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ComEd Data Centers Efficiency Program Impact Evaluation Report

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

Presented to
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FINAL

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ComEd Data Centers Efficiency Program Impact Evaluation Report

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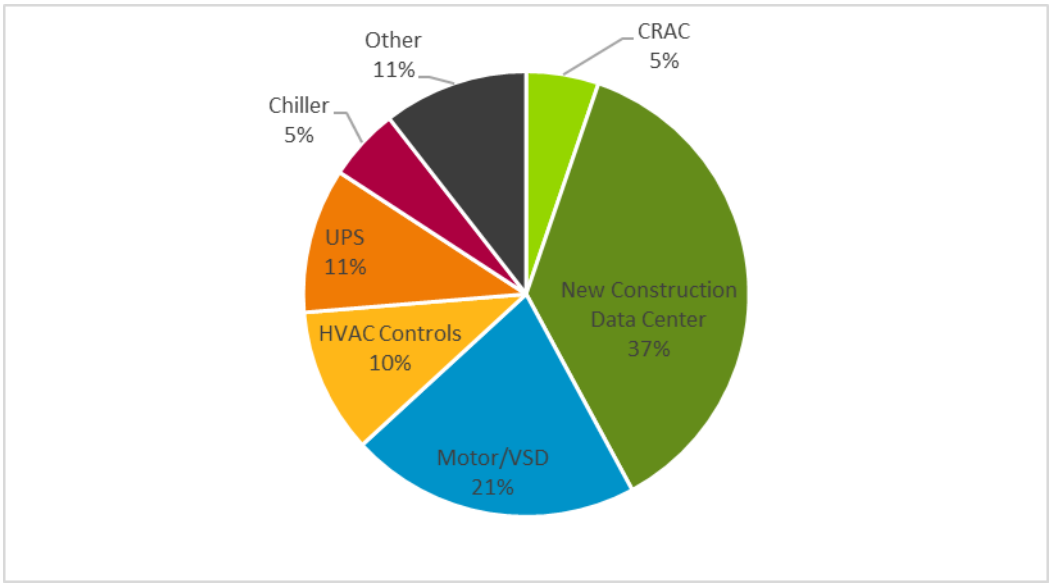
1. Introduction

This report presents the results of the impact evaluation of ComEd's PY9 Data Centers Efficiency Program. It presents a summary of the energy and demand impacts for the total program and broken out by strata. The appendix presents the impact analysis methodology. PY9 covers June 1, 2016 through December 31, 2017.

2. Program Description

The program had 19 participants in PY9 and consisted of mostly HVAC measures, as shown in Figure 2-1. Most sites contain multiple measures that improve the efficiency of the data center including both HVAC measures and IT improvements. The HVAC measures ranged from installing chilled water temperature reset, installing VFDs, installing new chillers and installing a water side economizer. All the projects in the population were mapped to an end use based on the project description. Figure 2-1 provides the distribution of projects by end-use.

Figure 2-1. Distribution of Projects by End Use



Source: Evaluation Analysis

3. Program Savings

Table 3-1 summarizes the incremental energy and demand savings the Data Centers Efficiency Program achieved in PY9.

Table 3-1. PY9 Total Annual Incremental Savings

Savings Category	Energy Savings (kWh)	Demand Savings (kW)	Peak Demand Savings (kW)
Ex Ante Gross Savings	46,300,381	N/A	5,123
Program Gross Realization Rate	102%	N/A	87%
Verified Gross Savings	47,111,833	N/A	4,471
Program Net-to-Gross Ratio (NTGR)	0.64	N/A	0.64
Verified Net Savings	30,151,573	N/A	2,861

Source: ComEd tracking data and Navigant team analysis.

4. Program Savings by Measure

The Data Centers Efficiency program does not claim savings by measure and therefore cannot be presented by measure. Savings for the Data Centers Incentive Program are based on a sample and reported at a strata level and do not have measure-level savings. More information about strata- and site-level savings are provided in Appendix 2.

5. Impact Analysis Findings and Recommendations

5.1 Impact Parameter Estimates

The evaluation team performed engineering calculations to derive evaluated gross energy and demand savings based on data collected during the on-site audit or the desk review process. The savings are site specific and therefore require site specific calculators and algorithms in conjunction with data collected from the site. The evaluation team used the data obtained during the M&V efforts to verify measure installation, determine installed measure characteristics, assess operating hours and relevant modes of operation, identify the characteristics of the replaced equipment, support the selection of baseline conditions and perform ex post savings calculations. Each site evaluation used peak kW savings calculation methodology that was consistent with PJM peak summer demand requirements[1] for each project to calculate the peak kW reduction. The lifetime energy and demand savings are estimated by multiplying the verified savings by the effective useful life for each measure.

