ComEd Voltage Optimization Program Impact Evaluation Report

Energy Efficiency / Demand Response Plan:
Program Year 2018 (CY2018)
(1/1/2018-12/31/2018)

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1. Introduction

This report presents the results of the impact evaluation of ComEd's CY2018 Voltage Optimization (VO) Program. It presents a summary of the energy and demand impacts for the total program and broken out by relevant substation details. The appendix presents the impact analysis methodology. CY2018 covers January 1, 2018 through December 31, 2018.

2. Program Description

The VO Program comprises ComEd's plan to install hardware and software systems on a significant fraction of its electric power distribution grid to achieve voltage and reactive power optimization (volt-var optimization, or VVO) over the 2018-2025 time frame. VVO is a smart grid technology that uses distributed sensors, two-way communications infrastructure, remote controls on substation transformer load-tap changers and line capacitor banks, and integrating/optimizing software to flatten voltage profiles and lower average voltage levels on an electric power distribution grid. ComEd is working with an automation-optimization hardware and software vendor[1] to implement the VO program on selected parts of its distribution grid over the 2018-2025 period.

Unlike energy efficiency programs that achieve savings by providing financial incentives to encourage customers to adopt energy-efficient equipment or behavioral suggestions to encourage them to adopt no-cost energy-saving behaviors, the VO Program involves no direct customer engagement. Instead, savings is achieved by operating the voltage and reactive power controls on VO-enabled feeders and substations in a manner designed to maintain the voltages delivered to affected customers in the lower part of the allowable voltage range.[2]

The program installed and commissioned VO systems on a total of 163 feeders at 38 substations in CY2018, as shown in the following table.[3]

Table 2-1. CY2018 Volumetric Findings Detail

Participation	Count
VO-Enabled Substations	38
VO-Enabled Feeders	162

Source: ComEd tracking data and Navigant team analysis.

3. Program Savings Detail

Table 3-1 summarizes the incremental energy savings the VO Program achieved in CY2018. This evaluation did not assess gas savings. The evaluation methodology produces an estimate of net savings directly and so no net-to-gross adjustment is needed. The program did not claim and the evaluation did not examine gas savings.

[1] Open Systems International (OSI) of Medina, Minnesota.
[2] The bulk of the energy savings that occurs is thus expected to occur on the customer side of the meter.
[3] VO did not go live on many of these feeders until the very end of 2018. ComEd also worked on installing VO on other substations and feeders during CY2018. Table 2-1 shows only those on which installation, commissioning and system testing were completed by December 31, 2018.

Table 3-1. CY2018 Total Annual Incremental Electric Savings

Savings Category	Energy Savings (kWh)	Demand Savings (kW)	Summer Peak Demand Savings (kW)
Electricity			
Ex Ante Gross Savings	99,381,000	-	-
Program Gross Realization Rate	0.39	NA	NA
Verified Gross Savings	38,581,268	4,404	60
Program Net-to-Gross Ratio (NTG)	NA	NA	NA
Verified Net Savings	38,581,268	4,404	60
Converted from Gas*			
Ex Ante Gross Savings	NA	NA	NA
Program Gross Realization Rate	NA	NA	NA
Verified Gross Savings	NA	NA	NA
Program Net-to-Gross Ratio (NTG)	NA	NA	NA
Verified Net Savings	NA	NA	NA
Total Electric Plus Gas			
Ex Ante Gross Savings	99,381,000	-	-
Program Gross Realization Rate	0.39	NA	NA
Verified Gross Savings	38,581,268	4,404	60
Program Net-to-Gross Ratio (NTG)	NA	NA	NA
Verified Net Savings	38,581,268	4,404	60

* Gas savings converted to kWh by multiplying therms * 29.31 (which is based on 100,000 Btu/therm and 3,412 Btu/kWh).
Note: The coincident Summer Peak period is defined as 1:00-5:00 PM Central Prevailing Time on non-holiday weekdays, June through August.
Source: ComEd tracking data and Navigant team analysis.

4. Cumulative Persisting Annual Savings

The total ex ante gross savings for the VO Program and the cumulative persisting annual savings (CPAS) for the measures installed in CY2018 are shown in the following tables and figure. The total CPAS across all measures is 38,581,268 kWh. This evaluation did not assess gas savings.

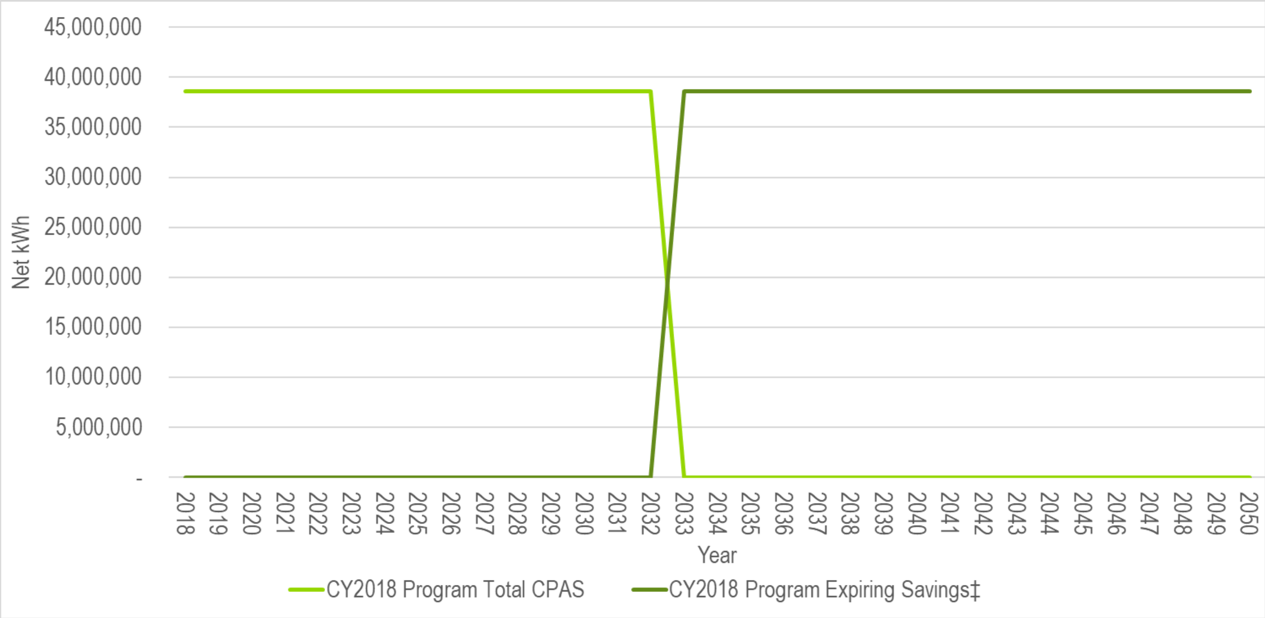
Table 4-1. Cumulative Persisting Annual Savings (CPAS) – Electric

End Use Type	Research Category	EUL	CY2018 Verified Gross Savings	NTG*	Lifetime Net Savings†	Verified Net kWh Savings 2018	2019	2020	2021	2022	2023	2024	2025	2026
All	VO	15.0	38,581,268	1.00	578,719,020	38,581,268	38,581,268	38,581,268	38,581,268	38,581,268	38,581,268	38,581,268	38,581,268	38,581,268
CY2018 Program Total Electric CPAS			**38,581,268**		**578,719,020**	**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**
CY2018 Program Expiring Electric Savings‡							**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

End Use Type	Research Category	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
All	VO	38,581,268	38,581,268	38,581,268	38,581,268	38,581,268	38,581,268						
CY2018 Program Total Electric CPAS		**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**	**-**	**-**	**-**	**-**	**-**	**-**
CY2018 Program Expiring Electric Savings‡		**-**	**-**	**-**	**-**	**-**	**-**	**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**	**38,581,268**

Note: The green highlighted cell shows program total first year electric savings.
* The VO Program does not have a NTG ratio assigned to it, but the methodology Navigant used to measure its energy savings produces a net savings estimate, which is the equivalent of assigning it a NTG value of 1.0.
† Lifetime savings are the sum of CPAS savings through the EUL.
‡ Expiring savings are equal to CPAS Yn-1 - CPAS Yn + Expiring Savings Yn-1.
Source: Navigant analysis

Figure 4-1. Cumulative Persisting Annual Savings



‡ Expiring savings are equal to CPAS Yn-1 - CPAS Yn + Expiring Savings Yn-1.
Source: Navigant analysis

5. Program Savings by Measure

The evaluation analyzed savings for the Voltage Optimization Program at the feeder and substation levels and does not have measure-level savings. For more information about substation-level savings see Appendix 2.

6. Impact Analysis Findings and Recommendations

6.1 Impact Parameter Estimates

The Voltage Optimization Program does not have relevant impact parameters.

