Opinion Dynamics

Boston | Headquarters

617 492 1400 tel
617 497 7944 fax
800 966 1254 toll free

1000 Winter St
Waltham, MA 02451

Ameren Illinois Company 2022 Voltage Optimization Program Impact Evaluation Report

Final
April 21, 2023

Table of Contents

Table of Tables

Table of Equations

1. Executive Summary

This report presents the impact evaluation results from Ameren Illinois Company's (AIC) Voltage Optimization (VO) Program implemented during 2022. The objective of the 2022 impact evaluation was to determine energy and peak demand savings associated with the VO Program in 2022 as well as to verify continued operation of voltage optimization for a sample of previously evaluated circuits.

1.1 Background

VO is a form of energy efficiency technology implemented by electric utilities at the distribution substation or circuit level that optimizes voltage levels along distribution circuits to reduce electricity usage. AIC's VO Program implements hardware, software, and communications solutions using VO technologies. There are two main VO technologies used: Volt-VAR Optimization (VVO) and Conservation Voltage Reduction (CVR). VVO improves the power factor to reduce line losses, and CVR reduces customer energy consumption by reducing line voltage. Once implemented, VO technologies are intended to operate 24 hours a day, 365 days a year. This report discusses the investigation and analysis of circuits that are integrated with VO technology, and these will herein be referred to as "circuits."

By 2024, AIC anticipates deploying VO technology on 1,047 circuits.[1] Prior to the program launch, AIC identified multiple technology upgrades required to deploy the VO Program successfully. In 2017, AIC began installing VO hardware, software, and communications components on a subset of the 1,047 eligible circuits on a phased basis.[2] As defined in the AIC Voltage Optimization Plan,[3] AIC claims savings only for circuits that are operational during a full calendar year. Therefore, 2022 represents the fourth full calendar year in which AIC is claiming energy savings for the program.

In 2022, evaluation activities included estimating energy and peak demand savings from 181 circuits that were deployed in 2021, as well as verifying the continued operation of circuits previously evaluated in 2019, 2020, and 2021 (19, 125, and 180 circuits respectively).

[1] The number of circuits planned for VO deployment was determined based on calculated assumptions, industry results, and past AIC VO pilot results. The actual number of circuits with VO could fluctuate based on deployment results.

[2] AIC staff used voltage level as the primary criteria for establishing the initial pool of potential candidate circuits and excluded circuits served by voltage levels > 20 kilovolt (kV) or that serve only customers exempt at the time of this determination (a customer whose highest 15-minute demand is ≥ 10 MW). In addition, only circuits that were estimated to be cost-effective based on a TRC test were deemed eligible.

[3] Ameren Illinois Voltage Optimization Plan, filed in ICC Docket 18-0211 on January 25, 2018. Accessed at: https://www.icc.illinois.gov/downloads/public/edocket/463457.pdf.

1.2 2022 Voltage Optimization Program Savings

1.2.1 Annual Savings

The evaluation team estimated energy and peak demand savings for the 181 circuits that became operational in 2022. Overall, the 2022 VO Program achieved 86,892 MWh of verified net energy savings and 13.52 MW of verified net peak demand savings (Table 1).

Table 1. 2022 VO Program Annual Savings

	Energy Savings (MWh)	Demand Savings (MW)	Gas Savings (Therms)
Ex Ante Gross Savings	74,590[a]	N/A[b]	N/A
Gross Realization Rate	116%	N/A	N/A
Verified Gross Savings	86,892	13.52	N/A
NTGR	N/A	N/A	N/A
Verified Net Savings	86,892	13.52	N/A

[a] Ex ante gross savings sourced from AIC. Ex ante gross savings assume 0.80 CVR factor and 3.2% voltage reduction across the 181 measured circuits.
[b] There are no ex ante demand savings estimates for this program.

1.2.2 Cumulative Persisting Annual Savings

Table 2 summarizes cumulative persisting annual savings (CPAS) and the weighted average measure life (WAML) for the 2022 VO Program. The overall WAML for the VO Program is 15 years. For additional detail around CPAS and measure life, please see Appendix B of this report.

Table 2. 2022 VO Program CPAS and WAML

Evaluation Measure Category	Measure Life	First-Year Verified Gross Savings (MWh)	NTGR	CPAS - Verified Net Savings (MWh)							Lifetime Savings (MWh)
				2022	2023	2024	2025	...	2030	...	
Voltage Optimization – 2022 Cohort	15.0	86,892	N/A	86,892	86,892	86,892	86,892	...	86,892	...	1,303,386
2022 CPAS		**86,892**	**N/A**	**86,892**	**86,892**	**86,892**	**86,892**	**...**	**86,892**	**...**	**1,303,386**
Expiring 2022 CPAS				**0**	**0**	**0**	**0**	**0**	**0**	**...**	
Expired 2022 CPAS				**0**	**0**	**0**	**0**	**0**	**0**	**...**	
WAML	**15.0**										

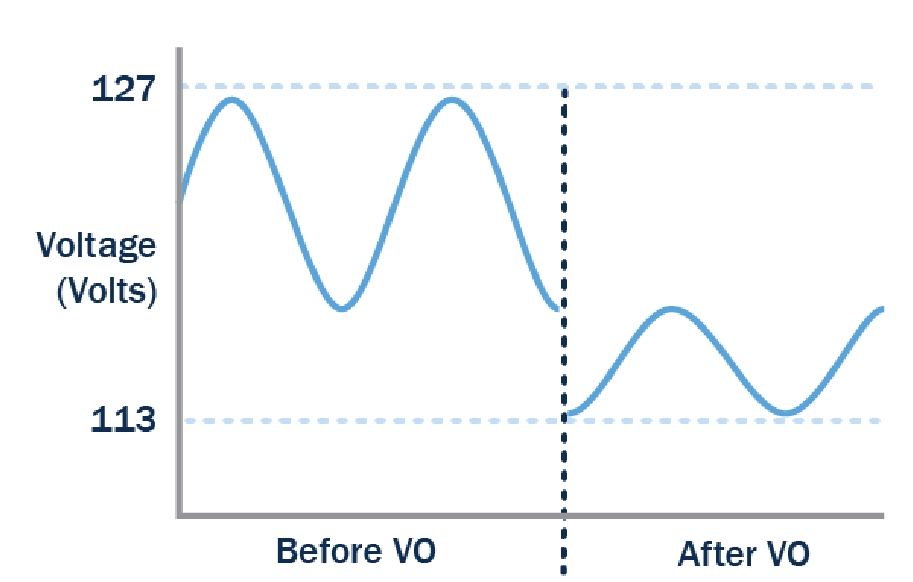
2. Overview of Voltage Optimization Program

Illinois state law[4] defines voltage optimization as an energy efficiency measure and allows AIC to make a cost-effective voltage optimization investment as part of its energy efficiency portfolio.

2.1 Background

VO is a form of energy efficiency technology implemented by electric utilities at the distribution substation or circuit level. VO optimizes voltage levels along distribution circuits to reduce electricity usage by reducing power consumed by connected loads. AIC defines VO as a combination of VVO and CVR, which are implemented first to reduce the reactive power flows on a circuit,[5] and then to lower the voltage to reduce end-use customer energy consumption and utility distribution system losses. VVO optimizes capacitor bank[6] operations to improve power factor[7] and reduce system losses. CVR utilizes voltage regulators, transformer load tap changers, and capacitors to control and reduce end-user voltages, which, in turn, lowers customers' energy consumption. In other words, these technologies reduce distribution line voltage by regulating voltage in the lower portion of the allowable range. Historically, utilities have regulated voltage in the upper portion of the range to avoid low-voltage violations. Regulating voltage in the lower portion of the range does not compromise power quality. At lower voltage due to VO technologies (Figure 1), most end-uses use less energy.

Figure 1. Illustration of VO Effect on Voltage



VO technologies can operate 24 hours a day, 365 days a year. Energy savings are predominantly driven through end-use load reduction and, to a lesser extent, distribution line loss reductions. AIC's VO Program was developed to provide energy savings, not peak demand savings. However, there will naturally be some demand reduction on some circuits during the hours of operation of the system in a given year.

[4] Specifically, 220 ILCS 5/8-103B(b-20).
[5] Reactive power is measured in Volt-Amperes Reactive (VAR).
[6] Capacitor banks are groupings of several capacitors and are used to store or condition electricity (e.g., by correcting power factor).
[7] Power factor is the ratio of working power (kW) to apparent power (kVA). Higher power factors indicate higher efficiency.

2.2 Program Description

In order to comply with Illinois state law and to achieve energy savings that support its energy efficiency portfolio goals, AIC developed the VO Program as described in the Ameren Illinois Voltage Optimization Plan.[8] Per the Plan, AIC anticipates deploying VO on all circuits for which VO is estimated to be cost-effective by 2024. Based on calculated assumptions, industry results, and past AIC VO pilot results, AIC anticipates deploying VO on a total of 1,047 circuits by 2024. The actual number of circuits with VO could fluctuate based on deployment results.

Before the program launch, AIC identified multiple technology upgrades required to deploy VO. In 2017, AIC began installing VO hardware, software, and communications components on a subset of the 1,047 eligible circuits on a phased basis using four different VO vendor solutions: Utilidata, DVI, OSI, and ABB.[9] AIC staff used voltage level as the primary criteria for establishing the initial pool of potential candidate circuits and excluded circuits served by voltage levels >20 kilovolt (kV) and circuits that at the time served only customers exempt under Illinois state law (customers whose highest 15-minute demand is greater than or equal to 10 MW).[10]

Table 3 provides AIC's original implementation plan and savings estimates for the VO Program.

Table 3. Original VO Implementation Plan

Year Ending	2018	2019	2020	2021	2022	2023	2024	2025
Estimated Cumulative Persisting Annual Savings (MWh)	0	7,650	59,994	128,433	201,725	275,006	348,287	421,568
% Annual Cumulative Persisting Savings	0%	0.03%	0.21%	0.46%	0.72%	0.98%	1.25%	1.50%
Estimated Incremental # of Circuits Deployed	19	130	170	182	182	182	182	0
Estimated Incremental Construction Cost (Capital Cost)	$2M	$14M	$18M	$19M	$19M	$19M	$19M	$0
Estimated Incremental Total Investment Cost (Construction Capital, Construction O&M, Upfront Capital)	$5M	$17M	$20M	$20M	$20M	$20M	$20M	$0

Source: Ameren Illinois Voltage Optimization Plan.

VO is a major part of AIC's 2022–2025 energy efficiency plan. Per AIC's most recent filing,[11] VO was expected to produce 73,292 MWh in energy savings in 2022, about 16% of AIC's estimated 2022 portfolio energy savings goal. In 2021, AIC completed deployment of VO technology to 181 circuits that were then evaluated as part of the 2022 program year. These circuits delivered VO benefits to an estimated 55,623 low-income customers. For a detailed list of circuits evaluated in 2022, see Appendix A to this document.

[8] Ameren Illinois Voltage Optimization Plan, filed in ICC Docket 18-0211 on January 25, 2018. Accessed at: https://www.icc.illinois.gov/downloads/public/edocket/463457.pdf
[9] AIC has now selected a primary vendor, and remaining circuit construction is proceeding with only one solution.
[10] Note that as a result of the Climate and Equitable Jobs Act, customers with >10MW demand are no longer automatically exempt.
[11] Appendix F to AIC's 2022–2025 EE Plan. Accessed at: https://www.icc.illinois.gov/docket/P2021-0158/documents/322771/files/561827.pdf

3. Voltage Optimization Evaluation Approach

3.1 Evaluation Research Objectives

The 2022 VO evaluation approach was primarily governed by the Illinois Technical Reference Manual for Energy Efficiency (IL-TRM) Version 10.0,[12] which prescribes the use of an algorithmic approach to estimating electric energy and peak demand savings from VO activities. In addition to the IL-TRM, we leveraged a previously agreed-upon methodology and approach to verifying the continued operation of previously installed circuits during 2022.[13]

In this report, the VO evaluation team addresses the following key research questions:

- What are the estimated energy savings from VO?
- What are the estimated peak demand savings from VO?
- Did 10 sampled circuits from 2019, 20 sampled circuits from 2020, and 29 sampled circuits from 2021 operate over a 90% threshold in 2022?