The EM&V team conducted research to validate the non-deemed parameters for this custom program that were not specified in the Illinois Technical Reference Manual (IL TRM). The results are shown in Table 5-1.

[1] PJM defines the coincident summer peak period as 1:00-5:00 PM Central Prevailing Time on non-holiday weekdays, during the months of June through August.

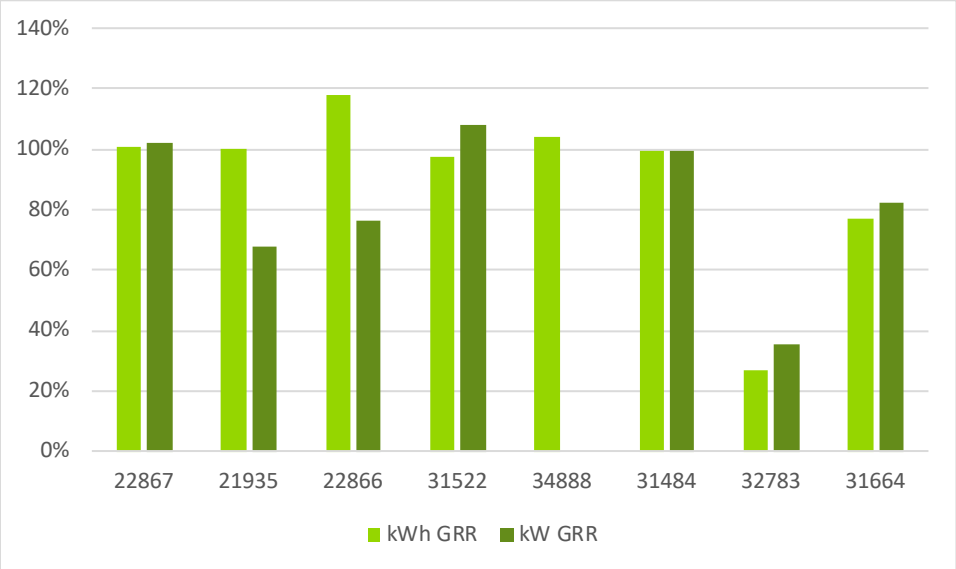
Table 5-1. Verified Gross Savings Parameters

Gross Savings Input Parameters	Value	Deemed * or Evaluated?
Gross Energy Savings Realization Rate	102%	Evaluated
Gross Peak Demand Savings Realization Rate	87%	Evaluated
NTG Ratio	0.64	Deemed*
Net Energy Savings (kWh)	30,151,573	Evaluated
Net Peak Demand Savings (kW)	2,861	Evaluated

** Source: ComEd_NTG_History_and_PY8_Recommendation_2016-02-26_Final_EMV_Recommendations.xlsx, which is to be found on the IL SAG web site here: http://ilsag.info/net-to-gross-framework.html*

Figure 5-1 below shows a comparison of the energy and demand realization rates for every site. The PY9 energy-savings realization rate results ranged from 0.27 to 1.18, which resulted in a program level realization rate of 1.02. The demand-savings realization rates for the eight projects in the gross sample ranged from 0.0 to 1.08. The realization rate was at or above 1.0 for five of the eight projects examined. For six out of the eight projects, the realization rates were within 10 percent of one for the energy savings; whereas, only three of the eight were within 10 percent of one for the demand savings.

Figure 5-1. Energy and Demand Realization Rates



5.2 Other Impact Findings and Recommendations

The evaluation team has developed several recommendations based on findings from the PY9 evaluation, as follows:

Finding 1: The evaluation team identified two sites where a regression analysis was performed by the implementation team on binned energy consumption data. While this will generally result in better correlations with higher R^2 values, bins may contain widely varying numbers of

data points. This can cause certain data points to carry a higher weight than other points in the regression which might bias the results.

Recommendation 1: The implementation team's regression analysis should not be performed on binned data. If the correlation on the non-binned data does not show a strong correlation, then using simple average is more appropriate.

Finding 2: The evaluation found that the implementation team calculated demand savings as average demand rather than peak demand for multiple projects.

Recommendation 2: Peak demand kW for weather-dependent measures should be calculated using peak hours defined as 1PM to 5PM, non-holiday weekdays from June through August.

Finding 3: The phased new construction data center projects should be treated consistently, regardless of the IT loading of the project. The ability to true up savings in subsequent phases should not be grounds for inconsistency in calculated savings.