6.2 Other Impact Findings and Recommendations

The evaluation team has developed several recommendations based on findings from the CY2018 evaluation, as follows:

Finding 1: Navigant's verified CY2018 energy savings for the VO program is 38,581 MWh, or approximately 39 percent of ComEd's ex ante energy savings estimate of 99,381 MWh.
Finding 2: Navigant's verified average voltage reduction from VO in CY2018 is 2.56 percent, or roughly 85 percent of ComEd's expected VO voltage reduction of 3 percent.[4]

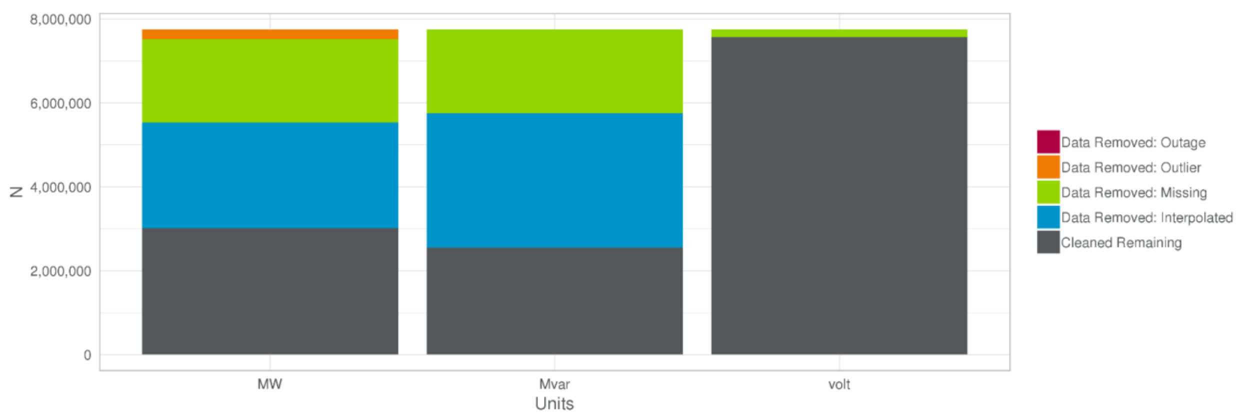
[4] ComEd VO team, personal communication.

Finding 3: Navigant's verified average CVR factor[5] for the CY2018 VO feeders is 0.53, or about two-thirds of ComEd's expected CVR factor value of 0.8.[6]

Finding 4: Navigant also examined the impacts of the feeder conditioning steps undertaken on many of the CY2018 VO feeders prior to VO installation.[7] Since the energy impacts from feeder conditioning were not statistically significant, they are not included in the above findings. They are discussed in the appendices.

Finding 5: Data Quality: Navigant relied on two types of feeder-level time-series data for its impact evaluation: 30-minute interval readings on real power (MW) and reactive power (Mvar) obtained from each VO-enabled substation's SCADA system[8], and averaged customer AMI data for voltage.[9] The voltage data was, by and large, quite clean. However, we removed large amounts of the SCADA data during data cleaning prior to the analysis. In aggregate, approximately 61 percent of the available time-series observations for MW, and 67 percent for Mvar, were removed. The vast majority of these deletions were due to missing or interpolated values. Less than 3 percent of the voltage data was removed during data cleaning. (See Figure 6-1.)

Figure 6-1. Aggregate Data Cleaning Results



Source: ComEd tracking data and Navigant team analysis.

Finding 6: SCADA data interpolation: Navigant encountered many cases where the SCADA system did not record real and reactive power values on all VO-enabled feeders at 30-minute intervals as expected. Instead, for many feeders fewer than 10 readings per day were recorded for extended periods, with interpolated values inserted in the remaining intervals.[10] Besides dramatically reducing the quantity of usable data available for analysis (with 30-minute intervals 48 readings per day are expected), this likely also understated the actual range of values experienced each day for these feeders, including the daily peaks. This affected both the accuracy and the precision of the savings estimates.

Recommendation 1: Ensure that the SCADA systems at all VO substations record actual readings every 30 minutes for every VO-enabled feeder.

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[5] CVR factor is defined as the ratio of the percentage energy reduction to the percentage voltage reduction from VO.
[6] ComEd VO team, ComEd Proposed CVR_MV_Protocol_v2_2018.pptx, slide 3.
[7] Feeder conditioning may include adding LTC controls, capacitor banks, and voltage regulators, as well as load balancing, phase balancing, and reconductoring.
[8] SCADA stands for Supervisory Control and Data Acquisition, and represents the primary means by which data are collected and stored on distribution substation and feeder status and performance at regular intervals.
[9] Feeder-level load-weighted averages of interval voltage readings from customer AMI meters at 30-minute intervals were provided by ComEd.
[10] When this occurs, runs of adjacent values lie along a straight line between pairs of vertices, which represent actual reads.

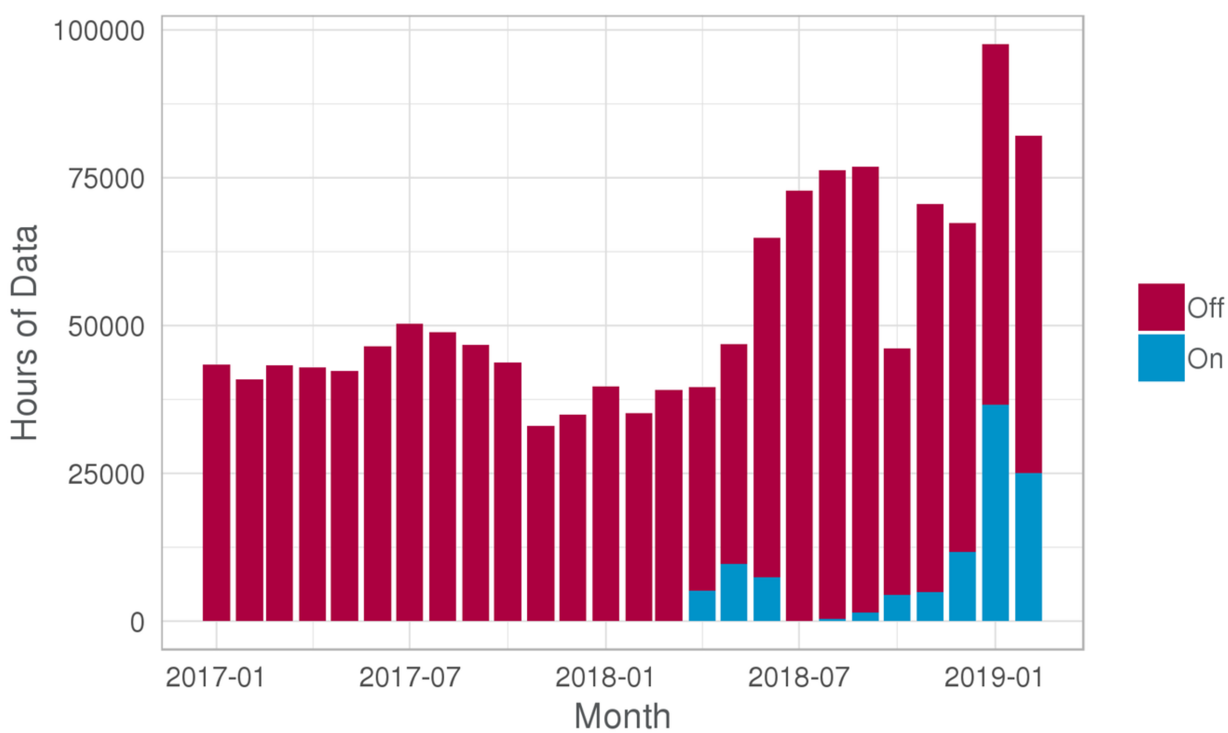
Finding 7: SCADA missing, bad quality and outlier data: Navigant removed large amounts of data due to values that were missing, flagged as "bad quality" readings by the SCADA system, or anomalous, unexplained spikes. Some of the power spikes appear to have resulted from load-shifting events that were not recorded in the events log. In the absence of other information, these data were also removed.

Recommendation 2: Clean SCADA data prior to sending it to the evaluation team to identify and, if necessary, correct, anomalous outliers.

Recommendation 3: Ensure that all events that result in large changes in measured load are recorded in the events log, including dates and times of the start and stop of each event.