3.2 Verified Impact Analysis Approach

As described in Section 3.1, the 2022 VO evaluation approach estimated annual energy savings and peak demand savings resulting from the VO Program. The 2022 evaluation estimated energy and peak demand savings for the 181 circuits that were operational as of January 1, 2022.

3.2.1 Energy Savings Methodology

The IL-TRM requires the use of an algorithmic approach to evaluating VO energy savings. The algorithmic approach combines deemed parameter values with measured reductions in voltage to calculate energy savings. The algorithm used for AIC's VO Program energy savings evaluation is shown in Equation 1.

Equation 1. AIC VO Energy Savings Algorithm

$$Annual\ Energy\ Savings_i = Annual\ Energy\ Use_{2014-2016_i} * CVR_f * \%\Delta V_i$$

where

- $Annual\ Energy\ Use_{2014-2016_i}$ = the average annual customer energy use for circuit *i* over the 2014–2016 timeframe, excluding exempt customers;
- CVR_f = the estimate of the conservation voltage reduction factor (deemed as 0.80), defined as the percent change in energy usage divided by the percent change in voltage; and,
- $\%\Delta V_i$ = the percent change in voltage for circuit *i* resulting from VO implementation relative to the pre-period, using a regression model to control for exogenous factors that may contribute to changes in voltage (e.g., weather).

[12] Illinois Statewide Technical Reference Manual for Energy Efficiency Version 10.0, Volume 4, Cross-Cutting Measures and Attachments, Measure 6.2.1. Accessed at: https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010122_v10.0_Vol_4_X-Cutting_Measures_and_Attach_09242021.pdf

[13] Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach Memo, accessed at: https://www.ilsag.info/wp-content/uploads/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf

3.2.2 Peak Demand Savings Methodology

Peak demand savings were also estimated with an algorithmic approach. The peak period is defined as 1:00 p.m. – 5:00 p.m. (CDT) on non-holiday weekdays from June 1 – August 31.[14] The algorithm used for AIC's VO peak demand savings program evaluation is shown in Equation 2.

Equation 2. AIC VO Peak Demand Savings Algorithm

$$Peak\ Demand\ Savings_i = Avg\ Peak\ Demand_{2014-2016_{i,PEAK}} * CVR_{f,PEAK} * \%\Delta V_{i,PEAK}$$

where

- $Avg\ Peak\ Demand_{2014-2016_{i,PEAK}}$ = the average demand in the peak hour for circuit *i* over the 2014–2016 timeframe during the peak period adjusted by a calibration factor that captures the relationship between peak demand and average demand in the peak period, excluding >10 MW customers;
- $CVR_{f,PEAK}$ = the estimate of the peak conservation voltage reduction factor (deemed as 0.68), defined as the percent change in energy usage divided by the percent change in voltage during the peak period; and,
- $\%\Delta V_{i,PEAK}$ = the percent change in voltage for circuit *i* resulting from VO implementation relative to the peak hours of the pre-period, using a regression model to control for exogenous factors that may contribute to changes in voltage (e.g., weather). Per the guidance in the IL-TRM, this is to be calculated in the same manner as energy savings but with the intention of measuring peak demand savings rather than total energy savings.

3.2.3 Verification of Continued Operation

The IL-TRM V10.0 deems VO savings for 15 years[15] after completion of the initial evaluation of a circuit, and no retroactive changes can subsequently be made to deemed savings.[16] Therefore, in the Illinois evaluation framework, impact evaluation for VO does not require retroactive or ongoing verification.

Nevertheless, in 2020, Opinion Dynamics, AIC, and Illinois Commerce Commission (ICC) Staff agreed that ongoing verification of VO should be conducted for process purposes to provide information to stakeholders and other parties as to the level of continued VO operation and, if needed, to provide context as to why VO may not have operated continuously. After the evaluation of each year of circuits, all parties agreed that Opinion Dynamics would conduct verification activities to assess the degree to which VO continued to operate throughout each year. The acceptable uptime threshold of operation was set to ensure that circuits operated over a 90% threshold.[17]

[14] Illinois Technical Reference Manual for Energy Efficiency, Version 10.0, Volume 1, Section 3.7.
[15] Note that the approved IL-TRM V11.0, nominally in effect beginning in 2023, outlines a process through which the measure life for VO, including circuits that have already been evaluated and had savings claimed, can be "extended." AIC and its evaluator will revisit past circuits at the expiration of their existing measure life, beginning in the 2034 program year.
[16] Illinois Energy Efficiency Policy Manual Version 2.1, Section 11.2. Accessed at: https://www.ilsag.info/wp-content/uploads/IL_EE_Policy_Manual_Version_2.1_Final_12-7-2021-1.pdf
[17] Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach Memo, accessed at: https://www.ilsag.info/wp-content/uploads/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf

As part of the 2022 evaluation, Opinion Dynamics conducted ongoing verification of circuits evaluated in 2019, 2020, and 2021. To determine whether these circuits operated at or over the target 90% uptime threshold during 2021, the evaluation team conducted the following analytical activities:

- Selected a random sample of 10 of the 19 circuits evaluated in 2019, 20 of the 125 circuits evaluated in 2020, and 29 of the 180 circuits evaluated in 2021;
- Requested operation log summaries for the sample of circuits. Our variable of interest for this effort included the VO status (e.g., "On/Off") for specific hours throughout 2022 at a circuit level;
- Removed excludable events;[18] and,
- Divided the total number of hours in which the status logs indicated that VO was 'On' by the total number of non-excludable hours in the year.

3.2.4 Consideration of Voltage Optimization Net Effects

Because AIC is the sole operator and "participant" in the VO Program, no adjustments to savings are made to reflect net effects (free-ridership and spillover) that are often present for other, more traditional energy efficiency programs.

3.3 Sources and Mitigation of Error

Because the evaluation team relied on regression models to estimate the change in voltage and peak demand, there is some uncertainty to be expected in the model-produced estimates. The team therefore designed analyses to address the following types of errors:

- **Model Specification Error:** The most difficult type of modeling error, in terms of bias and the ability to mitigate it, is specification error. In this type of error, variables that predict model outcomes are included when they should not be, or excluded when they should not be, with the potential of producing biased estimates. The team addressed this type of error by carefully examining the model diagnostics and goodness-of-fit statistics of the data variables.
- **Measurement Errors:** Measurement error can come from variables such as weather data, which are commonly included in consumption analysis models. If an inefficient base temperature is chosen for calculating degree-days or an incorrect climate zone weather station is chosen, the model results could be subject to measurement error. The evaluation team mitigated this type of error by meticulously choosing the closest weather station for each circuit in the model to ensure the most accurate weather data was used in the model. Specifying an incorrect time period (either VO "On" or VO "Off") can also lead to measurement error. Our team worked extensively with AIC to ensure that all data anomalies were discussed and addressed where possible.
- **Multi-collinearity**: This type of modeling error can both bias and produce substantial variances in the results. The team dealt with this type of error by using evaluation model diagnostics, though the models used in the impact analysis are unlikely to have problems with multi-collinearity.
- **Heteroskedasticity:** This type of modeling error can result in imprecise model results due to variance changing across circuits with different levels of consumption. The team addressed this type of error by using robust standard errors. Most statistical packages offer a robust standard error option and make

[18] For the rationale behind and definition of excludable events, please see the IL-TRM Voltage Optimization measure: Illinois Statewide Technical Reference Manual for Energy Efficiency Version 10.0, Volume 4 Cross-Cutting Measures and Attachments, Measure 6.2.1. Accessed at: https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010122_v10.0_Vol_4_X-Cutting_Measures_and_Attach_09242021.pdf

conservative assumptions in calculating the errors, which has the additional beneficial effect of making significance tests conservative as well.

4. 2022 Voltage Optimization Program Verified Savings

In this section, we present the results of the impact evaluation of the 2022 VO Program. Additional details on the impact analysis methodology used for this evaluation are presented herein in Appendix B.

4.1 Annual Savings Summary

The 2022 VO Program achieved 86,892 MWh of verified net energy savings and 13.52 MW of verified net peak demand savings. Table 4 presents the 2022 VO Program annual energy and peak demand savings. Detailed results by circuit are also available in Appendix B.

Table 4. 2022 VO Program Annual Savings

	Energy Savings (MWh)	Peak Demand Savings (MW)	Gas Savings (Therms)
Ex Ante Gross Savings	74,590[a]	N/A[b]	N/A
Gross Realization Rate	116%	N/A	N/A
Verified Gross Savings	86,892	13.52	N/A
NTGR	N/A	N/A	N/A
Verified Net Savings	86,892	13.52	N/A

[a] Ex ante gross savings sourced from AIC. Ex ante gross savings assume 0.80 CVR factor and 3.2% voltage reduction across the 181 measured circuits.
[b] There are no ex ante demand savings estimates for this program.

Factors driving program performance include the following:

- The VO Program exceeded its ex ante gross energy savings due to larger estimated percent changes in voltage than assumed values (3.20% ex ante compared to 3.73% verified average).
- The greater changes in voltage resulted in greater than expected energy savings and a gross realization rate of 116%.

4.1.1 Detailed Energy Savings

Table 5 presents the average energy savings impacts across the 181 circuits. Savings were calculated using the annual energy savings algorithm, which includes average annual customer energy use over the 2014–2016 timeframe, excluding exempt customers, CVR_f,[19] and percent change in voltage resulting from VO implementation relative to the baseline. We used a regression model to estimate a percent change in voltage for each circuit and applied that to the assumed baseline and CVR_f for each circuit. Table 5 summarizes the total results across all 181 circuits (see Appendix B for circuit-level percent change in voltage results).

[19] The estimate of the conservation voltage reduction factor, CVR_f, which represents the percent change in load for each percent change in voltage.

Table 5. Ex Ante and Verified Algorithmic Inputs and Associated Energy Savings

Metric	Annual Gross Energy Use (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
Ex Ante[a]	2,913,670	0.80	3.20%	74,590
Verified	2,913,670	0.80	3.73%	86,892
Realization Rate	100%	100%	116%	116%

[a] Ex ante gross savings sourced from AIC. Ex ante gross savings assumes 0.80 CVR factor and 3.2% voltage reduction across the 181 measured circuits.

4.1.2 Detailed Peak Demand Savings

We estimated peak demand savings using an individual regression analysis approach for each circuit given variability of load across circuits. The percent voltage reduction for each circuit was multiplied by the peak period CVR_f of 0.68 (deemed) and the annual peak demand baseline value (measured in MW). The resulting annual demand savings were summed across circuits to determine the total peak demand reduction of 13.52 MW. The average percent change in voltage during peak demand periods was 2.74%, as shown in Table 6. AIC does not report ex ante demand savings, and therefore there are no ex ante savings or realization rates reported.

