Massachusetts Grid Modernization Program Year 2022 Evaluation Report: Volt-VAR Optimization

Massachusetts Electric Distribution Companies

Submitted by:

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Reference No.: 219514
June 30, 2023

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Introduction

As a part of their Grid Modernization Plans (GMPs), the Massachusetts Electric Distribution Companies (EDCs) are investing to enable Volt/VAR Optimization (VVO) on selected feeders across their distribution networks. VVO optimizes distribution voltage to reduce energy consumption and demand without the need for customer interaction or participation. The principle behind VVO is that power demand is reduced at voltages in the lower end of their allowable range for many end-use loads.

This evaluation focuses on the progress and effectiveness of each EDC's preauthorized VVO investments toward meeting the Department of Public Utilities (DPU) grid modernization objectives for Program Year (PY) 2022.

Evaluation Process

The DPU requires a formal evaluation process, including an evaluation plan and evaluation studies, for the EDCs' preauthorized grid modernization plan investments. Guidehouse is completing the evaluation to establish a uniform statewide approach and to facilitate coordination and comparability. The evaluation is to measure and assess progress toward achieving the DPU's grid modernization objectives. The evaluation uses the DPU-established Infrastructure Metrics and Performance Metrics along with a set of Case Studies to understand if the GMP investments are meeting the DPU's objectives.

The original Evaluation Plan developed by Guidehouse[1] was submitted to the DPU by the EDCs in a petition for approval on May 1, 2019. Modifications to this original Evaluation Plan were required to enable evaluation of PY 2022. These modifications included an 1) extension of the evaluation window from the four year term spanning 2018 – 2021[2] (hereon referred to as Term 1) to incorporate the new four year term spanning 2022 – 2025 (hereon referred to as Term 2), and 2) revisions required to reflect the new Term 2 investment activity. Modifications to the original Evaluation Plan were submitted to the EDCs for approval on March 1, 2023. The modified Evaluation Plan has been used to develop the analysis and evaluation provided below in this document.

Table 1 illustrates the key Infrastructure Metrics and Performance Metrics relevant for the VVO evaluation by EDC.

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[1] Guidehouse had previously filed as "Navigant Consulting" and did so during the initial evaluation plan filing.

[2] On May 10, 2018, the Massachusetts DPU issued its Order regarding the individual GMPs filed by the three Massachusetts EDCs. In the Order, the DPU preauthorized grid-facing investments over 3 years (2018-2020) for each EDC and adopted a 3-year (2018-2020) regulatory review construct for preauthorization of grid modernization investments. On May 12, 2020, the DPU issued an Order extending the 3-year grid modernization plan investment term to a 4-year term, which introduced a 2021 program year. In addition, on July 1, 2020, Eversource filed a request for an extension of the budget authorization associated with grid modernization investments. The 2018-2021 GMP term results provided for Eversource reflect these changes.

Table 1. VVO Evaluation Metrics

Type	VVO Evaluation Metrics	ES	NG	UTL
IM-4	Number of Devices or Other Technologies Deployed	✓	✓	✓
IM-5	Cost for Deployment	✓	✓	✓
IM-6	Deviation between Actual and Planned Deployment for the Plan Year	✓	✓	✓
IM-7	Projected Deployment for the Remainder of the GMP Term	✓	✓	✓
PM-1	VVO Baseline	✓	✓	
PM-2	VVO Energy Savings	✓	✓	
PM-3	VVO Peak Load Impact	✓	✓	
PM-4	VVO Distribution Losses without Advanced Metering Functionality (AMF) (Baseline)	✓	✓	
PM-5	VVO Power Factor	✓	✓	
PM-6	VVO – GHG Emissions	✓	✓	
PM-7	Voltage Complaints	✓	✓	

IM = Infrastructure Metric, PM = Performance Metric, ES = Eversource, NG = National Grid, UTL = Unitil

* The EDCs are responsible for these metric calculations and the calculations are not addressed in this evaluation

Source: Stamp Approved Performance Metrics, July 25, 2019

Data Management

Guidehouse worked with the EDCs to collect data to complete the VVO evaluation for the assessment of Infrastructure Metrics and Performance Metrics. A consistent methodology was used across Investment Areas and EDCs for evaluating and illustrating EDC progress toward the GMP metrics.

Table 2 summarizes data sources used throughout the VVO evaluation for PY 2022. Section 3.1.1 details each of the data sources.

Table 2. VVO Data Sources

Data Source	Description
2021 Grid Modernization Plan Term Report[3,4,5]	Planned device deployment and cost information from each EDC's appendix to the *2021 GMP Term Report* (filed April 1, 2022). Data was used as the reference to track progress against the GMP targets and are referred to as the GMP Plan in summary tables and figures throughout the report.

[3] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2020. Submitted to Massachusetts DPU on April 1, 2021 as part of DPU 21-30.

[4] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2020. Submitted to Massachusetts DPU on April 1, 2021 as part of DPU 21-30. Note that Eversource Energy filed an updated Appendix 1 filing in December of 2021; however that update did not affect any of the data or results in the evaluation.

[5] Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2020. Submitted to Massachusetts DPU on April 1, 2021 as part of DPU 21-30.

Data Source	Description
2022 Grid Modernization Plan Annual Report[6,7,8]	All PM-related data are from these 2022 GMP Annual Report Appendices. In addition, data collected as part of EDC Data Template (below) was compared to the data submitted by the EDCs to the DPU in the 2021 Grid Modernization Plan Term Reports and associated Appendix 1 filings. The evaluation team confirmed the consistency of the data from the various sources and reconciled any differences
EDC Device Deployment Data Template	Captures planned and actual device deployment and spend data. Actual device deployment and cumulative spend information were provided by work order ID and specified at the feeder- or substation-level as appropriate. Device deployment information and estimated spend for 2022 were provided as well.
VVO Supplemental Data Template	Includes additional information unique to the VVO Investment Area spanning inputs required for the Infrastructure Metrics and the Performance Metrics. Data covers actual versus planned VVO schedule, IT work schedule, customer demand response events, system events, distributed generation information, and voltage complaints. Information was requested at the feeder-level where possible.
Eversource's 2021 DPU-Filed Plan[9]	Eversource's GMP extension request was approved by the DPU on February 4, 2021. It includes budgets for PY 2021 deployment at the Investment Area level. This data source is included in the EDC Plan for Eversource planned spend at the Investment Area level.
2022-2025 Grid Modernization Plan Track 1 Order[10]	The GMP Track 1 Order was filed by the DPU on October 7, 2022. It includes budgets for PY 2022-PY 2025 deployment at the Investment Area level. This data source is included in the EDC Plan for each EDC's planned spend at the Investment Area level.
EDC DOER Response Appendix[11]	Planned device deployment and cost information from each EDC's Appendix 1 filing was provided in response to DOER requests for information. Data was used as the reference to track progress against the GMP targets and are referred to as the GMP Plan in summary tables and figures throughout the report.

Source: Guidehouse analysis

Findings and Recommendations

Table 3 and Table 4 summarizes the Term 1 Infrastructure Metrics results for Eversource's VVO Investment Area through PY 2022.

[6] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Annual Report for Calendar Year 2022. Submitted to Massachusetts DPU on April 24, 2023, as part of DPU 23-30.
[7] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Annual Report for Calendar Year 2022. Submitted to Massachusetts DPU on April 24, 2023, as part of DPU 23-30.
[8] Fitchburg Gas and Electric Light Company d/b/a Unitil, 2022 Grid Modernization Plan Annual Report. Submitted to Massachusetts DPU on April 24, 2023, as part of DPU 23-30.
[9] Grid Modernization Program Extension and Funding Report. Submitted to Massachusetts DPU on July 1, 2020 as part of DPU 15-122.
[10] Massachusetts DPU 21-80/DPU 21-81/DPU 21-82 Order on Previously Deployed Technologies issued October 7, 2022.
[11] Plan data is sourced from EDC responses to the first set of information requests issued by the Department of Energy Resources (DOER). These responses were filed on October 4th, December 2nd, and October 5th, 2021, for Eversource, National Grid, and Unitil under DPU dockets 21-80, 21-81, and 21-82.

Table 3. Term 1 VVO Infrastructure Metrics Summary

Infrastructure Metrics			Eversource
GMP Plan Total, PY 2018-2022		Devices	1,142
		Spend, $M	$17.23
IM-4	Number of devices or other technologies deployed PY 2018-2022*	# Devices Deployed***	1,038
		% Devices Deployed	91%
IM-5	Cost for Deployment PY 2018-2022*	Total Spend, $M	$16.87
		% Spend	98%
IM-6	Deviation Between Actual and Planned Deployment for PY 2022	% On Track (Devices)	70%
		% On Track (Spend)	85%
IM-7	Projected Deployment for the remainder of the GMP Term (i.e., Term 1)**	# Devices Remaining	0
		Spend Remaining, $M	$0.00

*The metric names have been slightly changed here to clarify the time span used in analysis.

** This metric has been interpreted here (i.e., within the context of the 2022 Program Year Evaluation) as the units and spending that the EDC plans to complete their most recent 4-year Term 1 plans. Additional Grid Modernization units and dollars incurred in 2022 are attributed to Term 2, as appropriate, and all units and dollars spent during 2023 through 2025 will be considered as part of Term 2 GMPs.

***Note that "Deployed" here refers to commissioned devices. For full definitions of deployment stages, see Docket 20-46 Response to Information Request DPU-AR-4-11, September 3, 2020.

Source: Guidehouse analysis of 2021 GMP Term Reports and 2022 EDC Data

Table 4. Term 1 Infrastructure Metrics for VVO Feeder Deployment Progress

IM	Parameter*	Eversource	National Grid	Unitil
IM-4	# Feeders with VVO Enabled	26	20	3
	% Feeders with VVO Enabled	81%	100%	100%
IM-6	% On Track (Feeders with VVO Enabled)	81%	100%	100%
IM-7	# Feeders Remaining for VVO Enablement**	0	0	0

* VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

** Does not include additional feeders that were not laid out in the original 3-Year Grid Modernization Plans.

Source: Guidehouse analysis of 2021 GMP Term Report and 2022 EDC Data

Table 5 and Table 6 summarizes the Term 2 Infrastructure Metrics results for each EDC's VVO Investment Area through PY 2022.

Table 5. Term 2 VVO Infrastructure Metrics Summary

Infrastructure Metrics		Eversource	National Grid**	Unitil
GMP Plan Total, PY 2022-2025	# Devices Planned	2,629	987	180
	Spend, $M	$38.64	$76.44	$5.42
EDC Data Total, PY 2022-2025	# Devices Planned	1711	1715	143
	Spend, $M	$38.61	$76.44	$2.24

Infrastructure Metrics			Eversource	National Grid**	Unitil
IM-4	Number of devices or other technologies deployed thru PY 2022	# Devices Deployed	0	42	37
		% Devices Deployed	0%	4%	21%
IM-5	Cost for Deployment thru PY 2022	Total Spend, $M	$0.04	$7.61	$0.28
		% Spend	0%	10%	5%
IM-6	Deviation Between Actual and Planned Deployment for PY 2022	% On Track (Devices)	0%	25%	119%
		% On Track (Spend)	0%	69%	105%
IM-7	Projected Deployment for the Remainder of the Term	# Devices Remaining	1711	1673	106
		Spend Remaining, $M	$38.58	$68.83	$1.96

*Note that "Deployed" here refers to commissioned devices. For full definitions of deployment stages, see Docket 20-46 Response to Information Request DPU-AR-4-11, September 3, 2020.

** To more closely align spend projections with DPU pre-authorized budgets, National Grid operations and maintenance (O&M) spend is included in actual and planned spend presented here. O&M spend is provided in aggregate for each investment area and is therefore excluded from device-specific summaries of spend.

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Table 6. Term 2 Infrastructure Metrics for VVO Feeder Deployment Progress

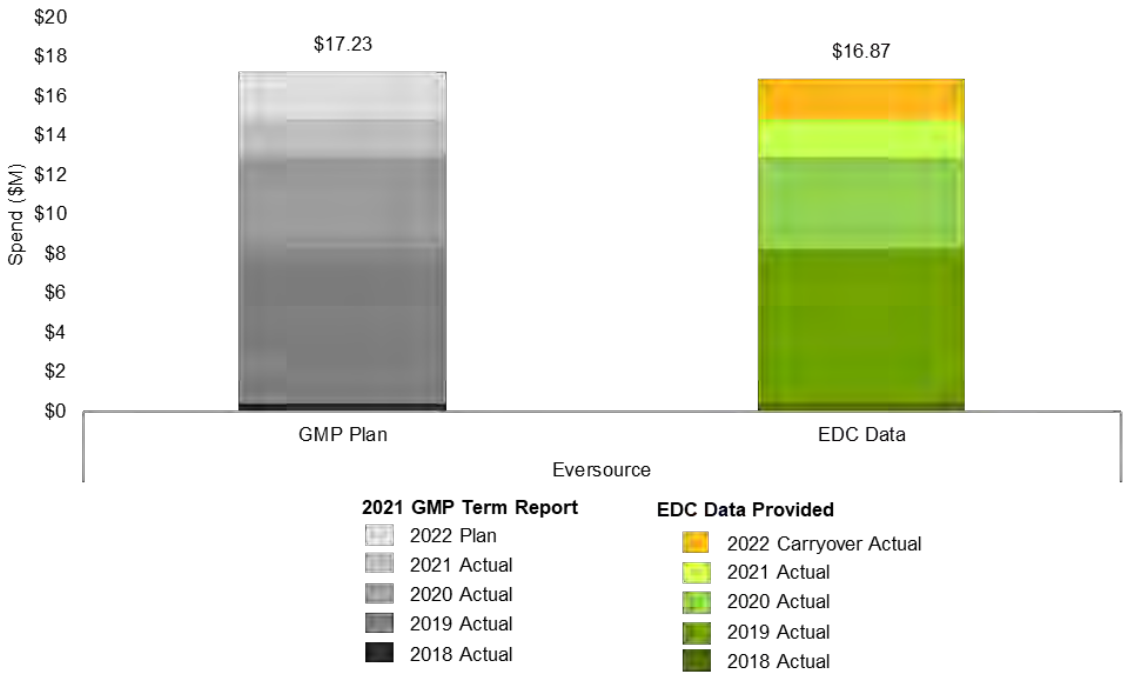
IM	Parameter*	Eversource	National Grid	Unitil
IM-4	# Feeders with VVO Enabled	0	18	4
	% Feeders with VVO Enabled	0%	35%	50%
IM-6	% On Track (Feeders with VVO Enabled)	0%	35%	50%
IM-7	# Feeders Remaining for VVO Enablement	95	34	4

*VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Source: Guidehouse analysis of 2022 EDC Data

Figure 1 compares the Term 1 GMP Plans and EDC Data totals and year-over-year spending for each EDC.

Figure 1. VVO Term 1 Spend Comparison (2018-2022, $M)

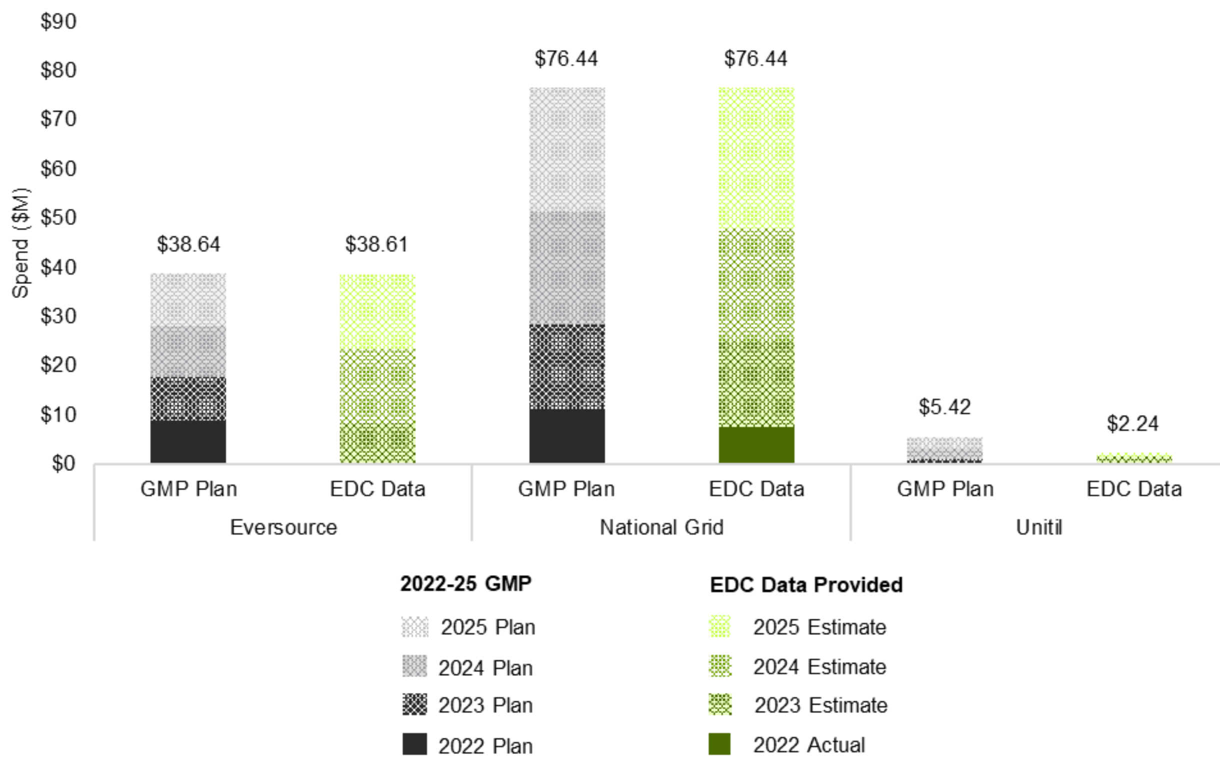


Note: Includes the Eversource planned spend on activity from 2021 that was transferred to 2022, set forth in Eversource's 2021 GMP Term Report, filed on April 1, 2022.

Source: Guidehouse analysis of 2021 GMP Term Report, "GMP Extension and Funding Report," and 2022 EDC Data

Figure 2 compares the Term 2 GMP Plans and EDC Data totals and year-over-year spending for each EDC.

Figure 2. VVO Term 2 Spend Comparison (2022-2025, $M)



Note: To more closely align spend projections with DPU pre-authorized budgets, National Grid operations and maintenance (O&M) spend is included in actual and planned spend presented here. O&M spend is provided in aggregate for each investment area and is therefore excluded from device-specific summaries of spend.

Source: Guidehouse analysis of DPU Order (October 7, 2022) and 2022 EDC Data

Key Findings for VVO Infrastructure Metrics

Guidehouse's review of Eversource's VVO progress on Term 1 revealed that Eversource was approximately on-track with planned spend and deployment outlined in their *2021 GMP Term Report*. However, some spend and deployment remain in order to complete activities from Term 1. Key findings related to Eversource's progress include:

Device Deployment

- Eversource made headway on deploying 2021 investments in 2022, with Capacitor Banks and Grid Monitoring Line Sensors comprising the bulk of deployed devices. Eversource exceeded plans (25 devices) for Capacitor Banks, as refinements made during the planning and design process placed more priority on Capacitor Banks, less on Regulators, for VVO operation. At the close of 2022, Eversource was awaiting delivery of 3 ordered VVO Regulators from its vendor. Line Sensor and Micro-capacitor deployment also fell short of plans.

Total Spend

- Eversource made substantial progress on PY 2021 work that was planned for 2022. Total spend through the end of 2022 was approximately on track with plans for all device types, with total spend on VVO ($16.87M) being slightly below planned spend ($17.23M) laid out for Term 1.

VVO Enablement

- Eversource completed deployment of VVO at four of its six Term 1 plan substations (Agawam, Piper, Podick, and Silver) by the end of 2021, and conducted On/Off testing at these substations throughout 2022. Eversource stopped VVO On/Off testing on these four substations in May 2023, transitioning towards leaving VVO in its enabled state moving forward. Meanwhile, the Gunn and Oswald substations will be VVO enabled in 2023, with On/Off testing to begin shortly thereafter.

PY 2022's VVO Infrastructure Metrics findings show that the EDCs are at varying stages in VVO deployment for Term 2. Details pertaining to device deployment progress, total spend, and VVO enablement progress are shown below:

Device Deployment:

- Eversource did not meet VVO deployment goals for PY 2022. Eversource progress on VVO investments targeted for 2022 through 2025 was comprised of progressing engineering/design work for all VVO device types, as well as planning for future VVO deployments, while awaiting DPU decisions on continued VVO investment for 2022 through 2025. Given limited deployment on Term 2 investments in 2022, Eversource has adjusted plans for the remainder of Term 2, with the majority of deployment and spend activity projected to occur in 2024 and 2025. At the technology-level, planned deployment has declined for Regulators, Line Sensors, and Microcapacitors, and planned Capacitor Bank deployment has increased slightly. Capacitor Bank deployment has been revised upwards to reflect refinements made during the planning and design process.
- National Grid conducted less deployment than initially planned in PY 2022. A late-2022 DPU decision on preauthorizing 2022 through 2025 investment activity, resource constraints, and vendor lead times were all key contributors to this outcome. In response to lower-than-expected deployment in 2022, National Grid has accelerated its deployment timeline for 2023 through 2025. National Grid has also adjusted total deployment plans for numerous device types, increasing projected deployment for Capacitor Banks, Line Sensors, and LTC Controls, while reducing projected deployment for Regulators. National Grid cites that these revisions are primarily due to the VVO planning work that has been conducted since the 2022-2025 GMP was filed.
- Unitil deployment was below plans for 2022, with variation by technology. Unitil was on-track with deployment of VVO Capacitor Banks and Line Sensors in 2022, deploying 100% and 210% of planned units, respectively. However, deployment was under plans for Regulators and LTC Controls. Lower deployment than plans for these technologies may be attributed to Unitil's efforts to resolve LTC radio and control issues and cancelation of 4 deployments that were found to be unnecessary. Unitil has adjusted deployment plans for the remainder of Term 2 to conduct most deployment during 2023 and 2025. Additionally, Unitil has reduced its planned deployments of VVO Regulators and Capacitor Banks, as Unitil reassessed deployment plans and determined there were fewer Regulator and Capacitor Bank deployments needed than initially planned. Work in 2024 will be limited to material orders in preparation for construction work at the Beech Street substation.

Total Spend:

- Eversource spend on Term 2 investments amounted to $0.04M, short of the $8.70M that was initially planned for 2022. Given limited deployment and spend on Term 2 investments in 2022, as well as ongoing vendor delays in fulfilling material orders, Eversource has adjusted plans for the remainder of Term 2. In 2023, Eversource will be conducting additional design work, submitting material orders, and, when material orders are received, deploying VVO investments. Eversource has projected that most spend activity will occur in 2024 and 2025.
- National Grid spend on VVO was below plans for 2022. The majority of spend occurred on Capacitor Banks, while spend on Regulators and Line Sensors was well below plans. Lower-than-anticipated spend on Line Sensors can, in part, be attributed to National Grid's previous line sensor vendor discontinuing their selected model. For VVO Regulators, vendor delays in fulfilling material orders was a key contributor to lower spend than initially planned. In response to its 2022 experience with Line Sensors and Regulators, National Grid has begun to increase diversification of vendors that it sources materials from.
- Unitil spend on VVO was below initial plans. Unitil met 48% of its planned spend for Regulators. Spend and deployment of all other devices met or exceeded initial plans. Spend plans for the remainder of Term 2 have been revised downwards across all device types. Reduced spend on Regulators and Capacitor Banks can be attributed to a reduction in the units that Unitil plans to deploy, as well as lower than expected costs for deployment of Regulators. Reduced spend on LTC Controls and Line Sensors may be tied to process efficiencies implemented in 2022 that brought unit costs below plans. Most spend is planned for 2023 and 2025, with work in 2024 limited to material orders in preparation for construction work at the Beech Street substation.

VVO Enablement:

- For its Term 2 substations, Eversource is currently in the VVO Investment phase, and is conducting engineering / design work for the selected substations. Eversource anticipates completing deployment during 2024 and 2025. Once VVO investments are deployed, Eversource plans to conduct VVO On/Off testing, with testing start dates ranging from July 2024 through July 2025. Once VVO On/Off testing has begun, Eversource anticipates conducting this testing for 9 – 12 months to collect one summer, one winter, and one shoulder season of testing data.
- National Grid conducted VVO On/Off testing at its East Methuen and Maplewood Term 1 substations throughout 2022. Among its Term 2 substations, National Grid conducted On/Off testing at the East Bridgewater substation throughout 2022, as VVO deployment was completed at the substation in 2021. Additionally, National Grid completed VVO deployment at the Easton and West Salem substations and began VVO On/Off for these substations in winter 2022/23 and spring 2022, respectively. National Grid projects that it will complete VVO deployment and enable VVO at its remaining Term 2 substations in 2023.
- Unitil completed VVO deployment for its Term 1 substation (Townsend) in 2021, enabling VVO on December 1, 2021, and On/Off testing is expected to begin in spring 2023. Among its Term 2 substations, Unitil completed deploying VVO investments at the Summer Street substation and enabled VVO in December 2022, with VVO On/Off testing projected to begin at the substation in December 2023. Lunenburg and West Townsend are currently receiving VVO investments and Unitil plans to enable VVO at the substations in January and

November 2024, respectively. Unitil then plans to conduct On/Off testing at the substations beginning in December 2024. For its remaining substations, Unitil is currently conducting planning and engineering/design work for its Beech Street, Pleasant Street, and Princeton Road substations. These substations are expected to be enabled after the close of Term 2 in 2026 and 2027.

Key Findings and Recommendations for VVO Performance Metrics

Table 7 includes the Performance Metrics results and key findings for the Spring 2022 – Winter 2022/23 M&V period. It can be difficult to compare the results from Performance Metrics analysis between Eversource and National Grid. For example, there are differences in the granularity of telemetry (e.g., 5-minute versus 15-minute), data quality at different times of the year (e.g., sustained pauses in VVO On/Off testing for one EDC, data outages during On/Off testing for another EDC). As such, certain portions of the M&V period, such as the Spring season, may be represented more for one EDC than the other. Additionally, there are numerous differences in DG penetration, customer types, and geographic areas served by Eversource and National Grid feeders that limit the ability to directly compare Eversource and National Grid VVO outcomes.

Table 7. Performance Metrics Results for the Spring 2022 – Winter 2022/23 M&V Period

Performance Metrics		Eversource		National Grid	
Feeders Included in Evaluation		26		34	
PM-1	Spring 2022 – Winter 2022/23 Baseline	524,992 MWh		882,631 MWh	
PM-2	Energy Savings – All Hours VVO On†	2,128 ± 476 MWh	0.41 ± 0.09%	6,769 ± 1,162 MWh	0.84 ± 0.15%
	Energy Savings – Actual VVO On Hours‡	879 ± 184 MWh	0.41 ± 0.09%	1,867 ± 302 MWh	0.84 ± 0.15%
-	Voltage Reduction	1.52 ± 0.01 V	1.24 ± 0.01%	0.08 ± <0.001 V	0.62 ± 0.01%
-	CVRf^	0.60		0.36	
PM-3^^	Peak Load Reduction	-369 ± 245 kW	-0.70 ± 0.46%	-2,189 ± 1,173 kW	-2.41 ± 1.28%
PM-4	Reduction in Distribution Losses	0.01%		-1.95%¶	
PM-5	Change in Power Factor	<0.001 ± <0.001	0.06 ± 0.02%	-0.01 ± 0.002¶	-0.96 ± 0.2%¶
PM-6	GHG Reductions (CO_2) All Hours VVO On†	723 ± 162 tons CO_2		2,301 ± 395 tons CO_2	
	GHG Actual VVO-On Hours‡	299 ± 63 tons CO_2		645 ± 103 tons CO_2	
PM-7	Voltage Complaints	53 (13% decrease from 2015 – 2017 baseline period average)		136 (16% decrease from 2016 – 2017 baseline period average)§	

* National Grid feeders at the Easton substation did not begin testing until mid-January, 2023. All overall estimates are inclusive of Easton feeders and only incorporate impact estimates from this feeder during the Winter period. Additionally, even-numbered Maplewood feeders underwent a prolonged period over which VVO On/Off testing was paused, resulting in their removal from analysis that informed PM-1 through PM-6.
† Calculation assumes VVO was enabled for all hours between March 1, 2022 and February 28, 2023.
‡ Calculation uses actual number of VVO On hours spanning the analysis period. Actual VVO On Hours are the number of hours VVO was engaged between March 1, 2022 and February 28, 2023 for each feeder.
^The CVR factor provided for each EDC is the load-weighted average of CVR factors estimated for each feeder with a voltage response to VVO On/Off testing.[12]
^^Guidehouse evaluated the impact of VVO during peak load periods, defined by ISO-NE as 1:00 p.m. to 5:00 p.m. ET from June 1 to August 31 on non-holiday weekdays.
¶ Changes in power factor and distribution losses could not be estimated for substations going through VVO On/Off testing during Spring 2022 through Winter 2022/23 due to data quality issues. Results presented for these metrics are based off of VVO substations that completed VVO On/Off testing prior to this evaluation period. For this evaluation period, the only substation to conclude On/Off testing is Stoughton.
§ National Grid did not start tracking voltage complaints until 2016.
Source: Guidehouse analysis

[12] All of Eversource's Podick 18G feeders and Silver feeders 30A2, 30A4, and 30A6 are removed from aggregated CVRf results due to unreliable voltage and energy responses to VVO On/off testing. National Grid's West Salem feeders 29W2, 29W4, and 29W6, as well as East Bridgewater feeders 797W1, 797W23, 797W29, and 797W42 are also removed from aggregated CVRf results due to unreliable voltage and energy responses to VVO On/off testing.

Findings from the evaluation of Performance Metrics indicate that VVO allowed Eversource and National Grid to realize energy savings and voltage reductions during the Spring 2022 – Winter 2022/23 M&V period.[13] More specifically:

- During the Spring 2022 – Winter 2022/23 M&V period, Eversource's Agawam, Piper, Podick, and Silver substations realized 879 MWh (0.41%) energy savings and 1.52 V (1.24%) voltage reduction associated with VVO. The CVR Factor, which provides an estimate of energy savings possible with voltage reductions, was 0.60.[50] During the same M&V period, National Grid's East Methuen, East Bridgewater, Easton, Maplewood, Stoughton, and West Salem substations realized 1,867 MWh (0.84%) energy savings and 0.08 kV (0.62%) voltage reduction associated with VVO. National Grid's CVR factor was 0.36.[50]
- Eversource energy savings of 879 MWh yielded a 299 short ton reduction of CO_2 emissions. National Grid energy savings of 1,867 MWh yielded a 645 short ton reduction in CO_2 emissions.
- Eversource and National Grid VVO feeders experienced a minimal benefit associated with peak load, power factor, and distribution losses. Eversource VVO feeders experienced a statistically significant increase (0.70%) in peak load, a statistically significant decrease (0.06%) in power factor, and a minimal decrease in distribution losses when VVO was engaged. National Grid VVO feeders experienced a statistically significant increase in peak load (2.41%), a small increase (0.96%) in power factor, and a 1.95% increase in distribution losses when VVO was engaged.
- For Eversource, a total of 53 voltage complaints were received from customers connected to the Agawam, Piper, Podick, and Silver VVO feeders during the Spring 2022 – Winter 2022/23 M&V period. This is a 13% decrease relative to the average voltage complaints per year received between 2015 – 2017. For National Grid, a total of 136 voltage complaints were received from customers connected to the East Methuen, East Bridgewater, Easton, Maplewood, Stoughton, and West Salem VVO feeders during the period. This is a 16% decrease relative to the average voltage complaints per year received between 2016 – 2017. For both EDCs, there is not sufficient evidence to support changes in voltage complaints being attributed to VVO.

In 2023 and beyond, Guidehouse recommends that Eversource and National Grid:

- Ensure VVO On/Off testing is running according to plan, with limited pauses to the VVO On/Off testing schedule. Across the VVO feeders, one-quarter to one-half of data points were removed due to extended pauses in VVO On/Off testing. For some feeders, this resulted in the vast majority of provided data to be unusable for components of this evaluation (e.g., for estimation of distribution loss and power factor reductions). Sustained On/Off testing will increase the amount of usable data in the evaluation and improve the ability for Guidehouse to provide a comprehensive evaluation of VVO performance metrics.

[13] It can be difficult to compare the results from Performance Metrics analysis between Eversource and National Grid. For example, there are differences in the granularity of telemetry (e.g., 15-minute versus 1 hour), data quality at different times of the year (e.g., sustained pauses in VVO testing, repeated data). As such, data cleaning can cause certain portions of the M&V period to be represented more for one EDC than the other. Additionally, there are numerous differences in DG penetration, customer types, and geographic areas served by Eversource and National Grid feeders that limit the ability to directly compare Eversource and National Grid VVO outcomes.