Finding 8: Sparseness of on/off test data: Navigant's analytical approach for measuring VO impacts relied on a representative sample of the CY2018 VO feeders being operated on an alternating (4-day-on/4-day-off) schedule. The goal was to have the sample feeders cycle between VO-on and VO-off (or baseline) control states on a regular, preset schedule for a period sufficient to cover the full range of expected weather and load conditions (i.e., summer, winter, and either spring or autumn), to permit the measurement the VO impacts. Unfortunately, due to difficulties with the installation, commissioning and testing of the VO system during CY2018, with few exceptions on/off testing did not commence until very late in the year, and did not succeed in capturing the expected number of "on" observations; nearly all of the available test data was from the winter months, much of it from January and February 2019 (see Figure 6-2).[11]

Figure 6-2. Hours of Test Sample Data Available by VO Status and Month



Source: ComEd tracking data and Navigant team analysis.

[11] Navigant agreed to include SCADA test data from January and February 2019 in its training set for the CY2018 VO feeders to enlarge the size of the sample, but this did not alleviate the dearth of test data during the other seasons.

Finding 9: Less certainty about results during summer peak periods: Because almost all of the available on/off testing data, which formed the basis for the energy and demand impact measurements, fell during winter months, the savings estimates are less reliable than they would have been had a fuller sample data set been available. The peak demand impacts, in particular, should be taken with a grain of salt.[12]

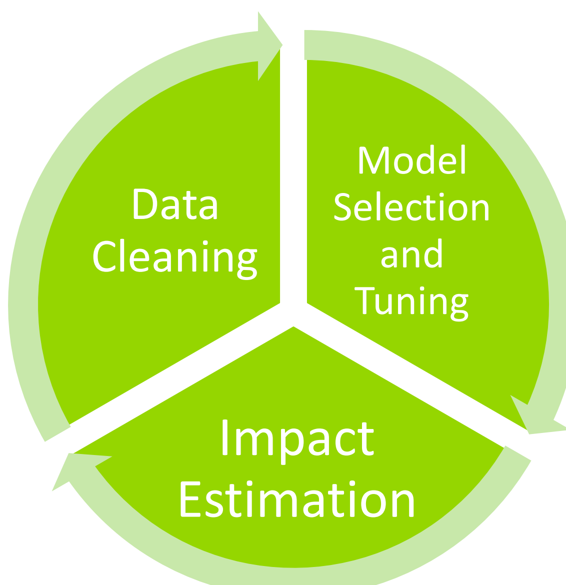
Recommendation 4: Although the CY2018 VO feeders in the test sample will continue in testing mode in 2019 until they have accumulated the full desired length of time, under the post-FEJA rules the verified savings for these feeders can't be adjusted to reflect this additional data.[13] ComEd should strive to get VO on/off testing started on the CY2019 feeders as early in the year as possible so as to have on/off test data available during the summer, winter, and shoulder seasons in order to demonstrate the impact of VO on energy usage and demand over the full range of expected weather and load conditions.

7. Appendix 1. Impact Analysis Methodology

The overarching goal of Navigant's analysis was to use the available empirical data to develop statistical models to represent each CY2018 VO feeder's annual load and voltage profiles, and then use these fitted models to simulate these profiles under normal weather assumptions and either pre-feeder conditioning (FC), post-FC/pre-VO, or post-VO conditions. Implicitly, the FC impacts are measured by comparing the post-FC/pre-VO profiles to the relevant pre-FC baseline profiles. The VO impacts, in turn, are measured by comparing the post-VO/VO-on profiles to the corresponding post-VO/VO-off profiles. The primary benefit of this approach, in principle, is that each VO-enabled feeder serves as its own control.

Navigant's approach to measuring the energy and demand impacts of the CY2018 VO program consists of three broad steps, which are illustrated in Figure 7-1 below.

Figure 7-1. Overview of Methodology



[12] Navigant used the definition of summer peak provided by PJM's Manual 18B (i.e., between the hour ending 15:00 and the hour ending 18:00, prevailing local time, during all days from June 1 through August 31 inclusive, that do not fall on a weekend day or federal holiday") to estimate peak demand impacts.

[13] Navigant will, however, use the additional data collected on the CY2018 VO feeders to help improve the estimates of savings from the VO feeders added in CY2019 and beyond.

An in-depth and granular data assessment and cleaning methodology was the cornerstone of this analysis, and recurred repeatedly while we fitted, tuned, and assessed the quality of the models. Clean data fed into model selection and tuning, where the load at each substation was modelled with an augmented load forecasting model, built and tuned especially for this counterfactual analysis. After fitting each model and assessing its quality, counterfactual predictions of power, voltage, and reactive power were calculated at every 30-minute timestamp in CY2018 and used to calculate the impact of VO without feeder conditioning, feeder conditioning without VO, and both VO and feeder conditioning. Any results which Navigant deemed unrealistic were analyzed in-depth and tied into the subsequent round of data cleaning.

7.1 Data Cleaning

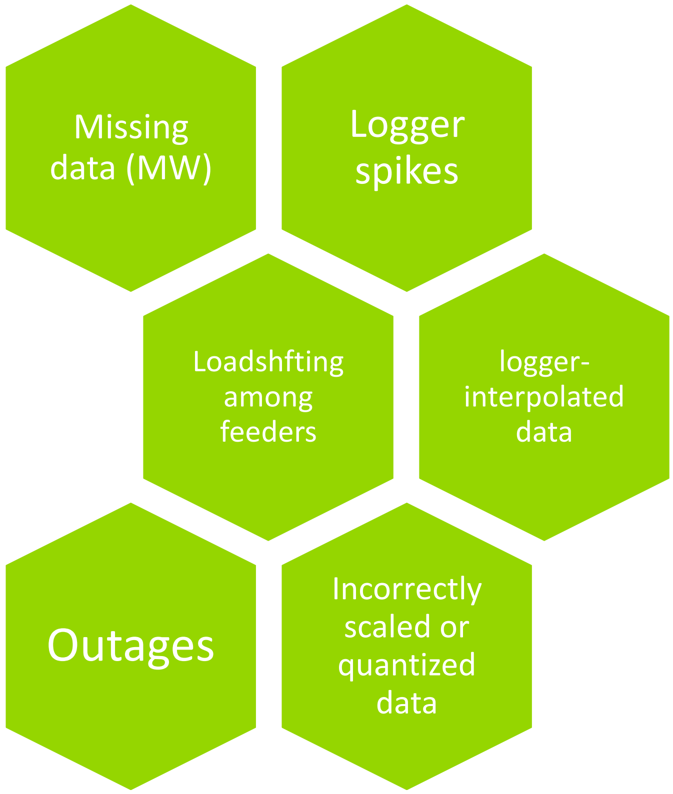
The data Navigant used as the basis of its analysis consisted of four broad types (see Figure 7-2):

- Substation and bus data, which included VO and bus voltage data
- Feeder-level data at 30-minute intervals, which included time-series values for power, current, voltage, and reactive power readings from the beginning of 2017
- Feeder characteristic data, such as conductor length, rated load, load factor, feeder conditioning data, regional, and demographic data
- Weather data at 30-minute intervals, which was downloaded from the National Oceanic and Atmospheric Administration’s (NOAA) FTP site for each feeder zip code

Navigant encountered several types of data issues, including:

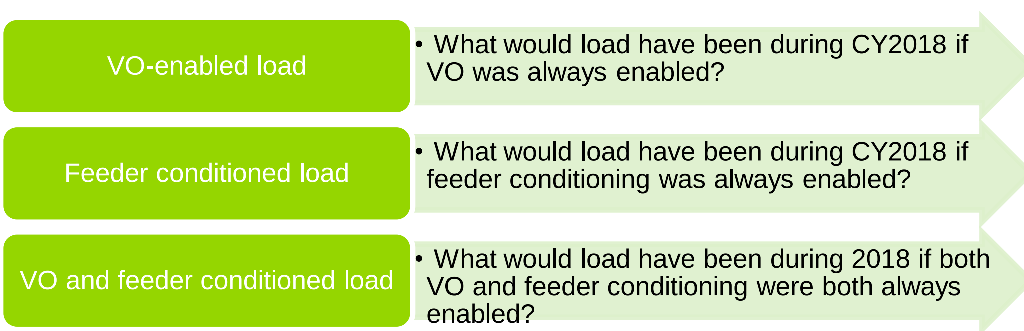
- **Missing data:** a large portion of the interval power data was had missing values or had been marked as bad quality by the SCADA system. Navigant attempted to re-calculate missing power using amperage and power factor where possible, but in the end this synthetic data was dropped due to accuracy concerns.
- **Load or voltage spikes:** spikes are inexplicable deviations from expected load or voltage that typically only last for a single or small handful of adjacent timestamps. Positive spikes were excluded using prescribed cutoffs of greater than 5 standard deviations from the mean value. All negative values were excluded. Navigant excluded some additional spikes that were non-negative and less than five standard deviations from the mean when they appeared to be causing implausible model results.
- **Load shifting:** apparent load shifting among feeders was an added complexity. Though this data was correct, the counterfactual analysis model was not set up to handle these scenarios. Power data was compared across substation and was excluded from the model if it was determined that load-shifting had taken place.
- **Interpolated data:** much of the data had a strange feature where 4-5 data points were taken per day and the rest of the 30-minute data was a linear interpolation between the actual data points. This data was not suitable for our model as weather data was implemented at the 30-minute interval and interpolated power readings would not follow weather trends as expected. These interpolated values were systematically removed.
- **Outages:** a file containing outages was obtained from ComEd and was used to exclude readings which occurred during known system outages.
- **Incorrect scaling or quantization:** Upon visual inspection, some of the feeder-level power data had extreme variance that lasted only during discrete time periods or was rounded to the nearest fourth or tenth of a megawatt. Time periods on a few feeders containing these issues were removed from the analysis.