Table 6. Verified Algorithmic Inputs and Associated Demand Savings

Metric	Peak Demand (MW)	CVR_f	Average Percent Change in Voltage	Peak Demand Savings (MW)
Verified	726.52[a]	0.68	2.74%	13.52

[a] Note that annual peak demand baseline usage was not provided for two of the 181 circuits analyzed, as discussed below in the second bullet. For these circuits, we imputed annual peak demand baseline usage using a model for completeness.

For three circuits, some information required for the simple algorithmic estimation of demand savings was missing. For these circuits, we made imputations to estimate demand savings as detailed below:

- For circuit Q23256, an excludable event (Repair/Maintenance) occurred in summer 2022 that excluded the entire 2022 peak period. As a result, the circuit did not reduce voltage during the peak period in 2022, and we therefore could not estimate the circuit's peak voltage reduction due to VO. However, the concept of excludable events is that these events are not expected to reoccur in future years, and therefore, assigning a peak voltage reduction value of 0% to this circuit does not appropriately represent expected behavior over the remaining life of the circuit. To address this, we imputed an estimated peak voltage reduction value for this circuit (3.43%), using a linear regression the relationship between the full-year savings and peak savings from the rest of the circuits (n=180).
- For circuits R41131 and R49265, we were able to estimate voltage reductions during the summer 2022 peak period, but AIC was not able to provide annual peak demand baseline usage. We therefore chose to impute the annual peak demand baseline values for these circuits (3.52 MW and 0.49 MW, respectively) using the linear relationship observed between the annual baseline energy usage and annual baseline peak demand for the rest of the circuits (n=179).

For one circuit, we did not estimate demand savings for the following reason:

- For circuit D72003, our modeled estimate of peak voltage reduction results (-0.01%) was not statistically significant. We report the change in voltage in Appendix B, but set peak demand savings to zero.

4.2 Cumulative Persisting Annual Savings

Table 7 presents CPAS and WAML for the 2022 Voltage Optimization Program. The total verified gross savings for the Program are summarized, and CPAS in 2022–2025 and 2030 are presented.[20] The WAML for the Program is 15 years.

Table 7. 2022 VO Program CPAS and WAML

Evaluation Measure Category	Measure Life	First-Year Verified Gross Savings (MWh)	NTGR	CPAS - Verified Net Savings (MWh)							Lifetime Savings (MWh)
				2022	2023	2024	2025	…	2030	…	
Voltage Optimization – 2022 Cohort	15.0	86,892	N/A	86,892	86,892	86,892	86,892	…	86,892	…	1,303,386
2022 CPAS		**86,892**	**N/A**	**86,892**	**86,892**	**86,892**	**86,892**	**…**	**86,892**	**…**	**1,303,386**
Expiring 2022 CPAS				**0**	**0**	**0**	**0**	**0**	**0**	**…**	
Expired 2022 CPAS				**0**	**0**	**0**	**0**	**0**	**0**	**…**	
WAML	**15.0**										

[20] For further details, including achieved CPAS in years not presented in this table, please see Appendix C of this report.

4.3 Verification of Continued Operations

As discussed in Section 3.2.3, we analyzed status logs for a randomly selected sample of previously implemented circuits to verify continued VO operation. In 2022, we sampled 10 circuits from the 2019 VO cohort, 20 circuits from the 2020 VO cohort, and 29 circuits from the 2021 VO cohort for verification. Per the terms of the verification agreement, detailed further in Section 3.2.3, we set an threshold of operation of 90% of non-excludable hours.

Our analysis found that all of the sampled 2019 and 2021 circuits were “On” for more than 90% of non-excludable hours in 2022. Nineteen of the 20 sampled 2020 circuits were “On” for more than 90% of non-excludable hours in 2022.

Circuit J99121, drawn as part of the sample of 2020 circuits for verification, was found to operate for 89.6% of non-excludable hours during 2022 and therefore did not meet the 90% operational threshold.

It is important to note that in 2020, the year circuit J99121 was evaluated for impact purposes, the circuit was found to operate for 91.4% of non-excludable hours. Because of how our impact evaluation approach works for VO, this means that impact estimates deemed for the life of the circuit already reflect that the circuit functions at less than 100% uptime. Therefore, this verification finding suggests only a very small differential between the conditions under which the circuit was initially evaluated and for which savings were deemed (91.4% uptime) and 2022 operating conditions (89.6% uptime). Nevertheless, we report this finding in alignment with the previously agreed upon verification approach for the VO Program.

Detailed reporting on the 2022 operation of circuit J99121 is provided in Table 8 below.

Table 8. Detailed Verification Information for Circuit J99121

Circuit	VO On Hours	VO Off Hours (Excludable)	VO Off Hours (Non-Excludable)	Hours in Year	VO Uptime[a]
J99121 (2020 Cohort)	7,125	788	826	8,760	89.6%

[a] Calculated as VO “On” hours in 2022 divided by non-excludable hours in 2022.

Note: Values are rounded to the closest hour and therefore may not sum or calculate as expected.

Detailed examination of the status logs for J99121 revealed 19 separate events in 2022 where VO shut off on this circuit, 14 of which were not excludable. Additional detail on these events is provided below:

- Two major events occurred causing approximately 618 hours of combined non-excludable VO downtime (~75% of total non-excludable downtime). Explanatory notes on both events indicate that the events were caused by loss of communication to the VO hardware.
  - A significant outage occurred January 9 through January 23, 2022, causing approximately 322 hours of non-excludable VO downtime.
  - A second significant outage occurred May 14 through May 26, 2022, causing approximately 296 hours of non-excludable VO downtime.
- Twelve events of 60 hours or less caused remaining non-excludable outages of approximately 209 hours (~25% of total non-excludable downtime).
  - Ten events distributed throughout the year, totaling approximately 147 hours, were caused by loss of communication to the VO hardware.
  - From May 1 to May 3, disaster recovery testing caused approximately 56 hours of non-excludable VO downtime.

    - On June 21, non-excludable VO system upgrades caused approximately 6 hours of non-excludable VO downtime.
- Five events, totaling approximately 788 hours, were excludable per IL-TRM definitions:
    - An unknown technology event causing the VO system to crash occurred in late January 2022, causing a roughly 65 hour excludable off period.
    - A repair/maintenance event occurred in late May through early June 2022, causing a roughly 264 hour excludable off period.
    - A system-wide technology upgrade in late June through early July 2022 caused a roughly 73 hour excludable off period.
    - A system-wide technology upgrade in November 2022 caused a roughly 300 hour excludable off period.
    - A system-wide technology upgrade in December 2022 caused a roughly 86 hour excludable off period.

More information on the verification approach can be found in Appendix D.

5. Conclusions and Recommendations

Based on the results of this evaluation, Opinion Dynamics offers the following key findings and recommendations for AIC's VO Program moving forward:

- **Key Finding #1:** The VO Program continues to provide a substantial amount of energy savings to the AIC portfolio and exceed AIC's initial expectations for achieved savings.
- **Key Finding #2:** Average percent changes in voltage due to VO were 16% higher than planning values but have substantial variation across circuits (0.64%–5.46% average change in voltage). For 139 of the 181 circuits, the percent change in voltage was estimated to be larger than the planning value of 3.2%.
  - Recommendation: Consider further updates to planning values to reflect the percent change in voltage derived from evaluated values. AIC updated the planning value from 3.0% to 3.2% in 2022, which better aligns with evaluation findings to date, but the planning value continues to significantly understate verified results. Updating the planning value could also support a more accurate assessment of the ex ante cost effectiveness for each circuit screened for inclusion in the program.
- **Key Finding #3:** One sampled circuit from the 2020 evaluation cohort was found to not meet the 90% uptime threshold of VO uptime set for retrospective VO verification. This is the first retrospective evaluation finding of a circuit operating below this threshold since the inception of the VO Program. However, verification results show a very small differential between the previously evaluated operation of the circuit and the 2022 verification results. In addition, all other analyzed circuits operated above the 90% threshold, which continues to suggest to us that the approach of prospectively deeming VO savings is likely to closely represent actual achieved energy savings over time.

Appendix A. 2022 Voltage Optimization Circuit Summary

Table 9 presents detailed characteristics for circuits evaluated in 2022. This table includes the substation and circuit name for each circuit as well as various circuit characteristics that may, potentially, affect voltage reductions. Because AIC prioritized low-income customers as part of its VO deployment,[21] we also note the number of low-income customers estimated to be served by each circuit evaluated in 2022.

Table 9. 2022 Evaluated VO Circuits

Circuit	Substation	Line Length (Miles)	% Res.	% Comm.	% Large C&I	Voltage Level (kV)	Low-Income Customers
340100	ALBY 1	7.9	96.3%	3.5%	0.3%	*	154
340101	ALBY 1	7.1	90.2%	9.5%	0.3%	4.16	297
340102	ALBY 1	3.4	94.2%	5.8%	0.0%	*	99
A26005	CORRINGTON 1	6.1	92.8%	6.9%	0.3%	7.62	330
A26006	CORRINGTON 1	7.6	97.6%	2.2%	0.2%	7.62	553
A36001	EUREKA 1	17.7	88.1%	11.5%	0.4%	7.62	436
A36002	EUREKA 1	35.3	90.1%	9.6%	0.3%	7.62	328
A45001	OZARK 1	22.4	90.9%	8.6%	0.5%	7.62	291
A45002	OZARK 1	35.1	89.9%	10.0%	0.2%	7.62	346
A45003	OZARK 1	89.0	95.3%	4.7%	0.1%	7.62	312
A48001	NEW YORK 1	0.8	0.0%	0.0%	100.0%	7.62	0
A48002	NEW YORK 1	4.0	94.7%	4.9%	0.4%	7.62	243
A48004	NEW YORK 1	5.1	86.6%	13.1%	0.3%	7.62	310
A48005	NEW YORK 1	7.8	95.1%	4.8%	0.2%	7.62	591
A56013	MEYER 1	12.3	92.6%	7.3%	0.1%	7.62	808
A56014	MEYER 1	7.5	72.2%	27.4%	0.4%	7.62	299
A56015	MEYER 1	5.1	88.9%	11.1%	0.0%	7.62	340
A56017	MEYER 1	8.2	68.2%	30.9%	0.9%	7.62	291
B10001	CRUGER 1	63.0	86.8%	12.9%	0.3%	7.62	233
B19001	LOGAN 1	29.7	92.1%	7.6%	0.3%	7.62	242
B19002	LOGAN 1	157.4	90.2%	9.8%	0.1%	7.62	502
B45002	Grandview 1	3.0	15.4%	69.2%	15.4%	7.62	2
B45003	Grandview 1	7.5	86.0%	13.1%	0.9%	7.62	356
B45004	Grandview 2	7.2	90.2%	9.3%	0.4%	7.62	328
B45005	Grandview 1	29.6	90.2%	9.0%	0.9%	7.62	583
B57001	COURT 1	10.2	85.5%	14.4%	0.1%	7.62	603
B57002	COURT 1	10.7	87.1%	12.4%	0.5%	7.62	405
B57003	COURT 1	6.7	72.3%	25.0%	2.7%	7.62	161
B68001	KICKAPOO 1	9.8	42.0%	54.2%	3.8%	7.20	40
B68002	KICKAPOO 1	47.0	90.4%	9.3%	0.3%	7.20	449
B68003	KICKAPOO 1	48.9	82.8%	16.2%	1.1%	7.20	74

[21] Ameren Illinois Voltage Optimization Low Income Prioritization Strategy, February 2019. Accessed at: https://www.ilsag.info/wp-content/uploads/SAG_files/Energy_Efficiency_Dockets/AIC_VO_Low_Income_Prioritization_Strategy_February_2019_FINAL.pdf