- Confirm adjustments to VVO On/Off testing schedule for any VVO feeders prior to implementation. VVO On/Off testing is designed similarly to a Randomized Controlled Trial (RCT), and adjustments to the testing schedule could, potentially, hinder the effectiveness of the testing design and cause biases to evaluation results. Ensuring there is proper balance in the number of VVO on and off hours throughout the evaluation period will allow for Guidehouse to provide a comprehensive and accurate evaluation of VVO performance metrics.
- Continue to investigate how to improve outcomes across VVO feeders. Many feeders across the EDCs underwent no material change in voltage. Correspondingly, energy reduction estimates were small-to-insignificant. These observations may indicate flaws in the VVO control scheme for these feeders. In order to improve VVO performance, Guidehouse recommends that the EDCs continue their efforts to investigate root causes to shortcomings in the VVO control schemes and work with distribution engineers and the VVO vendors to respond accordingly. If needed, Guidehouse can conduct in-depth case studies at these substations further understand shortcomings in the VVO control scheme.

1. Introduction to Massachusetts Grid Modernization

This section provides a brief background to the Grid Modernization Evaluation process and an overview of the Volt/VAR Optimization (VVO) Investment Area and specific VVO evaluation objectives. These are provided for context when reviewing the subsequent sections that address the specific evaluation process and findings.

1.1 Massachusetts Grid Modernization Plan Background

The following subsections summarize the progression of Massachusetts Grid Modernization Plans (GMPs) filed by the three Massachusetts Electric Distribution Companies (EDCs): Eversource, National Grid, and Unitil.

1.1.1 Grid Modernization Term 1 (2018-2021)

On May 10, 2018, the Massachusetts DPU issued its Order[14] regarding the individual Grid Modernization Plans (GMPs) filed by the three Massachusetts EDCs.[15,16] In the Order, the DPU preauthorized grid-facing investments over 3 years (2018-2020) for each EDC and adopted a 3-year (2018-2020) regulatory review construct for preauthorization of grid modernization investments. On May 12, 2020, the DPU issued an Order[17] extending the 3-year grid modernization plan investment term to a 4-year term, which introduced a 2021 program year.

During the GMP term spanning 2018-2021 (hereon referred to as Term 1) the grid modernization investments were organized into six Investment Areas to facilitate understanding, consistency across EDCs, and analysis.

- Monitoring and Control (M&C)
- Advanced Distribution Automation (ADA)
- Volt/VAR Optimization (VVO)
- Advanced Distribution Management Systems/Advanced Load Flow (ADMS and ALF)
- Communications/IoT (Comms)
- Workforce Management (WFM)

A certain level of spending for each of these GMP Investment Areas was preauthorized by the DPU, with the expectation they would advance the achievement of DPU's grid modernization objectives:

14 Massachusetts DPU 15-120/DPU 15-121/DPU 15-122 (Grid Modernization) Order issued May 10, 2018 (DPU Order).

15 On August 19, 2015, National Grid, Unitil, and Eversource each filed a grid modernization plan with the DPU. The DPU docketed these plans as DPU 15-120, DPU 15-121, and DPU 15-122, respectively.

16 On June16, 2016, Eversource and National Grid each filed updates to their respective grid modernization plans

17 Massachusetts DPU 15-120; DPU 15-121; DPU 15-122 (Grid Modernization) Order (1) Extending Current Three-Year Grid Modernization Plan Investment Term; and (2) Establishing Revised Filing Date for Subsequent Grid Modernization Plans (issued May 12, 2020).

- Optimize system performance by attaining optimal levels of grid visibility command and control, and self-healing
- Optimize system demand by facilitating consumer price responsiveness
- Interconnect and integrate distributed energy resources (DER)

For Term 1, the Massachusetts DPU's preauthorized budget for grid modernization varied by Investment Area and EDC. Eversource originally had the largest preauthorized budget at $133 million, with ADA and M&C representing the largest share ($44 million and $41 million, respectively). National Grid's preauthorized budget was $82.2 million, with ADMS representing over 50% ($48.4 million). Unitil's preauthorized budget was $4.4 million and VVO makes up 50% ($2.2 million).

On July 1, 2020, Eversource filed a request for an extension of the budget authorization associated with grid modernization investments.[18] The budget extension, approved by the DPU on February 4, 2021,[19] included $14 million for ADA, $16 million for ADMS/ALF, $5 million for Communications, $15 million for M&C, and $5 million for VVO.[20] These values are included in the Eversource total budget by Investment Area in Table 8.

Table 8. Term 1 (2018-2021) Preauthorized Budget, $M

Investment Areas	Eversource	National Grid	Unitil	Total
ADA	$58.00	$13.40	N/A	**$71.40**
ADMS/ALF	$33.00	$48.40	$0.70	**$79.10**
Comms	$23.00	$1.80	$0.84	**$25.60**
M&C	$56.00	$8.00	$0.35	**$64.75**
VVO	$18.00	$10.60	$2.22	**$30.80**
WFM	--	--	$0.30	**$1.00**
2018-2021 Total	**$188.00**	**$82.20**	**$4.41**	**$272.65**

Source: DPU Order, May 10, 2018, and Eversource filing "GMP Extension and Funding Report," July 1, 2020

1.1.2 Grid Modernization Term 2 (2022-2025)

On July 2, 2020, the Massachusetts DPU issued an Order[21] that triggered further investigation into modernization of the electric grid. In the order, the DPU required that the EDCs file a grid modernization plan on or before July 1, 2021. In accordance with this order, the Massachusetts EDCs filed grid modernization plans for a 4-year period spanning 2022-2025 (hereby referred to as Term 2).[22] In these plans, the EDCs outlined continued investment in the areas that received

[18] Grid Modernization Program Extension and Funding Report. Submitted to Massachusetts DPU on July 1, 2020 as part of DPU 15-122

[19] Massachusetts DPU 20-74 Order issued on February 4, 2021.

[20] The DPU allowed flexibility to these budgets to accommodate changing technologies and circumstances. For example, EDCs can shift funds across the different preauthorized investments if a reasonable explanation for these shifts is supplied.

[21] Massachusetts DPU 20-69: Investigation by the Department of Public Utilities on its own Motion into the Modernization of the Electric Grid – Phase Two (issued July 2, 2020).

[22] On July 1, 2021, Eversource, National Grid, and Unitil each filed a grid modernization plan with the DPU for the period spanning 2022-2025. The DPU docketed these plans as DPU 21-80, 21-81, and 21-82, respectively.

investment during Term 1 (referred to as Track 1 Investment Areas), and investment in new Investment Areas (Track 2 Investment Areas). The Track 2 grid modernization investments were organized into the following additional Investment Areas to facilitate understanding, consistency across EDCs, and analysis.

- Interconnection Automation
- Probabilistic Power Flow Modeling
- Distributed Energy Resource Mitigation (DER Mitigation)
- Distributed Energy Resource Management System (DERMS)
- Demonstration Projects

1.1.3 Investment Areas

Table 9 and Table 10 summarize the DPU pre-authorized GMP investments.

Table 9. Overview of Term 2, Track 1 Investment Areas

Investment Areas	Description	Objective
Monitoring and Control (M&C)	Remote monitoring and control of devices in the substation for feeder monitoring or online devices for enhanced visibility outside the substation	Enhancing grid visibility and control capabilities, reliability increase
Advanced Distribution Automation (ADA)	National Grid-only investment for Term 2. ADA allows for isolation of outage events with automated restoration of unaffected circuit segments	Reduces the impact of outages
Volt/VAR Optimization (VVO)	Control of line and substation equipment to optimize voltage, reduce energy consumption, and increase hosting capacity	Optimization of distribution voltage to reduce energy consumption and demand
Advanced Distribution Management Systems	New capabilities in real-time system control with investments in developing accurate system models and enhancing Supervisory control and data acquisition (SCADA) and outage management systems to control devices for system optimization and provide support for distribution automation and VVO with high penetration of DER	Enables high penetration of DER by supporting the ability to control devices for system optimization, ADA, and VVO
Communications/IoT	Fiber middle mile and field area communications systems	Enables the full benefits of grid modernization devices to be realized
Workforce Management (WFM)	Unitil-only investment for Term 2 to improve workforce and asset utilization related to outage management and storm response	Improves the ability to identify damage after storms

Source: Grid Mod RFP – SOW (Final 8-8-18).pdf; Guidehouse

Table 10. Overview of Term 2, Track 2 Investment Areas

Investment Areas	Description	Objective
Interconnection Automation	Eversource plans to integrate, into a single software, both their existing Distributed Generation (DG) tools and customer interconnection portal.	Improve the DG interconnection process with reductions in time & resources for a growing number of applications
Probabilistic Power Flow Modeling	Eversource plans to use a simulation of locational load and generation based on variables such as customer behavior and energy market prices.	Leverage GMP term 1 ALF investments into an automated approach to system modelling.
DER Mitigation	Unitil plans to install ground-fault overvoltage protection as well as upgrade either voltage regulators or load tap changers for three substations with reverse power flow issues	Address reverse power flow issues caused by DER saturation at three specific substations.
DERMS	Software that forms the hub of DER management functions and integrates with other applications such as a Demand Response Management System ("DRMS") and ADMS, to create the DERMS Platform.	Cost-effectively optimize system performance and integrate DERS with more granularity
Demonstration Projects	Two demonstration projects proposed by National Grid to test new tools. Includes Active Resource Integration (ARI) and Local Export Power Control	Facilitates the interconnection of DG in certain areas of the EDC's distribution system that are approaching saturation
Project Management and Third-Party Evaluation	Investment into evaluation and project management. Evaluation includes third party evaluator budget, where the evaluator will conduct studies on appropriate topics related to the deployment of preauthorized investments. Project management includes portfolio management and reporting.	Assess and report on GMP deployment progress and performance of grid modernizing investments.

Source: Massachusetts DPU 21-80/DPU 21-81/DPU 21-82 Order on New Technologies and Advanced Metering Infrastructure Proposals issued November 30, 2022.

The Massachusetts DPU preauthorized budget for Track 1 investments and Track 2 investments on October 7, 2022[23] and November 30, 2022,[24] respectively. The preauthorized budget for grid modernization varies by Investment Area and EDC. National Grid has the largest preauthorized track one budget at $300.8 million, with Communications and VVO representing the largest share ($103 million and $76 million, respectively). Eversource's preauthorized Track 1 budget is $176.6 million, with M&C representing about 50% ($76.3 million). Unitil's preauthorized track one budget is $9.1 million with VVO making up more than 50% ($5.4 million).

[23] Massachusetts DPU 21-80/DPU 21-81/DPU 21-82 Order on Previously Deployed Technologies issued October 7, 2022.

[24] Massachusetts DPU 21-80/DPU 21-81/DPU 21-82 Order on New Technologies and Advanced Metering Infrastructure Proposals issued November 30, 2022.

Table 11. Term 2 (2022-2025) Preauthorized Budget, $M

Investment Areas	Eversource	National Grid	Unitil	Total
ADA	--	$37.70	--	**$37.70**
ADMS*	$21.90	$61.00	$1.50	**$84.40**
Comms**	$38.00	$102.80	$0.82	**$141.62**
M&C	$76.30	$4.10	$1.10	**$81.50**
VVO	$40.40	$76.40	$5.40	**$122.20**
WFM	--	--	$0.25	**$0.25**
IT/OT	--	$18.80	--	**$18.80**
Track 1 Total	***$176.60***	***$300.80***	***$9.07***	***$486.47***
Interconnection Automation	$2.77	--	--	**$2.77**
Probabilistic Power Flow	$2.07	--	--	**$2.07**
DER Mitigation	--	--	$1.04	
DERMS	$16.00	$24.60	$0.16	**$41.80**
Demonstration Projects	--	$6.40	--	**$6.40**
Project Management and Third-Party Evaluation	$8.00	$4.40	$0.30	**$12.70**
Track 2 Total	***$29.00***	***$35.40***	***$1.50***	***$65.90***
2022-2025 Total	**$205.60*****	**$336.20**	**$10.57**	**$552.37**

* Given as $1.50M minus DERMS cost from DPU Order, Oct. 7, 2022, and calculated from DPU Order, Nov. 30, 2022.

** Includes Communications Modernization for Eversource, with added budget taken from DPU Order, Nov. 30, 2022.

*** Budget includes $16.3 million in funds remaining from the supplemental budget approved in D.P.U. 20-74 for DMS, substation automation, and VVO investments that Eversource sought to expend in calendar year 2022.

Source: DPU Order on Previously Deployed Technologies, October 7, 2022, and DPU Order on New Technologies, November 30, 2022 under docket 21-80, 21-81, and 21-82.

1.1.4 Evaluation Goals and Objectives

The DPU requires a formal evaluation process (including an evaluation plan and evaluation studies) for the EDCs' preauthorized GMP investments. Guidehouse is completing the evaluation to enable a uniform statewide approach and to facilitate coordination and comparability. The evaluation measures the progress made toward the achievement of DPU's grid modernization objectives. It uses the DPU-established Infrastructure Metrics and Performance Metrics, as well as Case Studies that illustrate the performance of specific technology deployments, to help determine if the investments are meeting the DPU's GMP objectives.

As previously noted, the Massachusetts DPU order on Track 2 technologies was released on November 30, 2022. The EDCs waited for DPU ruling on these technologies prior to commencing with significant investment, and thus were not able to complete deployment of

Track 2 technologies within the remaining 2022 calendar year.[25] Guidehouse has, therefore, not included evaluation findings for Track 2 technologies in this PY 2022 evaluation report, but instead will report GMP Track 2 evaluation findings for PY 2023 through PY 2025 in future program year reports.

1.1.5 Metrics for Evaluation

The DPU-required evaluation involves Infrastructure Metrics and Performance Metrics for each Investment Area. In addition, selected case studies have been added for some Investment Areas (e.g., M&C) as part of the evaluation to help facilitate understanding of how the technology performs in specific instances (e.g., in remediating the effects of a line outage).

1.1.5.1 Infrastructure Metrics

The Infrastructure Metrics assess the deployment of the GMP investments. Table 12 summarizes the Infrastructure Metrics.

Table 12. Infrastructure Metrics Overview

Metric		Description	Applicable IAs	Metric Responsibility*
IM-1	**Grid Connected Distribution Generation Facilities**	Tracks the number and type of distributed generation facilities in service and connected to the distribution system	ADMS/ALF	EDC
IM-2	**System Automation Saturation**	Measures the quantity of customers served by fully or partially automated devices.	M&C, ADA	EDC
IM-3	**Number and Percent of Feeders with Installed Sensors**	Measures the total number of feeders with installed sensors which will provide information useful for proactive planning and intervention.	M&C	EDC
IM-4	**Number of Devices or Other Technologies Deployed**	Measures how the EDC is progressing with its GMP from an equipment or device standpoint.	All IAs	Evaluator
IM-5	**Cost for Deployment**	Measures the associated costs for the number of devices or technologies installed; designed to measure how the EDC is progressing under its GMP.	All IAs	Evaluator
IM-6	**Deviation Between Actual and Planned Deployment for the Plan Year**	Measures how the EDC is progressing relative to its GMP on a year-by-year basis.	All IAs	Evaluator

25 Within PY 2022, there was limited spend for Track 2 technologies for both Unitil and Eversource. Unitil reported approximately $20k collectively across DER mitigation, workforce management, and Program Management and EM&V, while Eversource reported approximately $6k for DERMS.

Metric		Description	Applicable IAs	Metric Responsibility*
IM-7	**Projected Deployment for the Remainder of the GMP Term**	Compares the revised projected deployment with the original target deployment as the EDC implements its GMP.	All IAs	Evaluator

PM = Performance Metric, IA = Investment Area, ES = Eversource, NG = National Grid, UTL = Unitil

* Column indicates which EDC is responsible for calculating each metric, for statewide metrics, all EDCs are responsible

Source: Guidehouse Review of DPU Order, May 10, 2018[26]

1.1.5.2 Performance Metrics

The Performance Metrics assess the performance of all the GMP investments. Table 13 summarizes the Performance Metrics used for the various Investment Areas. This report discusses Performance Metrics that pertain specifically to the M&C Investment Area.

Table 13. Performance Metrics Overview

Metric		Description	Applicable IAs	Metric Responsibility*
PM-1	**VVO Baseline**	Establishes a baseline impact factor for each VVO-enabled feeder which will be used to quantify the peak load, energy savings, and greenhouse gas (GHG) impact measures.	VVO	All
PM-2	**VVO Energy Savings**	Quantifies the energy savings achieved by VVO using the baseline established for the feeder against the annual feeder load with the intent of optimizing system performance.	VVO	All
PM-3	**VVO Peak Load Impact**	Quantifies the peak demand impact VVO/CVR has on the system with the intent of optimizing system demand.	VVO	All
PM-4	**VVO Distribution Losses without Advanced Metering Functionality (AMF) (Baseline)**	Presents the difference between feeder load measured at the substation via the SCADA system and the metered load measured through advanced metering infrastructure.	VVO	All
PM-5	**VVO Power Factor**	Quantifies the improvement that VVO/CVR is providing toward maintaining feeder power factors near unity.	VVO	All

[26] Massachusetts DPU 15-120/DPU 15-121/DPU 15-122 (Grid Modernization) Order issued May 10, 2018 (DPU Order), pg. 198-201.

Metric		Description	Applicable IAs	Metric Responsibility*
PM-6	**VVO – GHG Emissions**	Quantifies the overall GHG impact VVO/CVR has on the system.	VVO	All
PM-7	**Voltage Complaints**	Quantifies the prevalence of voltage-related complaints before and after deployment of VVO investments to assess customer experience, voltage stability under VVO.	VVO	All
PM-8	**Increase in Substations with DMS Power Flow and Control Capabilities**	Examines the deployment and data cleanup associated with deployment of ADMS, primarily by counting and tracking the number of feeders and substations per year.	ADMS/ ALF	All
PM-9	**Control Functions Implemented by Feeder**	Examines the control functions of DMS power flow and control capabilities, focused on the control capabilities including VVO-CVR and FLISR.	ADMS/ ALF	All
PM-10	**Numbers of Customers that benefit from GMP funded Distribution Automation Devices**	Shows the progress of ADA investments by tracking the number of customers that have benefitted from the installation of ADA devices.	ADA	ES, NG
PM-11	**Grid Modernization investments' effect on outage durations**	Provides insight into how ADA and M&C investments can reduce outage durations (CKAIDI). Compares the experience of customers on GMP M&C-enabled feeders as compared to the previous 3-year average for the same feeder.	M&C, ADA	All
PM-12	**Grid Modernization investments' effect on outage frequency**	Provides insight into how ADA and M&C investments can reduce outage frequencies (CKAIFI). Compares the experience of customers on M&C-enabled feeders as compared to the prior 3-year average for the same feeder.	M&C, ADA	All
PM-ES-1	**Advanced Load Flow – Percent Milestone Completion**	Examines the fully developed ALF capability across Eversource's feeder population.	ADMS/ ALF	ES
PM-ES-2	**Protective Zone: Average Zone Size per Feeder**	Measures Eversource's progress in sectionalizing feeders into protective zones designed to limit outages to customers located within the zone.	ADA	ES

Metric		Description	Applicable IAs	Metric Responsibility*
PM-UTL1	**Customer Minutes of Outage Saved per Feeder**	Tracks time savings from faster AMI outage notification than customer outage call, leading to faster outage response and reduced customer minutes of interruption.	M&C	UTL
PM-NG-1	**Main Line Customer Minutes of Interruption Saved**	Measures the impact of ADA investments on the customer minutes of interruption (CMI) for main line interruptions. Compares the CMI of GMP ADA-enabled feeders to the previous 3-year average for the same feeder.	ADA	NG

PM = Performance Metric, IA = Investment Area, ES = Eversource, NG = National Grid, UTL = Unitil

* Column indicates which EDC is responsible for calculating each metric, for statewide metrics, all EDCs are responsible

Source: Stamp Approved Performance Metrics, July 25, 2019.[27]

[27] Massachusetts Department of Public Utilities, Grid Modernization Plan Performance Metrics. Submitted on July 25, 2019, as part of DPU 12-120,15-121, & 15-122

1.2 VVO Investment Area Overview

As a part of grid modernization, the Massachusetts EDCs are investing to enable VVO on selected feeders across their distribution networks. VVO optimizes distribution voltage to reduce energy consumption and demand without the need for customer interaction or participation. The principle behind VVO is that power demand is reduced at voltages in the lower end of their allowable range for many end-use loads.

VVO reduces feeder demand and energy consumption by flattening and lowering the voltage profile on the feeder while maintaining customer service voltage standards. In addition, VVO systems allow for more gradual and responsive control of reactive power control devices, such as capacitors, which can improve the overall system power factor and reduce system losses. VVO allows customers to realize lower consumption without experiencing a reduction in their level of service.

The VVO investment will first be used to condition feeders, install equipment, and commission software. Once the software commissioning is complete, and as feeders complete their conditioning and equipment installation, they will become VVO enabled.

Table 14 summarizes preauthorized budget for VVO for Eversource, National Grid, and Unitil.

Table 14. GMP Preauthorized Budget for VVO

Period	Eversource	National Grid	Unitil	Total
Term 1 (2018 – 2021)	$13.00	$10.60	$2.22	**$25.82**
Term 2 (2022 – 2025)	$40.40	$76.40	$5.40	**$122.20**

Source: Term 1 preauthorized budgets were populated using DPU Order, May 10, 2018, and Eversource filing "GMP Extension and Funding Report," July 1, 2020. Term 2 preauthorized budgets were populated using DPU Order, October 7, 2022, and DPU Order, November 30, 2022 under docket 21-80, 21-81, and 21-82.

The following subsection discusses EDC-specific approaches to VVO.

1.2.1 EDC Approach to VVO

The VVO investment process for each of the EDCs involves four core phases: VVO investment, VVO commissioning, VVO enablement, and VVO On/Off testing. Table 15 provides the four phases and a brief description of each phase, and Section 3 summarizes the status of each deployment phase by EDC.

Table 15. VVO Deployment Phases

Phase	Description
VVO Investment	Deployment and installation of VVO devices, including but not limited to capacitor banks, load tap changer (LTC) controls, and voltage regulators. Load rebalancing may occur during this time.
VVO Commissioning	Process of preparing VVO investments installed on conditioned feeders to begin VVO control.
VVO Enablement	Date at which the VVO system is enabled and managing voltage and reactive power.
VVO On/Off Testing Period	Dates over which the VVO system is cycled between the on and off states using a predetermined cycling schedule.

Source: Guidehouse

Table 16 defines the devices and technologies that each EDC has deployed as part of VVO investment. Sections 3 (Infrastructure Metrics) and 4 (Performance Metrics) below discuss specifics related to each EDCs' goals and objectives in the VVO Investment Area, while Section 2 below explains the evaluation process.

Table 16. Description of Devices Deployed Under VVO Investment

Device	Description	Term
Capacitor Bank Controls	Reactive compensation devices, equipment combined with two-way communications infrastructure, and remote-control capability to regulate reactive power (VAR) flows throughout the distribution network.	1 2
Inverter Demonstration*	Advanced inverters, which will be deployed at an Eversource-owned solar site in Western Massachusetts to support in coordination with VVO operations and set points.	2
Line Sensors	Voltage sensors, which relay verified field measurements to allow VVO algorithm to regulate voltage and reactive power appropriately.	1 2
Load Tap Changer (LTC) Controls	Transformer load tap changers, which automatically adjust feeder voltage based on local measurement. First of the two devices required to regulate voltage on a distribution feeder.	1 2
Voltage Regulators	Optimized for VVO and equipped with communications equipment to enable remote-control and monitoring of voltage; required to regulate voltage on a distribution feeder.	1 2
Micro-capacitors*	Installed at strategic locations in order to support system load, provide remote visibility and control of the devices, and prepare the feeder for conversion to VVO in the future. While not commissioned into the VVO system, microcapacitors enable additional voltage and power factor control on feeders.	1 2
Grid Monitoring Line Sensors*	Deployed at strategic locations like large side taps, step down transformers, and larger distributed generation sites that do not have SCADA reclosers. Grid monitoring line sensors also allow Eversource to gather additional telemetry from VVO enabled feeders.	1

* Microcapacitors and Grid Monitoring Line Sensors are VVO devices that are solely being deployed by Eversource. National Grid and Unitil have no plan to deploy these device types at this time.

Source: Guidehouse

1.2.2 VVO Evaluation Objectives

This evaluation focuses on the progress and effectiveness of the DPU preauthorized VVO investments for each EDC toward meeting the DPU's grid modernization objectives.[28] Table 17 illustrates the key Infrastructure Metrics and Performance Metrics relevant for the VVO evaluation.

Table 17. VVO Evaluation Metrics

Metric Type	VVO Evaluation Metrics	ES	NG	UTL
IM	Number of devices or other technologies deployed	✓	✓	✓
IM	Cost for deployment	✓	✓	✓
IM	Deviation between actual and planned deployment for the plan year	✓	✓	✓
IM	Projected deployment for the remainder of the term	✓	✓	✓
PM	VVO Baseline	✓	✓	
PM	VVO Energy Savings	✓	✓	
PM	VVO Peak Load Impact	✓	✓	
PM	VVO Distribution Losses w/o AMF (Baseline)	✓	✓	
PM	VVO Power Factor	✓	✓	
PM	VVO GHG Emissions	✓	✓	
PM	Voltage Complaints	✓	✓	

Note: Unitil will not be receiving an evaluation of VVO Performance Metrics until VVO On/Off testing has begun. Unitil anticipates conducting VVO On/Off testing beginning in April 2023.

Source: Guidehouse Stage 3 Evaluation Plan submitted to EDCs on March 1, 2023

The EDCs provided data supporting the Infrastructure Metrics to the evaluation team. Guidehouse presents results from analysis of Infrastructure Metrics data in Section 3. The Performance Metrics will be based on statistical analyses performed by the evaluation team using data provided by each EDC.

Table 18 summarizes the VVO evaluation objectives and associated research questions that will be addressed in the report. The scope of the VVO measurement and verification (M&V) includes tracking the VVO infrastructure deployment against the plan (Infrastructure Metrics) and measuring the energy, peak demand, greenhouse gas (GHG), and voltage complaint impacts of installing the VVO investments and operating VVO (Performance Metrics).

Table 18. VVO M&V Objectives and Associated Research Questions

VVO M&V Objective	Associated Research Questions
Infrastructure Deployment	• What is the extent, type, and cost of VVO investments? • How well does each EDC's deployment track the planned deployment?

[28] DPU Order, May 10, 2018, p.106.

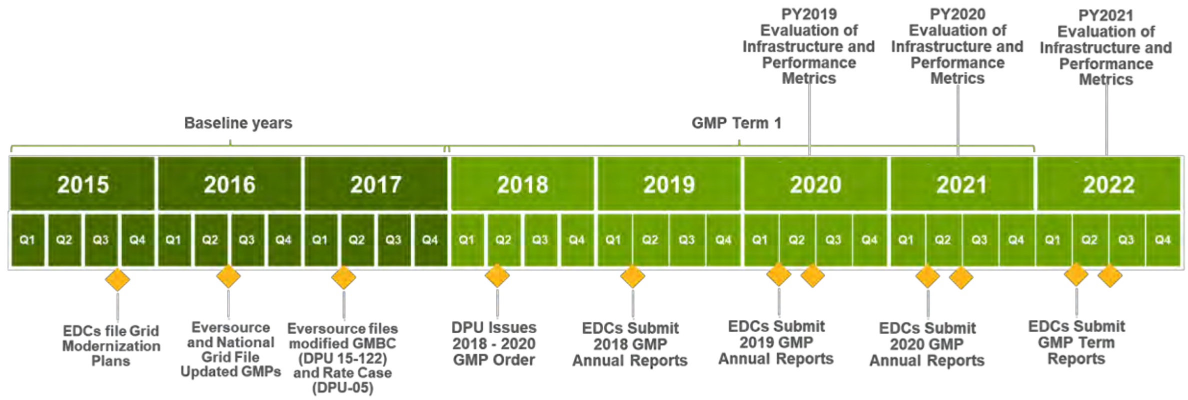
VVO M&V Objective	Associated Research Questions
Energy and Peak Savings by Feeder (Device Deployment)	• How many energy savings were realized from device deployment on VVO enabled feeders? • What is the impact on peak load from VVO investments operating on VVO enabled feeders? • How much GHG emissions reduction has been enabled from device deployment on VVO enabled feeders?
Energy and Peak Savings by Feeder (VVO-Operation)	• How many energy savings were realized from VVO operating on VVO enabled feeders? • What is the impact on peak load from VVO operating on VVO enabled feeders? • What is the impact on loss reductions and feeder-level power factor associated from VVO operating on VVO enabled feeders? • How much GHG emissions reduction was enabled from VVO operating on VVO enabled feeders?
Voltage Complaints	• What is the impact of VVO-related investments on the number of voltage complaints?

Source: Guidehouse Stage 3 Evaluation Plan submitted to EDCs on March 1, 2023

2. VVO Evaluation Process

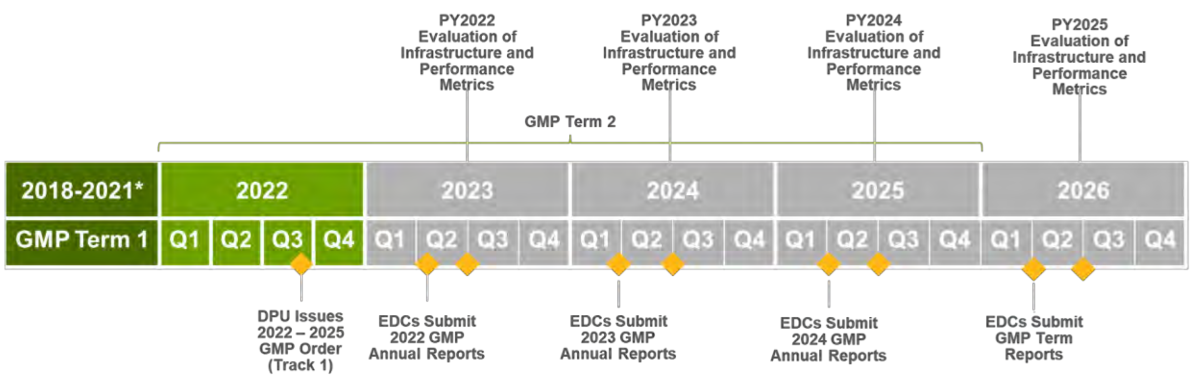
This section presents a high-level overview of the Guidehouse methodologies for the evaluation of Infrastructure Metrics and Performance Metrics. Figure 3 highlights the Term 1 filing background and timeline of the GMP Order and the evaluation process, and Figure 4 indicates the expected timeline for Term 2.

Figure 3. Term 1 Evaluation Timeline



Source: Guidehouse review of the DPU orders and GMP process

Figure 4. Term 2 Evaluation Timeline



Source: Guidehouse review of the DPU orders and GMP process

As a note, spend and deployment was conducted in PY 2022 to account for any spend and deployment from Term 1 (2018-2021 plan) as well as new spend to be included in Term 2 (2022 – 2025). Term 1 spend and deployment will be denoted separately within the analysis for Eversource, as Eversource provided data to support a comparison of Term 1 and Term 2 planned versus actual activity.

2.1 Infrastructure Metrics Analysis

Guidehouse annually assesses the progress of each of the EDCs toward deploying VVO on their feeders. Table 19 through Table 22 highlight the Infrastructure Metrics that were evaluated.

Table 19. GMP Term 1 Infrastructure Metrics Overview – Eversource Only

Infrastructure Metrics			Calculation
IM-4	Number of devices or other technologies deployed thru. PY 2022	# Devices Deployed	$\sum_{PY=2018}^{2021} (Devices\ Commissioned)_{PY} + Devices\ Commissioned_{CY2022(T1)}$
		% Devices Deployed	$\frac{\sum_{PY=2018}^{2021} (Devices\ Commissioned)_{PY} + Devices\ Commissioned_{CY2022(T1)}}{\sum_{PY=2018}^{2021} (Devices\ Commissioned)_{PY} + (Planned\ Devices)_{CY2022(T1)}}$
IM-5	Cost through PY 2022	Total Spend, $M	$\sum_{PY=2018}^{2021} (Actual\ Spend)_{PY} + Actual\ Spend_{CY2022(T1)}$
		% Spend	$\frac{\sum_{PY=2018}^{2021} (Actual\ Spend)_{PY} + Actual\ Spend_{CY2022(T1)}}{\sum_{PY=2018}^{2021} (Actual\ Spend)_{PY} + Planned\ Spend_{CY2022(T1)}}$
IM-6	Deviation Between Actual and Planned Deployment for PY 2022	% On Track (Devices)	$\frac{(Devices\ Commissioned)_{CY2022(T1)}}{(Planned\ Devices)_{CY2022(T1)}}$
		% On Track (Spend)	$\frac{(Actual\ Spend)_{CY2022(T1)}}{(Planned\ Spend)_{CY2022(T1)}}$
IM-7	Projected Deployment for the remainder of the GMP Term (i.e., Term 1)*	# Devices Remaining	N/A^*
		Spend Remaining , $M	N/A^*

Note: This table pertains to Infrastructure Metrics for Eversource only. Planned devices and spend are based on the 2021 GMP Term Report filing (filed on April 1, 2022 under DPU docket 21-80). All CY2022 spend and deployment data given above, to be calculated, includes only units/dollars dedicated to work intended for Term 1, and excludes any deployment and spend apportioned for Term 2.

