NAVIGANT

ComEd
Business Energy Analyzer Program
Impact Evaluation Report

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

Presented to
Commonwealth Edison Company

DRAFT

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1. Introduction

This report presents the results of the impact evaluation of ComEd's PY9 Business Energy Analyzer (BEA) Program. It presents a summary of the energy and demand impacts for the total program and broken out by relevant program structure details. The appendix presents the impact analysis methodology. PY9 covers June 1, 2016 through December 31, 2017.

2. Program Description

The ComEd BEA program is a free, opt-in pilot program designed for ComEd by Agentis Energy (Agentis) that enables ComEd business customers to leverage the energy usage data collected by their advanced metering infrastructure (AMI) and automated meter reading (AMR) meters to gain greater insight and control over their electricity use, improve their energy efficiency, and reduce their utility bills. BEA consists of a suite of self-serve tools that show participating customers how their current energy use compares to what it was in the previous year, as well as to that of other businesses of the same type as their own company. BEA also suggests possible energy efficiency projects to reduce usage and save money, and identifies ComEd Smart Ideas for Your Business® incentive programs customers may qualify for. Participating customers can use the BEA web platform at any time, and as frequently as they wish. To participate in the program, business customers only need to go to the BEA page on ComEd's website and provide their ComEd account ID, a valid email address, and the zip code for their business premise. No further actions are required.

Navigant received data for a total of 2,799 customers with billing data who participated in BEA. For its evaluation, Navigant included only the 2,666 customers whose enrollment dates fell within the PY6-PY9 period[1]. For the purposes of this analysis, Navigant divided participants in the BEA program into four waves corresponding to the program year in which they signed up. For instance, participants who enrolled within the PY6 timeframe are in Wave 1. Table 2-1 shows the breakdown of participants by program year (and corresponding wave notation), and Figure 2-1 shows the monthly enrollment history for all 2,799 BEA customers.

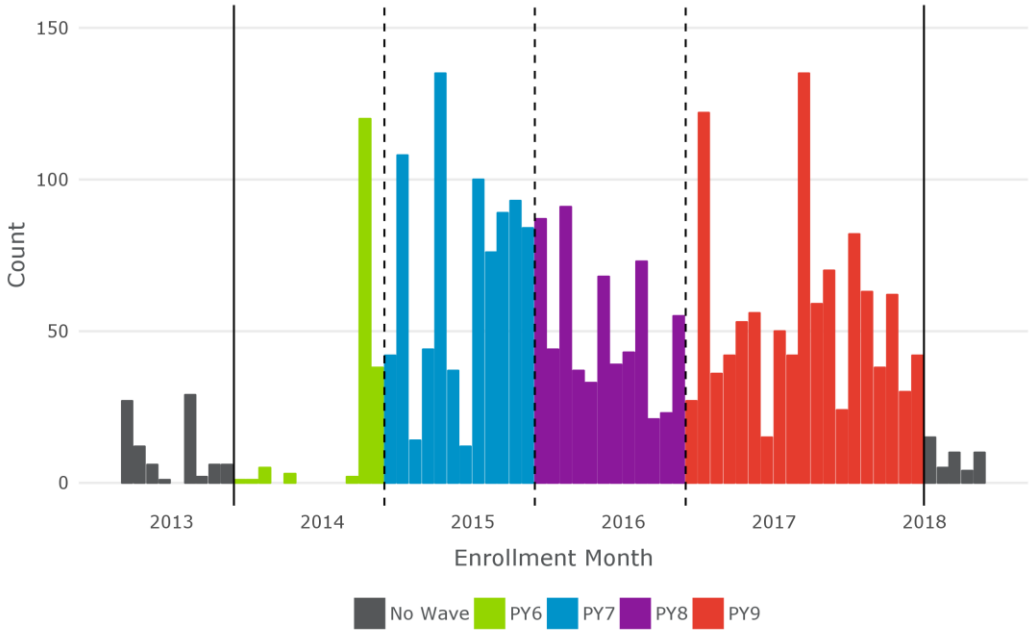
Table 2-1. Volumetric Findings Detail

Program Year and BEA Wave	Participant Count
PY6 (Wave 1)	170
PY7 (Wave 2)	834
PY8 (Wave 3)	614
PY9 (Wave 4)	1,048
Total	2,666

Source: Navigant analysis of Agentis BEA tracking data

[1] This period spans June 1, 2013 to December 31, 2017.

Figure 2-1. Enrollment History of Customers in BEA Program, by Month



* Navigant received data from customers with enroll dates as early as 2012 but restricted analysis to participants who initially logged onto BEA and linked their ComEd account information to the program within the PY6-PY9 timeframe.
Source: Navigant analysis of Agentis BEA tracking data

As seen in Figure 2-1, there is an uneven pattern of enrollment with a strong surge of customer sign-ups beginning several months after the initial roll-out on October 1, 2013 in late PY6. Enrollments peaked in early 2015 (late PY7), and steadily tapered off throughout PY8. PY9 saw additional surges and healthy enrollment throughout.

3. Program Savings

Table 3-1 summarizes the incremental energy savings the BEA program achieved in PY9. This program specifically focused on energy savings, and neither ComEd nor the evaluation estimated demand savings. In addition, the regression analysis used to estimate savings for this program estimates net savings and no further net-to-gross (NTG) adjustment is necessary.

Table 3-1. PY9 Total Annual Incremental Savings

Savings Category	Energy Savings (kWh)	Demand Savings (kW)	Peak Demand Savings (kW)
Ex Ante Gross Savings	53,000,000	N/A	N/A
Program Gross Realization Rate	518.7%	N/A	N/A
Verified Gross Savings	N/A	N/A	N/A
Program Net-to-Gross Ratio (NTGR)	N/A	N/A	N/A
Verified Net Savings	274,921,000	N/A	N/A

Source: ComEd data and Navigant analysis
* This type of analysis estimates net savings, no further NTG adjustment is necessary.
† This value is after the uplift adjustment. More details on the uplift adjustment are in Section 7.

