful life that may be approximated by the rate of decay found by the SWE's Persistence Study. Specifically, we assumed that the measure savings decrease by a steady 20% each year, relative to the first year 400 kWh savings, after the customers stop receiving the report. This means that customers who receive the HER will still realize savings of 320 kWh in the second year, 240 kWh in the third year, 160 kWh in the fourth year, and 80 kWh in the fifth year.[9]

The final defining characteristic of Scenario 2 (CR5A) is the way the SWE attributes annual benefits and calculates the TRC ratio each year. For Scenario 2, the first year savings (as well as the savings that

8 Energy savings are valued at an estimated value of $0.05 per kWh in PY1, and escalated by 1.74% in subsequent years. The nominal price of delivering the HER report ($27) is held constant in all program years. All benefits and costs are present valued back to PY1 using a nominal discount rate of 8.14%. The inflation rate is nominal discount rate are specific to an individual PA EDC that offered a HER program during Phase I PY4 of Act 129. These scenario TRC benefit examples do not factor in additional capacity benefits. The TRC ratios provided within are presented to allow for comparison between scenarios; readers are cautioned to not use the TRC results as indicators of actual HER program cost-effectiveness.

9 Given the findings detailed earlier in this study and the possible variation in decay rates by EDC and HER exposure rates, it was not possible to stipulate a statewide decay rate. For the cost-effectiveness scenarios discussed herein, the SWE selected a steady decay rate of 20% for illustrative purposes. A steady, linear decay rate (400 * 20%, or 80 kWh annually) was selected in lieu of a compound decay rate (400 kWh * 20% in first year, followed by 320 * 20% in the second year, etc.) to be consistent with the analysis detailed earlier in this report (See Section Error! Reference source not found.).

accrue in years after the HER is distributed) will be accounted for as savings and benefits attributable to the respective cohort group.

Table 6-3 below demonstrates the Scenario 2 incremental annual savings (shaded green) and lifetime savings (equal to the sum of the shaded green cells and the shaded yellow cells) for each cohort associated with the customer rotation / 5-yr measure life conditions. Each year, a new cohort receives the report, saves 400 kWh in that first year, and then continues to accrue savings for four subsequent years at a steady decay rate of 20% of the first year savings. The boxes drawn around each set of savings correspond to the total energy savings of each cohort group.

Table 6-3: Scenario 2 Incremental Annual and Lifetime Savings

		PY1	PY2	PY3	PY4	PY5	PY6	PY7	PY8	PY9	Report Year Savings	
	Report Year #										Incremental Annual (kWh)	Lifetime (kWh)
Cohort#1	Year 1	400	**320**	**240**	**160**	**80**					400	1,200
Cohort#2	Year 1		400	**320**	**240**	**160**	**80**				400	1,200
Cohort#3	Year 1			400	**320**	**240**	**160**	**80**			400	1,200
Cohort#4	Year 1				400	**320**	**240**	**160**	**80**		400	1,200
Cohort#5	Year 1					400	**320**	**240**	**160**	**80**	400	1,200
Program Year Savings Total		**400**	**720**	**960**	**1,120**	**1,200**	**-**	**-**	**-**	**-**		

Table 6-4 below provides the value of the benefits and the costs each year in Scenario 2. The benefits and costs are based on the lifetime savings and costs of each cohort in the year in which they first receive the report. For example, the Year 2 benefits represent the lifetime benefits of Cohort#2, which received their first and only reports in Program Year 2. The total column at the far right of the table provides the five-year totals for each category.

Table 6-4: Benefits and Costs Data for Scenario 2

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Scenario TRC Energy Savings (kWh)	1,200	1,200	1,200	1,200	1,200	**6,000**
NPV Benefits	$55.5	$52.2	$49.1	$46.2	$43.5	**$246.4**
NPV Costs	$27.0	$25.0	$23.1	$21.4	$19.7	**$116.1**
TRC Ratio	2.05	2.09	2.13	2.16	2.20	**2.12**

SCENARIO 3 (CR5B) | Customer Rotation; 5-Year Useful Life; TRC Based on 1-yr EUL

The third scenario, CR5B, is identical to CR5A in terms of the assumption of multiple cohort/customer rotation and a 5-yr useful life. The differentiating characteristic is the way we will attribute annual savings and calculate the TRC ratio each year. For CR5B, the savings that accrue in years after the HER is distributed will be accounted for as benefits in the program years in which those savings occur.