* This metric has been interpreted here (i.e., within the context of the 2022 Program Year Evaluation) as the units and spending that the EDC plans to complete their most recent 4-year Term 1 plans. Additional Grid Modernization units and dollars incurred in 2022 are attributed to Term 2, as appropriate, and all units and dollars spent during 2023 through 2025 will be considered as part of Term 2 GMPs.

Source: Guidehouse

Table 20. GMP Term 1 Infrastructure Metrics Overview by Feeder – Eversource Only

Infrastructure Metrics*			Calculation
IM-4	**Number of Devices or Other Technologies Deployed through PY 2022**	# Feeders with VVO Enabled	$(VVO\ Enabled\ Feeders)_{CY2022(T1)}$
		% Feeders with VVO Enabled	$\frac{(VVO\ Enabled\ Feeders)_{CY2022(T1)}}{\sum_{PY=2018}^{2021}(Actual\ \ VVO\ Enabled\ Feeders)_{PY}+(VVO\ Enabled\ Feeders)_{CY2022(T1)}}$
IM-6	**Deviation Between Actual and Planned Deployment for PY 2022**	% On Track (VVO Enabled Feeders)	$\frac{(VVO\ Enabled\ Feeders)_{CY2022(T1)}}{(Planned\ VVO\ Enabled\ Feeders)_{CY2022(T1)}}$
IM-7	**Projected Deployment for the remainder of the GMP Term (i.e., Term 1)***	# VVO Enabled Feeders Remaining	$N/A*$

Note: This table pertains to Infrastructure Metrics for Eversource. All CY2022 feeder status includes only feeders identified as receiving VVO within GMP Term 1 plans and excludes activity on any feeders planned for GMP Term 2.

* VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

** This metric has been interpreted here (i.e., within the context of the 2022 Program Year Evaluation) as the feeders that the EDC plans to complete their most recent 4-year Term 1 plans. Additional VVO feeders that were enabled 2022 are attributed to Term 2, as appropriate, and all VVO feeders that will be enabled during 2023 through 2025 will be considered as part of Term 2 GMPs.

Source: Guidehouse

Table 21. GMP Term 2 Infrastructure Metrics Overview – All EDCs

Infrastructure Metrics			Calculation
IM-4	**Number of devices or other technologies deployed thru. PY 2022**	# Devices Planned	$(Devices\ Commissioned)_{PY2022}$
		% Devices Deployed	$\frac{(Devices\ Comissioned)_{PY2022}}{(Devices\ Comissioned)_{PY2022}+\sum_{PY=2023}^{2025}(Planned\ Devices)_{PY}}$
IM-5	**Cost through PY 2022**	Total Spend, $M	$(Actual\ Spend)_{PY2022}$
		% Spend	$\frac{(Actual\ Spend)_{PY2022}}{\sum_{PY=2022}^{2025}(Planned\ Spend)_{PY}}$
IM-6	**Deviation Between Actual and Planned Deployment for PY 2022**	% On Track (Devices)	$\frac{(Devices\ Commissioned)_{PY2022}}{(Planned\ Devices)_{PY2022}}$
		% On Track (Spend)	$\frac{(Actual\ Spend)_{PY2022}}{(Planned\ Spend)_{PY2022}}$

Infrastructure Metrics			Calculation
IM-7	**Projected Deployment for the remainder of the GMP Term**	# Devices Remaining	$\sum_{PY=2022}^{2025}(Planned\ Devices)_{PY} - (Devices\ Comissioned)_{PY2022}$
		Spend Remaining, $M	$\sum_{PY=2022}^{2025}(Planned\ Spend)_{PY} - (Actual\ Spend)_{PY2022}$

Note: CY2022 spend and deployment data given above includes only units/dollars within Term 2 plans, and excludes any deployment and spend apportioned for Term 1 (carryover).

Source: Guidehouse

Table 22. GMP Term 2 Infrastructure Metrics Overview by Feeder – All EDCs

Infrastructure Metrics*			Calculation
IM-4	**Number of Devices or Other Technologies Deployed through PY 2022**	# Feeders with VVO Enabled	$(VVO\ Enabled\ Feeders)_{PY2022}$
		% Feeders with VVO Enabled	$\frac{(VVO\ Enabled\ Feeders)_{PY2022}}{(VVO\ Enabled\ Feeders)_{PY2022} + \sum_{PY=2023}^{2025}(\ Planned\ VVO\ Enabled\ Feeders)_{PY}}$
IM-6	**Deviation Between Actual and Planned Deployment for PY 2022**	% On Track (VVO Enabled Feeders)	$\frac{(VVO\ Enabled\ Feeders)_{PY2022}}{(Planned\ VVO\ Enabled\ Feeders)_{PY2022}}$
IM-7	**Projected Deployment for the remainder of the GMP Term***	# VVO Enabled Feeders Remainin g	$\sum_{PY=2022}^{2025}(Planned\ VVO\ Enabled\ Feeders)_{PY} - (VVO\ Enabled\ Feeders)_{PY2022}$

Note: CY2022 feeder data given above includes only feeders within Term 2 plans, and excludes any VVO feeders apportioned for Term 1 (carryover). These most recent plan totals were included in each EDC’s VVO Supplemental data submissions, provided February 2022. These submissions listed the date in which each Term 1 and Term 2 feeder were slated to have full VVO capability.

* VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Source: Guidehouse

Section 3.2 provides the results from the evaluation of Infrastructure Metrics. To evaluate Infrastructure Metrics, Guidehouse:

- Reviewed the data provided by the EDCs to confirm their progress through PY 2022 (see Section 3.1.2, “Data QA/QC Process”)
- Interviewed representatives from each EDC to understand the status of the VVO investments, including:
    - Updates to their planned VVO investments
    - Reasons for deviation between actual and planned deployment and spend

2.2 Performance Metrics Analysis

Guidehouse evaluated Performance Metrics for two of the three EDCs, focusing on the utility and customer experience with VVO. Table 23 describes the Performance Metrics evaluated in PY 2022.

Table 23. Performance Metrics Overview

PM	Performance Metrics	Description
PM-1	**VVO – Baseline**	Establishes a baseline impact factor for each VVO enabled feeder which will be used to quantify the peak load, energy savings, and GHG impact measures
PM-2	**VVO – Energy Savings**	Quantifies the energy savings achieved by VVO using the baseline established for the feeder against the annual feeder load with the intent of optimizing system performance
PM-3	**VVO – Peak Load Impact**	Quantifies the peak demand impact VVO/CVR has on the system with the intent of optimizing system demand
PM-4	**VVO – Distribution Losses without AMF (Baseline)**	Presents the difference between feeder load measured at the substation via the SCADA system and the metered load measured through advanced metering infrastructure
PM-5	**VVO – Power Factor**	Quantifies the improvement that VVO/CVR is providing toward maintaining feeder power factors near unity
PM-6	**VVO – GHG Emissions**	Quantifies the overall GHG impact VVO/CVR has on the system
PM-7	**Voltage Complaints**	Quantifies the prevalence of voltage-related complaints before and after deployment of VVO investments to assess customer experience, voltage stability under VVO

Source: Stamp Approved Performance Metrics, July 25, 2019.

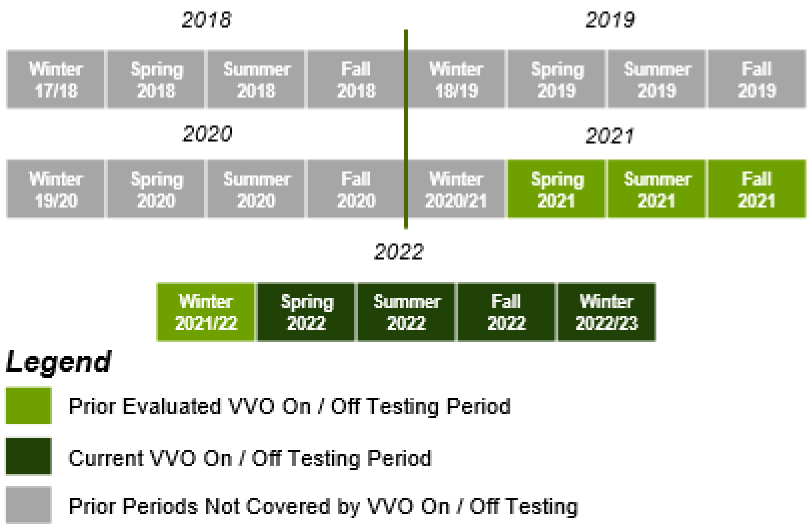
The metrics in Table 22 are based on a M&V process, which uses statistical analysis to quantify the impacts the VVO system has on the customers it serves. Quantifying VVO Performance Metrics requires interval measurements of feeder-level voltage and power demand while the voltage and reactive power controls are operated in both baseline (non-VVO) and VVO modes.

For changes associated with VVO being enabled to be quantified, Guidehouse and the EDCs have agreed to the plan for VVO On/Off testing to continue for at least 9 months, covering summer (June, July, and August), winter (December, January, and February), and one of the spring (March, April, and May) or fall (September, October, November) shoulder seasons.

2.2.1 Performance Metrics Timeline

Figure 5 highlights the key Performance Metrics analysis periods for Eversource. The Performance Metrics analysis provided for this report will be focused on results from VVO On/Off testing conducted during Spring 2022 – Winter 2022/23. Results from VVO On/Off testing conducted during Spring 2021 – Winter 2021/22 were provided in the Massachusetts Grid Modernization Program Year 2021 Evaluation Report for Volt-VAR Optimization.[29]

Figure 5. Performance Metrics Timeline



Source: Guidehouse analysis

[29] All Massachusetts Grid Modernization Program Year 2021 Evaluation Reports were filed on July 1, 2022 under DPU dockets 22-40, 22-41, and 22-42.

3. VVO Infrastructure Metrics

3.1 Data Management

Guidehouse worked with the EDCs to collect data to complete the evaluation for the assessment of VVO Infrastructure Metrics and Performance Metrics. The sections that follow highlight Guidehouse's data sources and data QA/QC processes used in the evaluation of Infrastructure Metrics.

3.1.1 Data Sources

Guidehouse used a consistent methodology (across Investment Areas and EDCs) for evaluating and illustrating EDC progress indicated by the GMP metrics. The subsections that follow summarize each of the data sources used to evaluate Infrastructure Metrics.

3.1.1.1 Term 1 Planned Deployment and Spend for PY 2022

To assess progress against planned carryover deployment and spend for Eversource, Guidehouse used the planned device deployment and cost information from each its *2021 GMP Term Report*[30,31,32], which were filed on April 1, 2022. These filings served as the sources for planning data in this report and are referred collectively as the *GMP Term 1 Plan* each EDC in summary tables and figures throughout this report.

Table 24 lists the sources for the planned and actual quantities reviewed, and it specifies the color/shade used to represent these quantities in graphics throughout the rest of the report.

Table 24. GMP Term 1 Deployment Categories Used for the EDC Plan

Representative Color	Data	Description
	2022 Plan	Projected 2022 Term 1 unit deployment and spend
	2021 Actual	Actual 2021 unit deployment and spend
	2020 Actual	Actual 2020 unit deployment and spend
	2019 Actual	Actual reported unit deployment and spend in 2018
	2018 Actual	Actual reported unit deployment and spend in 2018

Source: Plan and actual data is sourced from the EDCs' 2021 GMP Term Report Appendix 1 filed April 1, 2022.

30 Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2020. Submitted to Massachusetts DPU on April 1, 2021 as part of DPU 21-30.

31 NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2020. Submitted to Massachusetts DPU on April 1, 2021 as part of DPU 21-30. Note that Eversource Energy filed an updated Appendix 1 filing in December of 2021; however that update did not affect any of the data or results in the evaluation.

32 Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2020. Submitted to Massachusetts DPU on April 1, 2021 as part of DPU 21-30.

Guidehouse used the Feeder Status tab of the 2022 GMP Annual Report Appendix 1[33,34,35] to obtain feeder characteristics including system voltage, total feeder count, customer count, feeder length, and annual peak load.

3.1.1.2 Term 2 Planned Deployment and Spend for PY 2022

Guidehouse used the planned device deployment and cost information from each EDCs' filed responses to the first set of information requests issued by the Department of Energy Resources (DOER).[36] These responses were filed on October 4th, October 5th, and December 2nd, 2021, for Eversource, Unitil, and National Grid respectively. These filings served as the sources for planning data in this report and are referred collectively as the *DOER Responses* for each EDC in summary tables and figures throughout this report. Table 25 lists the different sources for the planned and actual quantities reviewed, and it specifies the color/shade used to represent these quantities in graphics throughout the rest of the report.

Table 25. GMP Term 2 Deployment Categories Used for the EDC Plan

Representative Color	Data	Description
	2025 Plan	Projected 2025 unit deployment and spend
	2024 Plan	Projected 2024 unit deployment and spend
	2023 Plan	Projected 2023 unit deployment and spend
	2022 Plan	Projected 2022 unit deployment and spend

Source: Plan data is sourced from EDC responses to the first set of information requests issued by the Department of Energy Resources, filed October 4, October 5, and December 2, 2021 under DPU dockets 21-80, 21-82, and 21-81 for Eversource, Unitil, and National Grid, respectively.

3.1.1.3 PY 2022 Actual Deployment and Spend, Planned Deployment and Spend for the Remainder of Term 2

Guidehouse collected device deployment data and VVO schedule information at the feeder-level using standardized data collection templates. Guidehouse developed these templates for all EDCs: the All Device Deployment data and VVO Supplemental workbooks, respectively.

Guidehouse collected data using standardized data collection templates (e.g., All Device Deployment) for all EDCs in January through March 2023. The data collected provides an update of planned and actual deployment, in dollars, device units, substations, and feeders through the end of PY 2022. Data from these sources are referred to as EDC Data in summary tables and figures throughout the report.

33 Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2022. Submitted to Massachusetts DPU on April 1, 2023 as part of DPU 22-41

34 NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2022. Submitted to Massachusetts DPU on April 1, 2023 as part of DPU 22-40

35 Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2022. Submitted to Massachusetts DPU on April 1, 2023 as part of DPU 22-42

36 Plan data is sourced from EDC responses to the first set of information requests issued by the Department of Energy Resources (DOER). These responses were filed on October 4th, December 2nd, and October 5th, 2021, for Eversource, National Grid, and Unitil under DPU dockets 21-80, 21-81, and 21-82.

The EDC device deployment data (collected in the All Device Deployment workbook) captured planned and actual device deployment and spend data. Actual device deployment and cumulative spend information were provided by work order ID and specified at the feeder- or substation-level, as appropriate. The evaluation team also collected the current implementation stage of the work order (commissioned, construction, or design), the commissioned date (if applicable), and all cumulative costs associated with the work order.

The VVO supplemental data collection template includes additional information unique to the VVO Investment Area. Table 26 summarizes the information requested. Data was provided in the data collection template or submitted in a separate file. Information was requested at the feeder-level where possible (except for IT work). The VVO schedule information and the IT work information are the only data within this template that are applicable to the Infrastructure Metrics. All additional information is applicable to the Performance Metrics.

Table 26. VVO Supplemental Data

Information	Description
Actual/Planned VVO Schedule	Actual and updated planned VVO deployment start/end dates by feeder, including feeder conditioning, load rebalancing, phase balancing, VVO commissioning, VVO enabled, and On/Off testing.
IT Work	Actual and updated planned IT work progress start/end dates and cost information.[37]
Customer Demand Response (DR) Events	Demand response events (time-stamped log of any systemwide demand response (or similar), for example: ISO-NE DR, EDC direct load control programs, EDC behavioral demand response programs).
System Events	Operational changes, a time-stamped log of changes to substation and feeders away from normal operating state (temporary or permanent), and power outages.
DG Log	Log of distributed generation facilities connected to VVO feeders (e.g., type, size, installation date, feeder).
Voltage Complaints	Voltage-related complaints based on voltage perturbation (e.g., high voltage, low voltage, flicker), duration (e.g., multiple days, sporadic).

Source: Guidehouse Stage 3 Evaluation Plan submitted March 1, 2023

Table 27 summarizes the file versions used for the evaluation, and the following subsections provide additional detail surrounding requested inputs in each workbook. The collected data was compared to the data submitted by the EDCs to the DPU in the 2021 Grid Modernization Plan Term Reports and associated Appendix 1 filings.[38,39,40] The evaluation team confirmed the consistency of the data from the various sources and reconciled any differences.

[37] IT work progress includes: planning, procurement, development, deployment, and go-live

[38] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2022. Submitted to Massachusetts DPU on April 1, 2021 as part of DPU 22-41

[39] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2021. Submitted to Massachusetts DPU on April 1, 2022 as part of DPU 22-40

[40] Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2021. Submitted to Massachusetts DPU on April 1, 2022 as part of DPU 22-42

Table 27. EDC Data Received for Analysis

Company	File Version Used for Analysis[41]	
	All Device Deployment	VVO Supplemental
Eversource	Received 3/20/2023	Received 3/31/2023
National Grid	Received 3/29/2023	Received 3/20/2023
Unitil	Received 3/30/2023	Received 2/14/2023

Source: Guidehouse

Table 28 and Table 29 summarize the categories used for the revised planned and actual deployment and spend and specifies the color and pattern used in bar graphs to represent each in the remainder of the report.

[41] Some minor additional updates to specific work orders were addressed after these dates via email.

Table 28. Term 1 EDC Device Deployment and Spending Data Legend – Eversource Only

Representative Color	Data	Description
Device Deployment Data		
Dark purple hatched	2022 Design/Engineering	Detailed design and engineering is in progress, but the device is not yet in construction (from All Device Deployment workbook)
Light pink hatched	2022 Construction	Field construction is in progress, but the device is not yet in-service (from All Device Deployment workbook)
Light pink striped	2022 In-Service	Device is installed and "used and useful" but not yet commissioned to enable all Grid Modernization functionalities (from All Device Deployment workbook)
Magenta	2022 Commissioned	Device is fully operational with all Grid Mod functionalities, and thus is considered "deployed" in PY 2022 (from All Device Deployment workbook)
Light blue	2021 Actual	Actual 2021 deployment (units) (provided in 2022 Appendix 1 filings)
Blue	2020 Actual	Actual 2020 deployment (units) (provided in 2021 Appendix 1 filings)
Dark blue	2019 Actual	Actual 2019 deployment (units) (provided in 2020 Appendix 1 filings)
Navy	2018 Actual	Actual 2018 deployment (units) (provided in 2019 Appendix 1 filings)
Spend Data		
Orange	2022 Actual	Actual 2022 spend (provided in All Device Deployment workbook)
Light yellow-green	2021 Actual	Actual 2021 spend ($) (provided in 2022 Appendix 1 filings)
Light green	2020 Actual	Actual 2020 spend ($) (provided in 2021 Appendix 1 filings)
Green	2019 Actual	Actual 2019 spend ($) (provided in 2020 Appendix 1 filings)
Dark green	2018 Actual	Actual 2018 spend ($) (provided in 2019 Appendix 1 filings)

Note: This legend for deployment and spend data summaries are provided for Eversource only, as National Grid and Unitil tracked all spending and all deployment for all of 2022, independent of Term status (i.e., whether the work was carried over from PY 2021 of Term 1).

Source: Guidehouse

Table 29. Term 2 EDC Device Deployment and Spending Data Legend

Representative Color	Data	Description
Device Deployment Data (from All Device Deployment workbook)		
	2025 Plan	Planned 2025 Deployment
	2024 Plan	Planned 2024 Deployment
	2023 Plan	Planned 2023 Deployment
	2022 Commissioned	Device is fully operational with all Grid Mod functionalities, and thus is considered “deployed” in PY 2021
	2022 In-Service	Device is installed and “used and useful” but not yet commissioned to enable all Grid Modernization functionalities
	2022 Construction	Field construction is in progress but the device is not yet in-service
	2022 Design / Engineering	Detailed design and engineering is in progress but the device is not yet in construction
Spend Data (from All Device Deployment workbook)		
	2025 Estimate	Planned 2025 spend
	2024 Estimate	Planned 2024 spend
	2023 Estimate	Planned 2023 spend
	2022 Actual	Actual 2022 spend

Source: Guidehouse

3.1.2 Data QA/QC Process

Guidehouse reviewed all data provided for Infrastructure Metrics analysis upon receipt of requested data. To ensure accuracy, Guidehouse conducted a QA/QC of all device deployment data received. This review involved following up with the EDCs for explanations regarding the following:

- Potential errors in how the forms were filled out (e.g., feeder information provided in the wrong field)
- Missing or incomplete information
- Large variation in the unit cost of commissioned devices
- Variance between the aggregated totals by device/technology and work order-level data
- Variance between the actual unit costs and planned unit costs

3.2 Deployment Progress and Findings

Guidehouse presents findings from the Infrastructure Metrics analysis for the VVO Investment Area in the following subsections. Throughout this section, Guidehouse will reference Term 1 feeders and Term 2 feeders. Term 1 feeders are the feeders identified by each of the EDCs Grid Modernization Plans as receiving full VVO functionality in 2018 through 2021. Term 2 feeders are feeders that are currently planned to receive VVO investments in Term 2 spanning 2022 through 2025. The number of Term 1 plan feeders that received VVO for Eversource, National Grid, and Unitil total to 26, 20, and 0, respectively. As of the end of 2022, the number of Term 2 feeders planned for full VVO functionality for Eversource, National Grid, and Unitil total to 6, 52, and 11, respectively. The number of feeders slated to receive VVO functionality is expected to grow as Term 2 progresses, as the EDCs were continuing to assess which substations should be prioritized during this term at the end of 2022.

3.2.1 Statewide Comparison

This section discusses the current scope of VVO investments relative to the number of feeders and customers within the EDCs in Massachusetts and it summarizes the deployment progress and findings across all three EDCs.

3.2.1.1 Anticipated Impact on Massachusetts

VVO deployment is anticipated to impact 191 feeders serving 323,944 customers (11.7% of all EDC customers) throughout Massachusetts by the end of 2025. This includes 55 Term 1 feeders and 137 Term 2 feeders. Table 30 highlights the anticipated impact by EDC. VVO investments are expected to be complete by the end of 2025 at the following substations:

- **Eversource:** Agawam, Piper, Podick, Silver, Gunn, and Oswald (Term 1 feeders); Amherst, Breckwood, Cross Road, Cumberland, Doreen, Duxbury, Franconia, Industrial Park, Mashpee, Montague, Orchard, Wareham (Term 2 feeders)
- **National Grid:** East Methuen, Maplewood, and Stoughton (Term 1 feeders, VVO capability active in 2021); Billerica, Depot Street, East Bridgewater, East Dracut, Easton, Melrose, Parkview, Westboro, and West Salem (Term 2 feeders)
- **Unitil:** Townsend (Term 1 feeders); Beech Street, Lunenburg, Pleasant Street, Princeton Road, Summer Street, West Townsend, (Term 2 feeders)

Table 30. Number of Feeders and Customers Covered by VVO

VVO Impact	Eversource		National Grid		Unitil		Total	
	Feeders	Customers	Feeders	Customers	Feeders	Customers	Feeders	Customers
Systemwide Total	2,278	1,352,952	1,141	1,346,266	44	61,214	**3,463**	**2,760,432**
Term 1 Feeders								
Count	32	55,491	20	53,204	3	2,109	**55**	**110,804**
% System Total	1.4%	4.1%	1.8%	4.0%	6.8%	3.4%	**1.6%**	**4.0%**
Term 2 Feeders								
Count	95	127,403	34	74,920	8	10,367	**137**	**212,690**
% System Total	4.2%	9.4%	3.0%	5.6%	18.2%	16.9%	**4.0%**	**7.7%**
Term 1 and Term 2 Total								
Count	**126**	**183,344**	**54**	**128,124**	**11**	**12,476**	**191**	**323,944**
% System Total	**5.5%**	**13.6%**	**4.7%**	**9.5%**	**25.0%**	**20.4%**	**5.5%**	**11.7%**

Source: Guidehouse analysis of 2022 GMP Annual Report Appendix 1, filed April 24, 2023

3.2.1.2 Approach to VVO

Each EDC has a unique approach to selecting feeders for VVO, deploying VVO devices, and implementing VVO control. Table 31 highlights the substations covered by VVO investment and the planned VVO On/Off testing period start date for each EDC. The following subsections include specifics related to each EDC's approach to VVO.

Table 31. VVO Substations and VVO On/Off Testing Start by EDC

Company	Substations (Feeder Count)	VVO On/Off Testing Start
Term 1 Feeders		
Eversource	Agawam (7)	Winter 2020/21
	Piper (6)	Winter 2020/21
	Podick (7)	Spring 2021
	Silver (6)	Winter 2020/21
	Gunn (4)	Spring 2022
	Oswald (2)	Summer 2022
National Grid	E. Methuen (6)	Spring 2021
	Maplewood (8)	Winter 2021/22
	Stoughton (6)	Winter 2020/21
Unitil	Townsend (3)	Spring 2023
Term 2 Feeders		
Eversource[42]	Amherst (8)	Winter 2024/25
	Breckwood (12)	Winter 2024/25
	Cross Road (5)	Fall 2024
	Cumberland (8)	Fall 2024
	Doreen (10)	Fall 2024
	Duxbury (4)	Spring 2025
	Franconia (8)	Fall 2024
	Industrial Park (10)	Fall 2025
	Mashpee (4)	Winter 2024/25
	Montague (8)	Winter 2024/25
	Orchard (14)	Winter 2024/25
	Wareham (4)	Winter 2024/25
National Grid	E. Bridgewater (7)	Summer 2021
	East Dracut (6)	Summer 2022
	Easton (5)	Winter 2022/23
	Melrose (5)	Winter 2022/23
	Westboro (5)	Winter 2022/23
	West Salem (6)	Summer 2022
Unitil	Lunenburg (2)	Winter 2024/25
	Summer St. (4)	Winter 2023/24
	W. Townsend (2)	Winter 2024/25

Source: Guidehouse analysis of 2022 EDC Data

[42] The feeder count is the total number of feeders supplied by the substation. For various technical reasons that become apparent during the VVO equipment locational analyses, not all feeders will be enabled with VVO.

3.2.1.3 VVO Timeline

Table 32 summarizes the expected timelines for completion of each of the four VVO investment phases for each EDC. Further detail surrounding these timelines follows.

Table 32. VVO Deployment Completion by Phase and EDC as of 12/31/2022

Deployment Phase	Number of Feeders*					
	Eversource		National Grid		Unitil	
	Complete	Remaining	Complete	Remaining	Complete	Remaining
Term 1 Feeders						
VVO Investment	32	0	20	0	3	0
VVO Commissioning	26	6	20	0	3	0
VVO Enabled**	26	6	20	0	3	0
VVO On/Off Testing	26	6	20	0	0	3
Term 2 Feeders						
VVO Investment	0	95	18	34	4	4
VVO Commissioning	0	95	18	34	4	4
VVO Enabled**	0	95	18	34	4	4
VVO On/Off Testing	0	95	18	34	0	8

*The count of feeders remaining for each deployment phase is based on deployment plans received in early 2023. As a part of the VVO planning process, additional feeders may be identified by the EDCs for VVO deployment in subsequent years of Term 2 (2023 through 2025).

** VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Source: Guidehouse analysis of 2022 EDC Data

Among Eversource's Term 1 feeders, VVO is enabled and VVO On/Off testing is ongoing at 26 feeders. Eversource began VVO On/Off testing at these feeders in winter 2020/21 for the Agawam, Piper, and Silver substations (19 feeders) and in spring 2021 for the Podick substation (7 feeders). For its Term 1 feeders yet to begin VVO On/Off testing, Eversource is finalizing commissioning of VVO investments and is expected to begin VVO On/Off testing at the Gunn and Oswald substations (6 feeders) in summer 2023 and winter 2023/24, respectively. Among its Term 2 feeders, Eversource is in the process of deploying VVO investments across all 95 currently identified feeders.

All 20 National Grid Term 1 plan feeders are VVO enabled. National Grid completed On/Off testing at the Stoughton substation (6 feeders) in winter 2021/22, and VVO On/Off testing is ongoing at the East Methuen and Maplewood substations (14 feeders). Of its Term 2 plan feeders, National Grid has completed VVO On/Off testing at the East Bridgewater substation (7 feeders) in winter 2022/23, and VVO On/Off testing is ongoing at the Easton and West Salem substations (11 feeders). National Grid is in the process of deploying VVO investments across the remainder of feeders in National Grid's current Term 2 plan (34 feeders).

Unitil has adjusted plans for its Summer Street, Lunenburg, and West Townsend substations (8 feeders) to have these substations receive VVO capability during Term 2, as Unitil was not able to complete VVO investments at these substations during Term 1. Unitil enabled VVO at the Townsend substation (3 feeders), the one substation remaining attributed to Term 1, in winter 2022/23. However, as is described in Section 3.2.4, Unitil was not able to conduct On/Off testing during 2022 due to ongoing vendor software troubleshooting. For the Term 2 feeders connected to the Summer Street, Lunenburg, and West Townsend substations (8 feeders), Unitil has completed VVO deployment at the Summer Street substation (4 feeders), with VVO currently enabled at this substation. VVO On/Off testing will not begin at the substation until winter 2023/24. Unitil is in the progress of deploying VVO investments across the remainder of feeders in Unitil's current Term 2 plan (4 feeders).

3.2.1.4 Term 1 Infrastructure Metrics Results

At the request of Eversource, Guidehouse provided analysis of Eversource's Term 1 spend and deployment. Table 33 summarizes the Infrastructure Metrics results for Eversource's M&C Investment Area through PY 2022. Subsequent sections explain each EDC's progress and plans in greater detail.

Table 33. Term 1 2022 Infrastructure Metrics for VVO

Infrastructure Metrics			Eversource
GMP Plan Total, PY-2018-2022*		# Devices Planned	1,142
		Spend, $M	$17.23
IM-4	Number of devices or other technologies deployed thru PY 2018-2022*	# Devices Deployed***	1,038
		% Devices Deployed	91%
IM-5	Cost for Deployment thru PY 2018 – 2022*	Total Spend, $M	$16.87
		% Spend	98%
IM-6	Deviation Between Actual and Planned Deployment for PY 2022	% On Track (Devices)	70%
		% On Track (Spend)	85%
IM-7	Projected Deployment for the remainder of the GMP Term (i.e., Term 1)*	# Devices Remaining	0
		Spend Remaining, $M	$0.00

*The metric names have been slightly changed here to clarify the time span used in analysis.

** This metric has been interpreted here (i.e., within the context of the 2022 Program Year Evaluation) as the units and spending that the EDC plans to complete their most recent 4-year Term 1 plans. Additional Grid Modernization units and dollars incurred in 2022 are attributed to Term 2, as appropriate, and all units and dollars spent during 2023 through 2025 will be considered as part of Term 2 GMPs.

***Note that "Deployed" here refers to commissioned devices. For full definitions of deployment stages, see Docket 20-46 Response to Information Request DPU-AR-4-11, September 3, 2020.

Source: Guidehouse analysis of 2021 GMP Term Report and 2022 EDC Data

Table 34 summarizes the total number of Term 1 feeders that were VVO enabled by the end of Term 1. National Grid and Eversource have completed deployment of VVO at 4 substations (26 feeders) and 3 substations (20 feeders), respectively. Two Eversource substations (6 feeders) will receive VVO capability later in 2023. Unitil had completed VVO deployment at 1 substation (3 feeders) of the 3 substations (8 feeders) that were initially planned to receive VVO during Term 1. Unitil has shifted the feeders that remain for deployment to its deployment plans for Term 2. As such, Unitil deployment of Term 1 feeders is presented as 100% complete.