Navigant estimated the per-participant per day savings at 237 kWh, which represents 2.76 percent savings. Agentis estimated the savings at 332 kWh/day. Comparing these two produces a realization rate of 72 percent. Agentis estimated 53,000 MWh of savings compared to the evaluation's 274,921 MWh, representing a 519 percent realization rate. There is not a clear driver of this huge difference in realization rate. Navigant is unclear of how Agentis calculated total savings from the per participant per day value.

4. Program Savings by Measure

The BEA program is a behavior program and does not track savings by measure. In PY9, the measure life for the program was one year. Detailed savings by wave are presented in Section 7.

5. Impact Analysis Findings and Recommendations

Navigant's analysis produced two key findings.

Finding 1. The BEA program achieved 292,407 MWh of net energy savings in PY9 for participants who enrolled from PY6 through PY9.[2] After adjusting for the savings created by other ComEd programs that the BEA participants participated in (our uplift analysis), the net savings is 274,921 MWh.

Finding 2. The BEA program per-participant savings were 237 kWh per day, which is 2.76 percent of average daily consumption.

Navigant's PY9 total program savings estimate (274,921 MWh) is more than 5 times larger than the ex ante savings value provided by Agentis (53,000 MWh). The reasons for this discrepancy are as yet unclear, as Navigant's average per-participant savings (237 kWh per day) is close to, but somewhat less than, Agentis's (331 kWh per day). Once we understand more about Agentis' calculation we may have a new finding and perhaps a recommendation.

[2] The savings estimate of 292,407 MWh is statistically significant at the 10% significance level in a 2-tailed test.

6. Appendix 1. Impact Analysis Methodology

For evaluating the impact of a behavior-based energy efficiency program, having a program that is designed as a randomized controlled trial (RCT) is considered optimal, since it results in estimates of program savings that are unbiased and robust. When a randomized design is not feasible or cost-effective, a quasi-experimental approach offers the best available option. Given the design of the BEA program, participants were intrinsically self-selected: BEA was marketed to all eligible ComEd customers, and any eligible customer could sign up and begin using the BEA tools at any time. Neither ComEd nor Agentis screened applicants or controlled the timing of either their enrollment or their use of the tools available on the BEA site. Thus, an RCT approach was not feasible.

For this reason, Navigant used a quasi-experimental approach to measure BEA program savings. The approach compared the energy consumption of program participants to that of a set of matched non-participants using regression analysis. This method, known as regression with pre-program matching (RPPM), is described in Ho, Imai, King, and Stuart.[3]

Matching Algorithm

The matching method relied on energy usage data obtained from the meters of program participants, as well as from a set of non-participating customers, to estimate program savings. The pool of non-participants from which the matches were drawn consisted of a large (N = 22,077) sample of non-participant ComEd business customers. For each BEA participant, Navigant compared the average daily energy consumption in each month during a participant's pre-enrollment year to that of all customers in the pool of potential matches over the same period. For each comparison, Navigant calculated the difference in average daily energy use in the given month, D_{PM} (**D**ifference between **P**articipant and potential **M**atch). The quality of the potential match was indicated by the Euclidean distance between their usage and that of the participant calculated over the matching period. Denoting the sum of squared D_{PM} over the matching period by SSD, the match quality was defined as $\sqrt{SSD}$. The non-participant whose energy usage minimized this distance during the participant's respective pre-enrollment year was chosen as the match for that participant. Matching was done with replacement.[4]

Data Used in Impact Analysis

In preparation for the impact analysis, Navigant combined and cleaned the data provided by the implementer. The dataset contained daily interval energy usage data for 2,799 treatment customers and 22,077 potential matched controls. Data covering each enrollment wave's time in the program, along with corresponding usage data from the year prior to each participant's enrollment month for matching purposes, was used in the regression analysis as described in the next subsection. Navigant rolled the one-day interval data up to calendar months for each customer for matching.

[3] Daniel Ho, Kosuke Imai, Gary King, Elizabeth A. Stuart, "Matching as Nonparametric Preprocessing for Reducing Model Dependence in Parametric Causal Inference," *Political Analysis* (2007) 15: 199-236. Downloadable at: http://gking.harvard.edu/files/matchp.pdf. See also Guido W. Imbens and Donald B. Rubin, *Causal Inference for Statistics, Social and Biomedical Sciences: An Introduction,* Cambridge University Press 2015; Paul J. Gertler et al., *Impact Evaluation in Practice,* International Bank for Reconstruction and Development 2011; and Joshua D. Angrist and Jörn-Steffen Pischke, *Mostly Harmless Econometrics: An Empiricist's Companion,* Princeton University Press 2009.

[4] Matching with replacement implies that the same matched control customer may be matched to more than one participant, and thus that there may be fewer (unique) matched controls than participants.

Prior to matching, Navigant removed customers and data points from the participant dataset based on the following criteria:

- Participants with an enrollment date outside of the PY6-PY9 timeframe
- Customer months with fewer than 28 days of billing data
- Observations with negative usage
- Outlier observations, defined as monthly observations with average daily usage plus or minus fifty times the median[5]
- Participants with less than 9 months of pre-enrollment data (for matching purposes)

A detailed account of the customers removed are included in Section 7 (Appendix 2).

Statistical Model Used in the Impact Evaluation

Navigant estimated program impacts using daily energy usage data and a lagged dependent variable (LDV) model.[6] Separate runs of the LDV model were used to obtain results for reporting total program savings by enrollment wave for PY9.