Circuit	Substation	Line Length (Miles)	% Res.	% Comm.	% Large C&I	Voltage Level (kV)	Low-Income Customers
B68004	KICKAPOO 1	14.7	90.7%	9.0%	0.2%	7.20	613
B73002	LINBERG 1	97.2	88.8%	10.8%	0.4%	7.62	277
B77001	NEBRASKA 1	13.9	93.4%	6.5%	0.1%	7.62	448
B77003	NEBRASKA 2	21.2	87.3%	12.7%	0.0%	7.62	530
B82001	STARK 1	65.7	84.4%	15.2%	0.4%	7.20	366
C37001	BISSELL 1	24.6	57.2%	41.6%	1.2%	7.20	143
C37002	BISSELL 1	15.8	82.2%	15.8%	2.0%	7.20	87
D28124	WASHBURN 1	150.3	83.4%	16.1%	0.4%	7.62	279
D72001	HARMON 1	7.0	86.1%	13.7%	0.2%	7.62	259
D72002	HARMON 1	23.4	86.5%	13.0%	0.5%	7.62	223
D72003	HARMON 1	18.7	91.6%	7.8%	0.5%	7.62	484
D96001	SALEM 1	49.1	87.7%	12.3%	0.1%	7.62	455
F22001	SIDNEY 1	40.4	89.7%	10.1%	0.2%	7.20	301
G30001	EMDEN 1	75.5	81.7%	17.6%	0.6%	7.20	197
H14342	WOOD RIVER BEN BOW 1	6.6	93.0%	7.0%	0.0%	7.20	412
H14343	WOOD RIVER BEN BOW 1	7.9	68.4%	31.0%	0.5%	7.20	191
H88101	JACKSONVILLE ANNA ST NEW 3	7.1	79.2%	20.5%	0.3%	7.20	344
H88109	JACKSONVILLE ANNA ST NEW 3	5.2	66.6%	32.6%	0.8%	7.20	141
HB6251	RICHLAND CREEK SUB 1	29.6	93.0%	6.8%	0.2%	7.20	171
HB6283	RICHLAND CREEK SUB 2	23.8	88.0%	12.0%	0.0%	7.20	333
HD5252	BELLEVILLE NEW WEST HAVEN 1	1.9	0.0%	70.6%	29.4%	7.20	0
HD5254	BELLEVILLE NEW WEST HAVEN 1	25.8	93.2%	6.7%	0.1%	7.20	459
HF7109	MT VERNON FAIRFIELD RD SUB 1	23.2	88.5%	11.5%	0.0%	7.20	385
J50185	BLOOMINGTON G. E. ROAD 1	6.0	60.0%	39.0%	1.0%	7.20	98
J50186	BLOOMINGTON G. E. ROAD 1	7.8	84.7%	15.0%	0.3%	7.20	195
J56341	BLOOMINGTON LINDEN ST 1	10.4	94.9%	5.1%	0.0%	7.20	239
J56342	BLOOMINGTON LINDEN ST 2	9.5	89.3%	10.3%	0.3%	7.20	305
J75272	BONDVILLE ROUTE 10 3	33.0	87.4%	12.5%	0.1%	7.20	368
J76804	BRIGHTON 1	37.6	90.8%	9.1%	0.1%	7.20	451
J76805	BRIGHTON 1	12.2	89.3%	10.7%	0.0%	*	31
J83138	BELLEVILLE 44TH ST 3	18.6	87.1%	12.2%	0.7%	7.20	311
J85160	BELLEVILLE 74TH ST 1	7.3	88.1%	10.9%	1.0%	7.20	292
J85161	BELLEVILLE 74TH ST 1	22.5	90.2%	9.7%	0.1%	7.20	416
K09863	CARLINVILLE 3	17.8	81.5%	17.6%	0.9%	7.20	420
K09864	CARLINVILLE 3	83.7	86.6%	12.9%	0.5%	7.20	430
K25164	CENTRALIA MITCHELL RD 2	2.7	63.3%	34.7%	2.0%	7.20	5
K25166	CENTRALIA MITCHELL RD 2	12.2	85.1%	14.5%	0.5%	7.20	388
K46389	COLLINSVILLE CLOVERLEAF 2	21.9	86.5%	13.2%	0.3%	7.20	469
K46422	COLLINSVILLE CLOVERLEAF 2	15.3	97.3%	2.7%	0.0%	7.20	218
K69116	CHAMPAIGN BRADLEY 1	11.6	70.9%	28.5%	0.6%	7.20	357
K73361	CHAMPAIGN LEVERETT RD 1	10.6	79.8%	19.4%	0.9%	7.20	502
K73362	CHAMPAIGN LEVERETT RD 1	4.1	82.2%	16.5%	1.3%	7.20	130

Circuit	Substation	Line Length (Miles)	% Res.	% Comm.	% Large C&I	Voltage Level (kV)	Low-Income Customers
K73365	CHAMPAIGN LEVERETT RD 2	6.4	74.7%	24.7%	0.7%	7.20	168
K73366	CHAMPAIGN LEVERETT RD 2	10.7	90.5%	8.9%	0.5%	7.20	209
K80381	CHAMPAIGN WINDSOR ROAD 1	23.7	92.6%	7.2%	0.2%	7.20	370
K80382	CHAMPAIGN WINDSOR ROAD 1	15.2	93.1%	6.8%	0.1%	7.20	336
K80386	CHAMPAIGN WINDSOR ROAD 2	12.8	95.9%	4.0%	0.1%	7.20	190
K80388	CHAMPAIGN WINDSOR ROAD 2	13.7	87.1%	12.4%	0.5%	7.20	375
K89143	DECATUR BALTIMORE AVE 2	46.5	89.3%	10.6%	0.1%	7.20	467
L00133	DECATUR GREENSWITCH ROAD 1	22.0	86.7%	13.0%	0.3%	7.20	291
L00134	DECATUR GREENSWITCH ROAD 1	12.0	93.3%	6.7%	0.0%	7.20	556
L59933	DUQUOIN 2	44.5	79.9%	19.7%	0.4%	7.20	352
L74191	DANVILLE HAZEL ST 1	11.1	81.5%	18.1%	0.5%	7.20	218
L74194	DANVILLE HAZEL ST 1	1.3	0.0%	94.0%	6.0%	7.20	0
L95110	EAST DECATUR 2	12.3	93.7%	6.2%	0.1%	7.20	506
M04364	EDWARDSVILLE SCHWARZ STREET 2	20.6	86.2%	13.6%	0.2%	7.20	322
M04365	EDWARDSVILLE SCHWARZ STREET 2	26.4	95.9%	4.0%	0.2%	7.20	287
M26161	FORSYTH 2	53.7	82.9%	16.5%	0.7%	7.20	317
M37191	GALESBURG IRWIN ST 1	38.9	93.2%	6.7%	0.1%	7.20	619
M37192	GALESBURG IRWIN ST 1	16.6	90.1%	9.6%	0.4%	7.20	624
M40116	GALESBURG MONMOUTH BLVD 2	10.5	79.3%	20.5%	0.1%	7.20	439
M40117	GALESBURG MONMOUTH BLVD 2	11.0	79.4%	19.5%	1.1%	7.20	252
M40132	GALESBURG MONMOUTH BLVD 1	58.7	91.1%	8.1%	0.8%	7.20	598
M73328	GRANITE CITY KATE STREET 2	4.2	93.0%	6.5%	0.5%	4.16	209
M81402	GRANITE CITY PARKVIEW 2	14.7	89.8%	10.1%	0.1%	7.20	317
M81404	GRANITE CITY PARKVIEW 2	6.3	95.0%	4.8%	0.2%	*	187
M83327	GRANITE CITY PONTOON ROAD 1	5.1	89.5%	10.5%	0.0%	7.20	182
N05172	GRANVILLE 1	126.1	83.3%	16.4%	0.3%	7.20	451
N05173	GRANVILLE 1	19.4	85.8%	12.7%	1.5%	7.20	176
N18210	GRIDLEY 1	18.9	86.1%	13.2%	0.7%	7.20	190
N18211	GRIDLEY 1	94.3	81.8%	17.7%	0.5%	7.20	237
N50331	JACKSONVILLE POWER PLANT 3	58.4	87.1%	12.8%	0.1%	7.20	857
N50332	JACKSONVILLE POWER PLANT 3	20.8	93.8%	6.0%	0.3%	7.20	228
N50333	JACKSONVILLE POWER PLANT 2	44.7	80.7%	18.4%	0.9%	7.20	175
N50334	JACKSONVILLE POWER PLANT 2	11.8	85.2%	14.6%	0.2%	7.20	318
N67309	KEWANEE NORTH MAIN ST 1	74.9	82.0%	17.4%	0.5%	7.20	327
N67310	KEWANEE NORTH MAIN ST 1	9.1	86.1%	13.6%	0.3%	7.20	402
N74230	LASALLE 5	5.5	93.1%	6.9%	0.0%	4.16	528
P20930	MARISSA 1	55.8	80.9%	18.4%	0.7%	7.20	325
P26280	MARSEILLES 1	60.8	85.7%	14.3%	0.0%	7.20	494
P42229	MILLSTADT 1	20.0	90.9%	8.9%	0.3%	7.20	217
P42230	MILLSTADT 1	38.7	88.3%	11.6%	0.1%	7.20	451
P60170	MT VERNON BROWNSVILLE ROAD 1	47.4	76.2%	23.5%	0.4%	7.20	372
P69174	MT ZION RTE 121 1	67.7	88.5%	11.1%	0.4%	7.20	411