Table 34. 2022 Infrastructure Metrics for VVO Feeder Deployment – Term 1 Plan Feeders

IM	Parameter*	Eversource	National Grid	Unitil
IM-4	# Feeders with VVO Enabled	26	20	3
	% Feeders with VVO Enabled	81%	100%	100%
IM-6	% On Track (Feeders with VVO Enabled)	81%	100%	100%
IM-7	# Feeders Remaining for VVO Enablement	0	0	0

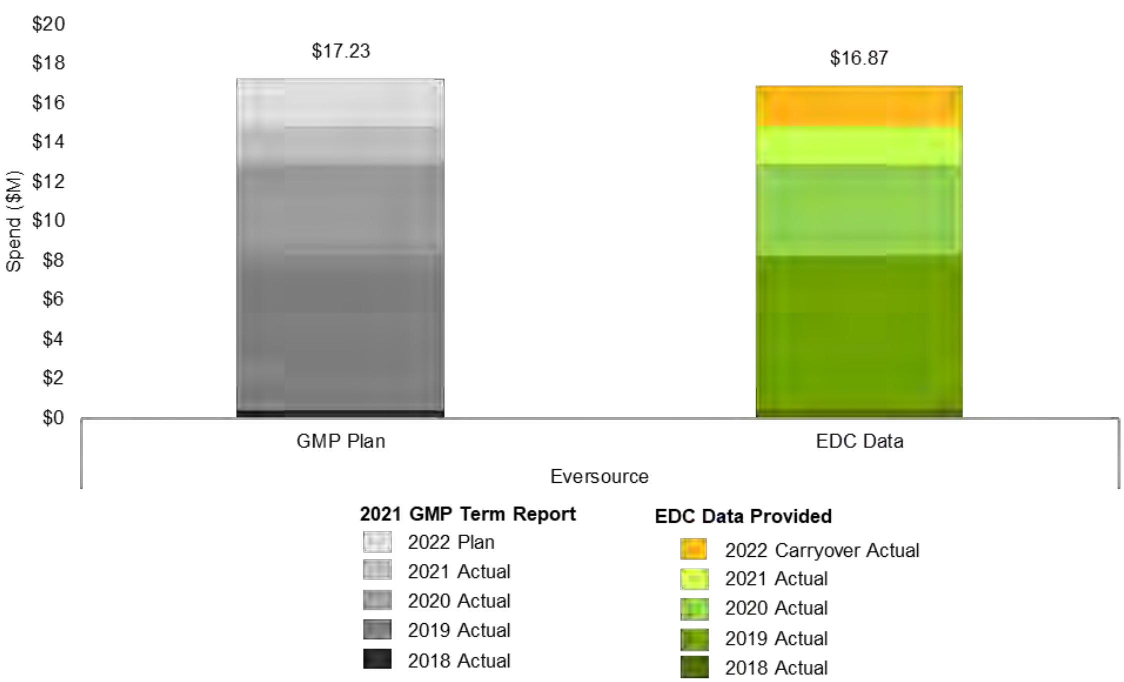
Note: This table considers Term 1 feeders for the three EDCs. Plan feeders for Term 1 may be found in Table 31.

* VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Source: Guidehouse analysis of 2021 GMP Term Report and 2022 EDC Data

Figure 6 highlights planned versus actual spend on VVO for Eversource.

Figure 6. Term 1 VVO Spend Comparison (2018–2022, $M)



Note: Includes the Eversource planned spend on activity from 2021 that was transferred to 2022, set forth in Eversource's 2021 GMP Term Report, filed on April 1, 2022.

Source: Guidehouse analysis of 2021 GMP Term Report, "GMP Extension and Funding Report," and 2021 EDC Data

In addition to the capital costs Figure 6 shows, Eversource incurred approximately $27,948 in Term 1 operations and maintenance (O&M) costs toward the VVO Investment Area in PY 2022. Further details on the differences between planned and actual spend are provided in the Eversource results subsections.

3.2.1.5 Term 2 Infrastructure Metrics Results

Table 35 and Table 36 summarize the Infrastructure Metrics results for each EDC's VVO Investment Area through PY 2022. Subsequent sections explain each EDC's progress and plans in greater detail.

Table 35. Term 2 2022 Infrastructure Metrics for VVO

Infrastructure Metrics			Eversource	National Grid**	Unitil
GMP Plan Total, PY 2022-2025		# Devices Planned	2,629	987	180
		Spend, $M	38.64	$76.44	$5.42
EDC Data Total, PY 2022-2025		# Devices Planned	1,711	1,715	143
		Spend, $M	$38.61	$76.44	$2.24
IM-4	Number of devices or other technologies deployed thru. PY 2022	# Devices Deployed*	0	42	37
		% Devices Deployed	0%	4%	21%
IM-5	Cost for Deployment thru. PY 2022	Total Spend, $M	$0.04	$7.61	$0.28
		% Spend	0%	10%	5%
IM-6	Deviation Between Actual and Planned Deployment for PY 2022	% On Track (Devices)	0%	25%	119%
		% On Track (Spend)	0%	69%	105%
IM-7	Projected Deployment for the Remainder of the GMP Term	# Devices Remaining	1,711	1,673	106
		Spend Remaining, $M	$38.58	$68.83	$1.96

*Note that "Deployed" here refers to commissioned devices. For full definitions of deployment stages, see Docket 20-46 Response to Information Request DPU-AR-4-11, September 3, 2020.

**To more closely align spend projections with DPU pre-authorized budgets, National Grid operations and maintenance (O&M) spend is included in actual and planned spend presented here. O&M spend is provided in aggregate for each investment area and is therefore excluded from device-specific summaries of spend.

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Table 36. 2022 Infrastructure Metrics for VVO Feeder Deployment – Term 2 Plan Feeders

IM	Parameter*	Eversource	National Grid	Unitil
IM-4	# Feeders with VVO Enabled	0	18	4
	% Feeders with VVO Enabled	0%	35%	50%
IM-6	% On Track (Feeders with VVO Enabled)	0%	35%	50%
IM-7	# Feeders Remaining for VVO Enablement	95	34	4

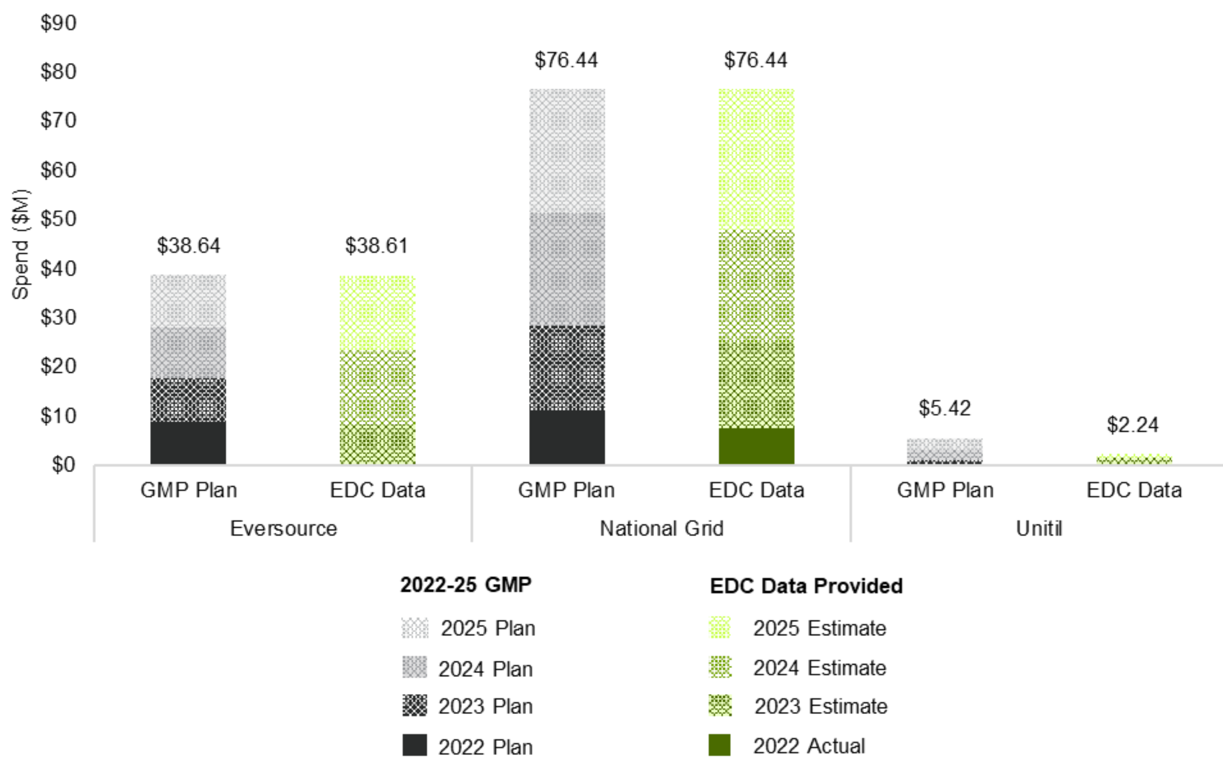
Note: This table considers Term 2 feeders for the three EDCs. Plan feeders for Term 2 may be found in Table 31.

* VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Source: Guidehouse analysis of 2022 EDC Data

Figure 7 compares the GMP plans and EDC data totals and year-over-year spending for each EDC.

Figure 7. Term 2 VVO Spend Comparison



Note: To more closely align spend projections with DPU pre-authorized budgets, National Grid operations and maintenance (O&M) spend is included in actual and planned spend presented here. O&M spend is provided in aggregate for each investment area and is therefore excluded from device-specific summaries of spend.

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

PY 2022's VVO Infrastructure Metrics findings show that the EDCs are at varying stages in VVO deployment for Term 2. Details pertaining to device deployment progress, total spend, and VVO enablement progress are shown below:

Device Deployment:

- Eversource did not meet VVO deployment goals for PY 2022. Eversource progress on VVO investments targeted for 2022 through 2025 was comprised of progressing engineering/design work for all VVO device types, as well as planning for future VVO deployments, while awaiting DPU decisions on continued VVO investment for 2022 through 2025. Given limited deployment on Term 2 investments in 2022, Eversource has adjusted plans for the remainder of Term 2, with the majority of deployment and spend activity projected to occur in 2024 and 2025. At the technology-level, planned deployment has declined for Regulators, Line Sensors, and Microcapacitors, and planned Capacitor Bank deployment has increased slightly. Capacitor Bank deployment has been revised upwards to reflect refinements made during the planning and design process.

- National Grid conducted less deployment than initially planned in PY 2022. A late-2022 DPU decision on preauthorizing 2022 through 2025 investment activity, resource constraints, and vendor lead times were all key contributors to this outcome. In response to lower-than-expected deployment in 2022, National Grid has accelerated its deployment timeline for 2023 through 2025. National Grid has also adjusted total deployment plans for numerous device types, increasing projected deployment for Capacitor Banks, Line Sensors, and LTC Controls, while reducing projected deployment for Regulators. National Grid cites that these revisions are primarily due to the VVO planning work that has been conducted since the 2022-2025 GMP was filed.
- Unitil deployment was below plans for 2022, with variation by technology. Unitil was on-track with deployment of VVO Capacitor Banks and Line Sensors in 2022, deploying 100% and 210% of planned units, respectively. However, deployment was under plans for Regulators and LTC Controls. Lower deployment than plans for these technologies may be attributed to Unitil's efforts to resolve LTC radio and control issues and cancelation of 4 deployments that were found to be unnecessary. Unitil has adjusted deployment plans for the remainder of Term 2 to conduct most deployment during 2023 and 2025. Additionally, Unitil has reduced its planned deployments of VVO Regulators and Capacitor Banks, as Unitil reassessed deployment plans and determined there were fewer Regulator and Capacitor Bank deployments needed than initially planned. Work in 2024 will be limited to material orders in preparation for construction work at the Beech Street substation.

Total Spend:

- Eversource spend on Term 2 investments amounted to $0.04M, short of the $8.70M that was initially planned for 2022. Given limited deployment and spend on Term 2 investments in 2022, as well as ongoing vendor delays in fulfilling material orders, Eversource has adjusted plans for the remainder of Term 2. In 2023, Eversource will be conducting additional design work, submitting material orders, and, when material orders are received, deploying VVO investments. Eversource has projected that most spend activity will occur in 2024 and 2025.
- National Grid spend on VVO was below plans for 2022. The majority of spend occurred on Capacitor Banks, while spend on Regulators and Line Sensors was well below plans. Lower-than-anticipated spend on Line Sensors can, in part, be attributed to National Grid's previous line sensor vendor discontinuing their selected model. For VVO Regulators, vendor delays in fulfilling material orders was a key contributor to lower spend than initially planned. In response to its 2022 experience with Line Sensors and Regulators, National Grid has begun to increase diversification of vendors that it sources materials from.
- Unitil spend on VVO was below initial plans. Unitil met 48% of its planned spend for Regulators. Spend and deployment of all other devices met or exceeded initial plans. Spend plans for the remainder of Term 2 have been revised downwards across all device types. Reduced spend on Regulators and Capacitor Banks can be attributed to a reduction in the units that Unitil plans to deploy, as well as lower than expected costs for deployment of Regulators. Reduced spend on LTC Controls and Line Sensors may be tied to process efficiencies implemented in 2022 that brought unit costs below plans. Most spend is planned for 2023 and 2025, with work in 2024 limited to material orders in preparation for construction work at the Beech Street substation.

VVO Enablement:

- Eversource conducted VVO On/Off testing at four of six of its Term 1 substations (Agawam, Piper, Podick, and Silver) in 2022. Meanwhile, Eversource has shifted VVO deployment plans for its remaining Term 1 substations, shifting VVO enabled dates for the Gunn and Oswald substations by approximately 14 months and 19 months, respectively. The Gunn substation is now expected to be VVO enabled by June 2023, and Eversource plans to begin VVO On/Off testing by late June 2023. The Oswald substation is now expected to be VVO enabled by December 2023, and Eversource plans to begin VVO On/Off testing by late December 2023. Among its Term 2 feeders, Eversource is in the process of deploying VVO investments across all 95 currently identified feeders.
- National Grid conducted VVO On/Off testing at its East Methuen and Maplewood Term 1 substations throughout 2022. Among its Term 2 substations, National Grid conducted On/Off testing at the East Bridgewater substation throughout 2022, as VVO deployment was completed at the substation in 2021. Additionally, National Grid completed VVO deployment at the Easton and West Salem substations and began VVO On/Off for these substations in winter 2022/23 and spring 2022, respectively. National Grid projects that it will complete VVO deployment and enable VVO at its remaining Term 2 substations in 2023.
- Unitil completed VVO deployment for its Term 1 substation (Townsend) in 2021, enabling VVO on December 1, 2021, and On/Off testing is expected to begin in spring 2023. Among its Term 2 substations, Unitil completed deploying VVO investments at the Summer Street substation and enabled VVO in December 2022, with VVO On/Off testing projected to begin at the substation in December 2023. Lunenburg and West Townsend are currently receiving VVO investments and Unitil plans to enable VVO at the substations in January and November 2024, respectively. Unitil then plans to conduct On/Off testing at the substations beginning in December 2024. For its remaining substations, Unitil is currently conducting planning and engineering/design work for its Beech Street, Pleasant Street, and Princeton Road substations. These substations are expected to be enabled after the close of Term 2 in 2026 and 2027.

3.2.2 Eversource

This section discusses Eversource's VVO investment progress through PY 2022 in two subsections:

- Term 1 Progress: a comparison of progress Eversource made in 2022 against plans detailed in its *2021 GMP Term Report*. These results consider only the deployment and spending that were planned in 2021 to be carried over into 2022.
- Term 2 Progress: a comparison of progress Eversource made towards its 2022 plans outlined in its *2022-2025 GMP Plan.* These results do not consider deployment or spending that were planned in 2021 to be carried over into 2022.

3.2.2.1 Overview of GMP Deployment Plan

Approach to VVO

In Term 1, Eversource deployed full VVO functionality across four substations, amounting to 26 feeders. Eversource is also completing VVO investments at its two remaining Term 1 substations, amounting to 6 feeders. In deployment planning, all substations and feeders were selected based on whether they could be controlled from a single control room, cover a mix of residential, commercial, and industrial customers, and cover a range of distributed generation capacities. Substation selections were based on engineering analysis and coordination with grid modernization teams.

Table 37 through Table 40 summarize the planned and actual deployment and spend for VVO for Term 1 and Term 2.

Table 37. Term 1 Eversource Cumulative VVO Feeder Deployment Year-over-Year Comparison

Data	2018	2019	2020	2021	2022	2018-2022
EDC Actual Progress	0	0	26	26	26	26
EDC Plan	26	26	26	26	32	32
% EDC Actual Progress/EDC Plan	0%	0%	100%	100%	81%	81%

Note: Due to rounding error, manual calculations of % EDC Actual Progress / EDC Plan will not precisely match calculated numbers provided in this table.

Source: Guidehouse analysis of 2021 GMP Term Report and 2022 EDC Data

Table 38. Term 2 Eversource Cumulative VVO Feeder Deployment Year-over-Year Comparison

Data	2022	2023	2024	2025	2022-2025
EDC Actual Progress	0	N/A	N/A	N/A	N/A
EDC Plan	95	N/A	N/A	N/A	N/A
% EDC Actual Progress/EDC Plan	0%	N/A	N/A	N/A	N/A

Note: Due to rounding error, manual calculations of % EDC Actual Progress / EDC Plan will not precisely match calculated numbers provided in this table.

Source: Guidehouse analysis of 2022 EDC Data

Table 39. Term 1 Eversource Cumulative VVO Investment Year-over-Year Comparison ($M)*

Data	2018	2019	2020	2021	2022	2018-2022
EDC Actual Progress	$0.4	$8.2	$12.9	$14.8	$16.9	$16.9
EDC Plan	$13.0	$13.0	$17.4	$18.9	$17.2	$17.2
% EDC Actual Progress/EDC Plan	3%	63%	74%	78%	98%	98%

Note: Due to a rounding error, manual calculations of % EDC Actual Progress / EDC Plan and % EDC Revised Plan / EDC Original Plan will not precisely match calculated numbers provided in this table.

Source: Guidehouse analysis of 2021 GMP Term Report, 2022 EDC Data

Table 40. Term 2 Eversource Cumulative VVO Investment Year-over-Year Comparison ($M)*

Data	2022	2023	2024	2025	2022-2025
EDC Actual Progress	$0.04	N/A	N/A	N/A	N/A
EDC Plan	$38.6	N/A	N/A	N/A	N/A
% EDC Actual Progress/EDC Plan	0.1%	N/A	N/A	N/A	N/A

Note: Due to a rounding error, manual calculations of % EDC Actual Progress / EDC Plan and % EDC Revised Plan / EDC Original Plan will not precisely match calculated numbers provided in this table.

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Across its Term 1 substations, Eversource has completed VVO deployment and VVO On/Off testing across 26 feeders connected to the Agawam, Piper, Podick, and Silver substations. Additionally, Eversource is in the process of deploying VVO investments at the Gunn and Oswald substations. Eversource expects VVO deployment to be complete at these substations by June and December of 2023, respectively. Through the end of 2022, Eversource spent roughly $16.9M of its final estimated budget for Term 1 of $17.2M, approximately 98% of plans, on completing activity from 2021. Through the end of 2022, Eversource has spent less than 1% of its planned spend for Term 2, as much of 2022 activity was comprised of completing work from Term 1.

Table 41 highlights Eversource feeder characteristics as of the end of 2022. Feeder lengths and customer counts vary considerably across VVO feeders. Selected substations also present a mix of distributed generation capacity across feeders, with distributed generation capacity ranging from 0.0 MW to 14.3 MW. Table 41 contains additional information related to the VVO feeders. Appendix A contains additional information related to the VVO feeders.

Table 41. 2022 Eversource VVO Feeder Characteristics

Substation	Feeder	Feeder Length (mi.)	Customer Count	Annual Peak Load (MVA)	Distributed Generation (MW)
Term 1 Feeders					
Agawam (13.8 kV)	**16C11**	24	1,350	5.8	2.2
	16C12	6	80	4.4	2.0
	16C14	15	1,632	6.2	0.2
	16C15	11	1,270	4.1	0.1
	16C16	22	2,563	7.4	2.5

Substation	Feeder	Feeder Length (mi.)	Customer Count	Annual Peak Load (MVA)	Distributed Generation (MW)
	16C17	29	2,388	7.0	1.3
	16C18	21	3,054	6.3	0.8
Piper (13.8 kV)	**21N4**	33	2,299	6.8	1.7
	21N5	15	829	8.4	0.2
	21N6	15	787	4.3	0.5
	21N7	5	2	4.8	0.0
	21N8	9	557	6.8	0.1
	21N9	24	2,404	6.4	1.0
Podick (13.8 kV)	**18G2**	5	9	0.5	0.0
	18G3	37	2,141	4.0	2.2
	18G4	35	2,347	4.7	5.7
	18G5	40	1,778	5.8	5.9
	18G6	38	1,289	5.0	3.6
	18G7	64	2,226	4.5	11.6
	18G8	47	1,089	7.5	8.7
Silver (13.8 kV)	**30A1**	37	2,519	6.8	1.5
	30A2	12	2,286	8.8	0.4
	30A3	12	239	7.8	5.1
	30A4	11	801	4.6	0.3
	30A5	21	1,659	4.4	0.9
	30A6	20	1,007	5.5	2.3
Gunn (23 kV)	**15A1**	78	3,142	8.2	5.5
	15A2	22	2,143	8.3	4.1
	15A3	96	3,755	8.4	10.1
	15A5	31	3,427	6.5	2.1
Oswald (23 kV)	**30B5**	34	2,462	4.4	5.0
	30B7	84	1,957	7.7	14.3
Term 2 Feeders					
Amherst (13.8 kV)	**17K1**	12.25	1,046	2.58	6.76
	17K2	51.41	2,069	4.66	3.94
	17K3	3.59	396	0.88	0.18
	17K4	9.20	1,076	4.49	4.20
	17K5	28.56	1,628	7.25	1.09
	17K6	13.44	868	4.89	2.61
	17K7	11.46	874	1.27	0.33
	17K8	34.41	1,652	3.64	2.38
Breckwood (13.8 kV)	**20A11**	1.19	0	1.90	0.00
	20A12	9.52	841	2.30	0.22
	20A13	9.63	1,430	3.30	0.76
	20A14	22.19	1,949	6.00	2.25
	20A21	27.76	2,656	7.60	1.75
	20A22	17.03	2,166	5.60	1.02
	20A23	7.07	710	1.70	0.34
	20A31	15.10	1,590	4.30	0.31
	20A32	21.90	2,602	5.90	2.08
	20A33	22.05	2,872	9.70	1.72
	20A34	24.59	2,081	6.50	2.25

Substation	Feeder	Feeder Length (mi.)	Customer Count	Annual Peak Load (MVA)	Distributed Generation (MW)
	20A35	17.25	1,749	4.80	1.12
Cross Road (13.2 kV)	**2-522-522**	34.10	872	3.08	3.49
	2-523-523	116.25	3,112	8.47	6.13
	2-524-524	45.71	751	1.21	1.20
	2-525-525	3.55	3	4.96	6.00
	2-528-528	118.70	0	7.06	3.55
Cumberland (13.8 kV)	**22B1**	46.79	1,220	7.44	2.19
	22B2	13.87	1,411	3.73	0.75
	22B3	25.59	969	3.11	2.76
	22B4	26.31	1,319	4.15	5.24
	22B5	66.47	1,110	2.22	8.20
	22B6	1.65	0	1.27	0.00
	22B7	90.79	2,187	6.73	2.56
	22B8	18.00	2,247		0.84
Doreen (23 kV)	**19A1**	27.89	1,900	2.50	1.60
	19A2	16.06	1,225	1.80	0.76
	19A3	8.64	99	1.80	2.41
	19A4	2.41	64	1.80	2.01
	19A5	22.99	999	4.50	1.72
	19A6	5.50	3	4.10	1.76
	19A7	25.53	3,390	4.60	0.82
	19A8	10.47	1,407	1.60	0.45
Duxbury (4.16 kV)	**3-24A-34J1**	14.05	662	14.04	0.38
	3-24A-34J2	1.08	61	3.16	0.01
	3-24A-35J1	7.56	250	5.13	0.07
	3-24A-35J2	0.08	0	0.00	0.00
Franconia (13.8 kV)	**22H11**	0.93	0	0.00	0.01
	22H12	13.29	837	3.50	1.11
	22H13	27.50	1,666	7.20	0.73
	22H14	32.70	3,691	9.70	0.97
	22H15	19.53	3,515	7.20	0.87
	22H16	19.37	3,498	7.00	1.05
	22H17	21.90	1,932	6.30	0.45
	22H18	4.61	1,534	6.50	0.07
Industrial Park (13.2 kV)	**2-101-101**	4.33	25	8.7	2.30
	2-102-102	34.68	1,757	11.5	11.72
	2-102-608	15.84	739	2.3	0.68
	2-103-103	8.87	19	6.5	5.52
	2-104-104	14.96	1,239	4.8	1.85
	2-105-105	21.53	2,557	8.0	1.76
	2-106-106	2.24	5	7.5	0.00
	2-106-160	15.34	1,251	1.4	0.91
	2-106-161	11.97	1,008	2.9	0.92
	2-107-107	30.66	531	6.6	13.59
	2-108-108	50.57	0	14.5	17.20
	2-151-151	1.24	6	1.9	2.64
	2-152-152	0.45	0	1.6	0.00

Substation	Feeder	Feeder Length (mi.)	Customer Count	Annual Peak Load (MVA)	Distributed Generation (MW)
Mashpee (22.8 kV)	**4-71-455**	94.17	3,408	7.26	4.20
	4-71-71	0.21	9	13.84	0.00
	4-77B-456	31.65	1,381	4.81	0.68
	4-77B-77B	7.56	294	12.15	0.01
Montague (13.8 kV)	**21C1**	58.52	1,475	7.19	6.68
	21C2	24.27	1,086	7.53	9.57
	21C3	0.44	0	0.00	0.00
	21C4	16.66	1,852	7.36	1.26
	21C5	41.76	1,387	2.79	0.61
	21C6	4.52	461	0.84	7.29
	21C7	69.68	1,730	3.42	1.50
	21C8	25.50	1,130	3.44	10.41
Orchard (13.8 kV)	**27A10**	10.41	1,301	2.60	3.96
	27A11	1.58	1	4.60	0.00
	27A12	1.56	6	4.60	7.62
	27A13	12.25	2,002	7.60	4.12
	27A14	0.60	0	1.10	0.00
	27A15	9.44	1	0.20	0.00
	27A16	0.66	0	1.10	0.00
	27A17	0.65	0	1.10	0.00
	27A4	12.72	1,337	3.90	0.82
	27A5	17.18	723	5.90	2.56
	27A6	18.32	2,969	7.10	4.74
	27A7	9.86	963	3.50	0.55
Wareham (22.8 kV)	**3-85-85**	76.51	2,469	15.78	6.45
	3-85-928	16.90	488	2.80	3.75
	3-85-957	11.43	278	0.99	0.26
	3-86-966	33.26	1,383	8.13	4.81

Note: Values presented in this table were published on April 24, 2023 and are reflective of data collected through the end of 2022.
Source: 2022 GMP Annual Report, Appendix 1 filed April 24, 2023

3.2.2.2 VVO Timeline

Table 42 summarizes substation-specific progress in each of the four VVO investment phases.

Table 42. Eversource Combined Plan Feeders Deployment Completion Dates

Substation	VVO Investment	VVO Commissioning[43]	VVO Enabled[44]	VVO On/Off Testing
Term 1 Plan Substations				

[43] VVO Commissioning is the time at which VVO devices are controlled by and have data visible to each EDC.

[44] VVO Enabled is the time at which the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Substation	VVO Investment	VVO Commissioning[43]	VVO Enabled[44]	VVO On/Off Testing
Agawam	1/14/2019 - 12/31/2019 (Complete)	11/1/2019 - 12/31/2019 (Complete)	12/2/2020 (Complete)	12/2/2020 - May 2023 (Complete)
Piper	1/14/2019 - 12/31/2019 (Complete)	11/1/2019 - 12/31/2019 (Complete)	12/2/2020 (Complete)	12/2/2020 - May 2023 (Complete)
Podick	3/29/2019 - 12/31/2019 (Complete)	11/1/2019 - 12/31/2019 (Complete)	12/2/2020 (Complete)	3/4/2021 - May 2023 (Complete)
Silver	1/14/2019 - 12/31/2019 (Complete)	11/1/2019 - 12/31/2019 (Complete)	12/2/2020 (Complete)	12/2/2020 - May 2023 (Complete)
Gunn	1/1/2021 - 6/1/2023 (In-Progress)	9/1/2022 - 6/1/2023 (In-Progress)	6/15/2023 (Planned)	6/30/2023 - TBD (Planned)
Oswald	1/1/2021 - 12/1/2023 (In-Progress)	9/1/2022 - 12/1/2023 (In-Progress)	12/15/2023 (Planned)	12/31/2023 - TBD (Planned)
Term 2 Plan Substations				
Amherst	TBD	TBD	TBD	1/1/2025 – TBD (Planned)
Breckwood	TBD	TBD	TBD	10/1/2024 – TBD (Planned)
Cross Road	TBD	TBD	TBD	7/1/2024 – TBD (Planned)
Cumberland	TBD	TBD	TBD	7/1/2024 – TBD (Planned)
Doreen	TBD	TBD	TBD	7/1/2024 – TBD (Planned)
Duxbury	TBD	TBD	TBD	4/1/2025 – TBD (Planned)
Franconia	TBD	TBD	TBD	7/1/2024 – TBD (Planned)
Industrial Park	TBD	TBD	TBD	7/1/2025 – TBD (Planned)

Substation	VVO Investment	VVO Commissioning[43]	VVO Enabled[44]	VVO On/Off Testing
Mashpee	TBD	TBD	TBD	10/1/2024 – TBD (Planned)
Montague	TBD	TBD	TBD	10/1/2024 – TBD (Planned)
Orchard	TBD	TBD	TBD	10/1/2024 – TBD (Planned)
Wareham	TBD	TBD	TBD	10/1/2024 – TBD (Planned)

Note: Term 2 feeder schedules were provided in quarterly form (e.g., Q4 2024). As such, Guidehouse has assigned VVO On/Off testing start dates as the first day of the quarter in which VVO On/Off testing is anticipated to begin.

Source: Guidehouse analysis of 2022 EDC Data

Eversource conducted VVO On/Off testing at four of its Term 1 substations throughout 2022. In tandem, Eversource conducted deployment of VVO devices across the Gunn and Oswald substations. In 2022, Eversource found that the existing LTC controls at the Oswald substation were incompatible with VVO and needed replacement and commissioning before being fully deployed. Additionally, Eversource is working through troubleshooting communications equipment before the Gunn substation will have full VVO capability. Eversource expects to complete LTC deployment and resolve communications issues in 2023. VVO On/Off testing is then expected to begin at the Gunn and Oswald substations in June and December 2023, respectively.

For its Term 2 substations, Eversource is currently in the VVO Investment phase, and is conducting engineering / design work for the selected substations. Eversource anticipates completing deployment during 2024 and 2025. Once VVO investments are deployed, Eversource plans to conduct VVO On/Off testing, with testing start dates ranging from July 2024 through July 2025. Once VVO On/Off testing has begun, Eversource anticipates conducting this testing for 9 – 12 months to collect one summer, one winter, and one shoulder season of testing data.

Table 43 presents an additional VVO enablement progress by substation, including actual and planned VVO enabled dates and notes on the status of VVO deployment.

Table 43. Eversource VVO Enabled Progress by Substation

Substation	January 2022 Planned/Actual VVO Enabled Date	January 2023 Planned/Actual VVO Enabled Date**	Current Status[45]
Term 1 Feeders			
Agawam	12/2/2020 (actual)	12/2/2020 (actual)	VVO On/Off testing complete
Piper	12/2/2020 (actual)	12/2/2020 (actual)	VVO On/Off testing complete
Podick	3/4/2021 (actual)	3/4/2021 (actual)	VVO On/Off testing complete
Silver	12/2/2020 (actual)	12/2/2020 (actual)	VVO On/Off testing complete
Gunn	4/15/2022 (planned)	6/15/2023 (planned)	VVO Commissioning in progress
Oswald	5/15/2022 (planned)	12/15/2023 (planned)	VVO Commissioning in progress
Term 2 Feeders			
Amherst	N/A*	1/1/2025 (planned)	VVO Investment in progress
Breckwood	N/A*	10/1/2024 (planned)	VVO Investment in progress
Cross Road	N/A*	7/1/2024 (planned)	VVO Investment in progress
Cumberland	N/A*	7/1/2024 (planned)	VVO Investment in progress
Doreen	N/A*	7/1/2024 (planned)	VVO Investment in progress
Duxbury	N/A*	4/1/2025 (planned)	VVO Investment in progress
Franconia	N/A*	7/1/2024 (planned)	VVO Investment in progress
Industrial Park	N/A*	7/1/2025 (planned)	VVO Investment in progress
Mashpee	N/A*	10/1/2024 (planned)	VVO Investment in progress
Montague	N/A*	10/1/2024 (planned)	VVO Investment in progress
Orchard	N/A*	10/1/2024 (planned)	VVO Investment in progress
Wareham	N/A*	10/1/2024 (planned)	VVO Investment in progress

* Guidehouse did not previously report on VVO schedules for Term 2 feeders in its PY 2021 report, and so all information has been listed as not applicable.