Recommendation 3: Phased new construction data center projects should account for all components of the data center in their calculations, including cooling systems, IT load, and UPS. This will ensure consistency across evaluation periods, and ensure the accuracy of claimed savings in that program year.

Finding 4: Most data center projects will not see fans with significant variability in their speed. For these projects, the relationship between power and fan speed can be approximated to be linear. However, when projects with variable fan speeds of more than a few percent are identified, savings should be calculated accordingly, as the fan power to speed relationship can no longer be considered linear, and will see an exponential relationship.

Recommendation 4: Variability in fan speeds should be considered when calculating savings for fan power. When fan speeds vary by more than a few percent, the relationship between fan power and speed is found to be exponential, requiring a more sophisticated approach, like a binned approach, to calculate savings.

Finding 5: The evaluation found two projects in the PY9 sample where ex-ante metered data which was not consistent with typical operation for the facility. In one facility (31164), the customer reported that the post-installation period of operation was not representative of the typical operation because of issues with the Building Automation System (BAS). In another facility, the metering data showed the CRAH fans running at nearly a consistent speed and power until the last five days of operation (31484). The customer reported that this may have been a result of floor panel adjustments.

Recommendation 5: The evaluation team realizes that it is not always possible to foresee changes in system operation, but whenever possible, the site contact should always be interviewed prior to metering to determine whether current operation will be representative of typical operation. Additionally, when discrepancies are identified in metered data, like seen in 31484, it is recommended that a thorough explanation be noted, so that a grounded determination can be made on how to handle the discrepancies.

Finding 6: The evaluation found one project where the implementation team took a simple ratio of IT loads for normalizing savings. This is not an ideal method of normalizing IT-load savings, as this simple ratio may over- or-underestimate the effects of incremental changes in IT load.

Recommendation 6: The implementation team should consider the actual effect of IT loads on mechanical requirements when normalizing savings. Using PUE as the dependent variable will make normalizing for changes in IT load more straightforward. The evaluation team recognizes that PUE may vary with changing IT loads, so care must be taken to account of incremental changes in PUE.

6. APPENDIX 1. IMPACT ANALYSIS METHODOLOGY

6.1 Sampling

6.1.1 *Profile of Population*

The table below presents the three sampling strata used in the evaluation of the Data Centers Efficiency program. This was based on a total of 19 tracking records. Table 6-1 presents the number of records by stratum, along with the claimed ex-ante gross MWh and kW.

Table 6-1. PY9 Program Participation by Sampling Strata

Sampling Strata	Ex Ante kWh Impact Claimed	Ex Ante kW Impact Claimed	Tracking Records	Incentive Paid to Applicant
1	16,274,747	1,809	1	1,255,476
2	19,129,513	2,626	2	1,339,066
3	10,896,121	687	16	754,719
PY9 Total	46,300,381	5,123	19	3,349,261

Source: Evaluation Team analysis

6.1.2 *Gross Impact (M&V) Sample*

Consistent with the evaluation plan, the evaluation team used a stratified random sampling approach to select the gross impact sample of eight projects. The evaluation team sorted projects based upon the level of ex-ante kWh savings and placed the projects in three strata.

Table 6-2 provides a profile of the gross impact M&V sample for the Data Centers Efficiency program in comparison with the program population. Shown below is the resulting sample that was drawn that consists of eight projects. These projects make up approximately forty million kWh of the ex-ante impact claim, which represents 87 percent of the ex-ante impact claim for the program population. Also shown are the ex-ante based kWh sample weights for each of the three strata.

Table 6-2. PY8 Gross Impact Sample by Strata

Population Summary				Completed Interviews		
Sampling Strata	Number of Tracking Records (N)	Ex-ante kWh Impact Claimed	kWh Weights	Number of Tracking Records (n)	Ex-ante kWh	Sampled % of Population kWh
1	1	16,274,747	0.35	1	16,274,747	100%
2	2	19,129,513	0.41	2	19,129,513	100%
3	16	10,896,121	0.24	5	4,758,812	44%
PY9 Total	19	46,300,381	-	8	40,163,072	87%

Source: Evaluation Team analysis

6.1.3 Roll-up of Savings

There are two basic statistical methods for combining individual gross realization rates from the sample projects into an estimate of verified gross kWh savings for the population when stratified random sampling is used. These two methods are referred to as "separate" and "combined" ratio estimation.[2] In the case of a separate ratio estimator, a separate gross kWh savings realization rate is calculated for each stratum and then combined. In the case of a combined ratio estimator, evaluation completes a single gross kWh savings-realization rate calculation without first calculating separate gross realization rates by stratum.