Figure 7-2. Main Data Issues



7.2 Model Selection and Tuning

The goal of model selection and tuning was to generate a model which could be used to simulate three counterfactual states during CY2018:



Navigant considered several approaches to modeling these counterfactual simulated states, given the available data, including preset linear regression models, simple CVR factor-based approaches, and machine-learning approaches. Ultimately, we chose the latter, because of machine-learning's superior ability to consider multiple, complex model specifications, including lagged terms and interaction terms, make accurate predictions, while avoiding overfitting.

The general specification for these models are shown in Equation 1.

Equation 1. Voltage Optimization Model

$$X_{i,t,p} = f(load\text{-}shape,\ weather,\ feeder\ characteristics,\ VVO\ status, FC\ status, Events, \Delta LRs)$$

where:

- i, t, and p index the feeder, time interval, and test period (i.e., summer, autumn, winter), respectively;
- $X_{i,t,p}$ is the interval load – in MW units in the case of real power, |MVAR| units in the case of reactive power – or voltage measured on feeder i during time interval t in period p. Interval power was (or should be) measured at feeder head-ends at the substation, while voltage was measured as the load-weighted average of interval voltage readings from the AMI meters of the connected customer service points on feeders (if any) where reliable AMI voltage data are available, or at the substation otherwise;
- *load-shape* refers to model elements included to capture underlying time-varying patterns observed in the data that repeat at daily, weekly, seasonal and annual periods, including hour of day, week of year, day of year, weekend, elapsed days since Jan 1, 2017, and holidays;
- *weather* refers to the model elements included to capture weather-related variations, including heating and cooling degree-days, normalized heat build-up, and various lagged values of these features;
- *feeder characteristics* refers to various static (or infrequently-changing) characteristics of each VVO-enabled feeder, such as average or typical load shares (by customer type), conductor miles, geographic location, load factor, 2017 annual peak, rated load, rated primary voltage, and number of capacitor banks and regulators;
- *VVO status* refers to whether the VVO controls are engaged or disengaged during time interval t;
- *Events* comprises a set of binary flags indicating whether a DR event falls within time interval t;
- *FC status* refers to whether time interval t falls before, during, or after the feeder-conditioning phase; and
- *ΔLR* comprises a set of binary flags indicating when a given load-regime change has occurred.

To tune the models, Navigant employed bootstrapped cross-validation, a technique in which a series of k models are fit to different bootstrapped resamples drawn with replacement from a subset of the data set. The remainder of the data is held back to permit out-of-sample predictions. Once the models were fitted, predictions were made and assessed using the hold-out validation data, by comparing the k model predictions produced using the hold-out sample to the actual hold-out sample data. The size and distribution of these cross-validation errors allowed us to assess the model's quality. Navigant used several error metrics to compare models during the validation phase, including the overall root mean-squared error (RMSE), as well as the RMSE during VO-enabled periods, during peak-load periods, during the coolest periods, and during the warmest periods.[14]

Navigant gave extra weight to the RMSE during VO-enabled periods, since most of the feeders had late 2018 go-live dates and, therefore, the amount of VO-enabled data was small. To achieve suitable VO-periods RMSE values, Navigant replicated the VO-enabled data that was fed into the sample model during the estimation phase to ensure the model fit well during these periods.

[14] For its final model runs, Navigant set k equal to 25.

7.3 Impact Estimation

After the model was fitted to the bootstrap resamples drawn from the training data set, the counterfactual simulations were produced. Simulations of 2018 load at the 30-minute interval were made for feeder conditioning (FC), VO plus feeder conditioning (VO&FC) effects, and pre-feeder conditioning (base). Using these three predictions on the load and voltage models, the following differences were calculated at the timestamp level for both load and voltage:

$$\Delta FC = base - FC$$
$$\Delta VO = FC - VO\&FC$$
$$\Delta VO\&FC = base - VO\&FC$$

Afterward, each of these were aggregated to generate distributions of savings and percent savings for all substations during 2018. The methodology to calculate savings was to take the average difference for each metric at the feeder and cross-validation set level. For the load model this was multiplied by 8760 to generate MWh readings. To generate percent savings, the percent savings was calculated at the timestamp level and then aggregated across timestamps using a weighted mean with the baseline predicted load. Finally, the CVR factor was then generated for each cross-validation set using the following formulation:

$$CVR_f = \%\Delta E / \%\Delta V$$

The standard errors of the impacts was generated not from the models individually, but empirically using the distributions of outputs from each of the cross-validation splits.

8. Appendix 2. Data Detail

Table 8-1 below shows the substations and feeders on which VO was installed, commissioned, and successfully launched in CY2018. Note that only four substations had go-live dates prior to November 30, 2018. And of these, as shown in Figure 6-2 above, relatively few VO-on observations were generated.

Table 8-1. CY2018 VO Substations and Feeders

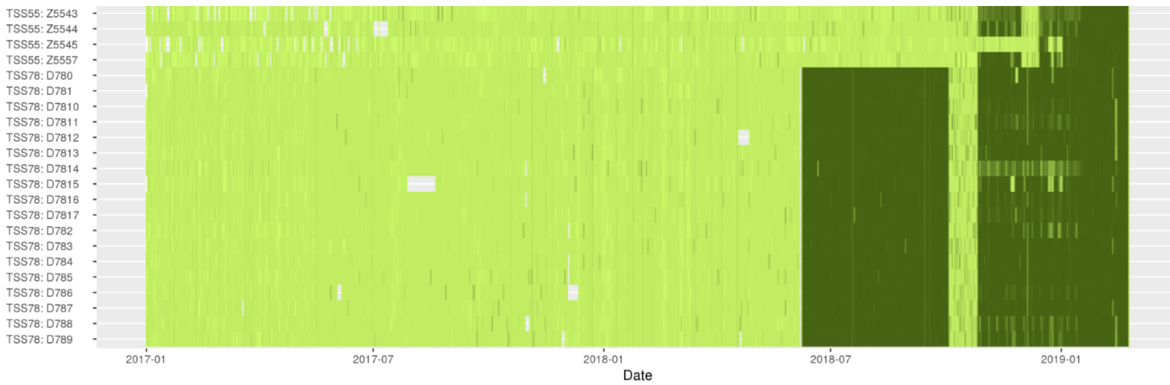
Substation	Substation Name	# of VO-Enabled Feeders	Sample?	Initial Ex Ante Energy Savings (MWh)	Final Ex Ante Energy Savings (MWh)	Planned Go-Live Month	Commissioning Start Date	Go-Live Date
TSS48	Highland Park	9	Added	3,387	3,387	Aug	8/13/2018	8/13/2018
TDC505	Oak Park	15	Original	8,499	8,499	Aug	10/16/2018	10/16/2018
TSS134	LaGrange	18	Original	13,204	13,204	Sep	9/28/2018	10/16/2018
TSS55	Hegwisch	12	Added	3,132	3,132	Aug	10/16/2018	10/16/2018
TSS118	Wallace	14	Original	9,186	9,186	Aug	11/30/2018	11/30/2018
DCD351	Hodgkins	1	No	1560	780	Oct	11/30/2018	12/7/2018
DCD69	Broadview	1	Added	693	693	Oct	11/30/2018	12/7/2018
DCW29	Winfield Twp	2	No	1230	1230	Nov	11/30/2018	12/7/2018
DCW346	Addison	1	Added	2,011	2,011	Sep	11/30/2018	12/7/2018
DCD62	Hillside	2	Added	1,348	1,348	Oct	12/31/2018	12/13/2018
DCC80	Glenview	1	Added	555	555	Oct	12/14/2018	12/14/2018
DCD114	Stickney	1	Added	726	726	Oct	12/14/2018	12/14/2018
DCD242	Bridgeview	1	Added	585	585	Oct	12/14/2018	12/14/2018
DCD46	North Lake	1	No	1568	784	Nov	12/14/2018	12/14/2018
DCE59	Algonquin	1	No	924	924	Oct	12/14/2018	12/14/2018
DCW202	Elgin	1	No	783	783	Oct	12/14/2018	12/14/2018
DCW30	Wheaton	2	Added	3,572	3,572	Oct	11/30/2018	12/14/2018
DCW354	York Center	1	Added	831	831	Aug	12/14/2018	12/14/2018
DCW71	Aurora	2	Added	1,764	1,764	Oct	12/14/2018	12/14/2018
TSS78	Franklin Park	18	Original	5,021	5,021	Sep	11/30/2018	12/14/2018
DCD63	Schiller Park	3	No	2043	2043	Nov	12/21/2018	12/21/2018
DCW216	Dundee/Meadowdale	1	Added	805	805	Oct	12/21/2018	12/21/2018
TDC414	Roberts Road	11	No	7451	7451	Dec	12/21/2018	12/21/2018
TDC457	Park Forest	8	No	4496	4496	Dec	12/21/2018	12/21/2018
TDC470	Orland Park	8	Original	6030	6030	Nov	12/21/2018	12/21/2018
DCS48	Otter Creek	1	No	780	780	Dec	12/31/2018	12/31/2018
DCD16	Lyons Twp	1	No	887	887	Dec	12/31/2018	12/31/2018
DCD80	Broadview	1	No	847	847	Dec	12/31/2018	12/31/2018
DCE28	Algonquin	3	No	1861	1861	Dec	12/31/2018	12/31/2018
DCE72	Fox River Grove	1	No	668	668	Oct	12/31/2018	12/31/2018
DCG99	Palos Heights	1	No	767	767	Dec	12/31/2018	12/31/2018
DCW236	Roselle	3	Added	3,732	3,732	Sep	12/31/2018	12/31/2018
DCW28	Sunset Park	1	No	679	679	Nov	12/31/2018	12/31/2018
DCW31	Milton TWN	2	Added	1,681	1,681	Aug	12/31/2018	12/31/2018
DCW343	Elmhurst	1	Added	768	768	Aug	12/31/2018	12/31/2018
DCW348	Bensenville	1	No	677	677	Nov	12/31/2018	12/31/2018
DCW51	Randall Road	1	Added	2,299	1,150	Oct	12/31/2018	12/31/2018
TDC549	Berkley	11	No	5044	5044	Nov	12/31/2018	12/31/2018
Total	**38**	**163**	**21**	**102,094**	**99,381**			