Once the matches were selected, Navigant applied the regression model in Equation 1 to the post-enrollment usage values of participants and their matched controls[7] from the date of each participant's program entry (as early as June 2013) through the end of PY9 (December 2017):

Equation 1. Lagged-Dependent Variable (LDV) Regression Model

$$DailykWh_{kt} = \beta_1 Treatment_k + \sum_j \beta_{2j} Month_{jt} + \sum_j \beta_{3j} Month_{jt} ADUkWh\_lag_{kt} + \varepsilon_{kt}$$

where:

$DailykWh_{kt}$	is daily kWh used by customer k on day t of the post-enrollment period
$Treatment_k$	denotes whether customer k is a participant (=1) or a matched control (=0)
$ADUkWh\_lag_{kt}$	is customer k's mean daily energy use (in kWh) in the same month of the pre-program year as that of the current observation
$Month_j$	comprises a set of binary variables indicating which month the current observation (indexed by t) falls into
ε_{kt}	is a cluster-robust disturbance term for customer k

In the above model, β_1, the regression coefficient on the $Treatment_k$ variable, estimates the average difference in *daily* energy use between the treatment and control groups in the post-enrollment period. To

[5] Median average daily energy usage for BEA customers was 1,591 kWh per day.
[6] The lagged usage terms interacted with month dummies serve a purpose in the LDV model that is conceptually similar to that of the customer fixed effect in a fixed-effects model – namely, controlling for innate inter-customer heterogeneity in energy consumption. The advantage of the LDV model over the customer fixed effects model is that in the LDV case the customer-specific control can vary seasonally, whereas in the fixed effects model it cannot.
[7] Navigant assumed that program exposure began for each participant on their start date, when they logged onto the BEA site and registered their account.

obtain the total program energy savings over the period of evaluation, Navigant multiplied this mean daily program effect by the total number of *post-enrollment customer-days* for all BEA program participants.[8]

Accounting for Uplift in other Energy Efficiency Programs

If participation rates in other EE programs were the same for BEA treatment and control groups before and after enrollment, there would be no need to make an uplift adjustment, since this would indicate that, on balance, the BEA pilot program neither increased nor decreased participation in other EE programs. However, if the BEA pilot program affected participation rates in other EE programs, the savings across all programs would be lower (or higher) than indicated by the simple summation of the savings identified in the evaluations of BEA and the other EE programs. For instance, if the BEA pilot program caused BEA participants to increase their participation in another EE program relative to that of the matched control group, the resulting increase in savings from that uplift may be allocated to either the BEA pilot program or the other EE program, but not to both programs simultaneously. Note that in cases when the BEA pilot program led to a decrease in participation in other EE programs there was no question of double-counting and thus no adjustment to the savings total was made.

Data permitting, Navigant used a difference-in-difference (DID) statistic to estimate the induced uplift in other EE programs. To calculate the DID statistic, the change in the participation rate in another EE program between PY9 and the pre-program year for the control group was subtracted from the same change for the treatment group. For instance, if the rate of participation in an EE program during PY9 was 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 BEA pilot program was two percent for the treatment group and one percent for the control group, then the rate of uplift due to the BEA pilot program was one percent, as reflected in Equation 2.

Equation 2. DID Statistic Calculation

$$\begin{aligned}&(PY9\ treatment\ group\ participation - prePY\ treatment\ group\ participation)\\&\quad - (PY9\ control\ group\ participation - prePY\ control\ group\ participation)\\&\quad = (5\% - 2\%) - (3\% - 1\%) = 1\%\end{aligned}$$

The DID statistic generates an unbiased estimate of the uplift in participation in the other EE programs that was induced by BEA when the baseline average rate of participation is the same for the treatment and control groups, or when they differ due only to differences between the two groups in time-invariant factors, such as the residence's square footage.

An alternative to the DID statistic is the post-only difference (POD) statistic, which is the simple difference in participation rates between the treatment and control groups during PY6 to PY9. The POD statistic generates an unbiased estimate of uplift when the baseline average rate of participation in the EE program is the same for the treatment and control groups. Navigant used this alternative statistic in cases where the EE program did not exist for the entire pre-program year.

Navigant examined the uplift associated with five EE programs: Standard, Custom, Data Center Efficiency, Retro-commissioning (RCx), and C&I New Construction.[9]

[8] Thus, the aggregate savings estimate is pro-rated based on the date each customer first logged onto the BEA website and registered.
[9] See Section 7 for a complete description of the uplift adjustment calculations.

7. Appendix 2. Impact Analysis Detail

Matching Results

In the RPPM approach, the development of a matched comparison group is a useful pre-processing step in the regression analysis to assure that the distributions of the covariates (i.e., the explanatory variables on which the outcome variable, energy consumption, depends) are the same in the treatment group and the comparison group. This minimizes the risk of selection bias.