Table 6-5 below demonstrates the Scenario 3 incremental and lifetime savings associated with the customer rotation / 5-yr measure life conditions. Each year, a new cohort will receive the report, save

400 kWh in that first year, and then continue to accrue savings for four more years at a decay rate of 20% of the first year savings. However, with this method, the savings that occur after the participants stop receiving the report are credited as savings to the program year in which they occur rather than the specific cohort group.

The boxes drawn around each set of savings correspond to the annual savings of each program year. For example, the Cohort #1 Program Year 2 savings (320 kWh) are grouped with the Cohort #2 Program Year 1 savings (400 kWh) to yield the total of 720 kWh of savings for Program Year 2. Since our analysis is limited to 5 years, the savings that may be expected to accrue in program years 6 through 9 are not counted using the approach.

Table 6-5: Scenario 3 Incremental Annual and Lifetime Savings

		PY1	PY2	PY3	PY4	PY5	PY6	PY7	PY8	PY9	Report Year Savings	
Report Year #											Inc. Annual (kWh)	Lifetime (kWh)
Cohort#1	Year 1	400	**320**	**240**	**160**	**80**					400	1,200
Cohort#2	Year 1		400	**320**	**240**	**160**	**80**				400	1,200
Cohort#3	Year 1			400	**320**	**240**	**160**	**80**			400	1,200
Cohort#4	Year 1				400	**320**	**240**	**160**	**80**		400	1,200
Cohort#5	Year 1					400	**320**	**240**	**160**	**80**	400	1,200
Program Year Savings Total		**400**	**720**	**960**	**1120**	**1200**	-	-	-	-		

Table 6-6 below provides the value of the benefits and the costs each year in Scenario 3. The first two rows show the present value of the benefits and costs. In contrast to Scenario 2 where the annual benefits reflect the lifetime benefits of the cohort introduced to HER reports in that year, the benefits in Scenario 3 are based on the program year total savings incurred each year. The total column at the far right of the table provides the five-year totals for each category.

Table 6-6: Benefits and Costs Data for Scenario 3

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Scenario TRC Energy Savings (kWh)	400	720	960	1,120	1,200	**4,400**
NPV Benefits	$20.0	$33.9	$42.5	$46.6	$47.0	**$190.0**
NPV Costs	$27.0	$25.0	$23.1	$21.4	$19.7	**$116.1**
TRC Ratio	0.74	1.36	1.84	2.18	2.38	**1.64**

SCENARIO 4 (SC1) | Single Cohort / No Customer-Rotation; 1-Year Useful Life

The fourth scenario is similar to the first scenario in that it assumes that the HER measure has a one-year useful life, produces 400 kWh of savings in the first year, and costs $27 per participant. However, this scenario also assumes that the same participants will receive the HER each year, as opposed to the customer rotation technique which gives the reports to different cohorts each year. As a result of the same cohort receiving the HER each year of the five year timeframe, the SWE has assumed an annual incremental increase in savings as providing reports to the same cohort group continues to impact customer behavior. Specifically, the SWE has assumed that the 400 kWh of savings in the first year increases to 510 kWh in the second year, 526 kWh in the third year, 537 kWh in the fourth year, and 542 kWh in the fifth year. This assumed increase in savings over time is based on research findings summarized and reported by Cadmus which demonstrate the persistence and growth of savings for participants who continue to receive reports for several years. For example, Cadmus found that second year savings are 27% greater than first year savings[10]. The SWE used these reported findings to project the savings for years three through five.