Source: ComEd tracking data and Navigant team analysis.

Figure 8-1 illustrates the scope of the SCADA data interpolation problem described above. Each row represents one CY2018 VO feeder, and the time dimension is measured along the horizontal axis. Given that 30-minute interval data should produce 48 unique observations per day, the light-green colored areas show where the number of actual readings logged was in the 4-8 per day range. Gray gaps indicate missing data.

Figure 8-1. SCADA Data Interpolations Heat Map

Figure 8-1. SCADA Data Interpolations Heat Map (Continued)



Source: ComEd tracking data and Navigant team analysis.

9. Appendix 3. Impact Analysis Detail

Table 9-1 presents VO Program energy savings by type (FC, VO, FC+VO) and substation.

Table 9-1. CY2018 Verified Energy Savings by Type and Substation

Type	Substation	Energy Savings (kWh)	Energy Savings Lower 90% CI	Energy Savings Upper 90% CI	%D Energy	%D Energy Lower 90% CI	%D Energy Upper 90% CI
FC	DCC80	-37,469	-735,942	562,504	-0.71	-8.75	5.70
FC	DCD114	99,954	-116,949	256,588	1.76	-2.16	4.55
FC	DCD16	-274,937	-896,874	392,725	-1.13	-3.73	1.61
FC	DCD242	511,932	210,443	937,730	22.10	11.55	37.98
FC	DCD351	161,164	35,631	301,094	2.26	0.51	4.18
FC	DCD46	-143,939	-441,768	188,690	-1.21	-3.69	1.60
FC	DCD63	2,562,930	1,132,057	3,846,929	8.91	4.20	13.33
FC	DCD69	747,496	335,579	1,354,944	10.51	5.05	18.40
FC	DCD80	338,655	106,042	547,343	3.58	1.15	5.80
FC	DCE28	-774,228	-1,887,602	484,265	-2.19	-5.43	1.32
FC	DCE59	-1,622,302	-2,012,935	-887,191	-6.84	-8.61	-3.79
FC	DCE72	91,506	-148,140	302,560	1.09	-1.89	3.71
FC	DCG99	-567,598	-1,186,681	91,332	-2.63	-5.55	0.40
FC	DCS48	1,501,350	1,112,496	1,876,543	7.03	5.33	9.11
FC	DCW202	22,668	-139,787	176,342	0.29	-2.01	2.45
FC	DCW216	-239,947	-505,913	25,746	-4.25	-8.88	0.44

Type	Substation	Energy Savings (kWh)	Energy Savings Lower 90% CI	Energy Savings Upper 90% CI	%D Energy	%D Energy Lower 90% CI	%D Energy Upper 90% CI
FC	DCW236	235,693	-292,985	779,451	0.48	-0.61	1.60
FC	DCW28	-420,267	-809,267	-4,360	-2.08	-4.05	-0.02
FC	DCW29	-3,224,616	-5,026,188	-1,253,014	-12.85	-20.29	-4.79
FC	DCW30	-1,334,813	-1,964,517	-691,030	-3.74	-5.56	-1.89
FC	DCW31	-225,998	-639,295	153,363	-1.15	-3.21	0.70
FC	DCW343	478,040	306,109	658,435	7.46	4.85	10.07
FC	DCW346	197,372	20,534	390,554	0.93	0.10	1.83
FC	DCW348	-146,740	-423,556	74,470	-0.63	-1.76	0.32
FC	DCW354	-30,991	-115,789	63,132	-0.12	-0.46	0.25
FC	DCW51	-307,550	-634,471	26,306	-1.28	-2.64	0.11
FC	DCW71	-358,710	-743,078	10,338	-1.91	-3.98	0.05
FC	TDC414	-4,404,721	-6,269,718	-2,736,360	-2.13	-3.04	-1.32
FC	TDC457	-2,581,328	-4,212,874	-970,527	-1.74	-2.86	-0.64
FC	TDC470	-887,672	-1,823,764	-190,623	-0.60	-1.24	-0.13
FC	TDC505	430,074	-117,427	994,546	0.15	-0.04	0.36
FC	TDC549	3,399,384	2,174,779	5,131,190	1.53	0.97	2.30
FC	TSS118	-1,601,198	-2,735,685	-839,126	-0.46	-0.79	-0.24
FC	TSS134	727,203	-366,872	1,749,423	0.21	-0.10	0.49
FC	TSS48	621,206	-232,528	1,347,019	0.44	-0.17	0.96
FC	TSS55	-371,561	-1,325,220	475,755	-0.24	-0.84	0.30
FC	TSS78	-999,839	-2,027,717	-100,541	-0.29	-0.59	-0.03
VO	DCC80	11,450	-51,149	53,496	0.10	-0.60	0.57
VO	DCD114	-68,915	-151,813	-15,530	-1.29	-2.79	-0.31
VO	DCD16	318,403	138,777	477,159	1.30	0.58	2.12
VO	DCD242	-114	-68,233	70,770	-0.64	-4.75	5.66
VO	DCD351	-51,997	-222,065	67,274	-0.76	-3.25	0.97
VO	DCD46	167,360	-41,900	366,344	1.36	-0.36	3.00
VO	DCD63	56,861	-172,230	276,635	0.26	-0.68	1.13

Type	Substation	Energy Savings (kWh)	Energy Savings Lower 90% CI	Energy Savings Upper 90% CI	%D Energy	%D Energy Lower 90% CI	%D Energy Upper 90% CI
VO	DCD69	-31,467	-154,658	93,547	-0.56	-2.58	1.50
VO	DCD80	-136,883	-272,327	-9,601	-1.56	-3.08	-0.13
VO	DCE28	592,530	296,508	890,419	1.62	0.81	2.42
VO	DCE59	1,213,791	665,198	1,746,791	4.73	2.63	6.86
VO	DCE72	24,501	-113,426	213,878	0.26	-1.46	2.66
VO	DCG99	50,563	-84,716	197,629	0.22	-0.37	0.85
VO	DCS48	670,255	370,388	939,667	3.54	2.22	4.69
VO	DCW202	-110,205	-208,180	-3,839	-1.58	-3.02	-0.09
VO	DCW216	-69,866	-191,617	72,245	-1.13	-3.17	1.17
VO	DCW236	709,602	279,929	1,044,341	1.47	0.55	2.22
VO	DCW28	228,442	105,955	357,972	1.10	0.52	1.73
VO	DCW29	229,563	72,740	447,480	0.80	0.24	1.57
VO	DCW30	232,288	121,359	382,437	0.62	0.34	1.03
VO	DCW31	94,353	-99,158	234,721	0.48	-0.53	1.21
VO	DCW343	24,804	-49,024	102,717	0.40	-0.84	1.75
VO	DCW346	189,065	71,888	353,432	0.91	0.35	1.71
VO	DCW348	70,526	-388,877	342,233	0.29	-1.67	1.44
VO	DCW354	116,890	9,821	247,306	0.46	0.04	0.97
VO	DCW51	110,729	-107,099	265,839	0.45	-0.43	1.07
VO	DCW71	-262,603	-538,553	-44,480	-1.36	-2.79	-0.23
VO	TDC414	2,366,342	1,693,530	3,091,716	1.13	0.81	1.48
VO	TDC457	1,481,411	769,046	2,017,323	0.98	0.51	1.31
VO	TDC470	2,343,548	1,901,365	2,798,386	1.57	1.28	1.86
VO	TDC505	5,956,811	5,425,078	6,612,142	2.14	1.96	2.38
VO	TDC549	2,730,906	1,823,532	3,841,248	1.24	0.82	1.74
VO	TSS118	4,854,610	3,942,999	5,834,006	1.40	1.14	1.69
VO	TSS134	6,928,300	5,735,193	8,166,214	1.95	1.61	2.28
VO	TSS48	2,284,869	1,981,119	2,609,028	1.65	1.42	1.88