The evaluation team used the separate ratio estimation technique to estimate verified gross impacts for the Data Centers Efficiency program. The separate ratio estimation technique follows the steps outlined in the California Evaluation Framework[3], which identifies best practices in program evaluation. The evaluation team matched these steps to the stratified random sampling method that they used to create the sample for the program. The evaluation team used the standard error to estimate the error bound around the estimate of verified gross impacts.

7. Appendix 2. Savings by Strata

The Data Centers Efficiency program sample includes 8 sites, across three strata as shown in Table 7-1. Most of the savings are due to three sites which make up the top two strata. These sites account for approximately 90% of the ex post energy savings and approximately 93% of the ex post demand savings. Each site's savings can be broken down into various high efficiency data center measure, such as high efficiency chillers, HVAC controls, economizers, CRAH VFDs, installing new split systems and high efficiency UPS. All the sites measures are HVAC related with the exception being high efficiency UPS.

Table 7-1. PY9 Energy Savings by Strata

Sample Strata	Sample Size	Ex Ante Gross Savings (kWh)	Verified Gross Realization Rate	Verified Gross Savings (kWh)	NTGR *	Verified Net Savings (kWh)	Technical Measure Life	Persistence	Effective Useful Life (EUL)†
1	1	16,274,747	101%	16,369,760	0.64	10,476,646	15	N/A	N/A
2	2	19,129,513	109%	20,790,041	0.64	13,305,626	15	N/A	N/A
3	5	10,896,121	91%	9,952,032	0.64	6,369,300	15	N/A	N/A
Total		46,300,381	102%	47,111,833	0.64	30,151,573	15	N/A	N/A

Source: ComEd tracking data and Navigant team analysis.
* A deemed value. Source: ComEd_NTG_History_and_PY9_Recommendations_2016-02-26_Final.xlsx, which is to be found on the IL SAG web site here: http://ilsag.info/net-to-gross-framework.html.
† EUL is a combination of technical measure life and persistence.

[2] A full discussion and comparison of separate vs. combined ratio estimation can be found in Sampling Techniques, Cochran, 1977, pp. 164-169.
[3] Tec Market Works, "The California Evaluation Framework," Prepared for the California Energy Commission, June 2004. Available at http://www.calmac.org

Table 7-2. PY9 Peak Demand Savings by Strata

Sample Strata	Sample Size	Ex-Ante Gross Demand Reduction (kW)	Verified Gross Realization Rate	Verified Gross Demand Reduction (kW)	NTGR*	Verified Net Demand Reduction (kW)
1	1	1,809	102%	1,851	0.64	1,185
2	2	2,626	72%	1,884	0.64	1,206
3	5	687	107%	736	0.64	471
Total		5,123	87%	4,471	0.64	2,861

Source: ComEd tracking data and Navigant team analysis.
* A deemed value. Source: ComEd_NTG_History_and_PY9_Recommendations_2016-02-26_Final.xlsx, which is to be found on the IL SAG web site here: http://ilsag.info/net-to-gross-framework.html.

8. Appendix 3. Impact Analysis Detail

The Data Centers Efficiency program sample includes 8 sites, across three strata as shown in Table 8-1. Most of the savings is due to projects 22867, 21935 and 22866; which account for approximately 90% of the ex post energy savings and approximately 93% of the ex post demand savings. These sites savings can be broken down into various high efficiency data center measure, such as high efficiency chillers, HVAC controls, economizers, CRAH VFDs, installing new split systems and high efficiency UPS. All the sites measures are HVAC related with the exception being high efficiency UPS.

Table 8-1. PY9 Energy Savings by Site

Sampled Application ID	Sample Strata	Ex Ante Gross Savings (kWh)	Verified Gross Realization Rate	Verified Gross Savings (kWh)	NTGR *	Verified Net Savings (kWh)
22867	1	16,274,747	101%	16,369,760	0.64	10,476,646
21935	2	9,856,716	100%	9,856,613	0.64	6,308,232
22866	2	9,272,797	118%	10,933,428	0.64	6,997,394
31522	3	2,433,757	98%	2,380,717	0.64	1,523,659
34888	3	915,905	104%	954,327	0.64	610,769
31484	3	613,250	100%	610,410	0.64	390,662
32783	3	421,691	27%	113,981	0.64	72,948
31664	3	374,209	77%	287,052	0.64	183,713
Total		40,163,072	103%	41,506,288	0.64	26,564,024

Source: ComEd tracking data and Navigant team analysis.
* A deemed value. Source: ComEd_NTG_History_and_PY9_Recommendations_2016-02-26_Final.xlsx, which is to be found on the IL SAG web site here: http://ilsag.info/net-to-gross-framework.html.