** Term 2 feeder schedules were provided in quarterly form (e.g., Q4 2024). As such, Guidehouse has assigned VVO On/Off testing start dates as the first day of the quarter in which VVO On/Off testing is anticipated to begin.

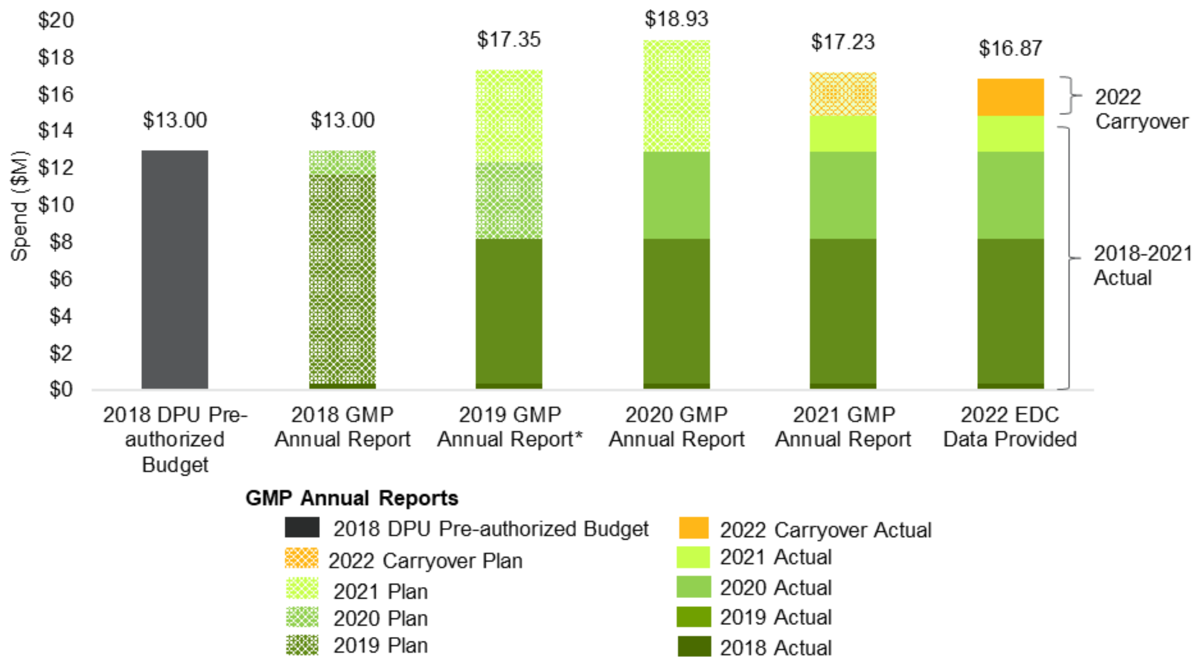
Source: Guidehouse analysis of 2021 and 2022 EDC Data

3.2.2.3 Term 1 VVO Deployment Plan Progression

Figure 8 shows the progression of Eversource's VVO deployment plans from DPU-approval in 2018 through PY 2022.

45 Status can be: planning, design, construction, device deployment complete, VVO commissioning in process, or VVO enabled. VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Figure 8. Term 1 Eversource VVO Planned vs. Actual Spend (2018–2022, $M)



*Note that Eversource received pre-authorization from the Department for another $5 million in spending for its VVO investment area in late 2020.

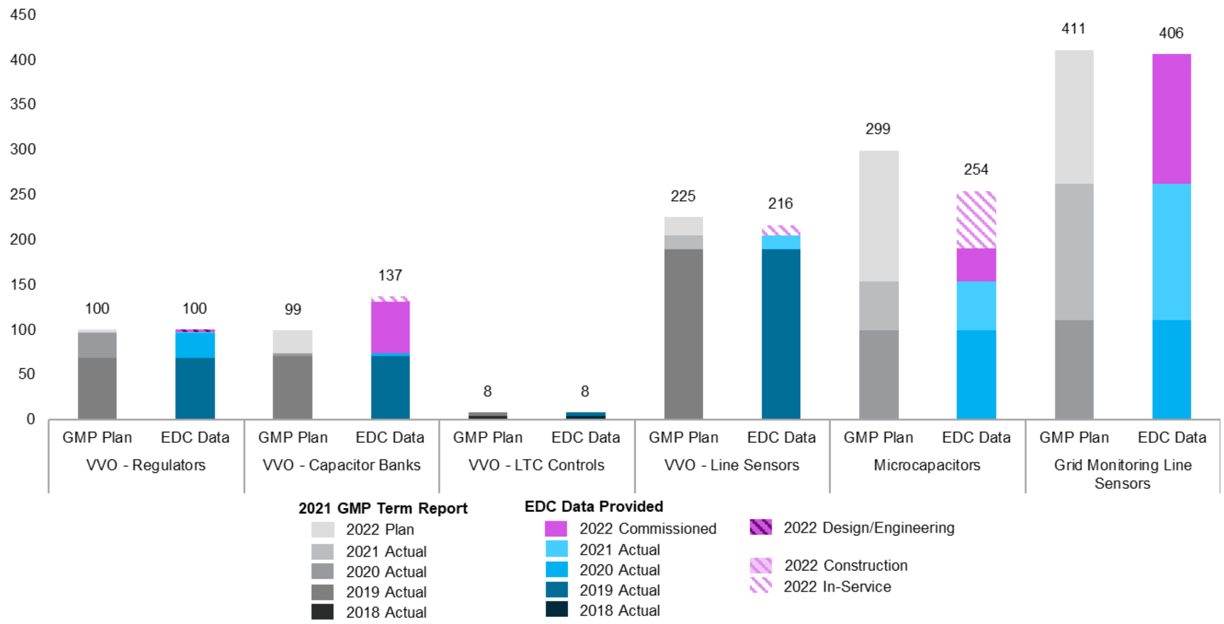
Source: Guidehouse analysis of DPU Order (May 10, 2018), 2021 GMP Term Report, Eversource GMP Extension and Funding Report filed on July 1, 2020, Eversource extension filing, and 2022 EDC Data

Eversource made progress towards meeting planned PY 2021 deployment and spend that was carried over to 2022. As of the end of 2022, total spend ($16.87M) was slightly below plans ($17.23M). This is largely attributed to vendor delays in fulfilling material orders.

3.2.2.4 Term 1 VVO Device Type Progress through PY 2022

Figure 9 shows the progress and details of each device type for the 2018-2022 period.

Figure 9. Term 1 Eversource Planned vs Actual Deployment (2018–2022, Unit Count)



Source: Guidehouse analysis of 2021 GMP Term Report and 2022 EDC Data

The EDC Data presented in Figure 9 is also shown in tabular form in Table 44. to provide the specific deployment units in each category.

Table 44. Term 1 Eversource VVO Deployment Progress

	VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors	Micro-capacitors	Grid Monitoring Line Sensors
2018-2022 Total	**97**	**131**	**8**	**205**	**0**	**191**
Engineering/Design during PY 2022*	0	0	0	0	0	0
Construction during PY 2022*	0	6	0	11	0	63
In-Service during PY 2022*	0	57	0	0	0	37
Commissioned in PY 2022	1	0	0	16	0	55
Commissioned in PY 2021	27	3	0	0	0	99
Commissioned in PY 2020	69	71	4	189	0	0
Commissioned in PY 2019	0	0	4	0	0	0
Commissioned in PY 2018	**97**	**131**	**8**	**205**	**0**	**191**

*Deployment of these devices began during PY 2022, but was not completed during the program year. All units and dollars spent to deploy remaining units during 2023 through 2025 will be considered as part of Term 2 GMPs.

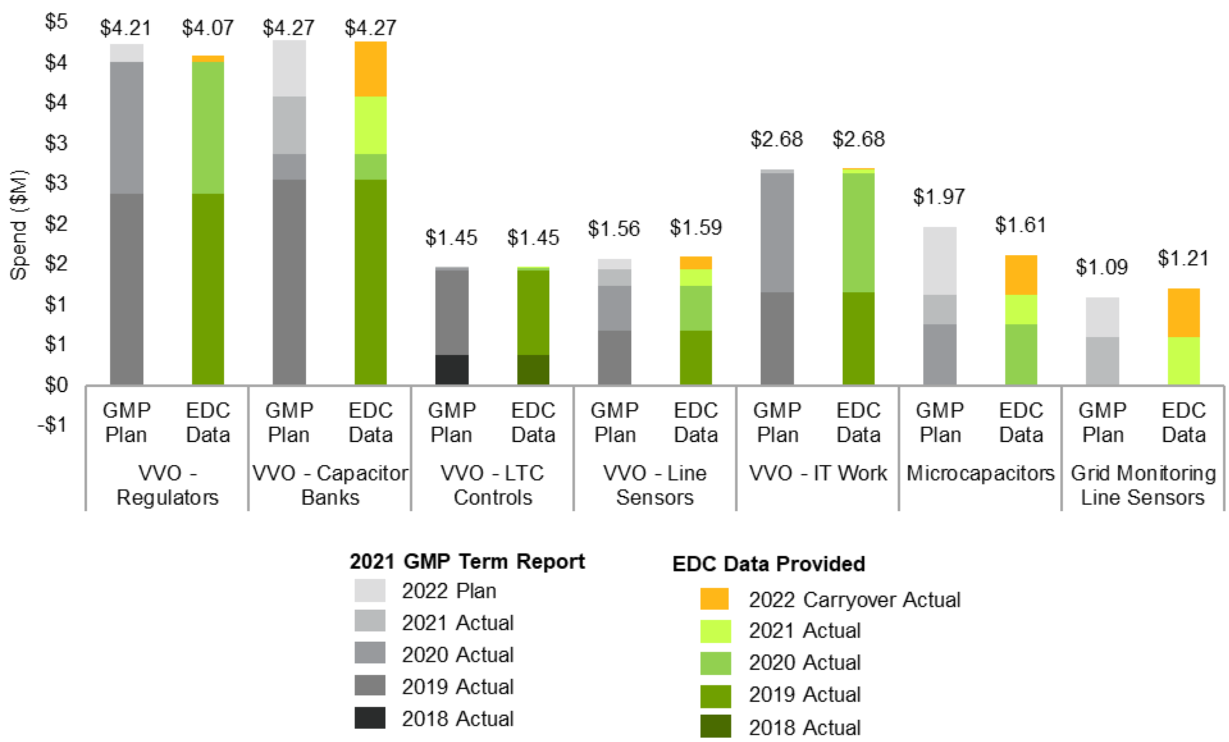
Source: Guidehouse analysis of 2021 GMP Term Report and 2022 EDC Data

Eversource made headway on deploying 2021 investments in 2022, with Capacitor Banks and Grid Monitoring Line Sensors comprising the bulk of deployed devices. Eversource exceeded plans (25 devices) for Capacitor Banks, deploying 57 devices, as refinements made during the planning and design process placed more priority on Capacitor Banks, less on Regulators, for VVO operation. Grid Monitoring Line Sensors deployed (141 devices) were approximately in-line with plans (148 devices).

Eversource had anticipated deploying three VVO Regulators during 2022, and ultimately was not able to meet this goal due to vendor delays on material orders. As of the end of 2022, Eversource was awaiting delivery of 3 ordered VVO Regulators from its vendor. Line Sensor and Micro-capacitor deployment also fell short of plans.

Figure 10 shows Eversource's corresponding planned versus actual spend over the 2018-2022 Term period, broken out by device type.

Figure 10. Term 1 Eversource VVO Spend Plan vs. Actual (2018-2022, $M)



Source: Guidehouse analysis of 2021 GMP Term Report and 2022 EDC Data

The EDC Data presented in Figure 10 is also shown in Table 45 to provide the specific dollar spend in each category.

Table 45. Term 1 Eversource Total Spend Comparison (2018–2022, $M)

	VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors	VVO - IT Work	Microcapacitors	Grid Monitoring Line Sensors
2018-2022 Total	**$4.07**	**$4.27**	**$1.45**	**$1.59**	**$2.68**	**$1.61**	**$1.21**
PY 2022 Actual	$0.08	$0.69	$0.00	$0.16	$0.00	$0.50	$0.61
PY 2021 Actual	-$0.02	$0.71	$0.00	$0.20	$0.05	$0.36	$0.59
PY 2020 Actual	$1.63	$0.31	$0.03	$0.56	$1.47	$0.75	$0.00
PY 2019 Actual	$2.38	$2.55	$1.04	$0.68	$1.16	$0.00	$0.00
PY 2018 Actual	$0.00	$0.00	$0.38	$0.00	$0.00	$0.00	$0.00

Source: Guidehouse analysis of 2021 GMP Term Report and 2022 EDC Data

Eversource made substantial progress on PY 2021 work that was planned for 2022. Total spend through the end of 2022 was approximately on track with plans for all device types. The largest variance from plans identified was for microcapacitors ($0.36M below plan). While total spend through 2022 exceeded plans for Grid Monitoring Line Sensors, spend being on-track for Capacitor Banks and lower than plans for other device types led to total spend on VVO ($16.87M) being slightly below planned spend ($17.23M).

3.2.2.5 Term 1 Infrastructure Metrics Results and Key Findings

Table 46 and Table 47 present the Infrastructure Metrics results through PY 2022 for each device type related to Eversource's VVO Investment Area.

Table 46. Term 1 2022 Eversource Infrastructure Metrics for VVO Devices

Infrastructure Metrics			VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors	VVO - IT Work	Microcapacitors	Grid Monitoring Line Sensors
GMP Plan Total, 2018-2022		Devices	100	99	8	225	0	299	411
		Spend, $M	$4.21	$4.27	$1.45	$1.56	$2.68	$1.97	$1.09
IM-4	Number of devices or other technologies deployed PY 2018-2022*	# Devices Deployed	97	131	8	205	0	191	406
		% Devices Deployed	97%	132%	100%	91%	N/A	64%	99%
IM-5	Cost for Deployment PY 2018-2022*	Total Spend, $M	$4.07	$4.27	$1.45	$1.59	$2.68	$1.61	$1.21
		% Spend	97%	100%	100%	102%	100%	82%	110%
IM-6	Deviation Between Actual and Planned Deployment for PY 2022	% On Track (Devices)	0%	228%	N/A	0%	N/A	26%	97%
		% On Track (Spend)	36%	99%	N/A	120%	N/A	59%	123%

Infrastructure Metrics			VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors	VVO - IT Work	Microcapacitors	Grid Monitoring Line Sensors
IM-7	Projected Deployment for the remainder of the GMP Term (i.e., Term 1)**	# Devices Remaining	0	0	0	0	0	0	0
		Spend Remaining, $M	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00

*The metric names have been slightly changed here to clarify the time span used in analysis.

** This metric has been interpreted here (i.e., within the context of the 2022 Program Year Evaluation) as the units and spending that the EDC plans to complete their most recent 4-year Term 1 plans. Additional Grid Modernization units and dollars incurred in 2022 are attributed to Term 2, as appropriate, and all units and dollars spent during 2023 through 2025 will be considered as part of Term 2 GMPs.

Source: Guidehouse analysis of 2021 GMP Term Report and 2022 EDC Data

Table 47. Term 1 2022 Eversource Infrastructure Metrics for VVO Feeders

IM	Metric	Parameter*	Number of Feeders
IM-4	Number of Devices/Technologies Deployed thru. 2022	# Feeders with VVO Enabled	26
		% Feeders with VVO Enabled	81%
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Feeders with VVO Enabled)	81%
IM-7	Projected Deployment for the Remainder of the GMP Term	# Feeders Remaining for VVO Enablement	0

Note: This table considers Term 1 plan feeders for Eversource. Feeders that were projected to receive VVO capability during Term 1 may be found in Table 31.

* VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Guidehouse's review of Eversource's VVO progress on Term 1 revealed that Eversource was approximately on-track with planned spend and deployment outlined in their *2021 GMP Term Report*. However, some spend and deployment remain in order to complete activities from Term 1. Key findings related to Eversource's progress include:

Device Deployment

- Eversource made headway on deploying 2021 investments in 2022, with Capacitor Banks and Grid Monitoring Line Sensors comprising the bulk of deployed devices. Eversource exceeded plans (25 devices) for Capacitor Banks, as refinements made during the planning and design process placed more priority on Capacitor Banks, less on Regulators, for VVO operation. At the close of 2022, Eversource was awaiting delivery of 3 ordered VVO Regulators from its vendor. Line Sensor and Micro-capacitor deployment also fell short of plans.

Total Spend

- Eversource made substantial progress on PY 2021 work that was planned for 2022. Total spend through the end of 2022 was approximately on track with plans for all device types, with total spend on VVO ($16.87M) being slightly below planned spend ($17.23M) laid out for Term 1.

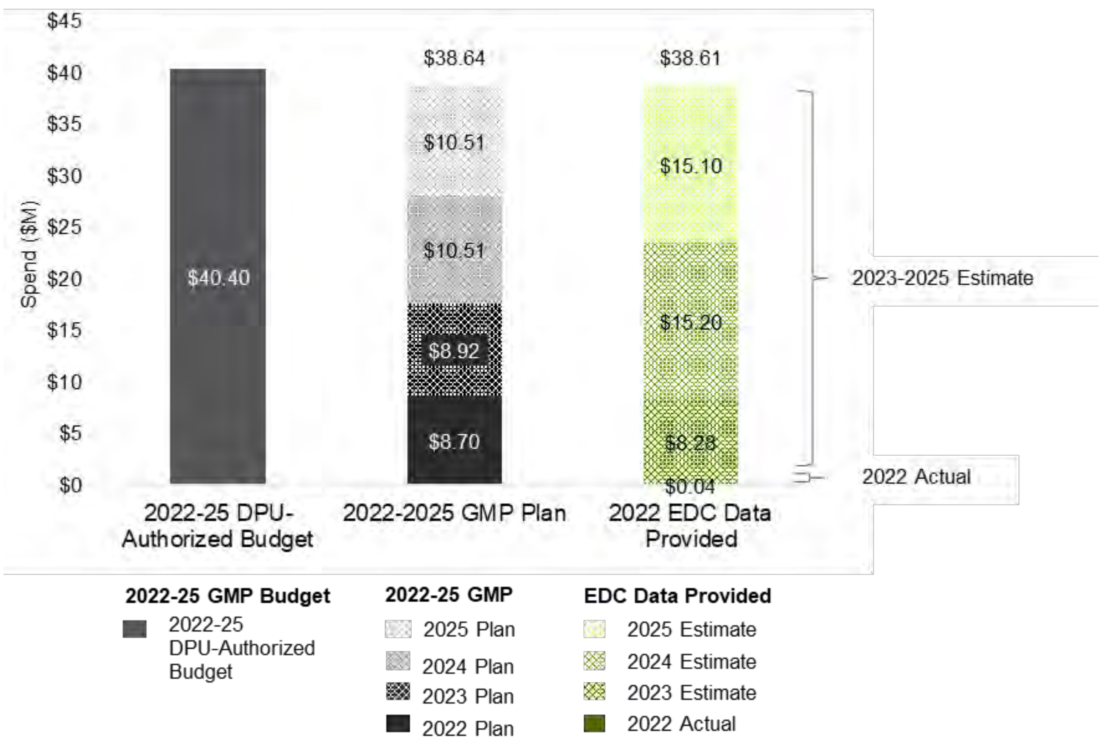
VVO Enablement

- Eversource completed deployment of VVO at four of its six Term 1 plan substations (Agawam, Piper, Podick, and Silver) by the end of 2021, and conducted On/Off testing at these substations throughout 2022. Eversource stopped VVO On/Off testing on these four substations in May 2023, transitioning towards leaving VVO in its enabled state moving forward. Meanwhile, the Gunn and Oswald substations will be VVO enabled in 2023, with On/Off testing to begin shortly thereafter.

3.2.2.6 Term 2 VVO Deployment Plan Progression

Figure 11 shows how Eversource's Term 2 VVO deployment spend has progressed since the Term 2 GMP was approved in late 2022.

Figure 11. Term 2 Eversource VVO Planned vs. Actual Spend (2022–2025, $M)



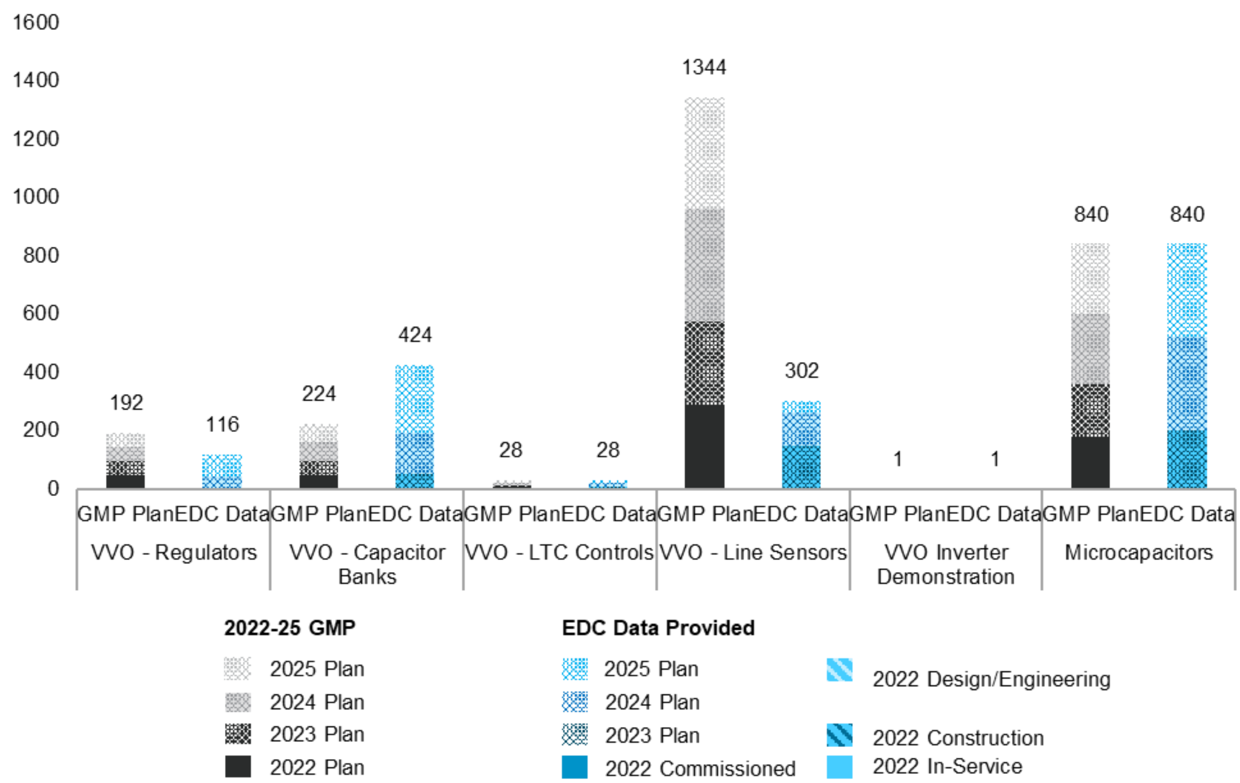
Source: Guidehouse analysis of DPU Order on Previously Deployed Technologies (October 7, 2022), 2021 DOER Responses, and *2022 EDC Data*

Eversource progress on VVO investments targeted for 2022 through 2025 was comprised of progressing engineering/design work for all VVO device types. Spend on Term 2 investments amounted to $0.04M, short of the $8.70M that was initially planned for 2022. Lower deployment and spend relative to plans can primarily be attributed to the timing of the DPU's rulings on Track 1 investments (Oct. 7, 2022) and Track 2 investments (Nov. 30, 2022). Engineering / design work conducted in 2022 enabled Eversource to begin submitting material orders once DPU decision was released. Given limited deployment and spend on Term 2 investments in 2022, as well as ongoing vendor delays in fulfilling material orders, Eversource has adjusted plans for the remainder of Term 2. In 2023, Eversource will be conducting additional design work, submitting material orders, and, when material orders are received, deploying VVO investments. To account for ongoing vendor delays, Eversource has projected that the majority of deployment and spend activity will occur in 2024 and 2025.

3.2.2.7 Term 2 VVO Device Type Progress through PY 2022

Figure 12 shows planned versus actual device deployment progress for PY 2022, as well as planned investment for PY 2023 through PY 2025.

Figure 12. Term 2 Eversource Planned vs Actual Deployment (2022-2025, Unit Count)



Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

The EDC Data presented in Figure 12 is also shown in tabular form in Table 48 to provide the specific deployment units in each category.

Table 48. Term 2 Eversource VVO Deployment Progress

	VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors	VVO - Inverter Demo	Micro-capacitors
2022-2025 Planned Deployment	**116**	**424**	**28**	**302**	**1**	**840**
PY 2025 Planned	72	234	10	39	0	320

	VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors	VVO - Inverter Demo	Micro-capacitors
PY 2024 Planned	44	140	10	117	0	320
PY 2023 Planned	0	50	8	146	1	200
Commissioned in PY 2022	0	0	0	0	0	0
In-Service during PY 2022	0	0	0	0	0	0
Construction during PY 2022	0	0	0	0	0	0
Engineering/Design during PY 2022	**116**	**424**	**28**	**302**	**1**	**840**

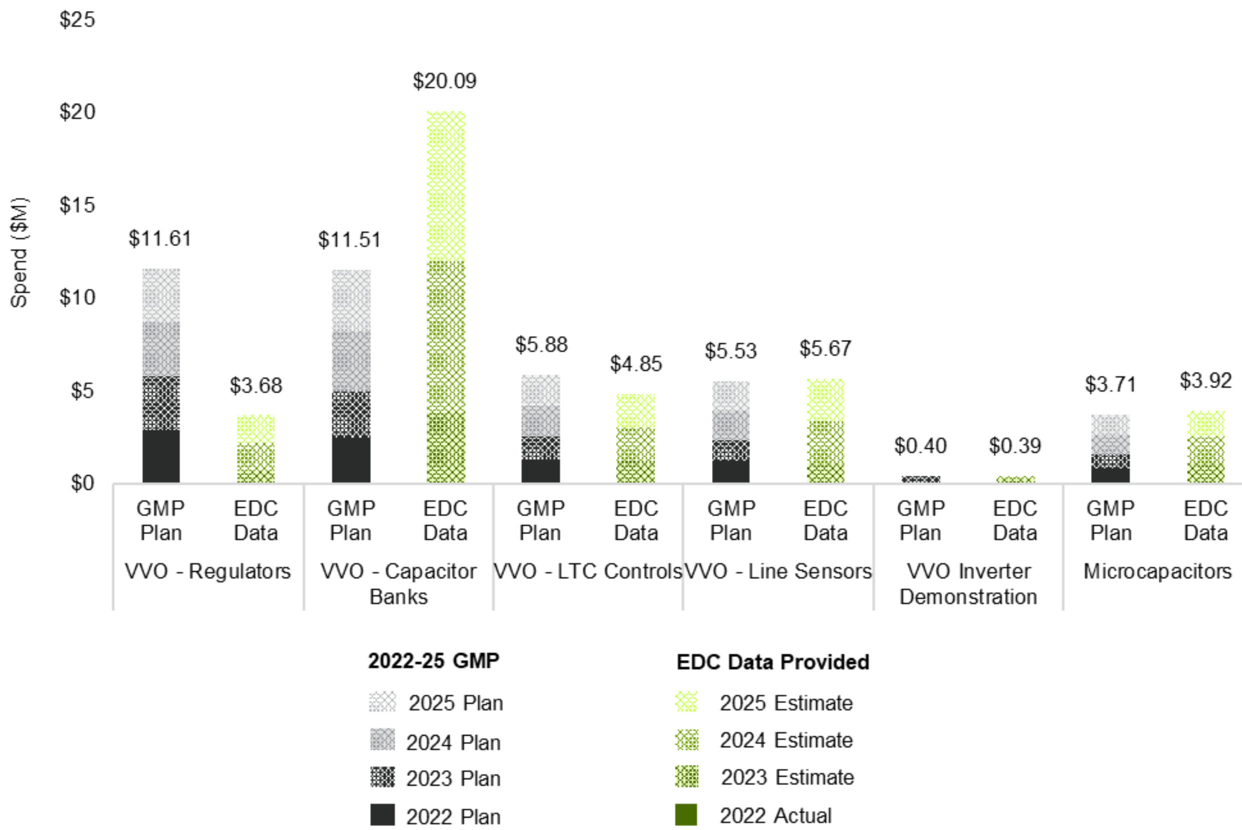
Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

During PY 2022, Eversource was not able to deploy VVO investments targeted for Term 2. Work on Term 2 investments was focused on engineering/design, as well as identification of substations to receive VVO during Term 2. Engineering/design work conducted in 2022 enabled Eversource to begin submitting material orders once DPU decisions were released in late 2022.

Since Eversource filed its 2022-2025 GMP, planned deployment has declined for Regulators, Line Sensors, and Microcapacitors. Meanwhile, planned deployment for LTC controls has not changed, and Capacitor Bank planned deployment has increased slightly. Capacitor Bank deployment has been revised upwards to reflect refinements made during the planning and design process, which placed more priority on Capacitor Banks, less on Regulators, for VVO operation. Vendor delays continued through 2022, with average lead times for Regulators and Capacitor Banks at around 56 weeks. Eversource has adjusted plans to conduct the most deployment in 2024 and 2025 to account for ongoing vendor delays and ongoing design work.

Figure 13 shows Eversource's corresponding planned versus actual spend for PY 2022, as well as planned investment for PY 2023 through PY 2025, broken out by device type.

Figure 13. Term 2 Eversource VVO Spend Plan vs. Actual (2022-2025, $M)



Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

The EDC Data presented in Figure 13 is also shown in Table 49 to provide the specific dollar spend in each category.

Table 49. Term 2 Eversource Total Spend Comparison (2022-2025, $M)

	VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors	VVO - Inverter Demo	Micro-capacitors
2022-2025 Total	**$3.68**	**$20.09**	**$4.85**	**$5.67**	**$0.39**	**$3.92**
PY 2025 Estimate	$1.50	$8.10	$1.80	$2.30	$0.00	$1.40
PY 2024 Estimate	$1.50	$8.10	$1.80	$2.30	$0.10	$1.40
PY 2023 Estimate	$0.68	$3.88	$1.23	$1.07	$0.29	$1.12
PY 2022 Actual	$0.00	$0.01	$0.02	$0.00	$0.00	$0.00

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Eversource has reduced planned spend for Regulators while increasing planned spend for Capacitor Banks. This shift in planned spend is consistent with a shift in deployment plans for Regulators and Capacitor Banks. However, Eversource has not changed planned spend for Line Sensors, despite a marked reduction in planned deployment of Line Sensors. In response to vendor delays and design work being in progress for numerous device types, Eversource has reduced spend plans for 2023, increased spend plans for 2024 and 2025.

3.2.2.8 Term 2 Infrastructure Metrics Results and Key Findings

Table 50 and Table 51 present the Infrastructure Metrics results through PY 2022 for each device type in Eversource's VVO Investment Area.

Table 50. Term 2 2022 Eversource Infrastructure Metrics for VVO Devices

Infrastructure Metrics			VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors	VVO Inverter Demo	Micro-capacitors
GMP Plan Total, 2022-2025		# Devices Planned	192	224	28	1344	1	840
		Spend, $M	$11.61	$11.51	$5.88	$5.53	$0.40	$3.71
EDC Data Total, 2022-2025		# Devices Planned	116	424	28	302	1	840
		Spend, $M	$3.68	$20.09	$4.85	$5.67	$0.39	$3.92
IM-4	Number of devices or other technologies deployed thru. PY 2022	# Devices Deployed	0	0	0	0	0	0
		% Devices Deployed	0%	0%	0%	0%	0%	0%
IM-5	Cost for Deployment thru PY 2022	Total Spend, $M	$0.00	$0.01	$0.02	$0.00	$0.00	$0.00
		% Spend	0%	0%	0%	0%	0%	0%

Infrastructure Metrics			VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors	VVO Inverter Demo	Micro-capacitors
IM-6	Deviation Between Actual and Planned Deployment for PY 2022	% On Track (Devices)	0%	0%	0%	0%	N/A	0%
		% On Track (Spend)	0%	0%	2%	0%	N/A	N/A
IM-7	Projected Deployment for the Remainder of the GMP Term*	# Devices Remaining	116	424	28	302	1	840
		Spend Remaining, $M	$3.68	$20.08	$4.83	$5.67	$0.39	$3.92

*The metric names have been slightly changed here to clarify the time span used in analysis.