Circuit	Substation	Line Length (Miles)	% Res.	% Comm.	% Large C&I	Voltage Level (kV)	Low-Income Customers
P69175	MT ZION RTE 121 2	45.3	91.7%	8.2%	0.1%	7.20	500
Q04410	NORMAL WHITE OAK ROAD 1	8.3	90.2%	9.6%	0.2%	7.20	178
Q04411	NORMAL WHITE OAK ROAD 1	17.8	93.8%	6.1%	0.1%	7.20	496
Q06131	NORTH CHAMPAIGN 5	10.0	74.2%	25.1%	0.6%	7.20	363
Q06142	NORTH CHAMPAIGN 6	12.7	68.8%	27.1%	4.1%	7.20	143
Q23255	O FALLON SEVEN HILLS ROAD 1	26.0	74.5%	25.0%	0.4%	7.20	127
Q23256	O FALLON SEVEN HILLS ROAD 1	14.6	91.6%	8.1%	0.3%	7.20	439
Q23258	O FALLON SEVEN HILLS ROAD 1	24.2	96.9%	2.6%	0.4%	7.20	103
R28870	STAUNTON SPRING STREET 1	11.6	88.3%	11.7%	0.0%	7.20	391
R28871	STAUNTON SPRING STREET 1	14.0	91.9%	7.9%	0.2%	7.20	397
R41131	TEXAS 1	75.7	84.3%	15.6%	0.1%	7.20	297
R49261	TRENTON 2	24.8	87.0%	12.6%	0.4%	7.20	334
R49265	TRENTON 2	2.4	100.0%	0.0%	0.0%	*	1
R49275	TRENTON 1	61.0	91.5%	8.4%	0.1%	7.20	448
R65451	URBANA SOUTH ORCHARD 2	17.2	91.7%	7.8%	0.5%	7.20	355
R65452	URBANA SOUTH ORCHARD 1	9.5	85.2%	14.5%	0.3%	7.20	563
S07536	BENTON, OIL FIELD 1	17.6	87.0%	13.0%	0.0%	7.20	395
S14510	CARBONDALE,PL HILL RD 1	5.1	90.9%	8.8%	0.3%	7.20	229
S15558	CARBONDALE,WALL ST 1	6.0	87.4%	12.6%	0.0%	7.20	408
S15559	CARBONDALE,WALL ST 1	7.1	77.1%	22.7%	0.2%	7.20	356
S22595	CARTERVILLE 1	16.2	94.4%	5.5%	0.1%	7.20	340
S30518	DESOTO 1	21.0	89.9%	10.1%	0.0%	7.20	418
S42579	HARRISBURG NORTH 1	25.4	90.9%	8.9%	0.3%	7.20	320
S61530	MARION 1	8.9	92.9%	7.0%	0.1%	7.20	344
S61531	MARION 1	21.1	89.7%	10.1%	0.2%	7.20	271
S66593	MARION,W 2	6.9	38.1%	61.9%	0.0%	7.20	60
S66594	MARION,W 2	5.8	85.1%	14.2%	0.7%	7.20	122
S88502	MURPHYSBORO,NW 1	20.3	90.8%	9.1%	0.1%	7.20	433
T05539	VIENNA 1	21.2	75.1%	24.5%	0.4%	7.20	364
T06505	WEST FRANKFORT 1	30.0	87.7%	11.7%	0.6%	7.20	348
T08501	WEST FRANKFORT IDA 1	17.9	89.2%	10.5%	0.4%	7.20	442
T29560	ILLINOIS CENTRE MALL SUB. 1	2.7	0.0%	40.0%	60.0%	7.20	0
T29561	ILLINOIS CENTRE MALL SUB. 1	17.2	83.1%	16.5%	0.4%	7.20	122
T29562	ILLINOIS CENTRE MALL SUB. 2	4.2	50.7%	39.4%	9.9%	7.20	12
U37579	CARTHAGE 1	43.4	77.3%	22.5%	0.2%	7.20	252
U68581	HAVANA 2	26.1	79.8%	20.2%	0.0%	7.20	295
U84566	JERSEYVILLE,W 3	31.1	94.0%	5.9%	0.1%	7.20	336
U84587	JERSEYVILLE,W 2	36.8	90.9%	8.2%	0.9%	7.20	351
V01001	MARBLEHEAD,N 3	5.9	31.4%	56.9%	11.8%	7.20	8
V01002	MARBLEHEAD,N 3	20.7	92.2%	6.9%	0.9%	7.20	231
V20502	PAYSON,S 1	58.2	86.5%	13.1%	0.4%	7.20	309
V24583	PLEASANT HILL 1	25.0	81.7%	18.2%	0.1%	7.20	403

2022 Voltage Optimization Circuit Summary

Circuit	Substation	Line Length (Miles)	% Res.	% Comm.	% Large C&I	Voltage Level (kV)	Low-Income Customers
V46552	QUINCY,42&COLUMBUS 1	10.5	52.5%	45.1%	2.4%	7.20	25
V46563	QUINCY,42&COLUMBUS 1	16.5	93.5%	6.1%	0.5%	7.20	250
V58507	ROSEVILLE,N 1	29.0	82.0%	17.6%	0.5%	7.20	269
V80506	WHITE HALL 1	22.9	89.1%	10.7%	0.2%	7.20	383
X09534	ARCOLA,N 1	26.9	85.0%	14.3%	0.7%	7.20	256
X09557	ARCOLA,N 1	18.0	82.3%	17.1%	0.6%	7.20	240
X66582	FARINA 1	27.7	83.8%	15.7%	0.5%	7.20	356
X96524	LAWRENCEVILLE,S 3	25.6	86.7%	12.6%	0.7%	7.20	266
X96543	LAWRENCEVILLE,S 3	39.5	79.2%	20.5%	0.3%	7.20	300
Y07575	MATTOON 3	7.0	98.7%	1.0%	0.3%	7.20	402
Y07576	MATTOON 3	40.0	92.2%	7.5%	0.2%	7.20	244
Y20522	MILFORD 1	47.1	84.3%	15.4%	0.4%	7.20	357
Y37592	OLNEY,S 1	21.0	91.2%	8.7%	0.1%	7.20	364
Y51505	PARIS HIGH ST 1	29.0	82.3%	17.0%	0.7%	7.20	254
Y51506	PARIS HIGH ST 1	30.0	88.8%	10.8%	0.4%	7.20	313
Y68581	ROSSVILLE,S 1	34.2	84.3%	15.2%	0.5%	7.20	213
Y73504	SAVOY 1	21.8	91.5%	8.4%	0.1%	7.20	241
Y73505	SAVOY 1	12.6	95.7%	4.3%	0.1%	7.20	365
Y93544	TAYLORVILLE, W 4	10.1	77.5%	22.0%	0.5%	7.20	278
Z04520	VILLA GROVE 1	26.2	89.1%	10.7%	0.1%	7.20	283
Z29579	ROSSVILLE,E 1	29.4	85.3%	14.6%	0.1%	7.20	323
Z41528	TEUTOPOLIS,WEST 1	22.1	75.5%	22.7%	1.8%	7.20	57
Z41536	TEUTOPOLIS,WEST 1	3.3	3.3%	90.0%	6.7%	7.20	0
Z50544	ARCOLA, EAST 1	3.9	3.7%	88.9%	7.4%	7.20	1

Source: AIC

Appendix B. Detailed Impact Analysis Methodology

Data Ingestion and Review

Opinion Dynamics used the following data to perform the energy and peak demand savings evaluation: (1) advanced metering infrastructure (AMI) data extracts; (2) VO status and operations logs; (3) circuit characteristics; and (4) hourly weather data.

- **AMI data extracts.** AIC provided Opinion Dynamics with AMI data containing hourly demand (kWh), instantaneous voltage, and average instantaneous voltage at four different base voltages. AMI data is the preferred source for all evaluations in Illinois and measures consumption at the customer meter rather than the circuit level. Because there may be over 1,000 AMI meters on a given circuit, AIC provided average normalized voltage and kWh data. For a given circuit, the AMI data reflects normalized voltage based on the voltage class (e.g., 120V, 240V, 480V) where each AMI meter was located on the circuit.
- **System operations log.** This log contains the VO "on" and "off" schedule, as well as information on critical system operation events that could cause data anomalies such as outages. AIC provided this log with a summary tab containing VO status events (VO "on" and VO "off"), timestamps for the events, and notes on the cause of the event. Within the system operations log, the evaluation team flagged certain time frames as excludable, adhering to guidance in the IL-TRM V10.0.
- **Circuit characteristics.** AIC provided Opinion Dynamics a number of datasets with descriptive circuit characteristic information, including data presented in Appendix A as well as baseline usage information.
- **Hourly weather data.** The evaluation team sourced weather data from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information, which were mapped to circuits using GPS coordinates. We then calculated the cooling and heating degree hours, using base temperatures of 75°F and 65°F[22], respectively, to generate the weather parameters used in modeling.

Energy Savings

Data Cleaning

To support the 2022 impact evaluation, we cleaned provided data to meet analytical needs. 2022 VO data was provided by AIC in increments during the year to support interim impact analyses. As such, before we took further data cleaning steps, we had to aggregate incrementally provided VO data together. During this aggregation, we took two steps to prepare data:

- **Remove duplicate observations:** Observations with duplicated values across all variables (e.g. perfect overlaps between data files) were flagged and removed from the analysis.
- **Aggregate remaining duplicate observations:** After removing perfect duplicates, a small number of observations remained with duplicate timestamps by circuit but different voltage data. In this case, we averaged observations to arrive at a dataset with a unique set of timestamps by circuit. This affected 0.4% of records.

[22] These base temperatures are commonly used in the industry.

Once data were aggregated, we conducted the following data cleaning steps prior to modeling:

- **Remove time periods without weather data:** As previously noted, we downloaded weather data from NOAA. We used circuit longitude and latitude to find the weather station closest to each circuit's location. For instances where weather data for a particular weather station was not recorded, we removed the corresponding time periods from the analysis.
- **Remove negative and zero values:** Negative and zero values in kV and MW data were flagged and removed from use in the analysis.
- **Remove outliers:** Outliers were screened on a circuit-by-circuit basis. Outliers are defined as hourly values that are greater than three times the standard deviation from the mean kV or MW for that specific circuit. All identified kV and MW outliers were flagged and removed from the analysis.
- **Flag excludable time periods:** In some circumstances, it is best practice or required to disable VO to support system changes, growth, outages, and maintenance, both planned and unplanned. AIC has indicated that a subset of VO events should be excluded in this analysis. In 2020, Opinion Dynamics, ICC Staff, and stakeholders reached agreement on specific VO events that could be considered excludable, and memorialized them in a memo.[23] VO events that were approved for exclusion were those for which (1) there was a circuit outage for any reason; (2) the circuit was under repair or maintenance, causing VO to be disabled; (3) VO was disabled due to any necessary switching event; (4) the circuit had experienced a failure in information or communication technology; and (5) any event was flagged for the worldwide pandemic or outages ordered by civil authorities. This information has now been memorialized in IL-TRM V10.0.
- **Remove "On" events in pre-period:** To construct a pre-period, "On" events were flagged and removed in 2021.

Table 10 provides a summary of the second stage of data cleaning for this analysis. Results include all 181 circuits within the analysis. The primary driver for removing observations were occurrences when VO was turned "Off" for an excludable event (3.6% of total observations), followed by occurrences where VO was turned "On" in the pre-period (0.6% of total observations). Overall, after data cleaning activity, 4.7% of observations were dropped. It should be noted that no circuits were removed from the energy savings analysis due to data insufficiency.

Table 10. Summary of Data Cleaning Results for 2022 VO Energy Savings Impacts

Step	Circuits	Records	Change	% Change
Initial Count	181	3,141,876	N/A	N/A
Time Periods Without Weather Data	181	3,126,476	15,400	0.5%
kV Less Than or Equal to 0	181	3,124,953	1,523	<0.1%
Outliers	181	3,124,914	39	<0.1%
On in Pre-Period	181	3,104,926	19,988	0.6%
Excludable Time Periods	181	2,986,523	118,403	3.6%
Final	**181**	**2,986,523**	**155,353**	**4.7%**

[23] Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach Memo, accessed at: https://www.ilsag.info/wp-content/uploads/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf

Modeling Percent Change in Voltage for Energy Savings

To develop a pre-period baseline for this evaluation, the evaluation team removed VO "On" periods in 2021. As a result, the baseline includes VO "Off" periods only. The post-period of interest is 2022, where all circuits are active. The post-period consists of largely "On" periods, as well non-excludable "Off" periods. The evaluation team used this structure to fit individual models on each circuit.

To estimate changes in voltage, we used a regression model described in Equation 3.

Equation 3. Voltage Reduction Model

$$kV_{it} = \alpha + \beta_1 Post_t + \beta_2 cdh_t + \beta_3 hdh_t + \beta_4 Weekend_t + \beta_5 Post_t * cdh_t + \beta_6 Post_t * hdh_t + \beta_7 Post_t * Weekend_t + \varepsilon_{it}$$

where

- kV_{it} = Kilovolts for circuit *i* at time *t*
- α = model intercept
- β_x = coefficients
- $Post_t$ = set of indicator variables on circuit *i* at time t for the time relative to VO deployment where the circuit is in the post-period (Post = 1) or in the pre-period (Post = 0)
- cdh_t = the number of cooling degree-hours at time *t*
- hdh_t = the number of heating degree-hours at time *t*
- $Weekend_t$ = indicator variable for weekend (weekend = 1) or weekday (weekend = 0)
- ε_{it} = error term

Calculating Annual Energy Savings

The IL-TRM V10.0 prescribes an algorithmic approach to evaluating VO energy savings. The algorithmic approach combines deemed parameter values with measured savings in voltage to calculate energy savings. Since we apply the estimated change in voltage to the circuit-level annual usage, the results are effectively annualized for the entire year.