Table 8-2. PY9 Peak Demand Savings by Site

Sampled Application ID	Sample Strata	Ex-Ante Gross Demand Reduction (kW)	Verified Gross Realization Rate	Verified Gross Demand Reduction (kW)	NTGR*	Verified Net Demand Reduction (kW)
22867	1	1,809	102%	1,851	0.64	1,184.640
21935	2	1,383	67%	933	0.64	596.928
22866	2	1,244	76%	951	0.64	608.640
31522	3	151	108%	164	0.64	104.704
34888	3	105	0%	0	0.64	0.000
31484	3	70	100%	70	0.64	44.608
32783	3	45	35%	16	0.64	10.176
31664	3	43	82%	35	0.64	22.464
Total		4,849	83%	4,019	0.64	2,572.160

Source: ComEd tracking data and Navigant team analysis.
* A deemed value. Source: ComEd_NTG_History_and_PY9_Recommendations_2016-02-26_Final.xlsx, which is to be found on the IL SAG web site here: http://ilsag.info/net-to-gross-framework.html.
† Based on evaluation research findings.

The evaluation team has provided ComEd with site-specific M&V reports for each verified project. These site-specific impact evaluation reports summarize the ex-ante savings in the Final Application submitted, as well as the ex-post M&V plan, data collected at the site and all the calculations and parameters used to estimate savings. Table 8-1 summarizes the results for each project. Although the overall project realization rate is close to 100%, the evaluation team uncovered some issues in five of the eight projects. This could have resulted in large discrepancies in realization rates if they were not offset by other large discrepancies that swung the other way. Some key observations from these site-specific evaluation results are discussed below for each project which saw large differences in savings.

- Project #21935: The ex post demand kW savings are much lower because the ex ante savings used the average annual PUE instead of limiting the analysis to summertime afternoon hours. As noted above, the average annual PUE of 1.307 used in the ex ante calculation is much lower than the 1.354 PUE calculated for hours between 1 PM and 5 PM for the June through August period.
- Project #22866: The primary cause of the increase in energy savings and decrease in demand savings is that the ex post analysis used a multivariable regression analysis to estimate hourly PUE. Plotting PUE as a function of critical IT load kW shows a slight reduction in PUE as IT load increases. This is expected as the systems become more efficient when operating closer to design conditions. In addition, the ex post analysis considers the average PUE for June through August daytime WBT between the hours of 1 PM and 5 PM.
- Project #34888: The ex post demand savings was reduced to zero because all the claimed savings are expected to occur during unoccupied periods, which would typically fall outside of the PJM peak demand hours. Therefore, no peak demand savings were considered in the ex post calculations.
- Project #32783: The ex post savings are significantly lower than ex ante savings because of the treatment of savings from the previous phase. The savings at each phase should be trued up at the project level and not at individual measure level. The ex ante approach for this project was to consider only CRAH savings for the first phase and only UPS savings for the second phase. The ex post demand savings realization rate is higher than the energy realization rate because of a

cell-reference error in the ex ante calculation. The Phase 1 demand savings were inadvertently used instead of the Phase 2 demand savings.

- Project #31664: The ex post calculations assumed that all the CRAC units that ran pre-retrofit would be running post-retrofit. Unit 15 did not run during the post-retrofit verification period so the ex ante analysis essentially claimed savings for turning the unit off. There is no evidence that this would be due to installing the ECM plug fans in the unit. The energy and demand savings were also reduced by using a bin analysis on post-case fan speeds instead of using a simple average.

9. APPENDIX 4. TOTAL RESOURCE COST SUMMARY

Total Resource Cost (TRC) related data for the eight projects in the Data Centers Efficiency Program sample can be found in Table 9-1.

Table 9-1. TRC Table. Total Resource Cost Savings Summary

Application ID	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)
22867	Data Center	Each	1	15	16,274,747	1,809	16,369,760	1,851
21935	Data Center	Each	1	15	9,856,716	1,383	9,856,613	933
22866	Data Center	Each	1	15	9,272,797	1,244	10,933,428	951
31522	Economization	Each	1	15	2,433,757	3	2,380,717	164
34888	LAN Closet Renovation	Each	1	15	915,905	105	954,327	-
31484	New Data Center	Each	1	15	613,250	70	610,410	70
32783	New Data Center	Each	1	15	421,691	45	113,981	16
31664	EC Fan Retrofit	Each	1	10	374,209	43	287,052	35