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Table 51. Term 2 2022 Eversource Infrastructure Metrics for VVO Feeders

IM	Metric	Parameter*	Number of Feeders
IM-4	Number of Devices/Technologies Deployed	# Feeders with VVO Enabled	0
		% Feeders with VVO Enabled	0%
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Feeders with VVO Enabled)	0%
IM-7	Projected Deployment for the Remainder of the GMP Term	# Feeders Remaining for VVO Enablement	95

Note: This table considers Term 2 plan feeders for Eversource. Feeders currently projected to receive VVO capability during Term 2 may be found in Table 31.

* VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Guidehouse's review of Eversource's VVO progress revealed that Eversource were below planned spend and deployment outlined in their 2022-2025 GMP. Key findings related to Eversource's progress include:

Device Deployment

- During PY 2022, Eversource was not able to deploy VVO investments targeted for Term 2. Lower deployment and spend relative to plans can primarily be attributed to the timing of the DPU's rulings on Track 1 investments (Oct. 7, 2022) and Track 2 investments (Nov. 30, 2022). Eversource progress on VVO investments targeted for 2022 through 2025 was comprised of progressing engineering/design work for all VVO device types, as well as planning for future VVO deployments. Engineering/design work conducted in 2022 enabled Eversource to begin submitting material orders once DPU decisions were released in late 2022.
- Given limited deployment and spend on Term 2 investments in 2022, as well as ongoing vendor delays in fulfilling material orders, Eversource has adjusted plans for the remainder of Term 2. In 2023, Eversource will be conducting additional design work, submitting material orders, and, when material orders are received, deploying VVO investments. To account for ongoing vendor delays, Eversource has projected that the majority of deployment and spend activity will occur in 2024 and 2025.

- In addition to an accelerated deployment timeline as compared to its 2022-2025 GMP, planned deployment has declined for Regulators, Line Sensors, and Microcapacitors. Meanwhile, Capacitor Bank deployment has been revised upwards to reflect refinements made during the planning and design process, which placed more priority on Capacitor Banks, less on Regulators, for VVO operation.

Total Spend

- Spend on Term 2 investments amounted to $0.04M, short of the $8.70M that was initially planned for 2022. Given limited deployment and spend on Term 2 investments in 2022, as well as ongoing vendor delays in fulfilling material orders, Eversource has adjusted plans for the remainder of Term 2. In 2023, Eversource will be conducting additional design work, submitting material orders, and, when material orders are received, deploying VVO investments. Eversource has projected that most spend activity will occur in 2024 and 2025.
- Consistent with shifts in planned deployment for Regulators and Capacitor Banks, Eversource has reduced planned spend for Regulators while increasing planned spend for Capacitor Banks.

VVO Enablement:

- For its Term 2 substations, Eversource is currently in the VVO Investment phase, and is conducting engineering / design work for the selected substations. Eversource anticipates completing deployment during 2024 and 2025. Once VVO investments are deployed, Eversource plans to conduct VVO On/Off testing, with testing start dates ranging from July 2024 through July 2025. Once VVO On/Off testing has begun, Eversource anticipates conducting this testing for 9 – 12 months to collect one summer, one winter, and one shoulder season of testing data.

3.2.3 National Grid

This section discusses National Grid's planned and actual VVO investment progress through PY 2022.

3.2.3.1 Overview of GMP Deployment Plan

During Term 1, National Grid completed deployment of VVO investments across the East Methuen, Stoughton, and Maplewood substations, amounting to 20 feeders. For Term 2, National Grid has currently identified 52 feeders for VVO investment. National Grid selected substations for VVO primarily based on whether they yielded the greatest customer savings. Other considerations in the selection process included the future or ongoing planned work scopes, resourcing availability, and a load flow and power quality analysis.

Table 52 and Table 53 summarize the planned and actual deployment and spending on VVO as of the end of 2022. In 2022, National Grid had identified 52 feeders to receive VVO functionality during Term 2. As of the end of 2022, National Grid has enabled VVO at 18 feeders, 35% of the feeders outlined in its Term 2 plans. To date, National Grid has spent roughly 10% of its Term 2 planned spend of $76.44M.

Table 52. Term 2 National Grid Cumulative VVO Feeder Deployment Year-over-Year Comparison

Data	2022	2023	2024	2025	2022-2025
EDC Actual Progress	18	N/A	N/A	N/A	N/A
EDC Plan	52	N/A	N/A	N/A	N/A
% EDC Actual Progress/EDC Plan	35%	N/A	N/A	N/A	N/A

Note: Due to rounding error, manual calculations of % EDC Actual Progress / EDC Plan will not precisely match calculated numbers provided in this table.

Source: Guidehouse analysis of 2022-2025 GMPs and 2022 EDC Data

Table 53. Term 2 National Grid Cumulative VVO Investment Year-over-Year Comparison ($M)*

Data	2022	2023	2024	2025	2022-2025
EDC Actual Progress	$7.6	N/A	N/A	N/A	N/A
EDC Plan	$76.4	N/A	N/A	N/A	N/A
% EDC Actual Progress/EDC Plan	10%	N/A	N/A	N/A	N/A

Note: Due to rounding error, manual calculations of % EDC Actual Progress / EDC Plan will not precisely match calculated numbers provided in this table.

Source: Guidehouse analysis of 2021 Responses to DOER IRs and 2022 EDC Data

Table 54 highlights National Grid VVO feeder characteristics as of the end of 2022. Feeder lengths and customer counts vary considerably across VVO feeders. Selected substations also present a mix of distributed generation capacity across feeders, with distributed generation capacity ranging from 0.6 MW to 7.9 MW. Appendix A contains additional information related to the VVO feeders.

Table 54. Term 1 2022 National Grid VVO Feeder Characteristics

Substation	Feeder	Feeder Length (mi.)	Customer Count	Annual Peak Load (MVA)	Distributed Generation (MW)
Original 2018–2020 Plan Feeders					
East Methuen (13.2 kV)	**74L1**	39	3,088	12.1	5.9
	74L2	17	1,574	6.7	0.9
	74L3	20	3,355	8.2	2.0
	74L4	9	1,609	6.6	1.2
	74L5	55	3,162	10.7	1.3
	74L6	8	1,781	5.0	0.7
Stoughton (13.8 kV)	**913W17**	14	1,350	5.5	1.8
	913W18	12	1,504	4.6	0.7
	913W43	32	2,132	7.1	1.5
	913W47	16	1,796	5.8	0.6
	913W67	13	755	3.0	1.0
	913W69	32	3,603	9.9	1.7
Maplewood	**16W1**	17	3,683	9.6	1.4

Substation	Feeder	Feeder Length (mi.)	Customer Count	Annual Peak Load (MVA)	Distributed Generation (MW)
(13.8 kV)	16W2	11	4,674	8.6	1.1
	16W3	13	3,352	7.6	0.7
	16W4	8	1,131	9.2	0.9
	16W5	7	1,710	5.7	1.0
	16W6	24	5,627	14.3	2.0
	16W7	14	3,891	10.9	2.0
	16W8	16	3,427	9.6	1.9
East Bridgewater (13.8 kV)	797W1	36	2,821	10.4	1.4
	797W19	38	2,563	8.3	2.8
	797W20	31	1,717	9.7	0.6
	797W23	41	2,650	9.7	1.7
	797W24	54	2,583	9.7	1.5
	797W29	37	2,338	8.3	2.7
	797W42	21	1,239	4.5	1.9
East Dracut (13.2 kV)	75L1	17	3,041	7.6	1.0
	75L2	39	2,613	8.4	1.1
	75L3	50	2,328	9.7	2.3
	75L4	9	387	3.3	0.2
	75L5	19	3,556	7.7	1.1
	75L6	25	1,485	6.5	0.9
Easton (13.8 kV)	92W43	28	1,973	7.1	1.2
	92W44	26	1,779	9.0	1.3
	92W54	34	2,284	7.3	7.9
	92W78	38	1,993	7.9	0.9
	92W79	24	1,655	6.4	5.3
Melrose (13.8 kV)	25W1	19	1,575	6.1	2.3
	25W2	17	1,245	6.1	0.8
	25W3	9	729	8.3	0.8
	25W4	22	4,770	11.5	1.3
	25W5	20	3,832	11.4	1.4
Westboro (13.8 kV)	312W1	30	2,278	9.8	2.0
	312W2	9	177	6.0	3.0
	312W3	21	1,492	8.0	0.9
	312W4	54	2,625	9.0	5.5
	312W5	14	424	9.6	0.9
West Salem (13.8 kV)	29W1	23	3,788	10.7	2.4
	29W2	16	1,653	6.0	0.7
	29W3	15	4,286	10.3	1.4
	29W4	18	2,700	8.2	2.1
	29W5	12	2,915	10.5	1.3
	29W6	17	1,426	6.8	1.3

Note: Values presented in this table were published on April 24, 2023 and are reflective of data collected through the end of 2022.
Source: 2022 GMP Annual Report, Appendix 1 filed April 24, 2023.

3.2.3.2 VVO Timeline

Table 55 and Table 56 summarize substation-specific progress in each of the four VVO investment phases. The evaluation of Infrastructure Metrics spans spending and deployment under the VVO investment and VVO commissioning stages.

Table 55. National Grid Combined Plan Feeders Deployment Completion Dates

Substation	VVO Investment	VVO Commissioning	VVO Enabled Date	VVO On/Off Testing Period
Term 1 Plan Substations				
E. Methuen	2/1/2020 - 8/31/2020 (Complete)	7/27/2020 - 1/22/2021 (Complete)	2/8/2021 (Complete)	3/1/2021 - 1/6/2023 (Complete)
Maplewood	1/15/2020 - 8/31/2020 (Complete)	9/1/2021 - 12/15/2021 (Complete)	12/16/2021 (Complete)	12/16/2021 - TBD (In-Progress)
Stoughton	11/15/2019 - 3/31/2020 (Complete)	5/1/2020 - 7/23/2020 (Complete)	7/24/2020 (Complete)	12/1/2020 - 9/15/2021 (Complete)
Term 2 Plan Substations				
Billerica	1/1/2022 - 7/1/2023 (in progress)	1/1/2023 - 8/1/2023 (planned)	9/1/2023 (in progress)	TBD (in progress)
Depot Street	1/1/2022 - 7/1/2023 (in progress)	1/1/2023 - 8/1/2023 (planned)	9/1/2023 (in progress)	TBD (in progress)
E. Bridgewater	5/15/2020 - 6/1/2021 (Complete)	6/1/2021 - 7/29/2021 (Complete)	7/29/2021 (Complete)	7/30/2021 - 1/6/2023 (Complete)
E. Dracut	1/1/2021 - 12/15/2022 (Complete)	12/15/2022 - 3/1/2023 (Planned)	3/1/2023 (Planned)	3/1/2023 - 2/1/2024 (Planned)
Easton	1/1/2021 - 6/13/2022 (Complete)	6/13/2022 - 12/1/2022 (Complete)	12/1/2022 (Complete)	12/31/2022 - 12/31/2023 (In-Progress)
Melrose	1/1/2021 – TBD (In-Progress)	3/1/2023 - 4/1/2023 (Planned)	5/1/2023 (Planned)	TBD (Planned)
Parkview	1/1/2022 - 7/1/2023 (in progress)	1/1/2023 - 8/1/2023 (planned)	9/1/2023 (in progress)	TBD (in progress)

Substation	VVO Investment	VVO Commissioning	VVO Enabled Date	VVO On/Off Testing Period
Westboro	1/1/2021 – 10/17/2022 (In-Progress)	10/17/2022 - 3/31/2023 (In-Progress)	3/31/2023 (Planned)	TBD (Planned)
W. Salem	1/1/2021 - 5/1/2022 (Complete)	5/1/2022 - 6/1/2022 (Complete)	6/1/2022 (Complete)	6/1/2022 - TBD (In-Progress)

Source: Guidehouse analysis of 2022 EDC Data

Table 56. 2022 National Grid VVO Enabled Progress by Substation

Substation	January 2022 Planned/Actual VVO Enabled Date	January 2023 Planned/Actual VVO Enabled Date	Current Status[46]
Term 1 Plan Feeders			
E. Methuen	2/8/2021 (actual)	2/8/2021 (actual)	VVO On/Off Testing complete
Maplewood	12/16/2021 (actual)	12/16/2021 (actual)	VVO On/Off testing in progress
Stoughton	7/24/2020 (actual)	7/24/2020 (actual)	VVO On/Off Testing complete
Term 2 Plan Feeders			
Billerica	N/A	9/1/2023 (planned)	VVO Investment in-progress
Depot Street	N/A	9/1/2023 (planned)	VVO Investment in-progress
E. Bridgewater	7/29/2021 (actual)	7/29/2021 (actual)	VVO On/Off Testing complete
E. Dracut	6/1/2022 (planned)	3/1/2023 (planned)	VVO Investment complete
Easton	11/15/2022 (planned)	12/1/2022 (actual)	VVO On/Off testing in progress
Melrose	11/15/2022 (planned)	5/1/2023 (planned)	VVO Investment in progress
Parkview	N/A	9/1/2023 (planned)	VVO Investment in-progress
Westboro	11/15/2022 (planned)	3/31/2023 (planned)	Commissioning in progress
W. Salem	6/1/2022 (planned)	6/1/2022 (actual)	VVO On/Off testing in progress

Source: Guidehouse analysis of 2021 and 2022 EDC VVO supplemental data submissions

National Grid conducted VVO On/Off testing at its East Methuen and Maplewood Term 1 substations throughout 2022. Among its Term 2 substations, National Grid conducted On/Off testing at the East Bridgewater substation throughout 2022, as VVO deployment was completed at the substation in 2021. Additionally, National Grid completed VVO deployment at the Easton and West Salem substations and began VVO On/Off for these substations in winter 2022/23 and spring 2022, respectively. National Grid projects that it will complete VVO deployment and enable VVO at its remaining Term 2 substations in 2023.

3.2.3.3 Term 2 VVO Deployment Plan Progression

Figure 14 shows how National Grid's Term 2 VVO deployment spend has progressed in 2022.

[46] Status can be: planning, design, construction, device deployment complete, VVO commissioning in process, or VVO enabled. VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Figure 14. Term 2 National Grid's VVO Planned and Actual Spend Progression, $M

Note: To more closely align spend projections with DPU pre-authorized budgets, National Grid operations and maintenance (O&M) spend is included in actual and planned spend presented here. O&M spend is provided in aggregate for each investment area and is therefore excluded from device-specific summaries of spend.

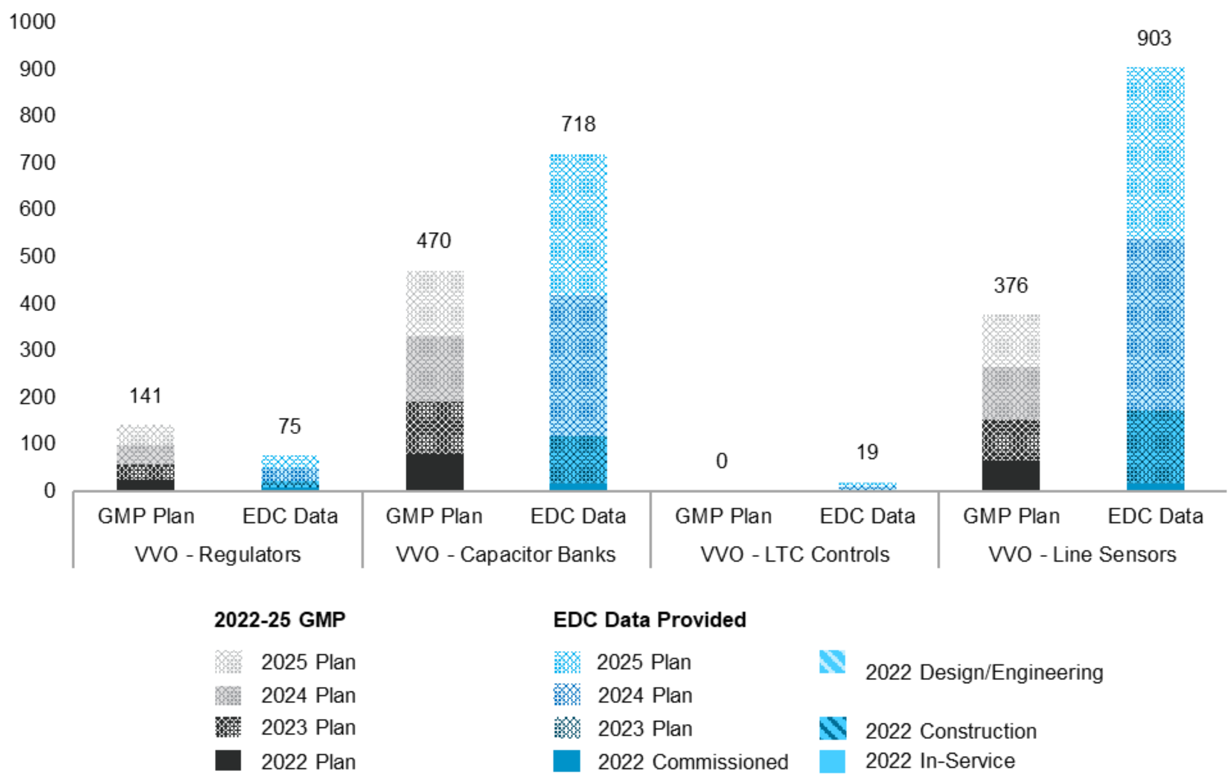
Source: Guidehouse analysis of DPU Order (October 7, 2022), DOER Responses and *2022 EDC Data*

National Grid spend and deployment were below plans for 2022, and progress was affected by a number of factors. National Grid's resourcing constraints led to shortfall of in-house planning and engineering resources to draw on, so National Grid needed to supplement in-house resources with incremental resources to maintain GMP progress. In addition, National Grid's previous line sensor vendor discontinued their model, requiring identification of a new vendor. In some cases, work that had previously passed the engineering/design phase required re-design. Lastly, procuring materials continues to be a difficult task for National Grid. Longer vendor lead times, present during PY 2021, continued into PY 2022, with Line Sensors and Regulators most affected by delays.

3.2.3.4 Term 2 VVO Investment Progress through PY 2022

Figure 15 and Table 57 show planned versus actual device deployment progress for PY 2022, as well as planned investment for PY 2023 through PY 2025.

Figure 15. Term 2 National Grid VVO Device Deployment (2022–2025)



Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Table 57. Term 2 National Grid VVO Planned and Actual Device Deployment (2022-2025)

	VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors
2022-2025 Planned Deployment	**75**	**718**	**19**	**903**
PY 2025 Planned	27	300	8	365
PY 2024 Planned	27	300	8	365
PY 2023 Planned	12	102	3	156
Commissioned in PY 2022	9	16	0	17
In-Service during PY 2022	0	54	0	0
Construction during PY 2022	3	57	0	26
Engineering/Design during PY 2022	9	25	0	3

Source: Guidehouse analysis of 2022 EDC Data

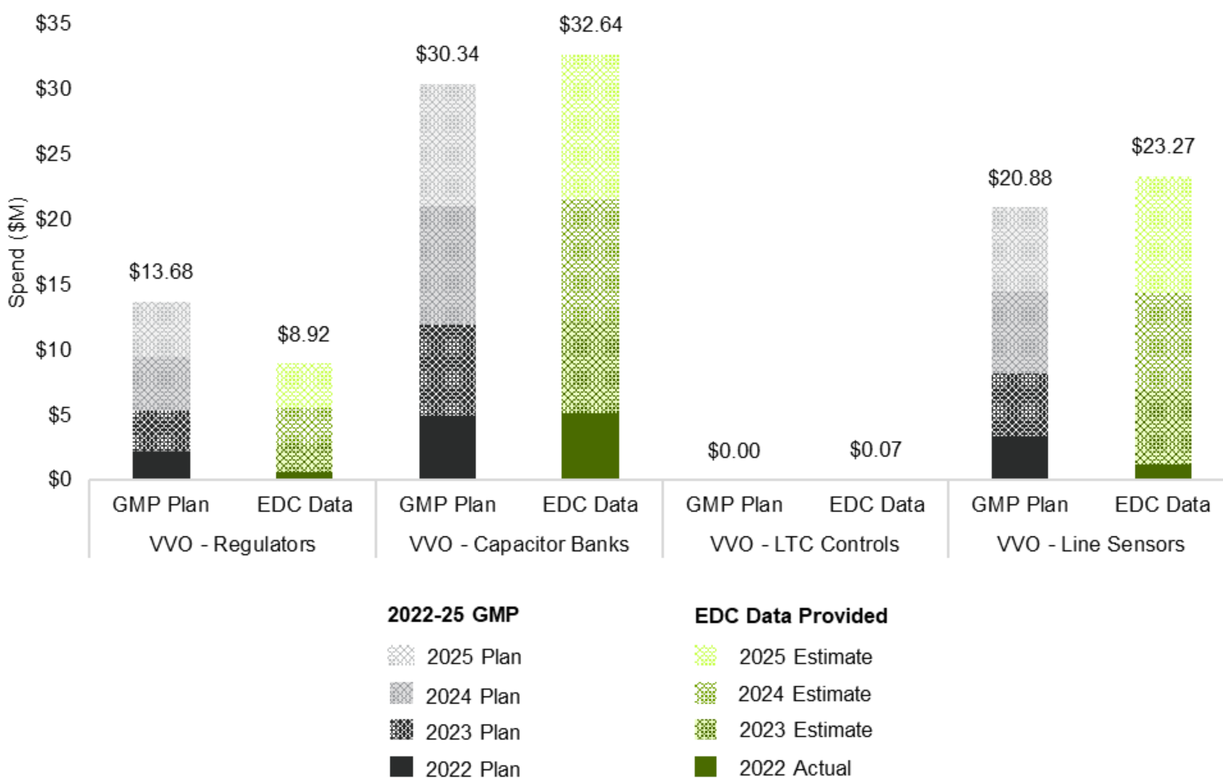
During PY 2022, National Grid deployed fewer devices than initially planned. National Grid deployed 20% of Capacitor Banks, 27% of Line Sensors, and 38% of Regulators that were initially planned for deployment during 2022. A late-2022 DPU decision, resource constraints, and vendor lead times were all key contributors to this outcome.

To account for a shortfall in deployment, National Grid has accelerated its deployment timeline for 2023 through 2025. Process improvements have increased rate of progress, which will enable National Grid to continue progressing with VVO deployment on this accelerated timeline. However, meeting deployment goals will require engineering/design and construction work on devices to be accelerated. National Grid will also need to coordinate schedules with vendors to ensure material orders can be fulfilled on its accelerated deployment schedule.

In addition to accelerating deployment plans for 2023 through 2025, National Grid has adjusted deployment plans for numerous device types. Similar to Eversource, National Grid has increased projected deployment for Capacitor Banks while reducing projected deployment for Regulators. In addition, National Grid has increased deployment plans for Line Sensors and LTC Controls. National Grid cites that these revisions are primarily due to the VVO planning work that has been conducted since the 2022-2025 GMP was filed.

Figure 16 shows National Grid's planned versus actual spend for PY 2022, as well as planned investment for PY 2023 through PY 2025.

Figure 16. Term 2 National Grid VVO Plan vs. Actual (2022–2025, $M)



Note: O&M spend is provided in aggregate for each investment area and is therefore excluded from device-specific summaries of spend.

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

The EDC Data presented in Figure 16 is also shown in Table 58 to provide the specific dollar spend in each category.

Table 58. Term 2 National Grid Total Spend Comparison (2022–2025, $M)

	VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors
2022-2025 Planned Spend	**$8.92**	**$32.64**	**$0.07**	**$23.27**
PY 2025 Planned	$3.35	$11.17	$0.00	$8.94
PY 2024 Planned	$2.78	$9.27	$0.00	$7.42
PY 2023 Planned	$2.13	$7.09	$0.00	$5.67
PY 2022 Actual	$0.66	$5.11	$0.07	$1.24

Note: O&M spend is provided in aggregate for each investment area and is therefore excluded from device-specific summaries of spend.

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

National Grid spend on VVO ($7.6M) was below plans for 2022 ($11.1M). The majority of spend occurred on Capacitor Banks ($5.1M), while spend on Regulators and Line Sensors was well below plans. Lower-than-anticipated spend on Line Sensors can, in part, be attributed to National Grid's previous line sensor vendor discontinuing their selected model. In response, National Grid identified a new vendor for its Line Sensors, but National Grid needed to restart some work that had previously passed the engineering/design phase. For VVO Regulators, National Grid cites that vendor delays in fulfilling material orders was a key contributor to lower spend than initially planned. In response to its 2022 experience with Line Sensors and Regulators, National Grid has begun to increase diversification of vendors that it sources materials from.

3.2.3.5 Term 2 Infrastructure Metrics Results and Key Findings

Table 59 and Table 60 summarize the Term 2 Infrastructure Metrics results through PY 2022 for each investment type related to National Grid's VVO Investment Area.

Table 59. Term 2 2022 National Grid Infrastructure Metrics Findings

Infrastructure Metrics			VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors
GMP Plan Total, 2022-2025		# Devices Planned	141	470	0	376
		Spend, $M	$13.68	$30.34	$0.00	$20.88
EDC Data Total, 2022-2025		# Devices Planned	75	718	19	903
		Spend, $M	$8.92	$32.64	$0.07	$23.27
IM-4	Number of devices or other technologies deployed thru. PY 2022	# Devices Deployed*	9	16	0	17
		% Devices Deployed	6%	3%	N/A	5%
IM-5	Cost for Deployment thru PY 2022	Total Spend, $M	$0.66	$5.11	$0.07	$1.24
		% Spend	5%	17%	0%	6%
IM-6	Deviation Between Actual and Planned	% On Track (Devices)	38%	20%	N/A	27%

Infrastructure Metrics			VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors
	Deployment for PY 2022	% On Track (Spend)	30%	104%	N/A	36%
IM-7	Projected Deployment for the Remainder of the GMP Term	# Devices Remaining	66	702	19	886
		Spend Remaining, $M	$8.26	$27.53	$0.00	$22.03

Note: The metric names have been slightly changed here to clarify the time span used in analysis. O&M spend is provided in aggregate for each investment area and is therefore excluded from device-specific summaries of spend.

*Note that "Deployed" here refers to commissioned devices. For full definitions of commissioned and in-service, see Docket 20-46 Response to Information Request DPU-AR-4-11, September 3, 2020.Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Table 60. 2022 National Grid Infrastructure Metrics for VVO Feeders

IM	Metric	Parameter*	Number of Feeders
Term 1 Plan Feeders			
IM-4	Number of Devices/Technologies Deployed	# Feeders with VVO Enabled	20
		% Feeders with VVO Enabled	100%
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Feeders with VVO Enabled)	100%
IM-7	Projected Deployment for the Remainder of the GMP Term	# Feeders Remaining for VVO Enablement	0
Term 2 Plan Feeders			
IM-4	Number of Devices/Technologies Deployed	# Feeders with VVO Enabled	18
		% Feeders with VVO Enabled	35%
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Feeders with VVO Enabled)	35%
IM-7	Projected Deployment for the Remainder of the GMP Term	# Feeders Remaining for VVO Enablement	34

* VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Source: Guidehouse analysis of EDC Data

Guidehouse's review of National Grid's deployment and spend revealed that National Grid was below initial plans for 2022 outlined in National Grid's 2022-2025 GMP. Key findings related to National Grid's progress include:

Device Deployment

- During PY 2022, National Grid deployed fewer devices than initially planned. National Grid deployed 20% of Capacitor Banks, 27% of Line Sensors, and 38% of Regulators that were initially planned for deployment during 2022. A late-2022 DPU decision, resource constraints, analysis that fewer devices were needed, and vendor lead times were all key contributors to this outcome.
- National Grid has accelerated its deployment timeline for 2023 through 2025. Process improvements have increased rate of progress, which will enable National Grid to continue progressing with VVO deployment on this accelerated timeline. National Grid has adjusted

total deployment plans for numerous device types, increasing projected deployment for Capacitor Banks while reducing projected deployment for Regulators. In addition, National Grid has increased deployment plans for Line Sensors and LTC Controls. National Grid cites that these revisions are primarily due to the VVO planning work that has been conducted since the 2022-2025 GMP was filed.

Total Spend

- National Grid spend on VVO was below plans for 2022. The majority of spend occurred on Capacitor Banks, while spend on Regulators and Line Sensors was well below plans. Lower-than-anticipated spend on Line Sensors can, in part, be attributed to National Grid's previous line sensor vendor discontinuing their selected model. For VVO Regulators, vendor delays in fulfilling material orders was a key contributor to lower spend than initially planned. In response to its 2022 experience with Line Sensors and Regulators, National Grid has begun to increase diversification of vendors that it sources materials from.

VVO Enablement

- National Grid conducted VVO On/Off testing at its East Methuen and Maplewood Term 1 substations throughout 2022. Among its Term 2 substations, National Grid conducted On/Off testing at the East Bridgewater substation throughout 2022, as VVO deployment was completed at the substation in 2021. Additionally, National Grid completed VVO deployment at the Easton and West Salem substations and began VVO On/Off for these substations in winter 2022/23 and spring 2022, respectively. National Grid projects that it will complete VVO deployment and enable VVO at its remaining Term 2 substations in 2023.

3.2.4 Unitil

This section discusses Unitil's planned and actual VVO investment progress through PY 2022.

3.2.4.1 Overview of GMP Deployment Plan

Approach to VVO

Unitil's approach to VVO investment is unique. Unitil initially planned to enable VVO for the Townsend substation in 2019, the Lunenburg substation in 2020, and the Summer Street substation in 2021. This timeline was revised to allow Unitil to complete all grid modernization activities at a single substation before moving to another, as VVO is tied to the ADMS and M&C Investment Areas. For instance, deployment of VVO relies on the SCADA system being in place, tying the VVO deployment to the M&C Investment Area. The VVO project is also tied with the FAN deployment plan which will allow communication from the ADMS to the field devices. Given VVO progress was ultimately tied to the ADMS and M&C progress made during Term 1, Unitil ultimately revised plans to deploy VVO across 3 feeders during Term 1. Unitil met this plan, deploying VVO at the Townsend substation in 2021.

Table 61 and Table 62 summarize the planned deployment and spending on VVO from 2022 through 2025.

Table 61. Term 2 Unitil Cumulative VVO Feeder Deployment Year-over-Year Comparison

Data	2022	2023	2024	2025	2022-2025
EDC Actual Progress	4	N/A	N/A	N/A	N/A
EDC Plan	8	N/A	N/A	N/A	N/A
% EDC Actual Progress/EDC Plan	50%	N/A	N/A	N/A	N/A

Note: Due to rounding error, manual calculations of % EDC Actual Progress / EDC Plan will not precisely match calculated numbers provided in this table.

Source: Guidehouse analysis of 2022-2025 GMPs and 2022 EDC Data

Table 62. Unitil VVO Investment Year-over-Year Comparison ($M)*

Data	2022	2023	2024	2025	2022-2025
EDC Actual Progress	$0.3	N/A	N/A	N/A	N/A
EDC Plan	$5.4	N/A	N/A	N/A	N/A
% EDC Actual Progress/EDC Plan	5%	N/A	N/A	N/A	N/A

Note: Due to rounding error, manual calculations of % EDC Actual Progress / EDC Plan will not precisely match calculated numbers provided in this table.

Source: Guidehouse analysis of 2021 Responses to DOER IRs and 2022 EDC Data

For Term 2, Unitil plans to deploy VVO across the Summer Street, Lunenburg, and West Townsend substations, amounting to 8 feeders. By the end of 2022, Unitil completed deployment of VVO at the Summer Street substation and its associated 4 feeders. Spend on VVO deployment has amounted to approximately $0.3M, or about 5% of planned spend for Term 2.

Table 63 highlights Unitil feeder characteristics for Term 1 and Term 2 plan feeders. Feeder lengths and customer counts vary considerably. Selected substations also present a mix of distributed generation capacity. Appendix A contains additional information related to the VVO feeders.