The algorithm used for the VO energy savings evaluation is shown in Equation 4.

Equation 4. AIC VO Energy Savings Algorithm

$$Annual\ Energy\ Savings_i = Annual\ Energy\ Use_{2014-2016_i} * CVR_f * \%\Delta V_i$$

where

- $Annual\ Energy\ Use_{2014-2016_i}$ = the average annual customer energy use for circuit *i* over the 2014–2016 timeframe, excluding >10MW customers;
- CVR_f = the estimate of the conservation voltage reduction factor (deemed as 0.80), defined as the percent change in energy usage divided by the percent change in voltage; and,
- $\%\Delta V_i$ = the percent change in voltage for circuit *i* resulting from VO implementation relative to the pre-period, using a regression model to control for exogenous factors that may contribute to changes in voltage (e.g., weather).

Detailed Circuit Results: Energy Savings

Table 11 provides each algorithmic input by circuit as well as the total estimated savings per circuit that can be attributed to the VO Program. For 139 of the 181 circuits, the percent change in voltage was estimated to be larger than the planned value of 3.2%. The overall average percent change in voltage was 3.73%.[24]

Table 11. Verified Algorithmic Inputs and Associated Energy Savings by Circuit

Circuit	Annual Gross Energy Use (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
340100	8,708.33	0.80	1.66%	115.51
340101	9,342.76	0.80	2.73%	204.26
340102	2,625.00	0.80	0.64%	13.38
A26005	8,197.37	0.80	3.95%	258.97
A26006	10,346.95	0.80	3.79%	313.63
A36001	17,868.63	0.80	4.10%	585.68
A36002	16,477.83	0.80	4.73%	622.96
A45001	23,581.13	0.80	2.70%	508.66
A45002	17,639.27	0.80	2.84%	401.45
A45003	24,401.83	0.80	3.20%	624.64
A48001	18,782.18	0.80	3.26%	490.28
A48002	5,455.25	0.80	2.81%	122.78
A48004	11,113.31	0.80	2.80%	248.73
A48005	14,056.04	0.80	2.73%	306.59
A56013	13,158.05	0.80	2.75%	289.40
A56014	9,873.36	0.80	2.79%	220.32
A56015	4,419.97	0.80	2.81%	99.40
A56017	13,767.77	0.80	2.85%	314.25
B10001	19,387.65	0.80	3.51%	543.66
B19001	10,229.82	0.80	2.97%	243.44
B19002	29,475.55	0.80	3.42%	806.04
B45002	16,272.70	0.80	1.83%	238.86
B45003	19,159.90	0.80	2.35%	360.26
B45004	15,768.91	0.80	2.29%	289.48
B45005	29,005.31	0.80	3.46%	802.20
B57001	16,953.25	0.80	2.91%	394.63
B57002	19,979.01	0.80	2.94%	470.20
B57003	2,918.13	0.80	2.93%	68.30
B68001	24,487.09	0.80	0.92%	179.38
B68002	25,035.26	0.80	1.46%	291.47
B68003	25,298.31	0.80	1.63%	329.30
B68004	20,002.61	0.80	0.95%	152.24
B73002	18,384.20	0.80	3.75%	550.82
B77001	9,611.96	0.80	4.67%	359.03

[24] Average percent change in voltage is weighted by annual gross energy use (MWh).

Circuit	Annual Gross Energy Use (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
B77003	17,087.27	0.80	3.45%	471.73
B82001	18,306.20	0.80	3.95%	578.19
C37001	9,878.15	0.80	3.83%	302.96
C37002	19,034.68	0.80	4.18%	636.40
D28124	12,625.94	0.80	2.18%	219.88
D72001	8,172.33	0.80	3.26%	213.25
D72002	21,243.02	0.80	3.32%	564.75
D72003	18,980.61	0.80	3.04%	462.17
D96001	20,033.62	0.80	4.01%	643.19
F22001	18,578.31	0.80	4.85%	720.41
G30001	10,400.49	0.80	2.69%	223.59
H14342	9,111.59	0.80	4.46%	325.20
H14343	12,246.37	0.80	2.79%	273.71
H88101	11,148.80	0.80	3.40%	302.91
H88109	12,277.59	0.80	4.01%	393.98
HB6251	10,578.37	0.80	3.93%	332.90
HB6283	16,490.31	0.80	3.22%	424.96
HD5252	7,237.55	0.80	3.67%	212.40
HD5254	15,058.50	0.80	3.91%	471.50
HF7109	18,634.89	0.80	4.14%	617.78
J50185	33,966.25	0.80	4.74%	1,288.57
J50186	23,198.20	0.80	4.38%	813.60
J56341	9,868.65	0.80	4.52%	356.97
J56342	18,908.31	0.80	4.35%	657.46
J75272	25,390.04	0.80	4.34%	882.16
J76804	20,054.06	0.80	3.82%	612.77
J76805	1,458.33	0.80	3.78%	44.14
J83138	20,974.34	0.80	3.58%	600.12
J85160	15,401.11	0.80	4.74%	584.32
J85161	13,715.17	0.80	4.25%	466.59
K09863	29,149.92	0.80	4.42%	1,030.40
K09864	23,013.69	0.80	4.00%	736.18
K25164	12,912.14	0.80	4.76%	491.99
K25166	14,558.40	0.80	3.86%	449.51
K46389	26,378.43	0.80	3.80%	802.43
K46422	7,883.50	0.80	3.44%	217.22
K69116	34,916.73	0.80	3.40%	951.01
K73361	37,404.24	0.80	3.35%	1,001.45
K73362	10,135.85	0.80	4.52%	366.37
K73365	22,294.05	0.80	4.80%	855.94
K73366	26,640.62	0.80	4.59%	978.22
K80381	23,780.81	0.80	5.01%	953.85

Circuit	Annual Gross Energy Use (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
K80382	15,153.98	0.80	4.85%	588.55
K80386	12,598.43	0.80	4.38%	441.15
K80388	36,668.38	0.80	1.48%	433.24
K89143	19,279.64	0.80	4.14%	637.99
L00133	11,319.09	0.80	4.79%	434.14
L00134	9,181.99	0.80	4.84%	355.25
L59933	19,899.78	0.80	4.56%	725.46
L74191	9,533.44	0.80	3.66%	278.88
L74194	9,002.25	0.80	5.44%	392.08
L95110	10,305.89	0.80	4.21%	346.81
M04364	17,537.02	0.80	4.02%	563.61
M04365	18,102.97	0.80	3.63%	525.62
M26161	37,667.32	0.80	4.63%	1,393.85
M37191	19,270.07	0.80	4.22%	650.30
M37192	21,624.51	0.80	3.38%	584.31
M40116	18,879.96	0.80	4.08%	615.67
M40117	14,499.70	0.80	1.66%	192.05
M40132	33,380.23	0.80	3.86%	1,031.16
M73328	9,919.75	0.80	3.66%	290.59
M81402	14,775.45	0.80	3.51%	414.50
M81404	7,166.67	0.80	3.40%	194.75
M83327	11,282.43	0.80	4.18%	376.98
N05172	17,547.97	0.80	4.13%	579.29
N05173	14,874.62	0.80	4.66%	554.80
N18210	24,660.22	0.80	4.10%	809.44
N18211	23,172.05	0.80	3.88%	719.05
N50331	23,677.78	0.80	4.12%	780.72
N50332	11,513.07	0.80	4.46%	410.76
N50333	18,596.71	0.80	4.62%	687.05
N50334	27,936.41	0.80	4.28%	956.83
N67309	16,942.08	0.80	3.57%	483.42
N67310	10,348.92	0.80	4.65%	385.11
N74230	10,585.80	0.80	3.43%	290.82
P20930	14,898.33	0.80	4.08%	486.57
P26280	17,674.48	0.80	4.26%	601.69
P42229	13,033.34	0.80	4.26%	444.64
P42230	20,414.21	0.80	3.85%	629.18
P60170	15,233.70	0.80	3.89%	473.85
P69174	24,741.88	0.80	3.91%	773.60
P69175	28,318.33	0.80	4.42%	1,001.96
Q04410	9,127.65	0.80	4.43%	323.39
Q04411	17,941.49	0.80	3.48%	498.89

Circuit	Annual Gross Energy Use (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
Q06131	18,528.98	0.80	4.30%	637.15
Q06142	30,787.80	0.80	2.55%	629.08
Q23255	9,968.66	0.80	4.70%	374.78
Q23256	20,840.52	0.80	4.31%	718.65
Q23258	18,395.94	0.80	2.85%	420.11
R28870	12,623.30	0.80	3.17%	319.97
R28871	17,898.83	0.80	3.08%	440.81
R41131	13,970.08	0.80	4.37%	488.63
R49261	22,429.43	0.80	4.32%	775.20
R49265	125.00	0.80	5.28%	5.28
R49275	25,795.94	0.80	3.18%	656.20
R65451	14,816.68	0.80	4.29%	508.17
R65452	20,317.69	0.80	5.08%	826.45
S07536	15,528.55	0.80	4.59%	569.93
S14510	10,233.20	0.80	4.96%	405.82
S15558	8,081.62	0.80	3.80%	245.70
S15559	10,279.93	0.80	2.29%	188.70
S22595	14,624.85	0.80	4.46%	521.63
S30518	11,398.60	0.80	3.78%	344.26
S42579	14,906.25	0.80	4.47%	532.71
S61530	13,702.89	0.80	1.52%	166.21
S61531	19,019.03	0.80	3.68%	559.97
S66593	13,241.83	0.80	4.99%	528.49
S66594	9,814.40	0.80	4.66%	365.89
S88502	13,902.79	0.80	4.76%	529.53
T05539	16,418.02	0.80	2.76%	362.22
T06505	14,824.97	0.80	4.77%	566.22
T08501	14,402.04	0.80	2.90%	333.98
T29560	10,291.78	0.80	5.46%	449.54
T29561	12,990.17	0.80	4.25%	442.16
T29562	30,656.59	0.80	4.67%	1,145.73
U37579	9,610.57	0.80	3.93%	301.87
U68581	9,052.60	0.80	3.90%	282.41
U84566	17,586.95	0.80	3.97%	558.73
U84587	26,094.88	0.80	4.11%	858.91
V01001	13,782.81	0.80	4.50%	496.20
V01002	13,257.66	0.80	4.01%	425.20
V20502	11,060.15	0.80	3.74%	330.63
V24583	8,954.48	0.80	4.13%	295.63
V46552	21,846.03	0.80	2.66%	464.56
V46563	15,628.09	0.80	4.35%	543.88
V58507	9,455.06	0.80	3.54%	267.75

Circuit	Annual Gross Energy Use (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
V80506	9,044.77	0.80	4.69%	339.17
X09534	14,439.50	0.80	3.55%	410.31
X09557	13,180.60	0.80	3.43%	362.19
X66582	10,117.77	0.80	4.29%	347.42
X96524	14,587.61	0.80	3.33%	388.96
X96543	12,448.09	0.80	3.53%	351.80
Y07575	9,702.60	0.80	3.11%	241.02
Y07576	16,511.20	0.80	4.52%	597.07
Y20522	11,780.76	0.80	3.97%	374.30
Y37592	9,735.18	0.80	4.45%	346.40
Y51505	12,721.30	0.80	3.16%	321.28
Y51506	15,249.14	0.80	3.27%	398.78
Y68581	11,716.90	0.80	3.72%	348.26
Y73504	12,023.45	0.80	4.49%	431.55
Y73505	12,450.60	0.80	4.20%	418.25
Y93544	15,811.12	0.80	3.92%	495.68
Z04520	10,935.35	0.80	3.60%	314.85
Z29579	10,473.89	0.80	4.14%	347.18
Z41528	19,162.37	0.80	4.47%	685.05
Z41536	16,869.27	0.80	3.69%	497.95
Z50544	8,362.99	0.80	4.16%	278.62
Total	**2,913,670.17**	**0.80**	**3.73%**	**86,892.37**

The approach we used to calculate energy savings for AIC's VO Program is designed to be the most rigorous possible with the data available. We employed regression analysis controlling for exogenous factors, such as weather, as documented in the evaluation plan. To validate the model, we evaluated a range of model specifications and selected the best fit determined by model diagnostics (R^2 and adjusted R^2). A detailed binder, provided upon request, details the coefficient estimates and model fit statistics for each circuit-level model. All modeled circuit results were statistically significant at the 90% confidence level.