Type	Substation	Energy Savings (kWh)	Energy Savings Lower 90% CI	Energy Savings Upper 90% CI	%D Energy	%D Energy Lower 90% CI	%D Energy Upper 90% CI
VO	TSS55	2,000,700	1,084,574	2,990,934	1.27	0.68	1.91
VO	TSS78	3,253,846	2,858,567	3,812,804	0.94	0.83	1.11
FC+VO	DCC80	-26,019	-763,431	580,188	-0.60	-9.08	5.93
FC+VO	DCD114	31,039	-199,567	223,662	0.51	-3.69	3.92
FC+VO	DCD16	43,466	-685,972	631,165	0.18	-2.83	2.58
FC+VO	DCD242	511,818	217,362	935,889	22.03	11.51	37.90
FC+VO	DCD351	109,166	-21,381	250,023	1.53	-0.31	3.47
FC+VO	DCD46	23,420	-344,651	461,061	0.18	-2.96	3.90
FC+VO	DCD63	2,619,791	991,473	3,931,191	9.09	3.68	13.62
FC+VO	DCD69	716,029	354,810	1,279,398	10.07	5.32	17.38
FC+VO	DCD80	201,772	-37,545	404,938	2.13	-0.41	4.28
FC+VO	DCE28	-181,698	-1,236,005	1,225,912	-0.55	-3.59	3.31
FC+VO	DCE59	-408,512	-827,384	199,542	-1.78	-3.59	0.83
FC+VO	DCE72	116,006	-141,166	325,007	1.40	-1.81	3.88
FC+VO	DCG99	-517,035	-1,085,802	252,527	-2.40	-5.00	1.09
FC+VO	DCS48	2,171,605	1,777,922	2,584,882	10.15	8.07	12.06
FC+VO	DCW202	-87,536	-266,712	81,774	-1.28	-3.88	1.15
FC+VO	DCW216	-309,813	-525,215	-12,337	-5.47	-9.36	-0.21
FC+VO	DCW236	945,295	193,532	1,679,430	1.95	0.41	3.48
FC+VO	DCW28	-191,825	-635,338	271,918	-0.96	-3.21	1.33
FC+VO	DCW29	-2,995,054	-5,228,907	-966,058	-11.96	-21.11	-3.82
FC+VO	DCW30	-1,102,525	-1,884,685	-464,554	-3.09	-5.30	-1.27
FC+VO	DCW31	-131,645	-732,607	386,020	-0.67	-3.38	1.78
FC+VO	DCW343	502,845	340,991	751,249	7.84	5.40	11.48
FC+VO	DCW346	386,437	67,151	766,710	1.83	0.32	3.64
FC+VO	DCW348	-76,214	-679,598	399,888	-0.33	-2.95	1.65
FC+VO	DCW354	85,900	-33,025	240,224	0.34	-0.13	0.94
FC+VO	DCW51	-196,822	-612,602	233,581	-0.83	-2.55	0.96

Type	Substation	Energy Savings (kWh)	Energy Savings Lower 90% CI	Energy Savings Upper 90% CI	%D Energy	%D Energy Lower 90% CI	%D Energy Upper 90% CI
FC+VO	DCW71	-621,313	-1,274,518	-136,154	-3.30	-6.91	-0.71
FC+VO	TDC414	-2,038,379	-3,545,705	-41,099	-0.99	-1.72	-0.02
FC+VO	TDC457	-1,099,917	-2,863,441	602,210	-0.75	-1.94	0.40
FC+VO	TDC470	1,455,876	824,825	2,371,521	0.97	0.56	1.57
FC+VO	TDC505	6,386,885	5,783,532	6,985,745	2.29	2.07	2.50
FC+VO	TDC549	6,130,291	4,272,018	8,058,005	2.75	1.92	3.63
FC+VO	TSS118	3,253,412	1,950,006	4,424,660	0.94	0.57	1.28
FC+VO	TSS134	7,655,503	6,332,941	8,809,059	2.17	1.80	2.49
FC+VO	TSS48	2,906,075	2,005,394	3,709,840	2.08	1.45	2.66
FC+VO	TSS55	1,629,140	585,781	2,625,898	1.03	0.37	1.67
FC+VO	TSS78	2,254,007	980,822	3,066,857	0.65	0.29	0.89
Total FC		**-8,429,797**					
Total VO		**38,581,268**					
Total FC+VO		**30,151,471**					

Source: ComEd tracking data and Navigant team analysis.

Table 9-2 presents VO program voltage impacts and CVR factors by substation.

Table 9-2. CY2018 Verified Voltage Reductions and CRV Factors by Type and Substation

Type	Substation	%Δ Energy	%Δ Volts	%Δ Volts Lower 90% CI	%Δ Volts Upper 90% CI	CVRf	CVRf Lower 90% CI	CVRf Upper 90% CI
FC	DCC80	-0.71	-1.73	-1.97	-1.54	0.49	-2.99	4.92
FC	DCD114	1.76	-0.61	-0.63	-0.58	-2.88	-7.39	3.38
FC	DCD16	-1.13	-0.33	-0.41	-0.25	3.89	-4.69	12.67
FC	DCD242	22.10	-0.44	-0.49	-0.39	-49.72	-79.16	-25.66
FC	DCD351	2.26	-0.62	-0.65	-0.60	-3.66	-7.00	-0.81
FC	DCD46	-1.21	-0.47	-0.52	-0.40	2.45	-3.41	8.53
FC	DCD63	8.91	-1.17	-1.23	-1.12	-7.58	-11.47	-3.53
FC	DCD69	10.51	0.85	0.79	0.90	12.40	5.84	22.62
FC	DCD80	3.58	-0.06	-0.10	-0.04	-61.88	-127.32	-16.76

Type	Substation	%Δ Energy	%Δ Volts	%Δ Volts Lower 90% CI	%Δ Volts Upper 90% CI	CVRf	CVRf Lower 90% CI	CVRf Upper 90% CI
FC	DCE28	-2.19	-0.51	-0.54	-0.47	4.38	-2.60	10.83
FC	DCE59	-6.84	-0.80	-0.85	-0.75	8.53	5.28	10.90
FC	DCE72	1.09	-0.79	-0.81	-0.76	-1.39	-4.56	2.35
FC	DCG99	-2.63	-1.03	-1.23	-0.83	2.58	-0.31	5.14
FC	DCS48	7.03	-0.76	-0.89	-0.66	-9.40	-11.60	-6.47
FC	DCW202	0.29	-0.58	-0.60	-0.54	-0.52	-4.11	3.30
FC	DCW216	-4.25	-0.51	-0.54	-0.47	8.47	-0.85	16.73
FC	DCW236	0.48	-0.52	-0.57	-0.48	-0.90	-3.04	1.16
FC	DCW28	-2.08	-0.27	-0.31	-0.24	7.67	0.08	13.94
FC	DCW29	-12.85	-0.67	-0.72	-0.63	19.25	7.48	31.68
FC	DCW30	-3.74	-1.27	-1.35	-1.19	2.94	1.57	4.57
FC	DCW31	-1.15	-0.22	-0.25	-0.18	5.48	-3.00	15.70
FC	DCW343	7.46	-1.74	-1.77	-1.71	-4.30	-5.87	-2.77
FC	DCW346	0.93	-0.59	-0.63	-0.55	-1.56	-3.21	-0.15
FC	DCW348	-0.63	-0.39	-0.44	-0.34	1.60	-0.86	4.71
FC	DCW354	-0.12	-0.50	-0.54	-0.45	0.25	-0.47	0.86
FC	DCW51	-1.28	-0.04	-0.09	0.02	-11.88	-67.42	41.78
FC	DCW71	-1.91	0.03	0.01	0.04	-82.86	-183.82	2.67
FC	TDC414	-2.13	-0.16	-0.18	-0.15	13.32	8.63	17.47
FC	TDC457	-1.74	-0.27	-0.30	-0.26	6.40	2.40	10.52
FC	TDC470	-0.60	-0.64	-0.66	-0.61	0.95	0.20	1.95
FC	TDC505	0.15	-0.29	-0.31	-0.28	-0.53	-1.17	0.14
FC	TDC549	1.53	-1.10	-1.12	-1.07	-1.40	-2.19	-0.90
FC	TSS118	-0.46	-0.31	-0.32	-0.30	1.49	0.75	2.73
FC	TSS134	0.21	-0.60	-0.61	-0.58	-0.34	-0.87	0.17
FC	TSS48	0.44	-0.09	-0.10	-0.07	-5.24	-12.71	2.42
FC	TSS55	-0.24	-1.32	-1.38	-1.29	0.18	-0.23	0.63
FC	TSS78	-0.29	-0.27	-0.28	-0.25	1.07	0.11	2.08