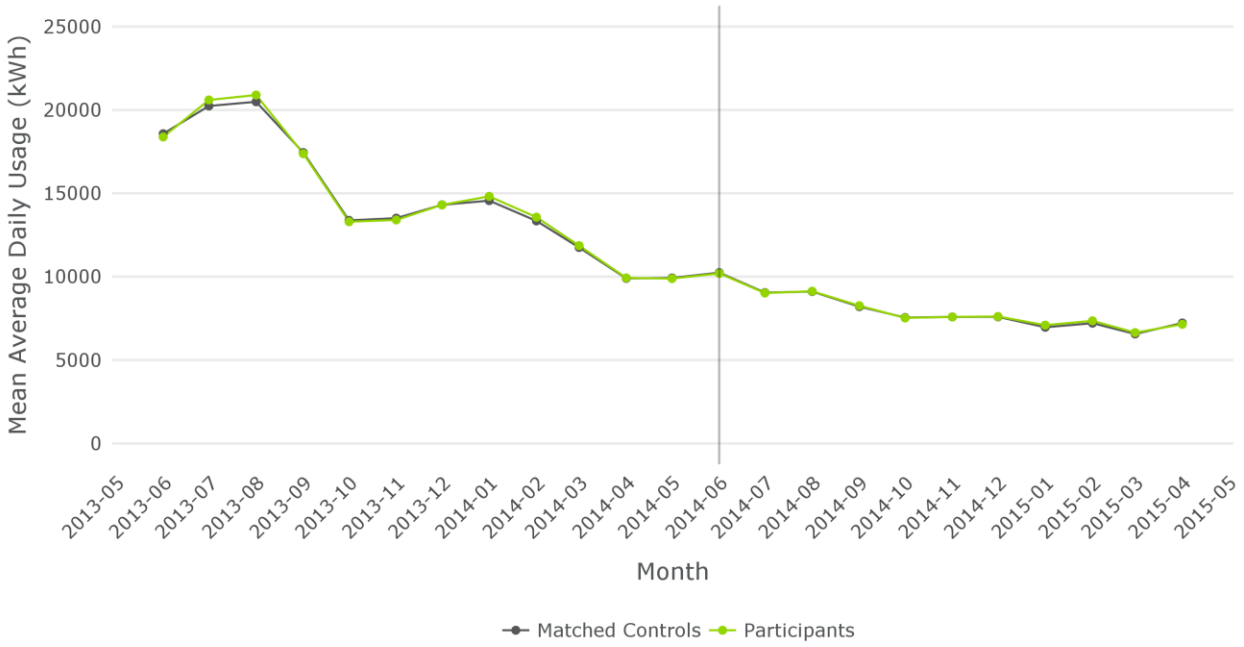
Figure 7-1 through Figure 7-4 show the quality of the matching results for each enrollment wave by incorporating the 12 months of usage data prior to each participant's enrollment date as well as their matched control's usage during that same period. These figures thus display the mean of customers' pre-program average daily usage values at the monthly level. Since the BEA program had rolling enrollment throughout a single program year, all possible pre-program monthly usage values are shown. Participants could enroll as late as the last month of the program year to qualify for that program year's wave, hence each figure presents more than 12 months of pre-period usage. In each of these figures, the start of the program year associated with the wave is indicated by a vertical line.

Figure 7-1. Mean Energy Use of Wave 1 (PY6), Participants and Matches, Rolling

* N = 141 participants

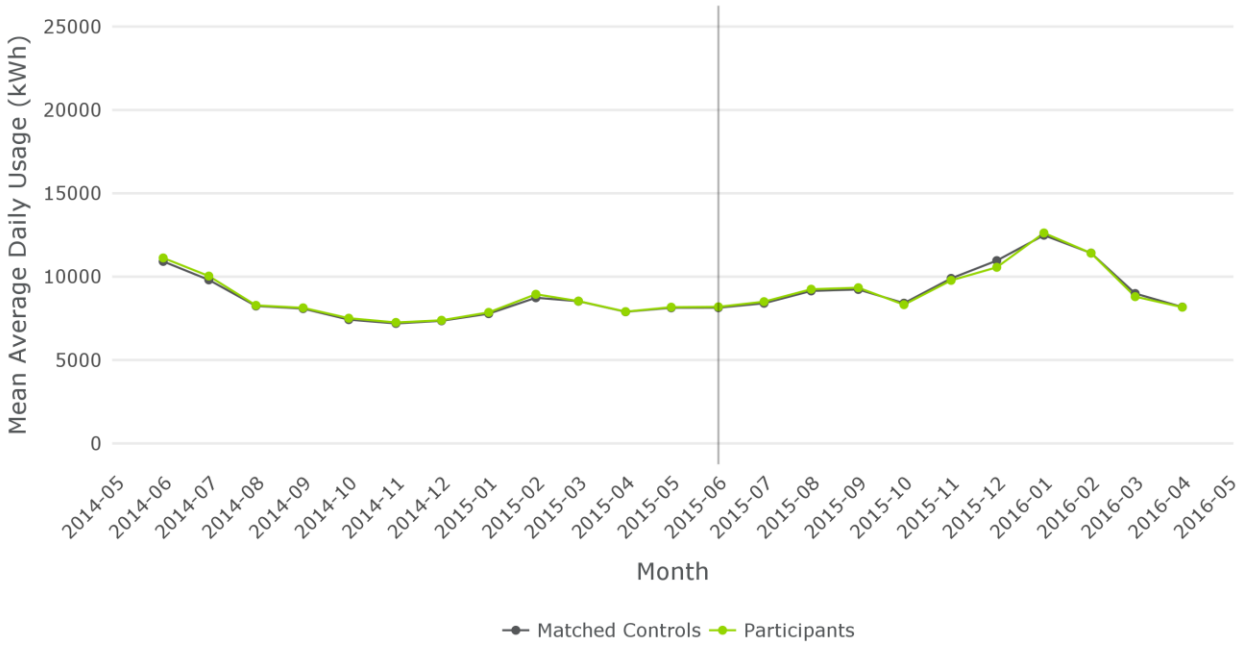
Source: Navigant Analysis of ComEd usage data