Measure Life and Cumulative Persisting Annual Savings

The statutorily-defined measure life of 15 years was applied for this measure.[25]

[25] 220 ILCS 5/8-103B(b-20).

Peak Demand Savings

Data Cleaning

Data cleaning for the peak demand analysis included all of the steps undertaken for the energy savings model, plus the following additional cleaning steps:

- **Peak Period Data Only:** The VO peak demand model includes only observations during the peak period, defined as the hours of 1:00 p.m.–5:00 p.m. (CDT) on non-holiday weekdays between June and August.
- **Less than 20 Days in Peak Period:** Circuits with less than 20 days in the peak period were removed from the analysis.
- **Missing Peak Period:** Circuits missing the 2021 or 2022 peak period were removed from the analysis. This affected circuit Q23256, as its 2022 peak period was dropped due to an excludable "Off" event.

Table 12 provides a summary of the data cleaning results for this analysis. After subsetting on the peak demand period, the data cleaning reduced the total number of observations by 15.08%.

Table 12. Summary of Data Cleaning Results for Peak Demand Savings

Step	Circuits	Records	Change	% Change
Initial Count	181	2,986,523	N/A	N/A
Peak Days	181	541,368	2,445,155	81.9%
Less than 20 Days in Peak Period	181	541,013	355	<0.1%
Missing Peak Period	180	539,433	1,580	0.1%
Peak Hours	180	89,185	450,248	15.1%
Total	**180**	**89,185**	**2,897,338**	**97.0%**

Modeling Percent Change in Voltage for Demand Savings

To develop a baseline, the evaluation team applied the cleaned data used for annual impacts and subset to the peak period. Individual models were run by circuit, and savings were aggregated similar to the annual savings, taking into account the peak CVR_f and the annual peak demand (MW). As with the energy savings model, the demand savings model uses 2021 as the pre-period. The model is run only on peak hours within the summer peak period subset.

To estimate changes in voltage, we used a regression model described in Equation 5.

Equation 5. Voltage Reduction Model

$$kV_{it} = \alpha + \beta_1 Post_t + \beta_2 cdh_t + \beta_3 Post_t * cdh_t + \varepsilon_{it}$$

where

- kV_{it} = Kilovolts for circuit *i* at time *t*
- α = model intercept
- β_x = coefficients
- $Post_t$ = set of indicator variables on circuit *i* at time t for the time relative to VO deployment where the circuit is in the post-period (Post=1) or in the pre-period (Post=0)

- cdh_t = the number of cooling degree-hours at time *t*
- ε_{it} = error term

Calculating Peak Demand Savings

VO peak demand savings are also estimated with an algorithmic approach. The peak period is defined as 1:00 p.m.–5:00 p.m. (CDT) on non-holiday weekdays from June 1–August 31.[26]

The algorithm used for the VO peak demand evaluation is shown in Equation 6.

Equation 6. AIC VO Peak Demand Savings Algorithm

$$Peak\ Demand\ Savings_i = Avg\ Peak\ Demand_{2014-2016_{i,PEAK}} * CVR_{f,PEAK} * \%\Delta V_{i,PEAK}$$

where

- $Avg\ Peak\ Demand_{2014-2016_{i,PEAK}}$ = the demand in the peak hour for circuit *i* over the 2014–2016 timeframe during the peak period adjusted by a calibration factor that captures the relationship between peak demand and average demand in the peak period, excluding >10 MW customers;[27]
- $CVR_{f,PEAK}$ = the estimate of the peak conservation voltage reduction factor (deemed as 0.68), defined as the percent change in energy usage divided by the percent change in voltage during the peak period; and,
- $\%\Delta V_{i,PEAK}$ = the percent change in voltage for circuit *i* resulting from VO implementation relative to the peak hours of the pre-period, using a regression model to control for exogenous factors that may contribute to changes in voltage (e.g., weather). Per the guidance in the IL-TRM, this is to be calculated in the same manner as energy savings but with the intention of measuring peak demand savings rather than total energy savings.

Detailed Circuit Results: Peak Demand Savings

Table 13 provides each algorithmic input by circuit as well as the total estimated peak demand savings per circuit that can be attributed to the VO Program. The overall peak demand voltage savings was 2.74%.[28]

Table 13. Verified Algorithmic Inputs and Associated Energy Savings by Circuit

Circuit	Annual Peak Demand (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Demand Savings (MW)
340100	2.34	0.68	2.31%	0.04
340101	2.40	0.68	2.94%	0.05
340102	0.75	0.68	1.19%	0.01
A26005	2.67	0.68	2.94%	0.05
A26006	3.09	0.68	2.65%	0.06
A36001	4.73	0.68	3.24%	0.10
A36002	4.29	0.68	3.89%	0.11
A45001	6.20	0.68	0.19%	0.01
A45002	6.12	0.68	0.80%	0.03

26 Illinois Technical Reference Manual for Energy Efficiency, Version 10.0, Volume 1, Section 3.7.
27 Peak demand was unavailable for seven circuits.
28 Average percent change in voltage is weighted by annual peak demand (MW).

Circuit	Annual Peak Demand (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Demand Savings (MW)
A45003	7.67	0.68	3.09%	0.16
A48001	2.69	0.68	2.86%	0.05
A48002	0.72	0.68	0.59%	0.00
A48004	1.10	0.68	0.48%	0.00
A48005	2.17	0.68	0.47%	0.01
A56013	3.79	0.68	1.65%	0.04
A56014	3.14	0.68	1.63%	0.03
A56015	1.97	0.68	1.64%	0.02
A56017	3.16	0.68	1.68%	0.04
B10001	4.37	0.68	3.41%	0.10
B19001	4.79	0.68	0.55%	0.02
B19002	7.37	0.68	2.99%	0.15
B45002	3.48	0.68	0.13%	0.00
B45003	5.53	0.68	0.61%	0.02
B45004	2.99	0.68	0.51%	0.01
B45005	6.98	0.68	1.50%	0.07
B57001	5.65	0.68	1.33%	0.05
B57002	6.38	0.68	1.42%	0.06
B57003	4.55	0.68	1.29%	0.04
B68001	7.11	0.68	-0.80%	-0.04
B68002	3.85	0.68	0.31%	0.01
B68003	5.17	0.68	0.80%	0.03
B68004	5.07	0.68	-0.38%	-0.01
B73002	4.44	0.68	2.47%	0.07
B77001	2.58	0.68	3.63%	0.06
B77003	4.73	0.68	1.81%	0.06
B82001	4.03	0.68	2.67%	0.07
C37001	4.12	0.68	2.68%	0.07
C37002	5.77	0.68	3.49%	0.14
D28124	2.54	0.68	1.85%	0.03
D72001	1.70	0.68	3.45%	0.04
D72002	4.71	0.68	1.06%	0.03
D72003	5.00	0.68	-0.01%[b]	0.00
D96001	5.35	0.68	2.23%	0.08
F22001	5.20	0.68	3.97%	0.14
G30001	2.89	0.68	1.12%	0.02
H14342	2.48	0.68	3.61%	0.06
H14343	2.33	0.68	2.25%	0.04
H88101	2.86	0.68	1.81%	0.04
H88109	2.89	0.68	2.63%	0.05
HB6251	3.25	0.68	3.31%	0.07
HB6283	4.49	0.68	2.01%	0.06

Circuit	Annual Peak Demand (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Demand Savings (MW)
HD5252	1.37	0.68	3.61%	0.03
HD5254	2.36	0.68	2.80%	0.05
HF7109	1.60	0.68	2.65%	0.03
J50185	3.75	0.68	4.13%	0.11
J50186	5.35	0.68	3.80%	0.14
J56341	1.88	0.68	3.31%	0.04
J56342	5.31	0.68	3.36%	0.12
J75272	7.70	0.68	4.06%	0.21
J76804	4.85	0.68	2.78%	0.09
J76805	0.34	0.68	2.93%	0.01
J83138	8.05	0.68	3.01%	0.16
J85160	3.89	0.68	3.53%	0.09
J85161	4.29	0.68	3.31%	0.10
K09863	6.70	0.68	3.52%	0.16
K09864	5.37	0.68	2.84%	0.10
K25164	2.16	0.68	5.06%	0.07
K25166	4.43	0.68	2.18%	0.07
K46389	6.66	0.68	2.27%	0.10
K46422	2.84	0.68	1.67%	0.03
K69116	7.56	0.68	2.57%	0.13
K73361	7.70	0.68	2.51%	0.13
K73362	2.69	0.68	4.88%	0.09
K73365	2.93	0.68	5.02%	0.10
K73366	9.35	0.68	5.00%	0.32
K80381	6.82	0.68	5.44%	0.25
K80382	4.91	0.68	4.22%	0.14
K80386	5.09	0.68	4.20%	0.15
K80388	8.95	0.68	0.86%	0.05
K89143	6.20	0.68	2.88%	0.12
L00133	2.72	0.68	4.02%	0.07
L00134	2.48	0.68	3.94%	0.07
L59933	4.54	0.68	3.38%	0.10
L74191	1.69	0.68	2.62%	0.03
L74194	1.76	0.68	5.59%	0.07
L95110	1.13	0.68	3.08%	0.02
M04364	5.57	0.68	2.75%	0.10
M04365	5.50	0.68	2.47%	0.09
M26161	9.20	0.68	3.66%	0.23
M37191	5.12	0.68	2.36%	0.08
M37192	6.67	0.68	2.56%	0.12
M40116	3.84	0.68	2.92%	0.08
M40117	2.94	0.68	0.66%	0.01