Table 6-7 below demonstrates the Scenario 4 incremental and lifetime savings associated with the single cohort / 1-yr measure life conditions. As discussed earlier, the savings increase each year based on research findings reported by Cadmus from 400 kWh in the first year to 542 kWh in the fifth year. The measure life is assumed to be one year, so there is no persistence, and the incremental annual savings are equal to the lifetime savings. This scenario is similar to Scenario 1, except here the same cohort receives the measure each year and therefore savings increase each year.

Table 6-7: Scenario 4 Incremental Annual and Lifetime Savings

		PY1	PY2	PY3	PY4	PY5	Report Year Savings	
	Report Year #						Inc. Annual (kWh)	Lifetime (kWh)
Cohort #1	Year 1	400					400	400
	Year 2		510				510	510
	Year 3			526			526	526
	Year 4				537		537	537
	Year 5					542	542	542
Program Year Savings Total		**400**	**510**	**526**	**537**	**542**		

Table 6-8 below provides the value of the benefits and the costs each year in Scenario 4. The first two rows show the present value of the benefits and costs in the year in which they are accrued and incurred, respectively. The total column at the far right of the table provides the five-year totals for each category.

Table 6-8: Benefits and Costs Data for Scenario 4

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Scenario TRC Energy Savings (kWh)	400	510	526	537	542	**2,515**
NPV Benefits	$20.0	$24.0	$23.3	$22.4	$21.2	**$110.9**
NPV Costs	$27.0	$25.0	$23.1	$21.4	$19.7	**$116.1**
TRC Ratio	0.74	0.96	1.01	1.05	1.08	**0.95**

SCENARIO 5 (SC5) | Single Cohort / No Customer-Rotation; 5-Year Useful Life

For the fifth and final scenario, SC5, we assumed that the HER has a useful life of five years, consistent with Scenarios 2 and 3. The SWE once again assumed the HER produces 400 kWh of savings in the first year, and costs $27 per participant and that the savings attributable to the single cohort group increases to 510 kWh in the second year, 526 kWh in the third year, 537 kWh in the fourth year, and 542 kWh in

[10] Figure 1 of the Cadmus whitepaper found that second year savings are 93% of the savings in the last year of treatment, and that first year savings are 73% of the savings in the last year of treatment. The ratio of the second year to first year savings (93%/73%) shows that the year 2 savings are 27% greater than the year 1 savings.

the fifth year. However, as a direct result of the assumed 5-year useful life, the SWE also assumes that a portion of those savings would have occurred even if the reports stopped being delivered. The assumption of persistence means that for the purposes of calculating benefits in a given year, only savings that occurred in a given year due to that year's HER measures are considered. For example, if the reports were no longer delivered after the first year, the savings would decay from 400 kWh to 320 kWh due to the decay rate of 20% of the first year savings. However, the continued delivery of the reports yields 510 kWh of savings in the second year. The difference between the 510 kWh savings that occur with the HER measure being delivered in the second year and the 320 kWh of savings that would have occurred anyway is 190 kWh. This amount of savings is attributed to the HER measures delivered in the second year. The 190 kWh is composed of a combination of avoided decay and an increase in the incremental annual (IA) savings. The avoided decay is 80 kWh and the increase in incremental annual savings is 110 kWh.

Table 6-9 below demonstrates in detail the accrual of savings in Scenario 5. The shaded green cells represent savings attributable to the HER measures in the year in which the reports are distributed (incremental annual) and the shaded yellow cells represent the additional lifetime savings attributable to these HER measures in years after the reports stop going to the customers to account for the five year useful life assumed by the scenario. The shaded orange cells provide the breakout of each year's incremental annual savings (shaded green) into avoided decay and the increase in incremental annual savings, each of which occur as a result of continuing to deliver the reports to the same customers. The boxes drawn around each set of savings correspond to the total energy savings credited to each report year assuming the same cohort group.