Figure 7-2. Mean Energy Use of Wave 2 (PY7), Participants and Matches, Rolling



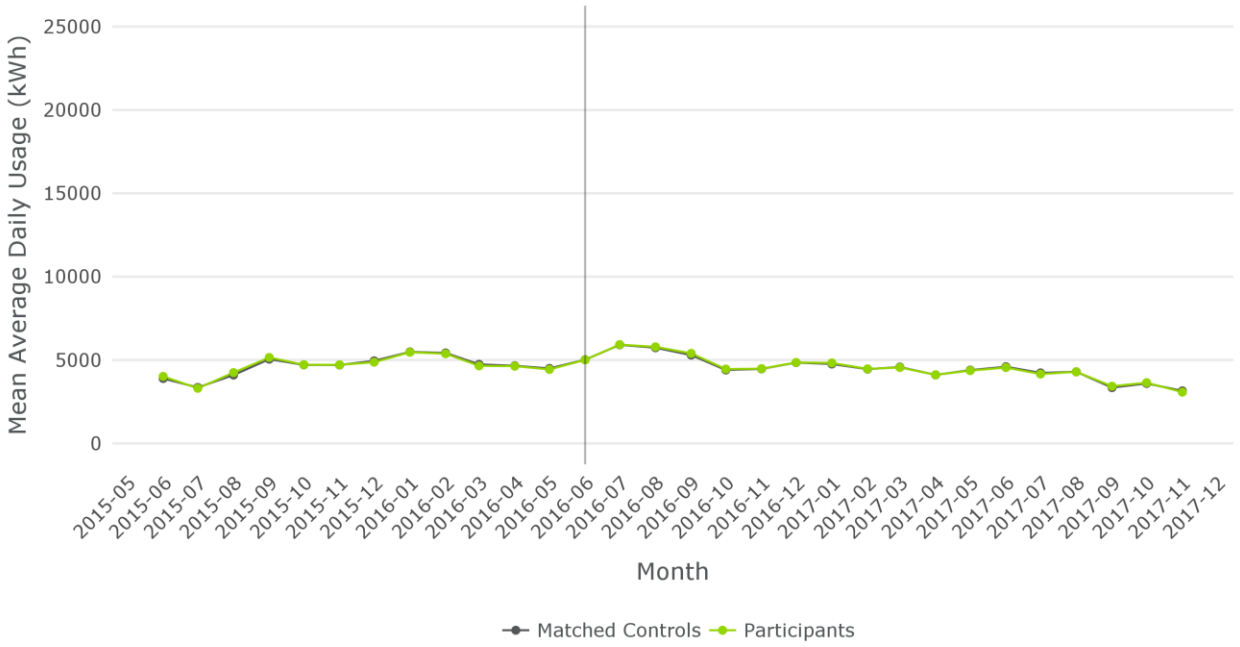
* N = 709 participants
Source: Navigant Analysis of ComEd usage data

Figure 7-3. Mean Energy Use of Wave 3 (PY8), Participants and Matches, Rolling



* N = 527 participants
Source: Navigant Analysis of ComEd usage data

Figure 7-4. Mean Energy Use of Wave 4 (PY9), Participants and Matches, Rolling

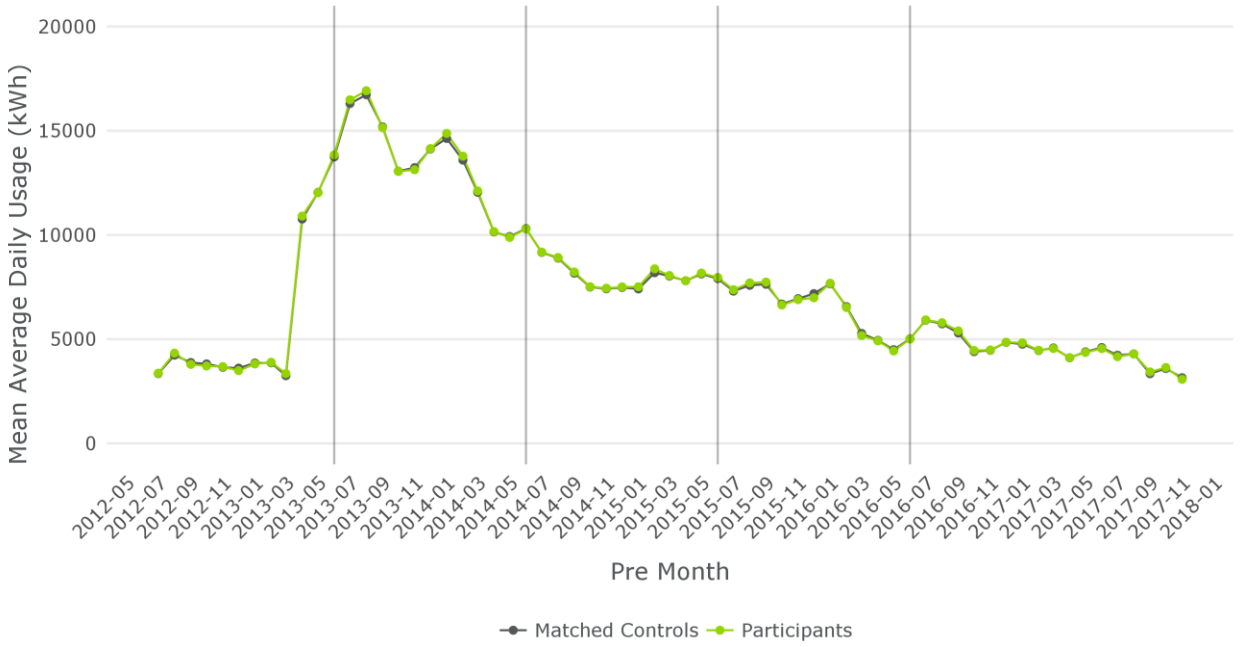


* N = 787 participants
Source: Navigant Analysis of ComEd usage data

Note that while the match quality was relatively good for all months of Wave 4 (PY9 enrollees), usage is generally lower than for the earlier waves. This lower usage for participants is a likely reason for more precise matches, as the earliest waves had both poorer match quality and higher average usage. Additionally, Wave 1 had the smallest sample size of participants in the regression data (141) while all other waves had at least three times as many participants, with Wave 4's participant pool the largest (787) due to the length of PY9.

In general, pre-program average daily use values for participants tend to decrease over time and with each consecutive wave. Figure 7-5 shows an aggregated comparison of the previous figures for all four waves, allowing for the overlap of pre-program months between waves and making apparent the downward trend of pre-program energy usage over time.