Type	Substation	%Δ Energy	%Δ Volts	%Δ Volts Lower 90% CI	%Δ Volts Upper 90% CI	CVRf	CVRf Lower 90% CI	CVRf Upper 90% CI
VO	DCC80	0.10	3.12	3.03	3.21	0.03	-0.20	0.19
VO	DCD114	-1.29	2.78	2.71	2.86	-0.46	-0.97	-0.11
VO	DCD16	1.30	2.57	2.48	2.67	0.51	0.23	0.85
VO	DCD242	-0.64	1.80	1.73	1.89	-0.38	-2.77	3.16
VO	DCD351	-0.76	2.96	2.84	3.04	-0.25	-1.09	0.33
VO	DCD46	1.36	2.42	2.33	2.54	0.56	-0.15	1.26
VO	DCD63	0.26	2.55	2.45	2.64	0.10	-0.27	0.44
VO	DCD69	-0.56	1.37	1.31	1.42	-0.41	-1.82	1.14
VO	DCD80	-1.56	2.58	2.47	2.69	-0.61	-1.24	-0.05
VO	DCE28	1.62	2.76	2.67	2.87	0.59	0.29	0.86
VO	DCE59	4.73	2.76	2.63	2.90	1.71	0.98	2.51
VO	DCE72	0.26	2.60	2.47	2.76	0.10	-0.53	1.05
VO	DCG99	0.22	2.21	2.03	2.42	0.10	-0.18	0.36
VO	DCS48	3.54	2.58	2.51	2.68	1.37	0.83	1.80
VO	DCW202	-1.58	2.28	2.16	2.39	-0.69	-1.37	-0.04
VO	DCW216	-1.13	2.60	2.55	2.67	-0.43	-1.23	0.45
VO	DCW236	1.47	2.73	2.63	2.81	0.53	0.21	0.80
VO	DCW28	1.10	2.77	2.67	2.85	0.40	0.18	0.63
VO	DCW29	0.80	2.80	2.72	2.88	0.29	0.08	0.57
VO	DCW30	0.62	2.84	2.72	2.96	0.22	0.13	0.37
VO	DCW31	0.48	2.45	2.36	2.57	0.20	-0.22	0.50
VO	DCW343	0.40	2.53	2.46	2.62	0.16	-0.33	0.69
VO	DCW346	0.91	2.94	2.84	3.03	0.31	0.12	0.58
VO	DCW348	0.29	2.75	2.65	2.85	0.10	-0.62	0.54
VO	DCW354	0.46	2.94	2.85	3.10	0.16	0.01	0.35
VO	DCW51	0.45	2.84	2.74	3.00	0.16	-0.14	0.38
VO	DCW71	-1.36	2.79	2.67	2.89	-0.48	-0.96	-0.08
VO	TDC414	1.13	2.70	2.63	2.79	0.42	0.30	0.56

Type	Substation	%Δ Energy	%Δ Volts	%Δ Volts Lower 90% CI	%Δ Volts Upper 90% CI	CVRf	CVRf Lower 90% CI	CVRf Upper 90% CI
VO	TDC457	0.98	2.12	2.05	2.20	0.46	0.24	0.62
VO	TDC470	1.57	2.84	2.79	2.90	0.55	0.45	0.66
VO	TDC505	2.14	3.05	3.00	3.13	0.70	0.64	0.80
VO	TDC549	1.24	2.03	1.97	2.07	0.61	0.41	0.82
VO	TSS118	1.40	2.02	1.97	2.08	0.69	0.56	0.83
VO	TSS134	1.95	2.88	2.83	2.95	0.68	0.56	0.81
VO	TSS48	1.65	2.71	2.67	2.76	0.61	0.52	0.69
VO	TSS55	1.27	2.46	2.40	2.53	0.52	0.28	0.78
VO	TSS78	0.94	2.38	2.33	2.43	0.40	0.34	0.47
FC+VO	DCC80	-0.60	1.44	1.18	1.71	-0.31	-6.39	3.85
FC+VO	DCD114	0.51	2.19	2.11	2.26	0.25	-1.64	1.81
FC+VO	DCD16	0.18	2.25	2.15	2.35	0.08	-1.31	1.14
FC+VO	DCD242	22.03	1.37	1.26	1.47	16.19	7.92	28.59
FC+VO	DCD351	1.53	2.35	2.27	2.44	0.66	-0.12	1.46
FC+VO	DCD46	0.18	1.96	1.89	2.08	0.08	-1.48	1.82
FC+VO	DCD63	9.09	1.41	1.34	1.50	6.50	2.71	9.97
FC+VO	DCD69	10.07	2.21	2.12	2.30	4.56	2.44	7.84
FC+VO	DCD80	2.13	2.52	2.42	2.61	0.85	-0.16	1.65
FC+VO	DCE28	-0.55	2.27	2.16	2.39	-0.22	-1.63	1.52
FC+VO	DCE59	-1.78	1.98	1.87	2.11	-0.91	-1.74	0.40
FC+VO	DCE72	1.40	1.83	1.72	1.97	0.76	-1.00	2.04
FC+VO	DCG99	-2.40	1.20	1.02	1.42	-1.90	-3.87	1.11
FC+VO	DCS48	10.15	1.84	1.69	1.96	5.56	4.51	7.52
FC+VO	DCW202	-1.28	1.71	1.61	1.83	-0.72	-2.39	0.70
FC+VO	DCW216	-5.47	2.11	2.03	2.19	-2.57	-4.41	-0.10
FC+VO	DCW236	1.95	2.23	2.12	2.33	0.88	0.19	1.52
FC+VO	DCW28	-0.96	2.50	2.38	2.61	-0.39	-1.27	0.54
FC+VO	DCW29	-11.96	2.14	2.05	2.22	-5.61	-9.97	-1.70

Type	Substation	%Δ Energy	%Δ Volts	%Δ Volts Lower 90% CI	%Δ Volts Upper 90% CI	CVRf	CVRf Lower 90% CI	CVRf Upper 90% CI
FC+VO	DCW30	-3.09	1.61	1.43	1.75	-1.96	-3.07	-0.75
FC+VO	DCW31	-0.67	2.24	2.15	2.35	-0.30	-1.54	0.80
FC+VO	DCW343	7.84	0.84	0.75	0.93	9.52	6.27	14.22
FC+VO	DCW346	1.83	2.37	2.23	2.50	0.78	0.14	1.64
FC+VO	DCW348	-0.33	2.37	2.29	2.47	-0.15	-1.26	0.69
FC+VO	DCW354	0.34	2.46	2.34	2.58	0.14	-0.05	0.40
FC+VO	DCW51	-0.83	2.80	2.70	2.94	-0.30	-0.90	0.33
FC+VO	DCW71	-3.30	2.82	2.70	2.92	-1.17	-2.38	-0.25
FC+VO	TDC414	-0.99	2.55	2.47	2.64	-0.39	-0.65	-0.01
FC+VO	TDC457	-0.75	1.85	1.77	1.93	-0.41	-1.05	0.22
FC+VO	TDC470	0.97	2.23	2.17	2.28	0.44	0.25	0.71
FC+VO	TDC505	2.29	2.77	2.73	2.84	0.83	0.75	0.92
FC+VO	TDC549	2.75	0.96	0.91	1.03	2.86	2.04	3.78
FC+VO	TSS118	0.94	1.71	1.67	1.78	0.55	0.34	0.76
FC+VO	TSS134	2.17	2.30	2.25	2.35	0.94	0.78	1.09
FC+VO	TSS48	2.08	2.63	2.59	2.67	0.79	0.55	1.02
FC+VO	TSS55	1.03	1.17	1.09	1.28	0.89	0.29	1.45
FC+VO	TSS78	0.65	2.12	2.06	2.17	0.31	0.14	0.43

Source: ComEd tracking data and Navigant team analysis.