Table 6-9: Scenario 5 Incremental Annual and Lifetime Savings

		PY1	PY2	PY3	PY4	PY5	PY6	PY7	PY8	PY9	Report Year Savings	
Report Year #											Inc. Annual (kWh)	Lifetime (kWh)
Total	Year 1	400	320	240	160	80					400	1,200
Avoided Decay	Year 2		80									
Increase in IA	Year 2		110									
Total	Year 2		190	152	114	76	38				190	570
Avoided Decay	Year 3			118								
Increase in IA	Year 3			16								
Total	Year 3			134	107	80	54	27			134	402
Avoided Decay	Year 4				145							
Increase in IA	Year 4				11							
Total	Year 4				156	125	93	62	31		156	467
Avoided Decay	Year 5					176						
Increase in IA	Year 5					5						
Total	Year 5					181	145	109	72	36	181	543
Program Year Savings Total (excluding persistence savings)		400	190	134	156	181						
Program Year Savings Total (including persistence savings)		400	510	526	537	542						

Table 6-10 below provides the value of the benefits and the costs each year in Scenario 5. The annual benefits, costs and TRC ratios are based on the lifetime savings and costs that result from each report year. For example, the NPV benefits in Year 2 represent the lifetime benefits that result from the cohort receiving the report a second reporting year, but exclude the lifetime benefits that were expected as a result of the distribution of reports in the initial report/program year. The total column at the far right of the table provides the five-year totals for each category.

Table 6-10: Benefits and Costs Data for Scenario 5

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Scenario TRC Energy Savings (kWh)	1,200	570	402	467	543	**3,182**
NPV Benefits	$55.5	$24.8	$16.4	$18.0	$19.7	**$134.4**
NPV Costs	$27.0	$25.0	$23.1	$21.4	$19.7	**$116.1**
TRC Ratio	2.05	0.99	0.71	0.84	1.00	**1.16**

6.2 COST-EFFECTIVENESS REVIEW

The SWE calculated example benefit/cost ratios of each of the five scenarios for each program year and a total across the five year timeframe of the analysis. Again, the TRC ratios provided within are presented to allow for comparison between scenarios, and readers are cautioned to not use the TRC results as indicators of actual HER program cost-effectiveness. Rather, these figures provide context regarding the directionality of cost-effectiveness when considering single vs. multiple cohort program delivery options and single year vs. multiple year useful life analysis. Table 6-11 below provides a summary of the benefit/cost ratio data for each of the five scenarios. For comparison purposes across program years, all benefits and costs have been present valued back to program year 1.

Table 6-11: Summary of TRC Calculations for each Scenario

TRC Ratios		PY1	PY2	PY3	PY4	PY5	Total
Scenario 1	Customer rotation / 1-yr EUL	0.7	0.8	0.8	0.8	0.8	0.8
Scenario 2*	Customer rotation / 5-yr EUL; TRC Based on 5-yr EUL	2.1	2.1	2.1	2.2	2.2	2.1
Scenario 3*	Customer rotation / 5-yr EUL; TRC Based on 1-yr EUL	0.7	1.4	1.8	2.2	2.4	1.6
Scenario 4	Single cohort / 1-yr EUL	0.7	1.0	1.0	1.1	1.1	1.0
Scenario 5	Single cohort / 5-yr EUL	2.1	1.0	0.7	0.8	1.0	1.2

*Recall that the HER measure life is 5 years in both Scenario 2 and 3 in terms of assuming that savings persist, but the difference between the scenarios is that Scenario 2 accounts for all lifetime savings in the program year in which the reports are distributed while Scenario 3 accounts for future year savings in the year in which they occur.

In Scenario 1, the savings are held at 400 kWh, each year at a cost of $27, so the only variables causing fluctuations in the TRC ratio are the discount rate and the assumed level of avoided costs. The TRC ratios in this scenario are stable at approximately 0.8 each year. Scenarios 2 and 3 yield the greatest TRC ratios among the five scenarios because of the assumed persistence of savings for five years and the use of multiple cohorts, or customer rotation. The delayed accounting of savings in Scenario 3 means that Scenario 2 looks more favorable and has more consistent TRC ratios over time, while Scenario 3 TRC ratios increase each year because savings are not accounted for in the benefit/cost calculations until the year in which the savings accrue.