Figure 7-5. Mean Energy Use of All Waves, Participants and Matches, Rolling

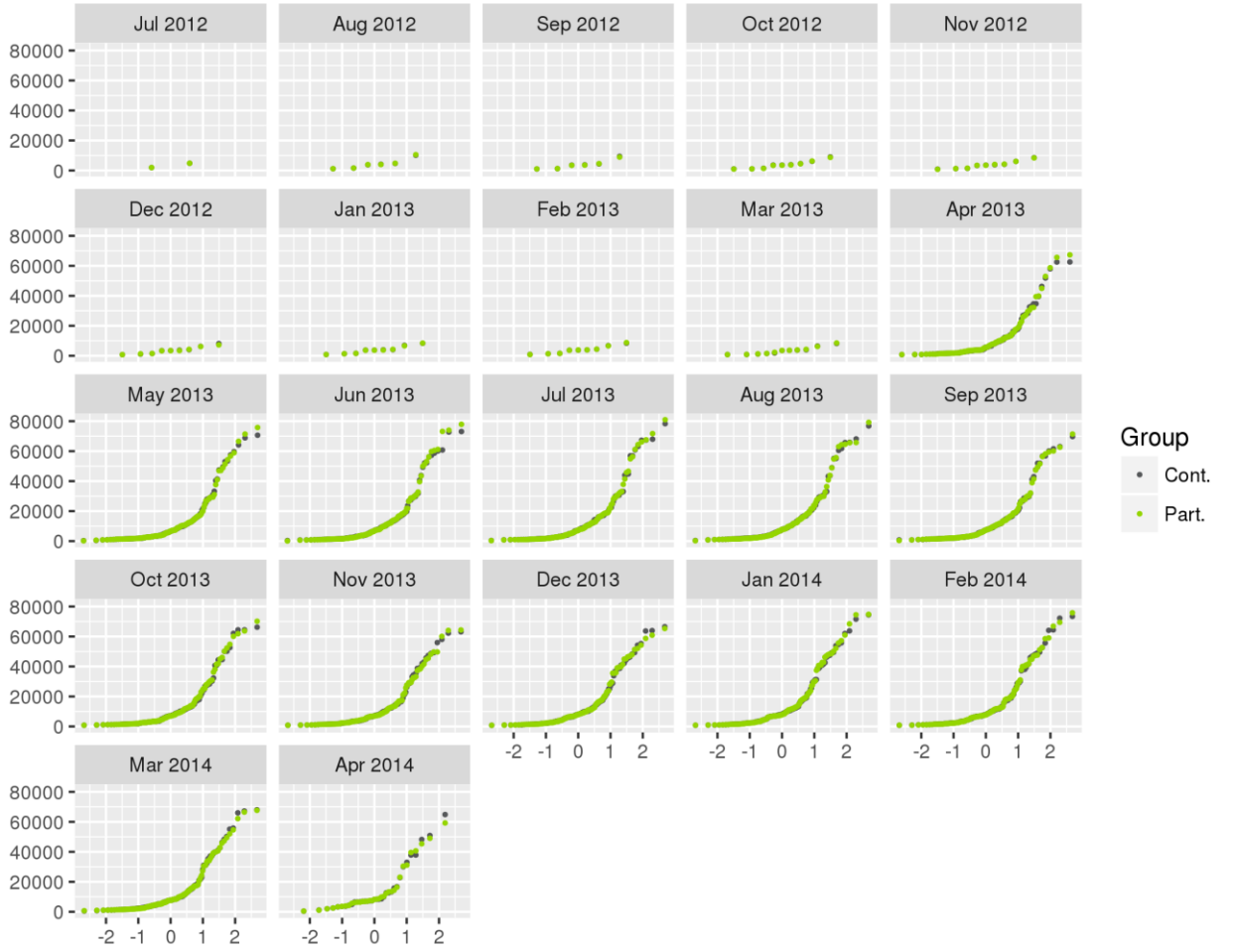


* N = 2,164 participants
Source: Navigant Analysis of ComEd usage data

To further assess match quality prior to performing the regression analysis, Navigant used quantile-quantile (QQ) plots to compare the distributions of energy usage of the participant and matched control groups in each enrollment wave across the full range of usage values in each month of the pre-enrollment year, rather than just at the means. QQ plots can be particularly useful when monthly usage is skewed or asymmetrically distributed, as is the case here. Figure 7-6 through Figure 7-9 show the monthly QQ plots for the participant and matched control customers for Wave 1, Wave 2, Wave 3, and Wave 4, respectively.[10]