Table 63. 2022 Unitil VVO Feeder Characteristics

Substation	Feeder	Feeder Length (mi.)	Customer Count	Annual Peak Load (MVA)	Distributed Generation (MW)
Term 1 Feeders					
Townsend (13.8 kV)	**15W15**	1	1	3.9	0.0
	15W16	42	1,535	5.2	1.8
	15W17	11	574	1.5	0.5
Term 2 Feeders					
Lunenburg (13.8 kV)	**30W30**	46	1,428	5.5	1.8
	30W31	46	1,695	4.4	4.1
Summer Street (13.8 kV)	**40W38**	1	67	0.1	0.0
	40W39	8	369	5.1	1.1
	40W40	18	1,578	7.5	1.7

Substation	Feeder	Feeder Length (mi.)	Customer Count	Annual Peak Load (MVA)	Distributed Generation (MW)
	40W42	13	1,920	3.6	0.7
West Townsend (13.8 kV)	**39W18**	51	1,974	0.0	3.2
	39W19	62	1,336	3.0	0.0

Note: Values presented in this table were published on April 24, 2023 and are reflective of data collected through the end of 2022.
Source: 2022 GMP Annual Report, Appendix 1 filed April 24, 2023

3.2.4.2 VVO Timeline

Table 64 and Table 65 summarize substation-specific progress in each of the four VVO investment phases, including anticipated and actual VVO enabled dates and notes on the current status of VVO deployment. The evaluation of Infrastructure Metrics spans spending and deployment under the VVO investment and VVO commissioning phases.

Table 64. Unitil VVO Deployment Completion Dates by Phase and Substation

Phase	VVO Investment	VVO Commissioning[47]	VVO Enabled Date[48]	VVO On/Off Testing Period
Term 1 Plan Substations				
Townsend	1/1/2019 – 6/1/2021 (Complete:)	6/1/2021 - 12/1/2021 (Complete)	12/1/2021 (Complete)	4/1/2023 - 3/1/2024 (Planned)
Term 2 Plan Substations				
Beech St.	1/1/2024 - 9/1/2026 (Planned:)	9/1/2026 - 10/1/2026 (Planned:)	11/1/2026 (Planned)	12/1/2026 - 9/1/2027 (Planned)
Lunenburg	1/1/2019 - 9/1/2023 (In Progress:)	10/1/2023 - 12/1/2023 (Planned)	1/1/2024 (Planned)	12/1/2024 - 9/1/2025 (Planned)
Pleasant St.	1/1/2025 - 9/1/2027 (Planned:)	9/1/2027 - 10/1/2027 (Planned:)	11/1/2027 (Planned)	12/1/2027 - 9/1/2028 (Planned)
Princeton Road	1/1/2025 - 9/1/2027 (Planned:)	9/1/2027 - 10/1/2027 (Planned:)	11/1/2027 (Planned)	12/1/2027 - 9/1/2028 (Planned)
Summer St.	1/1/2020 - 12/1/2022 (Complete:)	5/1/2022 - 12/13/2022 (Complete)	12/13/2022 (Complete)	12/1/2023 - 9/1/2024 (Planned)
W. Townsend	12/1/2020 - 11/1/2023 (In Progress:)	10/1/2023 - 12/1/2023 (Planned)	1/1/2024 (Planned)	12/1/2024 - 9/1/2025 (Planned)

Source: Guidehouse analysis of 2022 EDC Data

[47] VVO Commissioning is the time at which VVO devices are controlled by and have data visible to each EDC.
[48] VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Table 65. Unitil VVO Enabled Progress by Substation

Substation	January 2022 Actual/Planned VVO Enabled Date	January 2023 Actual/Planned VVO Enabled Date	Current Status[49]
Term 1 Plan Feeders			
Townsend	12/1/2021 (actual)	12/1/2021 (actual)	VVO Enabled
Term 2 Plan Feeders			
Beech St.	11/1/2026 (planned)	11/1/2026 (planned)	VVO Investment
Lunenburg	11/1/2023 (planned)	1/1/2024 (planned)	VVO Investment
Pleasant St.	11/1/2027 (planned)	11/1/2027 (planned)	VVO Investment
Princeton Road	11/1/2027 (planned)	11/1/2027 (planned)	VVO Investment
Summer St.	11/1/2022 (planned)	12/13/2022 (actual)	VVO Enabled
W. Townsend	11/1/2024 (planned)	11/1/2024 (planned)	VVO Investment

Source: Guidehouse analysis of 2021 and 2022 EDC VVO supplemental data submissions

For its Term 1 substation (Townsend) Unitil completed VVO deployment in 2021, enabling VVO on December 1, 2021, and had expected to begin On/Off testing at the Townsend substation in April 2022. However, testing was delayed for the Townsend substation, as Unitil worked with Hitachi to improve the results from the algorithm as the quantity of Regulators and Capacitor Banks increased on a given feeder. The issue has been resolved, and VVO On/Off testing is expected to begin in spring 2023 at the Townsend substation. For Unitil's future planned deployments, Unitil has factored in the additional time needed for internal unit testing prior to formal On/Off testing.

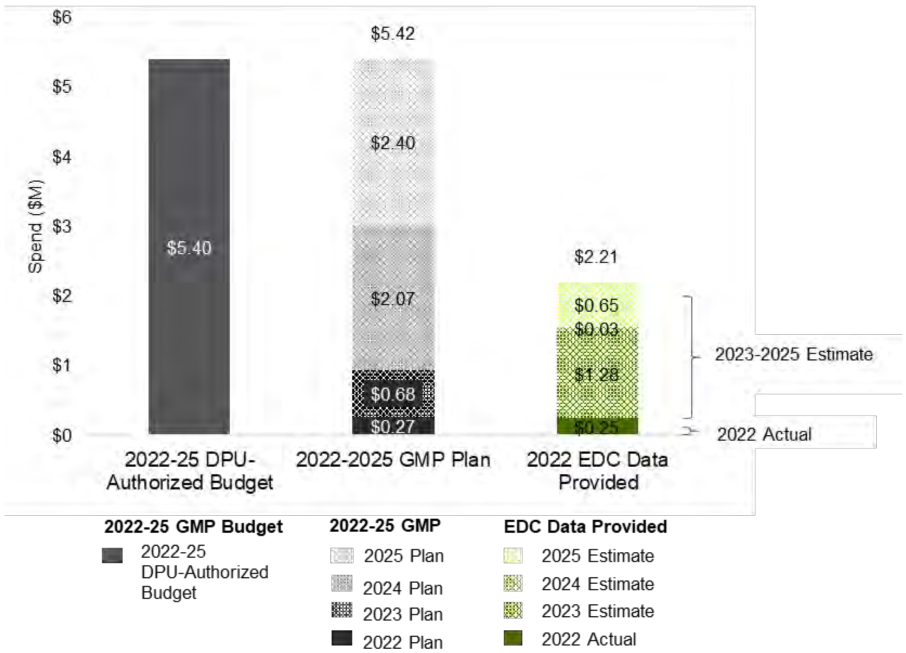
Among its Term 2 substations, Unitil completed deploying VVO investments at the Summer Street substation and enabled VVO after commissioning was completed in December 2022. VVO On/Off testing is projected to begin at the substation in December 2023. Lunenburg and West Townsend are currently receiving VVO investments and Unitil plans to enable VVO at the substations in January and November 2024, respectively. Unitil then plans to conduct On/Off testing at the substations beginning in December 2024. For its remaining substations, Unitil is currently conducting planning and engineering/design work for its Beech Street, Pleasant Street, and Princeton Road substations. These substations are expected to be enabled after the close of Term 2 in 2026 and 2027.

3.2.4.3 Term 2 VVO Deployment Plan Progression

Figure 17 shows the progression of Unitil’s M&C Term 2 deployment plans from DPU pre-authorization in PY 2022 through PY 2025.

[49] Status can be: planning, design, construction, device deployment complete, VVO commissioning in process, or VVO enabled. VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Figure 17. Term 2 Unitil VVO Planned and Actual Spend Progression, $M



Source: Guidehouse analysis of DPU Order (October 7, 2022), 2021 DOER Responses and *2022 EDC Data*

Deployment and spend for 2022 investments were approximately on-track with initial plans, with Unitil spending roughly $0.25M on VVO deployment as compared to its plan of $0.27M. Accomplishments in 2022 included resolution of LTC radio and control issues, as well as process efficiencies that brought unit costs below plans.

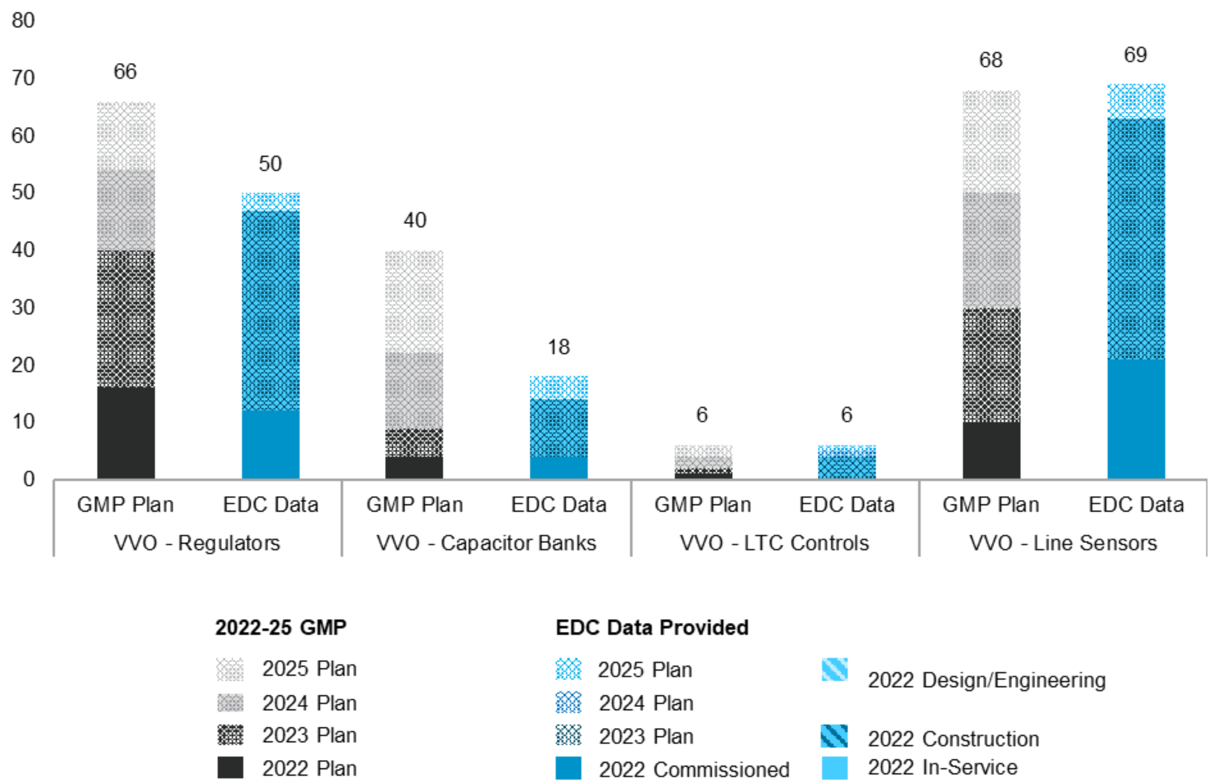
Unitil has reduced plans from what was filed in its 2022-2025 GMP, with spend plans for Term 2 revised downwards from $5.40M to $2.21M. Unitil projects spending most dollars in 2023 and 2025, with a small number of dollars planned for 2024. Most work in 2024 will be limited to engineering / design while Unitil awaits material shipments for orders submitted in 2023. Deployment and spend are projected to be below the DPU pre-authorized budget by the end of 2025.

Not reflected in spend data are challenges that Unitil faced with its VVO scheme. Although initially planned for VVO On/Off testing, testing was delayed for the Townsend substation, as Unitil worked with Hitachi to improve the results from the algorithm as the quantity of Regulators and Capacitor Banks increased on a given feeder. VVO On/Off testing is expected to begin in spring 2023 at the Townsend substation. Lessons learned included awareness of level of testing prior to putting VVO for feeders and substations into service. For Unitil's future planned deployments, Unitil has factored in the additional time needed for internal unit testing prior to formal On/Off testing.

3.2.4.4 Term 2 VVO Investment Progress through PY 2022

Figure 18 shows Unitil's planned versus actual device deployment progress for PY 2022, as well as planned investment for PY 2023 through PY 2025.

Figure 18. Term 2 Unitil VVO Device Deployment Comparison (2022–2025)



Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

The EDC Data presented in Figure 18 is also shown in tabular form in Table 66, to provide the specific deployment units in each category.

Table 66. Term 2 Unitil VVO Deployment Progress

	VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors
2022-2025 Planned Deployment	**50**	**18**	**6**	**69**
PY 2025 Planned	3	4	1	6
PY 2024 Planned	0	0	1	0
PY 2023 Planned	35	10	4	42
Commissioned in PY 2022	12	4	0	21
In-Service during PY 2022	0	0	0	9
Construction during PY 2022	31	9	3	36
Engineering/Design during PY 2022	0	0	1	0

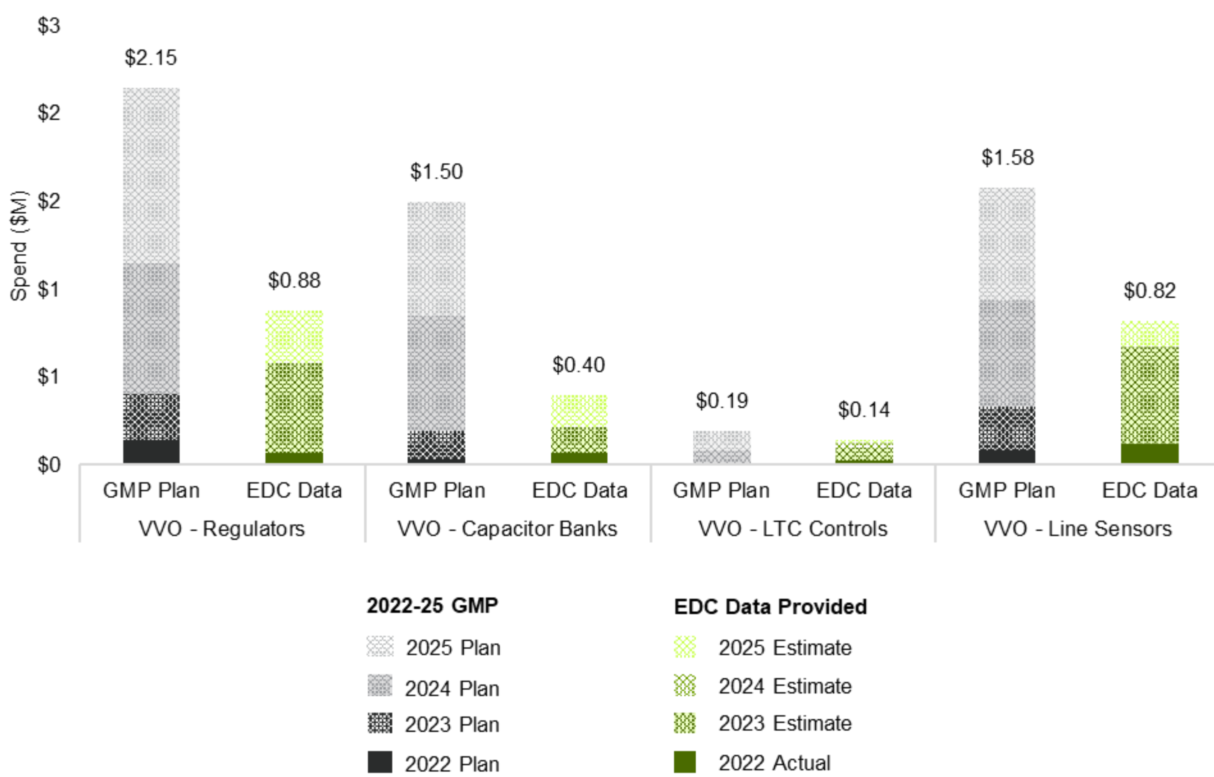
Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Unitil device deployment was slightly below initial plans for 2022 outlined in Unitil's 2022-2025 GMP. Work conducted in 2022 included deployment of VVO devices at the Summer Street and Lunenburg substations, construction work for the Princeton Road substation, and design/engineering work for the Canton Street substation. Unitil was on-track with deployment of VVO Capacitor Banks and Line Sensors in 2022, deploying 100% and 210% of planned units, respectively. However, deployment was under plans for Regulators and LTC Controls. Lower deployment than plans for LTC Controls may be attributed to Unitil's efforts to resolve LTC radio and control issues. Lower deployment than plans for Regulators can be attributed to cancelation of 4 deployments that were found to be unnecessary.

While deployment was initially projected to be evenly spread over Term 2, Unitil has adjusted deployment plans to conduct most deployment during 2023 and 2025. Additionally, Unitil has reduced its planned spend and deployment of VVO Regulators and Capacitor Banks, as Unitil reassessed deployment plans and determined there were fewer Regulator and Capacitor Bank deployments needed than initially planned. Work in 2024 will be limited to material orders in preparation for construction work at the Beech Street substation.

Figure 19 shows Unitil's planned versus actual spend for PY 2022, as well as planned investment for PY 2023 through PY 2025.

Figure 19. Term 2 Unitil VVO Plan vs. Actual (2022-2025, $M)



Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

The EDC Data presented in Figure 19 is also shown in Table 67 to provide the specific dollar spend in each category.

Table 67. Unitil Total Spend Comparison (2022–2025, $M)

	VVO – Regulators	VVO – Capacitor Banks	VVO – LTC Controls	VVO – Line Sensors
2022-2025 Planned Spend	**$0.88**	**$0.40**	**$0.14**	**$0.82**
PY 2025 Planned	$0.30	$0.18	$0.02	$0.15
PY 2024 Planned	$0.00	$0.00	$0.03	$0.00
PY 2023 Planned	$0.51	$0.15	$0.07	$0.55
PY 2022 Actual	$0.07	$0.07	$0.03	$0.12

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Unitil spend on VVO ($0.25M) was below initial plans ($0.27M), with variation in spend at the device level. Unitil met 48% of its planned spend for Regulators, which Unitil states was due to a reduction in work required to deploy Regulators. Spend and deployment of all other devices met or exceeded initial plans: Unitil met 100% of planned spend for Line Sensors and exceeded planned spend for Capacitor Banks (198%) and LTC Controls (289%).

In 2022, Unitil's costs incurred per Regulator and Line Sensor were lower than initially projected. Initial projections, estimated using the deployment experience from the prior GMP term, indicated a larger level of effort for deployment and larger overhead costs. Unitil credits internal process improvements for lower costs (e.g., revised control work process reducing commissioning costs for capacitor banks). Costs incurred for LTC Controls, at 289% of planned costs in 2022, may be attributed to Unitil's troubleshooting of radio and control issues, which have now been resolved.

Spend plans for the remainder of Term 2 have been revised downwards across all device types. Reduced spend on Regulators and Capacitor Banks can be attributed to a reduction in the units that Unitil plans to deploy, as well as lower than expected costs for deployment of Regulators. Reduced spend on LTC Controls and Line Sensors may be tied to process efficiencies implemented in 2022 that brought unit costs below plans. Most spend is planned for 2023 and 2025, with work in 2024 limited to material orders in preparation for construction work at the Beech Street substation.

3.2.4.5 Term 2 Infrastructure Metrics Results and Key Findings

Table 68 and Table 69 summarize the Term 2 Infrastructure Metrics results through PY 2022 for each investment type related to Unitil's VVO Investment Area.

Table 68. Term 2 Unitil Infrastructure Metrics Findings

Infrastructure Metrics			VVO - Regulators	VVO - Capacitor Banks	VVO - LTC Controls	VVO - Line Sensors
GMP Plan Total, 2022-2025		# Devices Planned	66	40	6	68
		Spend, $M	$2.15	$1.50	$0.19	$1.58
EDC Data Total, 2022-2025		# Devices Planned	50	18	6	69
		Spend, $M	$0.88	$0.40	$0.14	$0.82
IM-4	Number of devices or other technologies deployed thru. PY 2022	# Devices Deployed	12	4	0	21
		% Devices Deployed	18%	10%	0%	31%
IM-5	Cost for Deployment thru PY 2022	Total Spend, $M	$0.07	$0.07	$0.03	$0.12
		% Spend	3%	5%	13%	8%
IM-6	Deviation Between Actual and Planned Deployment for PY 2022	% On Track (Devices)	75%	100%	0%	210%
		% On Track (Spend)	48%	198%	289%	139%
IM-7	Projected Deployment for the Remainder of the GMP Term	# Devices Remaining	38	14	6	48
		Spend Remaining, $M	$0.81	$0.33	$0.12	$0.70

Note: The metric names have been slightly changed here to clarify the time span used in analysis.

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Table 69. 2022 Unitil Infrastructure Metrics for VVO Feeders

IM	Metric	Parameter*	Number of Feeders
Term 1 Plan Feeders			
IM-4	Number of Devices/Technologies Deployed	# Feeders with VVO Enabled	3
		% Feeders with VVO Enabled	100%
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Feeders with VVO Enabled)	100%
IM-7	Projected Deployment for the Remainder of the GMP Term	# Feeders Remaining for VVO Enablement	0
Term 2 Plan Feeders			
IM-4	Number of Devices/Technologies Deployed	# Feeders with VVO Enabled	4
		% Feeders with VVO Enabled	50%
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Feeders with VVO Enabled)	50%
IM-7	Projected Deployment for the Remainder of the GMP Term	# Feeders Remaining for VVO Enablement	4

* VVO Enabled denotes that the VVO system is commissioned and VVO is engaged. Feeders presented with VVO enabled may not be actively employing CVR.

Source: Guidehouse analysis of 2021 DOER Responses and 2022 EDC Data

Guidehouse's review of Unitil's deployment and spend revealed that Unitil was below initial plans for 2022 outlined in Unitil's 2022-2025 GMP, as several deployment plans were on hold until the late 2022 DPU approval of 2022-2025 GMPs. Key findings related to Unitil's progress include:

Device Deployment

- Unitil deployment was slightly below plans for 2022, with variation by device type. Unitil was on-track with deployment of VVO Capacitor Banks and Line Sensors in 2022, deploying 100% and 210% of planned units, respectively. However, deployment was under plans for Regulators and LTC Controls. Lower deployment than plans for LTC Controls may be attributed to Unitil's efforts to resolve LTC radio and control issues. Lower deployment than plans for Regulators can be attributed to cancelation of 4 deployments that were found to be unnecessary.
- While deployment was initially projected to be evenly spread over Term 2 in its 2022-2025 GMP filing, Unitil has adjusted deployment plans to conduct most deployment during 2023 and 2025. Additionally, Unitil has reduced its planned deployments of VVO Regulators and Capacitor Banks, as Unitil reassessed deployment plans and determined there were fewer Regulator and Capacitor Bank deployments needed than initially planned. Work in 2024 will be limited to material orders in preparation for construction work at the Beech Street substation.

Total Spend

- Unitil spend on VVO ($0.25M) was below initial plans ($0.27M), with variation in spend at the device level. Unitil met 48% of its planned spend for Regulators. Spend and deployment of all other devices met or exceeded initial plans: Unitil met 100% of planned spend for Line Sensors, and exceeded planned spend for Capacitor Banks (198%) and LTC Controls (289%). Initial plans, informed by the deployment experience from Term 1, overestimated the level of effort and overhead costs for Regulators and Line Sensors, reducing unit costs for these devices. Costs overruns on LTC Controls, at 289% of planned costs in 2022, may be attributed to Unitil's troubleshooting of radio and control issues, which have now been resolved.

- Spend plans for the remainder of Term 2 have been revised downwards across all device types. Reduced spend on Regulators and Capacitor Banks can be attributed to a reduction in the units that Unitil plans to deploy, as well as lower than expected costs for deployment of Regulators. Reduced spend on LTC Controls and Line Sensors may be tied to process efficiencies implemented in 2022 that brought unit costs below plans. Most spend is planned for 2023 and 2025, with work in 2024 limited to material orders in preparation for construction work at the Beech Street substation.

VVO Enablement

- For its Term 1 substation (Townsend) Unitil completed VVO deployment in 2021, enabling VVO on December 1, 2021, and On/Off testing is expected to begin in spring 2023. Among its Term 2 substations, Unitil completed deploying VVO investments at the Summer Street substation and enabled VVO in December 2022, with VVO On/Off testing projected to begin at the substation in December 2023. Lunenburg and West Townsend are currently receiving VVO investments and Unitil plans to enable VVO at the substations in January and November 2024, respectively. Unitil then plans to conduct On/Off testing at the substations beginning in December 2024. For its remaining substations, Unitil is currently conducting planning and engineering/design work for its Beech Street, Pleasant Street, and Princeton Road substations. These substations are expected to be enabled after the close of Term 2 in 2026 and 2027.

4. VVO Performance Metrics

4.1 Data Management

Guidehouse worked with the EDCs to collect data to complete the evaluation for the assessment of VVO Infrastructure Metrics and Performance Metrics. The sections that follow highlight Guidehouse's data sources and data QA/QC processes used in the evaluation of Performance Metrics.

4.1.1 Data Sources

Guidehouse used numerous datasets to evaluate Performance Metrics. The subsections that follow summarize the data sources used to evaluate Performance Metrics.

4.1.1.1 VVO Supplemental Data Template

The VVO supplemental data collection template includes additional information unique to the VVO Investment Area. Table 70 summarizes the information requested and included in the analysis. The EDCs provided data to the team in the data collection template or submitted it in a separate file. Guidehouse requested information at the feeder level where possible.

Table 70. VVO Supplemental Data

Information	Description
Actual/Planned VVO Schedule	Actual and updated planned VVO deployment start/end dates by feeder, including feeder conditioning, load rebalancing, phase balancing, VVO commissioning, VVO enabled, and On/Off testing.
Customer DR Events	DR events (time-stamped log of any systemwide DR (or similar), for example: ISO-NE DR, EDC direct load control programs, EDC behavioral DR programs).
Voltage Complaints	Voltage-related complaints based on voltage perturbation (e.g., high voltage, low voltage, flicker) and duration (e.g., multiple days, sporadic).

Source: Guidehouse Stage 3 Evaluation Plan submitted to EDCs on March 1, 2023

4.1.1.2 Additional VVO Data Required for Performance Metrics Evaluation

Table 71 summarizes the additional data inputs required for Performance Metrics analysis. Except for the weather data, the team obtained all fields from the EDCs.

Table 71. Additional Data Required for Evaluation Performance Metrics

Data Type	Description
EDC system information	• Feeder characteristics (e.g., rated primary voltage, rated capacity, feeder length, number of customers [residential, commercial, industrial, etc.]), load factor (ratio of average load to peak load), ZIP code or town, number of capacitors, number of regulators
Time series data (hourly)	• Feeder head end data (voltage, real power, current, apparent power or reactive power, power factor) • VVO status flags (e.g., VVO On/Off)
VVO system information	• Time-stamped log of VVO state changes between on and off states and any other VVO modes
Weather data	• Hourly temperature data from selected weather stations and collected by the National Oceanic and Atmospheric Administration (NOAA)

Source: Guidehouse Stage 3 Evaluation Plan submitted to EDCs on March 1, 2023

4.1.2 Data QA/QC Process

Guidehouse reviewed all data provided for Performance Metrics analysis upon receipt of requested data. The QA/QC of Performance Metrics data included checks to confirm each of the required data inputs could be incorporated within the Performance Metrics analysis. Examples of the QA/QC include the following criteria:

- Time series data cover each feeder receiving VVO investments and include variables needed to facilitate analysis of Performance Metrics, including voltage, real power, and reactive or apparent power
- Time series data are complete in time and extent of devices and do not include erroneous data (e.g., interpolated values and outliers)
- Voltage complaints data have been received for each feeder receiving VVO investments and are at an adequate level of detail for analysis

After Performance Metrics data are received at the end of every season, Guidehouse provides status update memos that summarize the QA/QC to the EDCs, confirming receipt of the datasets and indicating quality. Any additional follow-up based on standing questions is required to confirm all EDC-provided data can be applied to Performance Metrics analysis.

4.2 VVO Performance Metrics Analysis and Findings

Guidehouse presents findings from the Performance Metrics analysis for the VVO Investment Area in the following subsections.

4.2.1 Statewide Comparison

This section summarizes the Performance Metrics analysis results and key findings for Eversource and National Grid. Results and key findings are provided for the Spring 2022 – Winter 2022/23 M&V period. It can be difficult to compare the results from Performance Metrics analysis between Eversource and National Grid. For example, there are differences in data quality at different times of the year (e.g., sustained pauses in VVO On/Off testing for one EDC, data outages during On/Off testing for another EDC). As such, certain portions of the M&V period, such as the Spring season, may be represented more for one EDC than the other. Additionally, there are numerous differences in DG penetration, customer types, and geographic areas served by Eversource and National Grid feeders that limit the ability to directly compare Eversource and National Grid VVO outcomes.

4.2.1.1 Performance Metrics Analysis Results

Table 72 includes the Performance Metrics results for Spring 2022 – Winter 2022/23 for Eversource and National Grid. The following EDC-specific subsections provide further detail.

Table 72. Performance Metrics Results for the Spring 2022 – Winter 2022/23 M&V Period

Performance Metrics		Eversource		National Grid*	
Feeders Included in Evaluation		26		34	
PM-1	Spring 2022 – Winter 2022/23 Baseline	524,992 MWh		882,631 MWh	
PM-2	Energy Savings – All Hours VVO On†	2,128 ± 476 MWh	0.41 ± 0.09%	6,769 ± 1,162 MWh	0.84 ± 0.15%
	Energy Savings – Actual VVO On Hours‡	879 ± 184 MWh	0.41 ± 0.09%	1,867 ± 302 MWh	0.84 ± 0.15%
-	Voltage Reduction	1.52 ± 0.01 V	1.24 ± 0.01%	0.08 ± <0.001 kV	0.62 ± 0.01%
-	CVRf^	0.60		0.36	
PM-3^^	Peak Demand Reduction	-369 ± 245 kW	-0.70 ± 0.46%	-2,189 ± 1,173 kW	-2.41 ± 1.28%
PM-4	Reduction in Distribution Losses	0.01%		-1.95%¶	
PM-5	Change in Power Factor	<0.001 ± <0.001	0.06 ± 0.02%	-0.01 ± 0.002¶	-0.96 ± 0.2%¶
PM-6	GHG Reductions (CO_2) All Hours VVO On†	723 ± 162 tons CO_2		2,301 ± 395 tons CO_2	
	GHG Actual VVO-On Hours‡	299 ± 63 tons CO_2		645 ± 103 tons CO_2	
PM-7	Voltage Complaints	53 (13% decrease from 2015 – 2017 baseline period average)		136 (16% decrease from 2016 – 2017 baseline period average)§	

* National Grid feeders at the Easton substation did not begin testing until mid-January, 2023. Unless otherwise noted, all overall estimates are inclusive of Easton feeders and only incorporate impact estimates from this substation during the Winter period. National Grid feeders at the West Salem substation did not begin testing until early June, 2022. Unless otherwise noted, all overall estimates are inclusive of West Salem feeders and only incorporate impact estimates from this substation during the Summer 2022 – Winter 2023 period. Additionally, even-numbered Maplewood feeders underwent a prolonged period over which VVO on/off testing was paused, resulting in their removal from analysis that informed PM-1 through PM-6. Lastly, although the Stoughton substation ended VVO testing prior to this current evaluation, impact estimates for several performance metrics were calculated for Stoughton and, unless otherwise noted, these estimates are included in the aggregate estimates provided in this report.
† Calculation assumes VVO was enabled for all hours between March 1, 2022 and February 28, 2023.
‡ Calculation uses actual number of VVO On hours spanning the analysis period. Actual VVO On Hours are the number of hours VVO was engaged between March 1, 2022 and February 28, 2023 for each feeder.