Scenario 4 provides stronger TRC results than Scenario 1, because of the modest growth in savings associated with the single cohort approach as they continue to receive reports in subsequent program years and behavioral changes and reminders are reinforced. However, Scenario 4 effectively ignores the persistence issues identified in this study and other studies. The TRC ratios in Scenario 4 increase slightly from 0.8 to 1.1 across the five years. Last, the TRC ratios in Scenario 5 show a decline in the first three years. This is a function of the decay rate of 20%, which means that the lifetime savings in years two and three are much less than the first year after accounting for the savings that are expected to persist had the reports been terminated. However, the TRC ratios in the fourth and fifth years begin to rebound as the continued delivery of home energy reports would offset additional decay each year.

7 RECOMMENDATIONS

Based on the analysis conducted and the review presented herein, the SWE makes the following recommendations as related to Residential Behavioral Programs.

7.1 IMPLICATIONS FOR TECHNICAL REFERENCE MANUAL

The results of the SWE's HER persistence analysis for PPL and Duquesne produced different estimates of the annual decay rate following withdrawal of HER exposure. To a lesser extent, a different decay rate was observed between the PPL Legacy and Expansion cohorts. Based on these findings, the SWE believes it would be premature to stipulate a statewide decay rate for all residential HER programs offered as part of Act 129.[11]

7.2 IMPLICATIONS FOR COST-EFFECTIVENESS

The study results clearly indicate that a simple one-year useful life assumption for HER programs does not fully capture the lifetime savings produced by such programs for purposes of a TRC test. Although it is premature to stipulate a statewide decay rate and more analysis may be required to determine an appropriate measure life for home energy reports, this report discusses several scenarios for reporting the cost-effectiveness of HER programs assuming a multiple year useful life. The SWE believes that Scenario 2 (for multiple cohort program delivery) and Scenario 5 (for single cohort program delivery) represent the accounting methods for TRC testing most consistent with the prescribed methods used by other Act 129 energy efficiency programs with long-term useful lives, and accounts for what the empirical data shows regarding the persistence of energy savings.

7.3 RECOMMENDATIONS FOR FURTHER RESEARCH AND EVALUATION

The SWE believes additional research is needed in the following areas as related to HER programs:

- Examination of HER decay for PECO Energy Company and the FirstEnergy companies (Metropolitan Edison Company, Pennsylvania Electric Company, Pennsylvania Power Company and West Penn Power Company). The differences observed in the PPL and Duquesne results indicate that there may be significant differences in the decay rate across EDCs and HER implementations.
- Relationship between duration of exposure and decay rate. The homes in the PPL and Duquesne implementations examined in this study received HERS for a relatively brief period before the program was suspended. It may not be appropriate to extrapolate these decay rates to programs where participants have received HERs continuously for 4 or 5 years.
- Long-term effects of HER cessation. Both the PPL and Duquesne programs were restarted in PY6 so the SWE analysis was based on a relatively short time horizon (less than 24 months). The SWE used a linear model to extrapolate the observed decay rate and estimated what would happen beyond two years, but such predictions carry potentially significant uncertainty. The SWE recommends studying these long-term effects in more detail before implementing any policy changes about how HER compliance savings or TRC ratios are determined.

The SWE recommends each EDC include a plan to assess HER persistence in its Phase III energy efficiency and conservation (EE&C) and EM&V plans. The general framework of these studies should mirror the quasi-experimental design leveraged by the SWE in this analysis. After some period of

[11] It should be noted that the TRM does not deem the savings for these programs either.

exposure to HERs, EDCs should randomly select a subset of treatment group customers and stop mailing reports to them. The Persistence Study group should be large enough to detect statistically valid differences between the “continued treatment” and “withdrawn treatment” groups. A general recommendation is 20,000 homes, but EDC evaluation contractors have flexibility to customize the design given EDC-specific program sizes, strata of interest, or other research objectives. An alternative approach EDCs may wish to consider is rotation of treatment groups. In this model groups of customers are identified and only a subset of the groups receive energy reports for a given program year. In this scenario, the groups that are not exposed create a sample in which to study decay of energy impacts.