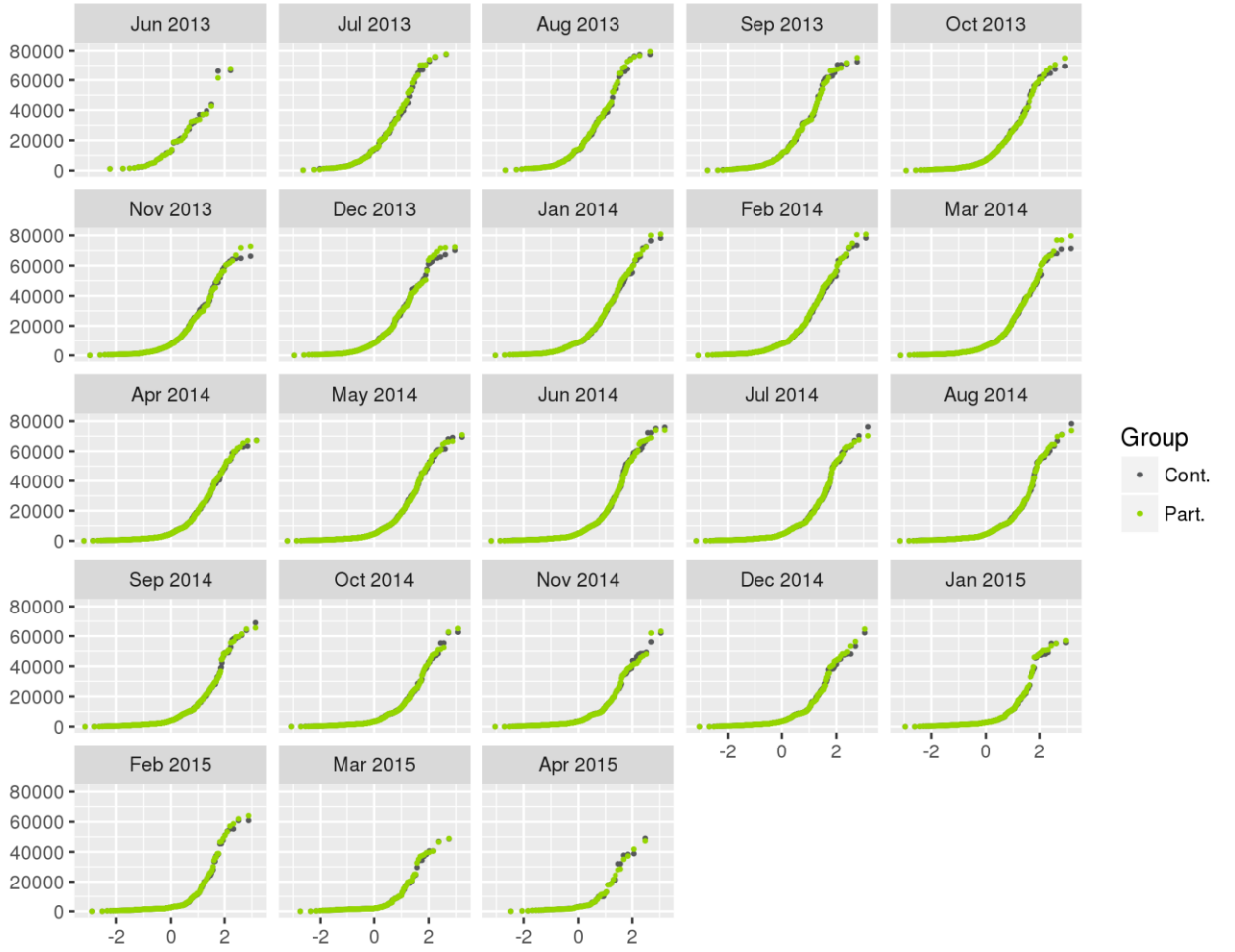
[10] Each QQ plot contains one pane per month of the relevant possible pre-enrollment year. The green and gray curves consist of the percentile values of usage per day in kWh (measured on the vertical axis) plotted against the number of standard deviations from the mean (horizontal axis). As in Figure 7-1 through Figure 7-4, match quality is indicated by the size of the vertical gap between the treatment and control groups – but in this case by percentile rather than just at the means. A perfect match at every percentile would cause the green and gray curves to perfectly coincide.

Figure 7-6. Plots of Participant and Control Group Usage Quantiles by Month – Wave 1



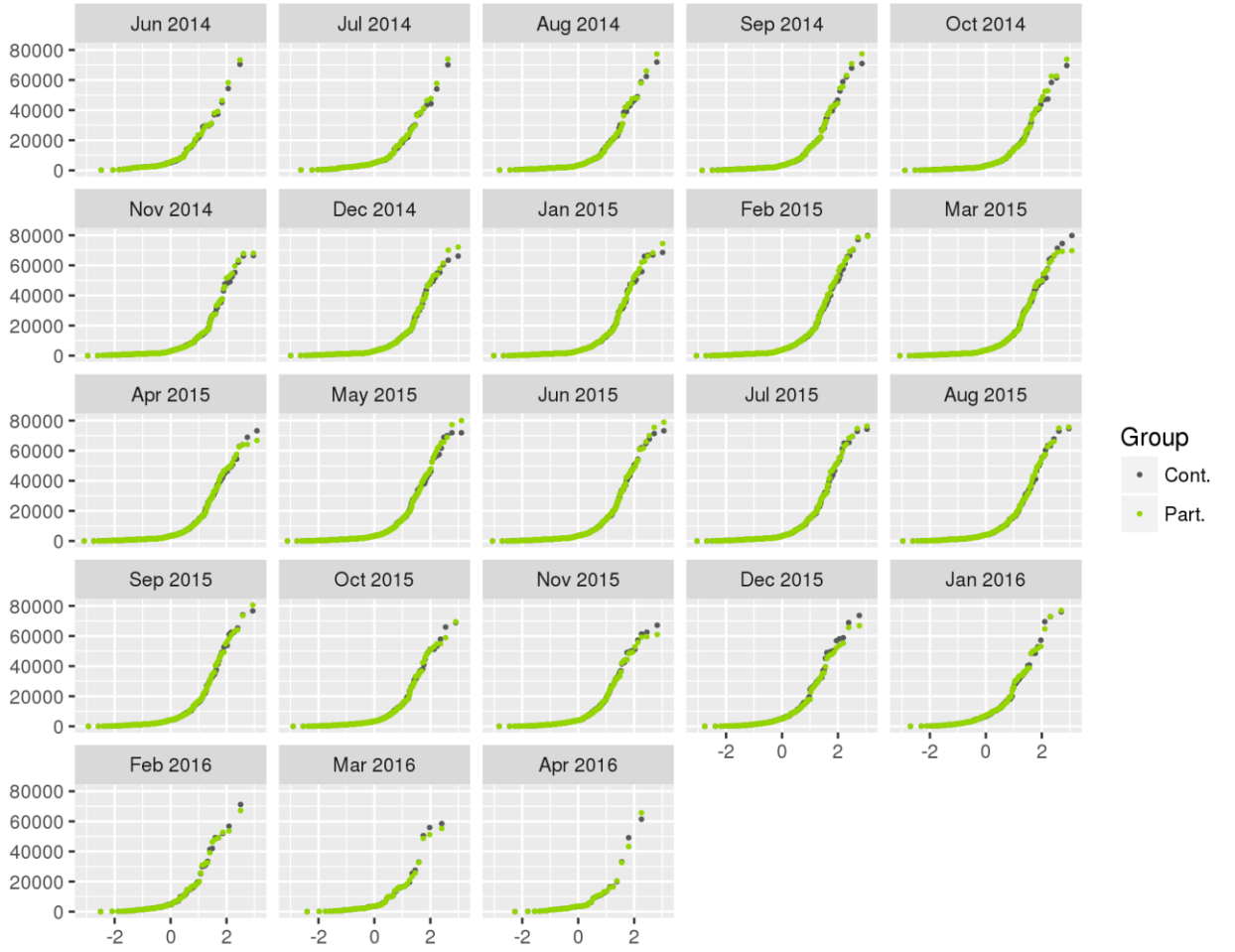
Source: Navigant Analysis of billing data