Table 9-3 presents CY2018 VO Program demand impacts.

Table 9-3. CY2018 VO Program Demand Impacts

Type	Substation	Demand Savings (kW)	Demand Savings Lower 90% CI	Demand Savings Upper 90% CI	Summer Peak Demand Savings (kW)	Summer Peak Demand Savings Lower 90% CI	Summer Peak Demand Savings Upper 90% CI
FC	DCC80	-4	-84	64	-67	-169	46
FC	DCD114	11	-13	29	17	-13	48
FC	DCD16	-31	-102	45	-164	-272	-58
FC	DCD242	58	24	107	85	24	142

Type	Substation	Demand Savings (kW)	Demand Savings Lower 90% CI	Demand Savings Upper 90% CI	Summer Peak Demand Savings (kW)	Summer Peak Demand Savings Lower 90% CI	Summer Peak Demand Savings Upper 90% CI
FC	DCD351	18	4	34	23	-20	68
FC	DCD46	-16	-50	22	-55	-132	13
FC	DCD63	293	129	439	5	-81	98
FC	DCD69	85	38	155	179	92	313
FC	DCD80	39	12	62	137	37	225
FC	DCE28	-88	-215	55	-168	-247	-80
FC	DCE59	-185	-230	-101	-283	-357	-206
FC	DCE72	10	-17	35	68	-15	199
FC	DCG99	-65	-135	10	-105	-207	-29
FC	DCS48	171	127	214	84	35	120
FC	DCW202	3	-16	20	9	-26	47
FC	DCW216	-27	-58	3	-95	-156	-6
FC	DCW236	27	-33	89	14	-40	72
FC	DCW28	-48	-92	0	-123	-215	-5
FC	DCW29	-368	-574	-143	-292	-467	-165
FC	DCW30	-152	-224	-79	-128	-187	-61
FC	DCW31	-26	-73	18	-32	-60	-1
FC	DCW343	55	35	75	87	44	132
FC	DCW346	23	2	45	88	31	133
FC	DCW348	-17	-48	9	-52	-124	15
FC	DCW354	-4	-13	7	-19	-35	-1
FC	DCW51	-35	-72	3	-18	-49	13
FC	DCW71	-41	-85	1	-7	-32	24
FC	TDC414	-503	-716	-312	-85	-105	-69
FC	TDC457	-295	-481	-111	-36	-92	4
FC	TDC470	-101	-208	-22	-12	-32	12
FC	TDC505	49	-13	114	9	1	18

Type	Substation	Demand Savings (kW)	Demand Savings Lower 90% CI	Demand Savings Upper 90% CI	Summer Peak Demand Savings (kW)	Summer Peak Demand Savings Lower 90% CI	Summer Peak Demand Savings Upper 90% CI
FC	TDC549	388	248	586	33	19	50
FC	TSS118	-183	-312	-96	-37	-49	-20
FC	TSS134	83	-42	200	-24	-35	-14
FC	TSS48	71	-27	154	-14	-47	7
FC	TSS55	-42	-151	54	0	-23	21
FC	TSS78	-114	-231	-11	-39	-52	-16
VO	DCC80	1	-6	6	19	3	34
VO	DCD114	-8	-17	-2	-5	-27	21
VO	DCD16	36	16	54	50	11	90
VO	DCD242	0	-8	8	6	-10	17
VO	DCD351	-6	-25	8	-11	-37	13
VO	DCD46	19	-5	42	38	-7	67
VO	DCD63	6	-20	32	1	-31	20
VO	DCD69	-4	-18	11	-12	-28	9
VO	DCD80	-16	-31	-1	-43	-96	2
VO	DCE28	68	34	102	52	30	69
VO	DCE59	139	76	199	170	108	246
VO	DCE72	3	-13	24	0	-35	33
VO	DCG99	6	-10	23	11	-33	51
VO	DCS48	77	42	107	58	35	90
VO	DCW202	-13	-24	0	-1	-21	30
VO	DCW216	-8	-22	8	-18	-49	1
VO	DCW236	81	32	119	57	31	103
VO	DCW28	26	12	41	37	-4	82
VO	DCW29	26	8	51	32	11	48
VO	DCW30	27	14	44	33	21	51
VO	DCW31	11	-11	27	20	0	49

Type	Substation	Demand Savings (kW)	Demand Savings Lower 90% CI	Demand Savings Upper 90% CI	Summer Peak Demand Savings (kW)	Summer Peak Demand Savings Lower 90% CI	Summer Peak Demand Savings Upper 90% CI
VO	DCW343	3	-6	12	5	-14	19
VO	DCW346	22	8	40	54	17	107
VO	DCW348	8	-44	39	-19	-115	51
VO	DCW354	13	1	28	48	19	79
VO	DCW51	13	-12	30	8	-45	50
VO	DCW71	-30	-61	-5	-29	-82	14
VO	TDC414	270	193	353	68	55	86
VO	TDC457	169	88	230	43	25	63
VO	TDC470	268	217	319	81	60	106
VO	TDC505	680	619	755	80	70	91
VO	TDC549	312	208	438	49	30	65
VO	TSS118	554	450	666	48	25	73
VO	TSS134	791	655	932	113	85	149
VO	TSS48	261	226	298	71	61	83
VO	TSS55	228	124	341	27	9	57
VO	TSS78	371	326	435	44	33	55
FC+VO	DCC80	-3	-87	66	-48	-162	49
FC+VO	DCD114	4	-23	26	12	-39	56
FC+VO	DCD16	5	-78	72	-113	-260	9
FC+VO	DCD242	58	25	107	91	35	151
FC+VO	DCD351	12	-2	29	13	-43	45
FC+VO	DCD46	3	-39	53	-17	-111	77
FC+VO	DCD63	299	113	449	6	-101	115
FC+VO	DCD69	82	41	146	167	76	330
FC+VO	DCD80	23	-4	46	94	39	151
FC+VO	DCE28	-21	-141	140	-116	-207	-22
FC+VO	DCE59	-47	-94	23	-113	-208	-2

Type	Substation	Demand Savings (kW)	Demand Savings Lower 90% CI	Demand Savings Upper 90% CI	Summer Peak Demand Savings (kW)	Summer Peak Demand Savings Lower 90% CI	Summer Peak Demand Savings Upper 90% CI
FC+VO	DCE72	13	-16	37	67	-24	239
FC+VO	DCG99	-59	-124	29	-94	-177	-4
FC+VO	DCS48	248	203	295	142	96	177
FC+VO	DCW202	-10	-30	9	8	-35	71
FC+VO	DCW216	-35	-60	-1	-113	-229	-13
FC+VO	DCW236	108	22	192	71	15	148
FC+VO	DCW28	-22	-73	31	-86	-189	40
FC+VO	DCW29	-342	-597	-110	-260	-439	-129
FC+VO	DCW30	-126	-215	-53	-94	-159	-28
FC+VO	DCW31	-15	-84	44	-12	-49	29
FC+VO	DCW343	57	39	86	92	46	143
FC+VO	DCW346	44	8	88	142	61	226
FC+VO	DCW348	-9	-78	46	-71	-166	18
FC+VO	DCW354	10	-4	27	28	-14	76
FC+VO	DCW51	-22	-70	27	-10	-70	67
FC+VO	DCW71	-71	-145	-16	-36	-90	36
FC+VO	TDC414	-233	-405	-5	-18	-39	4
FC+VO	TDC457	-126	-327	69	7	-37	49
FC+VO	TDC470	166	94	271	68	44	86
FC+VO	TDC505	729	660	797	89	69	108
FC+VO	TDC549	700	488	920	83	64	101
FC+VO	TSS118	371	223	505	12	-20	41
FC+VO	TSS134	874	723	1,006	89	44	132
FC+VO	TSS48	332	229	423	56	34	75
FC+VO	TSS55	186	67	300	27	2	57
FC+VO	TSS78	257	112	350	6	-17	25

Source: ComEd tracking data and Navigant team analysis.

10. Appendix 4. Total Resource Cost Detail

Table 10-1, below, shows the Total Resource Cost (TRC) table. It includes only the cost-effectiveness analysis inputs available at the time of finalizing this impact evaluation 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 later.

Table 10-1. Total Resource Cost Savings Summary

End Use Type	Research Category	Ex Ante Gross Savings (kWh)	Verified Gross Realization Rate	Verified Gross Savings (kWh)	NTG*	Verified Net Savings (kWh)	Effective Useful Life
N/A	VO	99,381,000	0.39	38,581,268	NA	38,581,268	15.0

Source: ComEd tracking data and Navigant team analysis.