Circuit	Annual Peak Demand (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Demand Savings (MW)
M40132	6.87	0.68	1.61%	0.08
M73328	2.67	0.68	2.12%	0.04
M81402	5.14	0.68	1.48%	0.05
M81404	2.03	0.68	1.43%	0.02
M83327	0.26	0.68	3.35%	0.01
N05172	4.59	0.68	3.26%	0.10
N05173	3.20	0.68	3.11%	0.07
N18210	2.93	0.68	3.17%	0.06
N18211	4.97	0.68	2.83%	0.10
N50331	5.66	0.68	2.85%	0.11
N50332	3.34	0.68	3.17%	0.07
N50333	3.82	0.68	4.24%	0.11
N50334	7.05	0.68	3.17%	0.15
N67309	3.61	0.68	3.34%	0.08
N67310	2.91	0.68	3.19%	0.06
N74230	2.88	0.68	2.50%	0.05
P20930	3.71	0.68	2.76%	0.07
P26280	3.00	0.68	2.91%	0.06
P42229	6.18	0.68	3.13%	0.13
P42230	6.00	0.68	2.83%	0.12
P60170	3.89	0.68	3.04%	0.08
P69174	7.31	0.68	2.45%	0.12
P69175	7.98	0.68	3.01%	0.16
Q04410	2.32	0.68	4.56%	0.07
Q04411	5.33	0.68	3.38%	0.12
Q06131	4.73	0.68	3.93%	0.13
Q06142	10.65	0.68	2.58%	0.19
Q23255	2.88	0.68	4.47%	0.09
Q23256	4.98	0.68	3.43%	0.12
Q23258	5.47	0.68	2.81%	0.10
R28870	3.55	0.68	1.38%	0.03
R28871	4.78	0.68	1.07%	0.03
R41131	3.52[a]	0.68	3.66%	0.09
R49261	6.34	0.68	2.66%	0.11
R49265	0.49[a]	0.68	5.43%	0.02
R49275	7.00	0.68	2.87%	0.14
R65451	4.01	0.68	3.42%	0.09
R65452	5.42	0.68	5.27%	0.19
S07536	2.36	0.68	3.15%	0.05
S14510	2.22	0.68	5.22%	0.08
S15558	1.47	0.68	2.21%	0.02
S15559	3.46	0.68	1.25%	0.03

Circuit	Annual Peak Demand (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Demand Savings (MW)
S22595	3.73	0.68	2.66%	0.07
S30518	2.73	0.68	2.66%	0.05
S42579	3.67	0.68	3.06%	0.08
S61530	3.60	0.68	0.80%	0.02
S61531	4.35	0.68	3.42%	0.10
S66593	1.97	0.68	4.13%	0.06
S66594	2.18	0.68	4.80%	0.07
S88502	3.54	0.68	3.63%	0.09
T05539	3.25	0.68	1.91%	0.04
T06505	3.95	0.68	4.26%	0.11
T08501	3.25	0.68	2.28%	0.05
T29560	5.15	0.68	5.93%	0.21
T29561	1.74	0.68	3.95%	0.05
T29562	3.73	0.68	3.41%	0.09
U37579	2.50	0.68	2.98%	0.05
U68581	3.03	0.68	2.89%	0.06
U84566	4.30	0.68	3.41%	0.10
U84587	5.27	0.68	2.81%	0.10
V01001	2.67	0.68	3.83%	0.07
V01002	3.61	0.68	2.91%	0.07
V20502	2.96	0.68	2.85%	0.06
V24583	2.53	0.68	2.87%	0.05
V46552	4.87	0.68	1.35%	0.04
V46563	3.32	0.68	3.42%	0.08
V58507	2.29	0.68	2.17%	0.03
V80506	3.08	0.68	2.86%	0.06
X09534	3.55	0.68	2.53%	0.06
X09557	2.94	0.68	4.02%	0.08
X66582	2.54	0.68	2.91%	0.05
X96524	3.06	0.68	2.76%	0.06
X96543	3.12	0.68	2.84%	0.06
Y07575	2.38	0.68	3.11%	0.05
Y07576	3.77	0.68	4.33%	0.11
Y20522	2.29	0.68	2.52%	0.04
Y37592	2.56	0.68	3.03%	0.05
Y51505	2.79	0.68	2.67%	0.05
Y51506	3.61	0.68	2.14%	0.05
Y68581	2.43	0.68	3.45%	0.06
Y73504	3.56	0.68	3.55%	0.09
Y73505	3.74	0.68	3.51%	0.09
Y93544	3.69	0.68	3.15%	0.08
Z04520	3.03	0.68	2.85%	0.06

Circuit	Annual Peak Demand (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Demand Savings (MW)
Z29579	2.76	0.68	2.62%	0.05
Z41528	3.43	0.68	4.39%	0.10
Z41536	3.37	0.68	2.90%	0.07
Z50544	1.76	0.68	3.52%	0.04
Total	**726.52**	**0.68**	**2.74%**	**13.52**

[a] Data was imputed using a linear regression as described in Section 4.1.2.

[b] Results were not statistically significant, and therefore savings are set to zero.

[c] The entire peak period for this circuit was encompassed by an excludable event where VO was “Off,” and therefore the peak savings were imputed using a linear regression as described in Section 4.1.2.

The approach we used to calculate peak demand savings for AIC’s VO Program is designed to be the most rigorous possible with the data available. We employed regression analysis controlling for exogenous factors, such as weather, as documented in the evaluation plan. To validate the model, we evaluated a range of model specifications and selected the best fit determined by model diagnostics (R^2 and adjusted R^2). A detailed binder, provided upon request, provides the coefficient estimates and model fit statistics for each circuit-level model. All modeled circuit results except those for D72003 were statistically significant at the 90% confidence level. The confidence interval around the peak savings estimate for D72003 overlaps with zero, and therefore we set peak savings to zero for this circuit.

Appendix C. Cumulative Persisting Annual Savings

Table 14 provides CPAS and WAML for the 2022 VO Program through 2037. Lifetime savings for the 2022 VO Program are 1,303,386 MWh.

Table 14. 2022 VO Program CPAS and WAML through 2037

Evaluation Measure Category	Measure Life	First-Year Verified Gross MWh	NTGR	CPAS (Verified Net MWh)							
				2022	2023	2024	2025	2026	2027	2028	2029
Voltage Optimization - 2022 Cohort	15.0	86,892	1.000	86,892	86,892	86,892	86,892	86,892	86,892	86,892	86,892
2022 CPAS		86,892	1.000	86,892	86,892	86,892	86,892	86,892	86,892	86,892	86,892
Expiring 2022 CPAS				0	0	0	0	0	0	0	0
Expired 2022 CPAS				0	0	0	0	0	0	0	0

Evaluation Measure Category	Measure Life	First-Year Verified Gross MWh	NTGR	CPAS (Verified Net MWh)							
				2030	2031	2032	2033	2034	2035	2036	2037
Voltage Optimization - 2022 Cohort	15.0	86,892	1.000	86,892	86,892	86,892	86,892	86,892	86,892	86,892	0
2022 CPAS		86,892	1.000	86,892	86,892	86,892	86,892	86,892	86,892	86,892	0
Expiring 2022 CPAS				0	0	0	0	0	0	0	86,892
Expired 2022 CPAS				0	0	0	0	0	0	0	86,892
WAML	15.0										

Appendix D. Verification of Continued Operations

Opinion Dynamics conducted a verification analysis on the 2019, 2020, and 2021 cohorts of circuits. Since VO savings are deemed for 15 years after completion of the initial evaluation of a circuit and no retroactive changes are subsequently made to the savings, verification is necessary to confirm continued operation.

In 2020, Opinion Dynamics, AIC, and ICC Staff agreed that ongoing verification of VO should be conducted for process purposes to provide information to stakeholders and other parties as to the level of continued VO operation and, if needed, to provide context as to why VO may not have operated continuously. After the initial evaluation of each year of circuits, all parties agreed that Opinion Dynamics would conduct verification activities to assess the degree to which VO continued to operate throughout each year. The acceptable uptime threshold of operation was set to ensure that circuits operated over a 90% threshold.[29]

The purpose of this verification is to provide information to stakeholders and other parties as to the level of continued operation of VO throughout the 15-year deemed period of savings and, if needed, to provide context as to why VO may not have operated continuously at the acceptable 90% uptime threshold throughout the period.

The evaluation team conducted the following activities to determine whether these circuits operated over a 90% uptime threshold.

- **Sample Selection**: The evaluation team randomly selected 10 of the 19 circuits evaluated in 2019, 20 of the 125 circuits evaluated in 2020, and 29 of the 180 circuits evaluated in 2021 using a cross-sectional sample design which optimizes the sample for each cohort while minimizing the overall sample size across all cohorts. Sample selection was performed retrospectively and provided AIC no knowledge of which circuits would be sampled until after the evaluation period had passed. Table 15 presents the sample of the circuits evaluated as part of the 2019, 2020, and 2021 circuit verification.

Table 15. Sample of 2019, 2020, and 2021 Evaluated VO Circuits

Circuit	Substation	Year Previously Evaluated
C52002	RIDGE	2019
D31015	LIMIT	2019
J34357	BETHALTO	2019
J34377	BETHALTO	2019
J83140	BELLEVILLE 44TH ST	2019
K11376	CASEYVILLE GARDENS	2019
L93132	EAST BELLEVILLE	2019
P58155	MT VERNON 27TH ST	2019
V41533	QUINCY 28ANDADAMS	2019
V42572	QUINCY 30ANDHAMP	2019
J87111	BELLEVILLE 8TH ST	2020
J87150	BELLEVILLE 8TH ST	2020
J99121	BELLEVILLE MARIKNOLL	2020
K39154	CLINTON RT 54	2020

[29] See Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach memo here: https://ilsag.s3.amazonaws.com/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf.

Circuit	Substation	Year Previously Evaluated
K52400	COLLINSVILLE REESE DR	2020
K52421	COLLINSVILLE REESE DR	2020
K76542	CHAMPAIGN OAK ST	2020
K76543	CHAMPAIGN OAK ST	2020
L93149	EAST BELLEVILLE	2020
M36184	GALESBURG FREMONT RD	2020
N35852	HILLSBORO	2020
N54107	JACKSONVILLE WEST SIDE	2020
N95823	LITCHFIELD	2020
P17108	MAHOMET	2020
P52306	MONTICELLO	2020
P58156	MT VERNON 27TH ST	2020
P73158	NASHVILLE	2020
Q64918	PINCKNEYVILLE	2020
U32579	CANTON S	2020
Y37593	OLNEY S	2020
349003	SUMMIT	2021
A97001	EAST PEORIA	2021
A97002	EAST PEORIA	2021
A97004	EAST PEORIA	2021
A97005	EAST PEORIA	2021
D36003	HALLOCK	2021
D66001	FAIRMOUNT	2021
D66004	FAIRMOUNT	2021
H22346	WOOD RIVER PICKER ST	2021
J01119	ABINGDON	2021
J84146	BELLEVILLE 65TH ST	2021
J89125	BELLEVILLE C ST	2021
L17104	DECATUR NORTHGATE	2021
M41112	GALESBURG NORTH SEMINARY ST	2021
M45212	GEORGETOWN INDIANOLA RD	2021
N70330	KEWANEE SOUTH STREET	2021
P98190	NORMAL MAIN ST	2021
P98192	NORMAL MAIN ST	2021
Q01281	NORMAL RTE 66	2021
Q85162	SANDOVAL	2021
R01153	SOUTH BLOOMINGTON	2021
R48167	TILTON ROSS LANE	2021
R58961	URBANA FIVE POINTS	2021
S64506	MARION NW	2021

Circuit	Substation	Year Previously Evaluated
U35511	CARROLLTON	2021
V04552	MEREDOSIA-SWITCHYARD	2021
W03570	NIOTA	2021
X30527	CHARLESTON E	2021
X34531	CHARLESTON HAYES ST.	2021

- **Review and request operation log summaries for the sample.** The variable of interest for this effort included the VO status (i.e., "On" and "Off") for specific hours throughout the year at a circuit level. We were able to rely on the VO status summaries for this analysis since we generally expected VO to run for nearly all hours in a year.
- **Data cleaning.** Opinion Dynamics did not perform any data cleaning prior to the verification activities, with the exception of removing excludable events. Excludable events are discussed in detail in Appendix B.
- **Calculated operation status.** We calculated the proportion of hours that each circuit's VO status was "On" for a given year. We then divided the total number of hours in which the status logs indicated that VO was operational by the total number of non-excludable hours in the year.

For more information, please contact:

Zach Ross
Director

617-301-4663 tel
zross@opiniondynamics.com

1000 Winter St.
Waltham, MA 02451