Figure 7-7. Plots of Participant and Control Group Usage Quantiles by Month – Wave 2



Source: Navigant Analysis of billing data

Figure 7-8. Plots of Participant and Control Group Usage Quantiles by Month – Wave 3



Source: Navigant Analysis of billing data

Figure 7-9. Plots of Participant and Control Group Usage Quantiles by Month – Wave 4

Source: Navigant Analysis of billing data

Earlier pre-enrollment months in each wave tend to have fewer data points compared to later pre-enrollment months due to only representing the earliest enrollees in that specific wave. A similar story applies to the later pre-enrollment months as well, as they only show data points for the latest enrollees.

Impact Analysis

Table 7-1 summarizes the key results by participation wave for the BEA program. In this table, the first row shows the number of BEA participants in each wave, while the values in the second and third rows indicate the number of participant and matched control customers with sufficient data for inclusion in the regression analysis. The weighted average per customer savings estimate was 2.76% (237 kWh per day) for all waves for PY9.

Table 7-1. Total PY9 BEA Pilot Program Results by Enrollment Wave

Type of Statistic	Wave 1	Wave 2	Wave 3	Wave 4	All Waves Combined*
Number of Participants in Wave (raw data)	170	834	614	1,048	2,666
Number of Participants used in Analysis†	141	709	527	787	2,164
Number of Unique Controls†	126	614	491	717	1,817
Percentage Net Savings	4.11%	3.58%	1.14%	1.94%	2.76%
Standard Error	*3.49%*	*2.77%*	*1.38%*	*1.42%*	*1.43%*
Average Savings Per Customer Per Day, kWh	500	371	92	94	237
Standard Error	*425*	*287*	*112*	*69*	*122*
Total Savings MWh‡	49,225	178,993	32,826	29,269	292,407
Standard Error	*41,787*	*138,744*	*39,773*	*21,350*	*151,081*
Uplift Adjustment§	-	-	-	-	17,486
Total Savings MWh, after Adjusting for Uplift	-	-	-	-	274,921

* Because this column represents a separate aggregate regression model, unique control customer counts and all savings estimates are not the sum (or average) of the individual waves.
† Participant count reductions reflect the results of data cleaning prior to the regression analysis. Control counts reflect the number of unique controls; matching was done with replacement, so some controls were matched to multiple participants.
‡ Total savings are prorated to account for participants' actual enrollment dates, as well as wave end dates.
§ Uplift consists of net 12,766 MWh of PY9 uplift and 4,720 MWh of legacy uplift.
Source: Navigant analysis of ComEd data

Detailed Data Cleaning

Table 7-2 below details the number of customers removed at specific steps in the data cleaning process. Out of the initial pool of 2,799 participants, a total of 2,164 (77.3%) were usable for the regression modeling after data cleaning. Of the possible 22,077 controls, 1,817 (8.2%) unique customers were used in the regression modeling as a result of Navigant's data screening and matching methodology.

Table 7-2. Customer Removed by Data Cleaning Step

Data Cleaning Step	Number of Participants Removed	Participants Remaining	Number of Controls Removed	Controls Remaining
Raw Data	-	2,799	-	22,077
Enrollment date outside PY6-PY9	133	2,666	-	22,077
Observations outside scope of analysis	1	2,665	16	22,061
Bill months with less than 28 days of data	3	2,662	15	22,046
Negative observations	0	2,662	16	22,030
Outlier observations	44	2,618	45	21,985
Participants with 9 months of pre-use data	454	2,164	-	21,985
Matched data (final data set)	-	**2,164**	20,168	**1,817**

Source: Navigant analysis

Savings Due to Participation Uplift in Other EE Programs

Table 7-3 shows the calculation of program savings due to participation uplift in other EE programs (Standard, Custom, Data Center Efficiency, RCx, and C&I New Construction) in PY9 across all the BEA waves. Table 7-4 shows the measure life and legacy uplift for the same EE programs.

Table 7-3. Uplift by Program across all BEA Waves

	Program				
	Custom	Data Center Efficiency	Standard	RCx	C&I New Construction
Median program savings (annual kWh per participant)	576,984	213,492	291,871	843,460	809,032
Number of treatment customers	2,164	2,164	2,164	2,164	2,164
Treatment rate of participation, PY9	3%	1%	2%	1%	3%
Change in rate of treatment participation from pre-program year	-2%	0%	2%	1%	-1%
Number of control customer	1,817	1,817	1,817	1,817	1,817
Control rate of participation, PY9	2%	0%	0%	0%	2%
Change in rate of control participation from pre-program year	-1%	0%	-1%	-1%	-1%
DID statistic	0%	1%	1%	1%	1%
Participant uplift	3	6	8	4	5
Statistically significant at the 90% confidence level?	No	No	Yes	No	No
Savings attributable to other programs (kWh)	1,730,952	1,280,954	2,334,966	3,373,840	4,045,162

Source: Navigant analysis

Table 7-4. Legacy Uplift

	Program				
	Custom	Data Center Efficiency	Standard	RCx	C&I New Construction
Measure Life	13	15	12	5	17
Legacy Uplift (kWh)	292,483	268,958	2,697,312	1,383,245	78,304

Source: Navigant analysis

8. Appendix 3. TRC Detail

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

Table 8-1. TRC Detail

End Use Type	Research Category	Units	Quantity	Effective Useful Life	Ex Ante Gross Savings (kWh)	Ex Ante Gross Peak Demand Reduction (kW)	Verified Gross Savings (kWh)	Verified Gross Peak Demand Reduction (kW)
Behavioral	NA	Business	2,666	1	NA	NA	274,921,000	NA

Source: ComEd tracking data and Navigant team analysis.