^The CVR factor provided for each EDC is the load-weighted average of CVR factors estimated for each feeder with a voltage response to VVO On/Off testing.[50]
^^Guidehouse evaluated the impact of VVO during peak demand periods, defined by ISO-NE as 1:00 p.m. to 5:00 p.m. ET from June 1 to August 31 on non-holiday weekdays. Aggregate peak demand reduction is calculated only for feeders with statistically significant reductions in voltage.
¶ Changes in power factor and distribution losses could not be estimated for any substations going through VVO On/Off testing during Spring 2022 through Winter 2022/23 due to data quality issues. Results presented for these metrics are based off of VVO substations that completed VVO On/Off testing prior to this evaluation period. For this evaluation period, the only substation to conclude On/Off testing is Stoughton.
§ National Grid did not start tracking voltage complaints until 2016.
Source: Guidehouse analysis

4.2.1.2 Key Findings and Recommendations

Findings from the evaluation of Performance Metrics indicate that VVO allowed Eversource and National Grid to realize energy savings and voltage reductions during the Spring 2022 – Winter 2022/23 M&V period.[51] More specifically:

- During the Spring 2022 – Winter 2022/23 M&V period, Eversource's Agawam, Piper, Podick, and Silver substations realized 879 MWh (0.41%) energy savings and 1.52 V (1.24%) voltage reduction associated with VVO. The CVR Factor, which provides an estimate of energy savings possible with voltage reductions, was 0.60.[50] During the same M&V period, National Grid's East Methuen, East Bridgewater, Easton, Maplewood, Stoughton, and West Salem substations realized 1,867 MWh (0.84%) energy savings and 0.08 kV (0.62%) voltage reduction associated with VVO. National Grid's CVR factor was 0.36.[50]
- Eversource energy savings of 879 MWh yielded a 299 short ton reduction of CO_2 emissions. National Grid energy savings of 1,867 MWh yielded a 645 short ton reduction in CO_2 emissions.
- Eversource and National Grid VVO feeders experienced a minimal benefit associated with peak demand, power factor, and distribution losses. Eversource VVO feeders experienced a statistically significant increase (0.70%) in peak demand, a statistically significant decrease (0.06%) in power factor, and a minimal decrease in distribution losses when VVO was engaged. National Grid VVO feeders experienced a statistically significant increase in peak demand (2.41%), a small increase (0.96%) in power factor, and a 1.95% increase in distribution losses when VVO was engaged.
- For Eversource, a total of 53 voltage complaints were received from customers connected to the Agawam, Piper, Podick, and Silver VVO feeders during the Spring 2022 – Winter

50 Both Eversource and National Grid aggregated CVRf calculations only include estimates from feeders that experienced a minimum change in voltage of ±0.25% Certain feeders with changes in voltage greater than ±0.25% were also excluded from aggregated CVRf calculations due to highly unstable voltage and energy responses to VVO On / Off testing. Feeders excluded from this calculation are all of Eversource's Podick 18G feeders and Silver feeders 30A2, 30A4, and 30A6, All of National Grid's West Salem 29W feeders, and East Bridgewater feeders 797W1, 797W23, 797W23, and 797W42 are also removed from aggregated CVRf results due to unreliable voltage and energy responses to VVO On / Off testing.

51 It can be difficult to compare the results from Performance Metrics analysis between Eversource and National Grid. For example, there are differences in the granularity of telemetry (e.g., 15-minute versus 1 hour), data quality at different times of the year (e.g., sustained pauses in VVO On / Off testing, repeated data). As such, data cleaning can cause certain portions of the M&V period to be represented more for one EDC than the other. Additionally, there are numerous differences in DG penetration, customer types, and geographic areas served by Eversource and National Grid feeders that limit the ability to directly compare Eversource and National Grid VVO outcomes.

2022/23 M&V period. This is a 13% decrease relative to the average voltage complaints per year received between 2015 – 2017. For National Grid, a total of 136 voltage complaints were received from customers connected to the East Methuen, East Bridgewater, Easton, Maplewood, Stoughton, and West Salem VVO feeders during the period. This is a 16% decrease relative to the average voltage complaints per year received between 2016 – 2017. For both EDCs, there is not sufficient evidence to support changes in voltage complaints being attributed to VVO.

In 2023 and beyond, Guidehouse recommends that Eversource and National Grid:

- Ensure VVO On/Off testing is running according to plan, with limited pauses to the VVO On/Off testing schedule. Across the VVO feeders, one-quarter to one-half of data points were removed due to extended pauses in VVO On/Off testing. For some feeders, this resulted in the vast majority of provided data to be unusable for components of this evaluation (e.g., for estimation of distribution loss and power factor reductions). Sustained On/Off testing will increase the amount of usable data in the evaluation and improve the ability for Guidehouse to provide a comprehensive evaluation of VVO performance metrics.
- Confirm adjustments to VVO On/Off testing schedule for any VVO feeders prior to implementation. VVO On/Off testing is designed similarly to a Randomized Controlled Trial (RCT), and adjustments to the testing schedule could, potentially, hinder the effectiveness of the testing design and cause biases to affect the results. Ensuring there is proper balance in the number of VVO on and off hours throughout the evaluation period will allow for Guidehouse to provide a comprehensive and accurate evaluation of VVO performance metrics.
- Continue to investigate how to improve outcomes across VVO feeders. Many feeders across the EDCs underwent no material change in voltage. Correspondingly, energy reduction estimates were small-to-insignificant. These observations may indicate flaws in the VVO control scheme for these feeders. In order to improve VVO performance, Guidehouse recommends that the EDCs continue to investigate root causes to shortcomings in the VVO control scheme and work with distribution engineers and the VVO vendor to respond accordingly. If needed, Guidehouse can conduct in-depth case studies at these substations to further understand shortcomings in the VVO control scheme.

4.2.2 Eversource

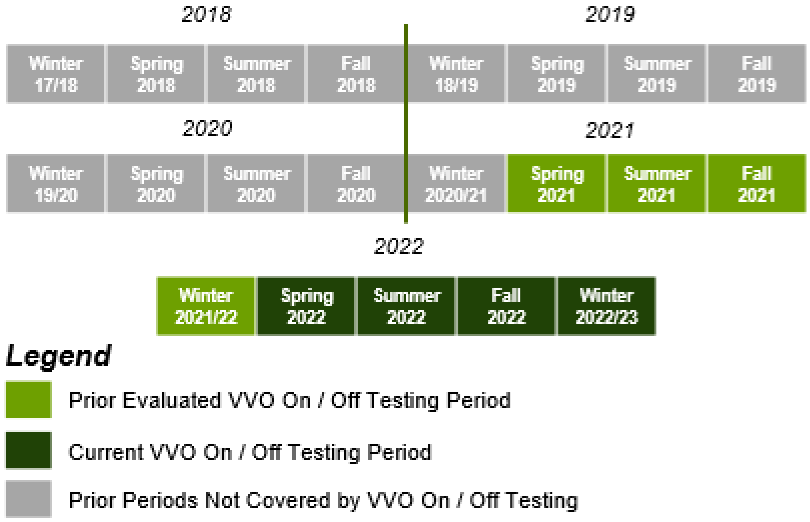
This section discusses Eversource's VVO Performance Metrics results following the Spring 2022 – Winter 2022/23 VVO M&V period.

4.2.2.1 Performance Metrics Analysis Timeline

Figure 20 highlights the key Performance Metrics analysis periods for Eversource. The Performance Metrics analysis provided for this report will be focused on results from VVO On/Off testing conducted during Spring 2022 – Winter 2022/23. Results from VVO On/Off testing conducted during Spring 2021 – Winter 2021/22 were provided in the Massachusetts Grid Modernization Program Year 2021 Evaluation Report for Volt-VAR Optimization.[52]

[52] All Massachusetts Grid Modernization Program Year 2021 Evaluation Reports were filed on July 1, 2022 under DPU dockets 22-40, 22-41, and 22-42.

Figure 20. Eversource Performance Metrics Analysis Timeline



Source: Guidehouse analysis

4.2.2.2 Evaluation Methodology

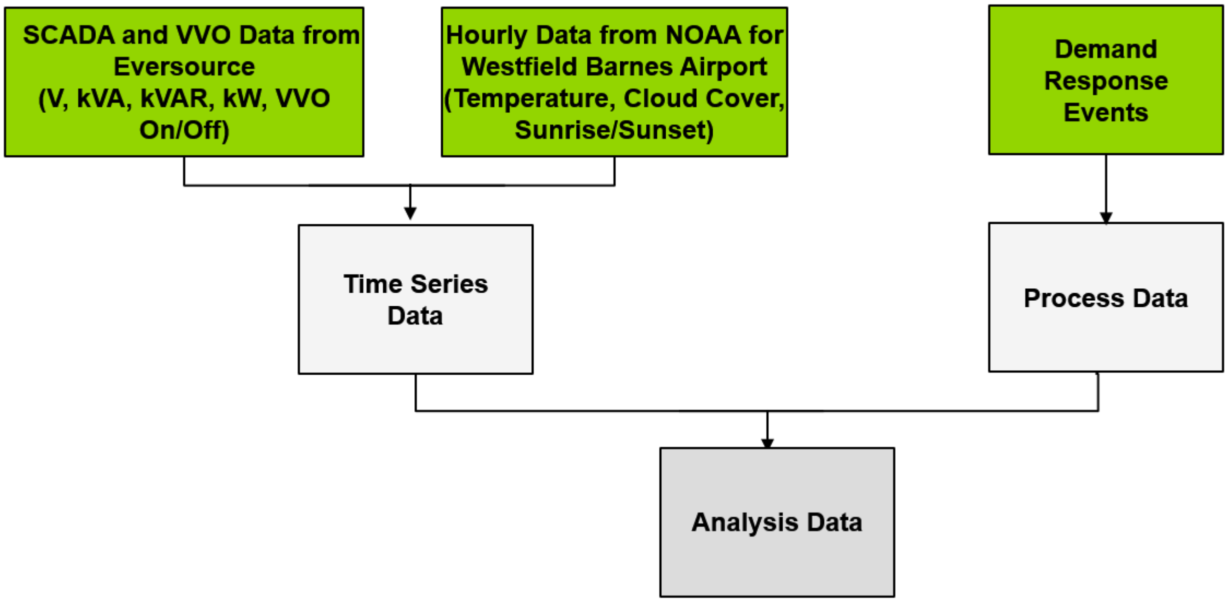
Guidehouse worked with Eversource to collect data necessary to complete the evaluation of VVO Performance Metrics. The sections that follow highlight the analysis data construction, analysis data cleaning, and the analysis approach.

Analysis Data Construction

To assess Performance Metrics, Guidehouse constructed an analysis dataset. This dataset was used in regression modeling to assess changes in multiple outcome variables, such as energy and peak demand. Figure 21 summarizes the data integration process used to construct the analysis dataset for the Eversource Performance Metrics analysis.[53]

[53] Guidehouse receives different data types and structures from the EDCs for estimating impacts across the performance metrics. These differences were minimized as much as possible, but any differences that remain may affect the comparability of performance metrics results across the EDCs.

Figure 21. Eversource Analysis Data Construction Flowchart



Source: Guidehouse

Guidehouse constructed time series and process data to arrive at a final analysis dataset for Eversource's Performance Metrics analysis. To construct time series data, the evaluation team first integrated SCADA interval data from Eversource that contained 15-minute measurements of voltage, real power, apparent power, and reactive power. Time-stamped logs of VVO state changes between VVO On (engaged) and Off (disengaged) states were also contained within the SCADA data provided by Eversource. To complete the construction of time series data, hourly dry bulb temperature and hourly cloud cover data from NOAA for Westfield Barnes Municipal Airport were then joined to SCADA interval data.[54]

To construct the process data, Guidehouse collected a log of demand response events during the evaluation period. The team joined resulting process data to time series data to construct a final analysis dataset.

Analysis Data Cleaning

After constructing the analysis dataset, the team conducted data cleaning steps to remove interval data that may bias the estimates of VVO impacts. Table 73 summarizes data observations made by the evaluation team and the resulting data cleaning steps that were executed.

[54] Westfield Barnes Municipal Airport was selected due to it having a quality controlled local climatological dataset and due to its being near the Eversource substations. Documentation on the NOAA dataset used in this analysis can be found here: https://data.noaa.gov/dataset/dataset/quality-controlled-local-climatological-data-qclcd-publication

Table 73. Data Cleaning Conducted for Eversource Analysis

Data Observation	Data Cleaning Step
Guidehouse identified a handful of periods of repeated, interpolated, and outlier values in the interval data received, as well as periods missing VVO-status data.	Guidehouse removed observations where anomalous data readings were flagged.
Guidehouse identified numerous periods where VVO events were longer than planned.	To reduce the risk of VVO estimates being biased by imbalance in the sample of VVO On/Off statuses (e.g., overrepresentation of VVO On during winter), Guidehouse removed all VVO events within the Spring – Fall seasons longer than 72 hours. Eversource switched to weekly VVO On/Off testing in mid-November; after the switch, Guidehouse removed all VVO events longer than ten days (240 hours).

Source: Guidehouse

Table 74 indicates the number of 15-minute intervals contained in the analysis dataset for the Agawam, Piper, Podick, and Silver substations. Much of the data removed during data cleaning was due to extended periods over which VVO was engaged or disengaged. Detailed data attrition information is included in Appendix B.10.

Table 74. Count of VVO On, VVO Off, and Removed Quarter-Hours for Eversource

Substation	Feeder	VVO On Quarter Hours	VVO Off Quarter Hours	Quarter Hours Removed by Data Cleaning	Spring 2022 – Winter 2022/23 Total
Agawam	16C11	9,965	10,215	14,860	35,040
	16C12	13,071	14,444	7,525	35,040
	16C14	13,126	13,313	8,601	35,040
	16C15	13,084	13,212	8,744	35,040
	16C16	13,138	13,316	8,586	35,040
	16C17	13,244	13,353	8,443	35,040
	16C18	13,383	13,391	8,266	35,040
Piper	21N4	15,839	15,489	3,712	35,040
	21N5	12,385	11,223	11,432	35,040
	21N6	16,104	15,797	3,139	35,040
	21N7	15,552	14,482	5,006	35,040
	21N8	16,125	15,836	3,079	35,040
	21N9	7,570	7,399	20,071	35,040
Podick	18G2	10,046	8,776	16,218	35,040
	18G3	12,395	10,957	11,688	35,040
	18G4	13,074	11,614	10,352	35,040
	18G5	12,679	11,252	11,109	35,040
	18G6	8,431	7,379	19,230	35,040
	18G7	12,410	10,600	12,030	35,040
	18G8	11,239	10,272	13,529	35,040
Silver	30A1	6,594	7,646	20,800	35,040
	30A2	11,662	12,545	10,833	35,040
	30A3	5,002	5,900	24,138	35,040
	30A4	11,275	12,877	10,888	35,040
	30A5	8,651	9,562	16,827	35,040
	30A6	10,280	11,568	13,192	35,040

Source: Guidehouse analysis

Analysis Approach

After the analysis data was constructed and cleaned, Guidehouse conducted regression modeling to assess the impacts of VVO on measured feeder-level energy and voltage. Equation 5-2 and Equation 5-3 in the Appendix summarizes the regression model used to estimate energy and voltage as a function of VVO.

To inform the regression model construction for estimation of energy and voltage, Guidehouse inspected the data to control for exogenous patterns. Table 75 summarizes observations made during this inspection and the implemented data analysis steps.

Table 75. Data Analysis Summary for Eversource

Data Observation	Data Analysis Step
Load and voltage data exhibit similar curvature from day-to-day, with load and voltage profiles for any two adjacent days being largely similar	A 24-hour lag of load (for energy models) and voltage (for voltage models) was included as a predictor of load (for energy models) and voltage (for voltage models)
Numerous feeders had a large nominal capacity of connected solar facilities.	Cloud cover and daylight hour data from NOAA were integrated and included in regression analysis to control for hourly generation observed under an array of solar conditions.
Large differences in energy and voltage were observed between most months in the analysis period	Monthly fixed effects were incorporated into regression modeling to capture energy and voltage differences observed across each week.
Numerous feeders were identified with non-residential customers making up a large portion of load, with drops in measured load during holidays and non-business hours.	Day type (i.e., weekday or weekend day) and hour of day fixed effects were incorporated into regression models to capture typical load shapes by day type and control for large drops in demand observed during non-business hours.
Numerous demand response events were called during the Spring 2022 – Winter 2022/23 M&V test period.	Intervals that occurred during demand response events were flagged and controlled for in the regression analysis to control for changes in energy and voltage associated with demand response events.

Source: Guidehouse

4.2.2.3 Performance Metrics Results

This section summarizes the Performance Metrics results for Eversource. Each of the subsections separately summarizes the evaluation results for each performance metric.

PM-1: Baseline

As detailed in the Stage 3 Plan submitted to the EDCs on March 1, 2023, Guidehouse provides a baseline using data collected when VVO was disabled during the evaluation period, which spans Spring 2022 – Winter 2022/23. Table 76 shows the energy baseline calculated using VVO Off data collected during Spring 2022 – Winter 2022/23 from the Agawam, Piper, Podick, and Silver substations.

Table 76. Eversource VVO Energy Baseline

Metric	Baseline Total Energy Use
Baseline Energy	524,992 MWh

Source: Guidehouse analysis

To estimate total baseline energy use, Guidehouse used regression models to first estimate energy savings that occurred for each feeder during Spring 2022 – Winter 2022/23. This resulted in an estimate of how energy use changed as a function of VVO. From there, Guidehouse fitted the model to a case in which VVO was off for the entirety of Spring 2022 – Winter 2022/23 for each VVO feeder, holding all other observable conditions constant (e.g., allowing weather to remain as it actually was when VVO was engaged). Guidehouse then summed this calculated energy usage across all hours and feeders to calculate a baseline total energy use for the Spring 2022 – Winter 2022/23 evaluation period. Baseline energy use is provided by VVO feeder in Appendix B.11.

PM-2: Energy Savings

Table 77. Eversource VVO Net Energy Reduction during Actual VVO On Hours provides Eversource's estimated energy savings for Spring 2022 – Winter 2022/23, as well as for each season. The ± figure indicates 90% confidence bounds associated with the energy savings estimates.

Table 77. Eversource VVO Net Energy Reduction during Actual VVO On Hours

Season	Net Energy Reduction	
	MWh†	%‡
Spring^	-282 ± 81 MWh	-0.58 ± 0.17%
Summer	1,257 ± 151 MWh	2.07 ± 0.25%
Fall	-391 ± 93 MWh	-0.74 ± 0.17%
Winter^^	582 ± 111 MWh	1.06 ± 0.26%
Spring 2022 – Winter 2022/23 Total	879 ± 184 MWh	0.41 ± 0.09%

† Total energy savings provided for each period is the sum of each feeder's energy savings within that period. Due to model noise, a manual sum of savings across periods may not equal the amount provided in the Total row.

‡ Percentage energy savings provided for each period is the load-weighted average of percentage savings estimated for each feeder.

^ Silver feeders 30A1, 30A3, and 30A5 are excluded from Spring estimate due to insufficient data.

^^Podick feeder 18G8 is excluded from Winter estimate due to insufficient data.

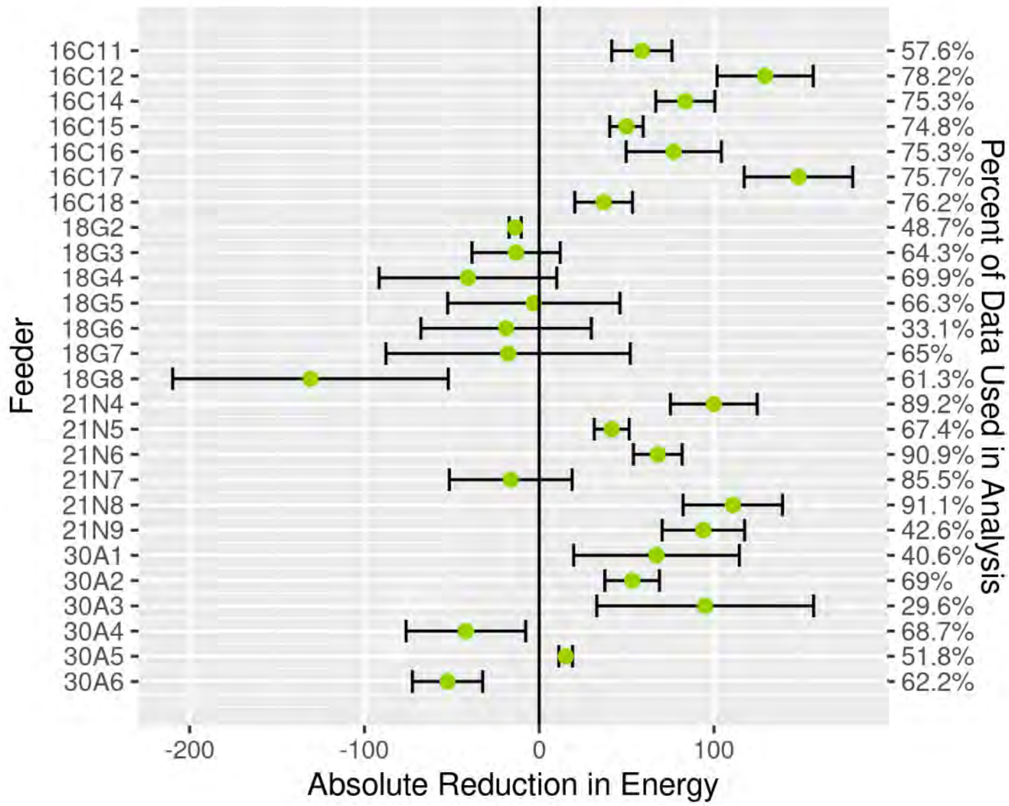
Source: Guidehouse analysis

Regression estimates indicate a statistically significant reduction in energy use associated with VVO, with 879 MWh (0.41%) in energy savings realized during the Spring 2022 – Winter 2022/23 M&V period.[55] Regression estimates indicate that there were statistically significant reductions in energy use for the Summer and Winter seasons, but statistically significant increases in energy use for the Spring and Fall seasons. The Summer season saw the largest reduction in energy, with an estimated value of 1,257 MWh, and the Fall season saw the largest increase in energy, with an estimated value of 391 MWh.

Figure 22 indicates the net energy reductions for each Eversource feeder in absolute terms (MWh), with green points indicating each feeder's MWh savings. The associated 90% confidence intervals are provided by the whiskers overlaid on each feeder's MWh savings estimate. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant. Of the 26 feeders included in the Spring 2022 – Winter 2022/23 M&V period, 16 experienced statistically significant reductions in energy. Of these 16 feeders, feeders 16C17 and 16C12 realized the greatest energy savings.

[55] Calculation uses actual number of VVO On hours spanning the analysis period. Actual VVO On Hours are the number of hours VVO was engaged in the clean analysis data between March 1, 2022 and February 28, 2023.

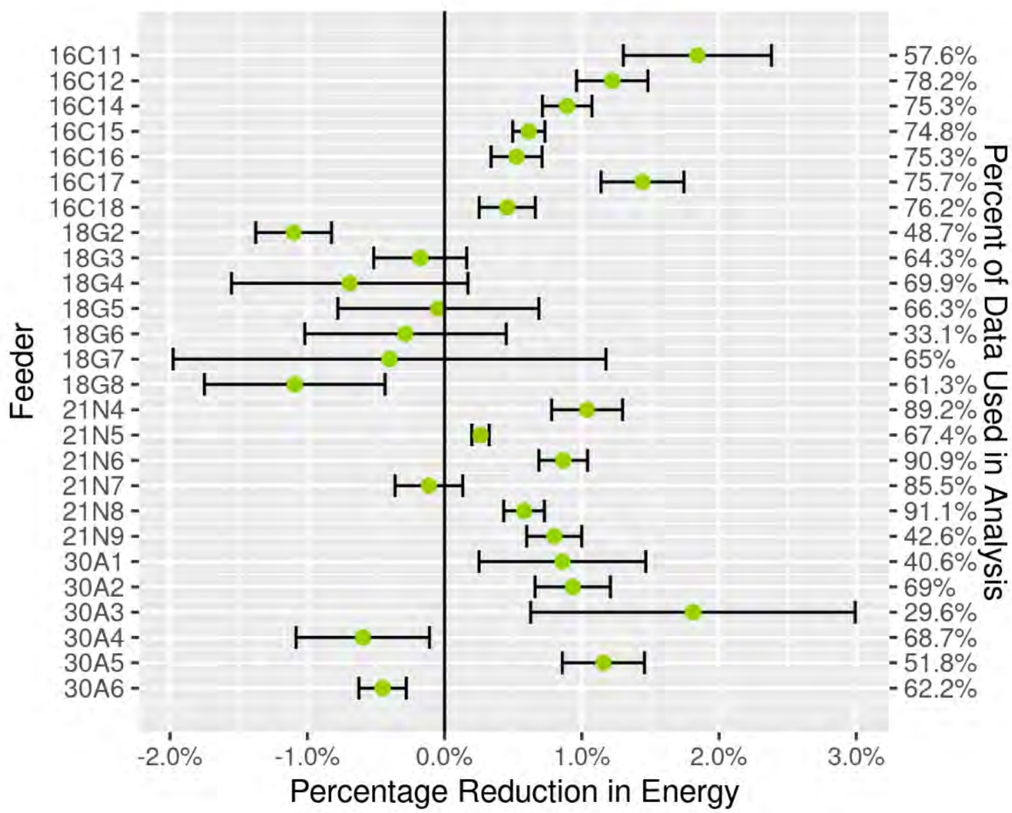
Figure 22. Net Energy Reduction (MWh) for Eversource VVO Feeders



Source: Guidehouse analysis

Figure 23 indicates the net energy reductions for each Eversource feeder in percentage terms, with green points indicating each feeder's percentage MWh savings. The whiskers overlaid on each feeder's percentage MWh savings estimate provide the associated 90% confidence levels. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant.

Figure 23. Net Energy Reduction (%) for Eversource VVO Feeders



Source: Guidehouse analysis

To further understand VVO impacts, Guidehouse estimated changes in voltage associated with VVO. Table 78 provides the evaluated voltage reductions for Eversource, with 90% confidence bounds associated with voltage reductions estimates indicated by the ± figure. Regression estimates indicate a statistically significant reduction in voltage associated with VVO, with a 1.52 V (1.24%) voltage reduction realized during the Spring 2022 – Winter 2022/23 M&V period.

Table 78. Eversource VVO Average Hourly Voltage Reduction*

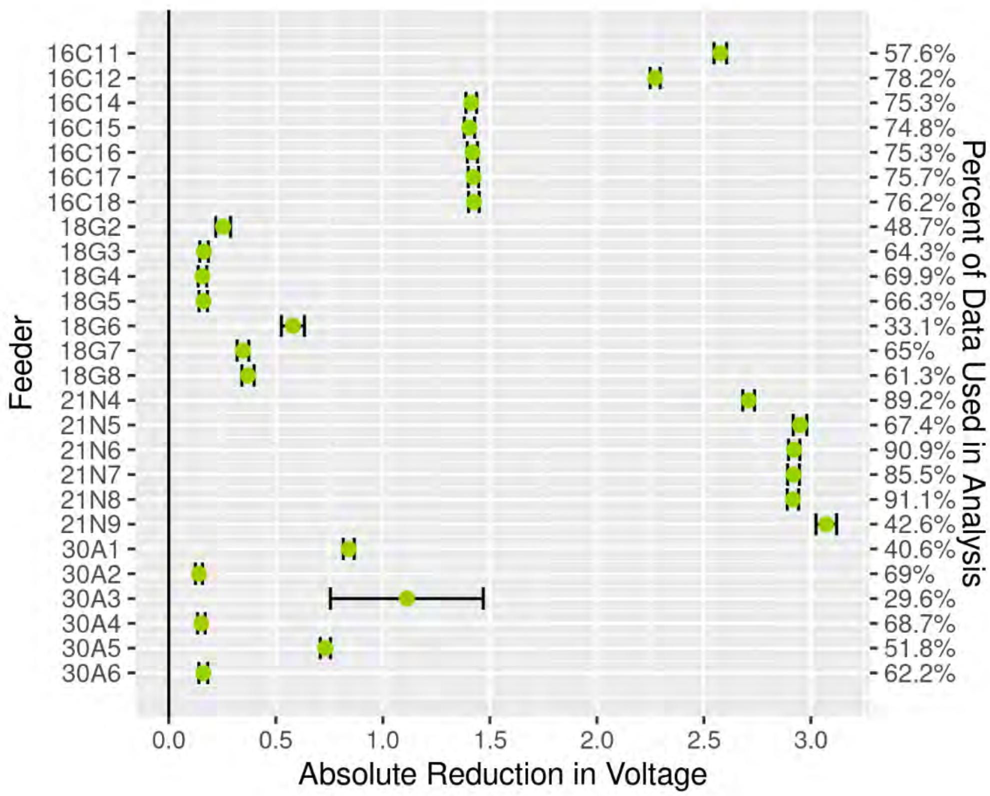
Average Hourly Reduction (V)	Average Hourly Reduction (%)
1.52 ± 0.01 Volts	1.24 ± 0.01%

* Absolute and percentage voltage reductions provided for each period is the load-weighted average of absolute and percentage voltage reductions estimated for each feeder.
Source: Guidehouse analysis

Figure 24 indicates the average hourly voltage reductions for each Eversource feeder, with green points indicating each feeder's voltage reduction. The whiskers overlaid on each feeder's voltage reduction estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant.

All 26 feeders experienced statistically significant reductions in voltage when VVO was engaged.

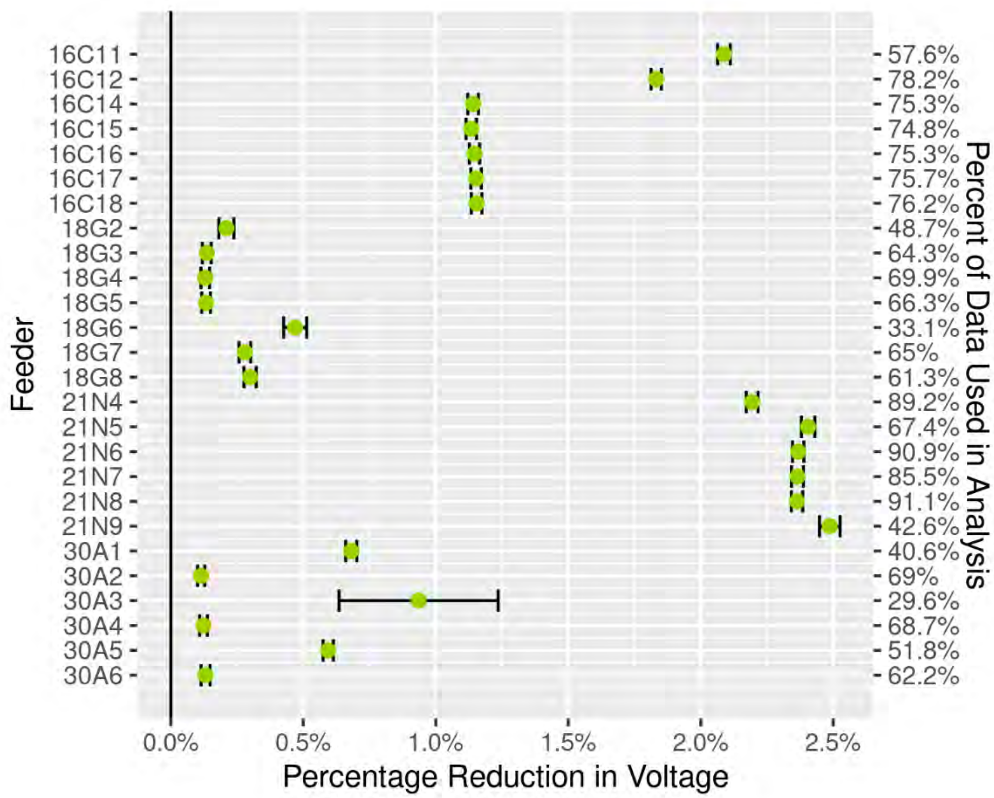
Figure 24. Average Hourly Voltage Reduction (V) for Eversource VVO Feeders



Source: Guidehouse analysis

Figure 25Figure 25 indicates the net voltage reductions for each Eversource feeder in percentage terms, with green points indicating each feeder's percentage voltage reduction. The whiskers overlaid on each feeder's percentage voltage reduction estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant.

Figure 25. Average Hourly Voltage Reduction (%) for Eversource VVO Feeders



Source: Guidehouse analysis

While all feeders underwent a statistically significant reduction in voltage, Podick 18G and even-numbered feeders at Silver 30A experienced a very minimal reduction in voltage, suggesting VVO was not operating as expected on these feeders. Energy reduction estimates are largely in-line with this finding, with most Podick feeders experiencing a statistically insignificant change in energy when VVO was engaged. In contrast, Piper 21N and Agawam 16C feeders experienced the largest reductions in voltage. Correspondingly, estimated energy savings for these feeders were statistically significant, with savings for most between 0.5% and 2.0%.

Following an estimation of percentage energy savings and percentage voltage reductions attributed to VVO, Guidehouse calculated the associated CVR factors for each feeder. The CVR factor, which is the ratio of percentage energy savings to percentage voltage reductions, can provide an estimate of the percentage energy savings possible with each percent voltage reduction. Equation 5-1 in the Appendix highlights how the CVR factor is calculated using an estimated percentage change in energy and in voltage. Table 79 provides the CVR factor for Eversource, and Figure 26 provides the CVR factors for the Spring 2022 – Winter 2022/23 M&V period for each feeder. Based on evaluation findings, the CVR factor for the Spring 2022 – Winter 2022/23 time period was 0.60.

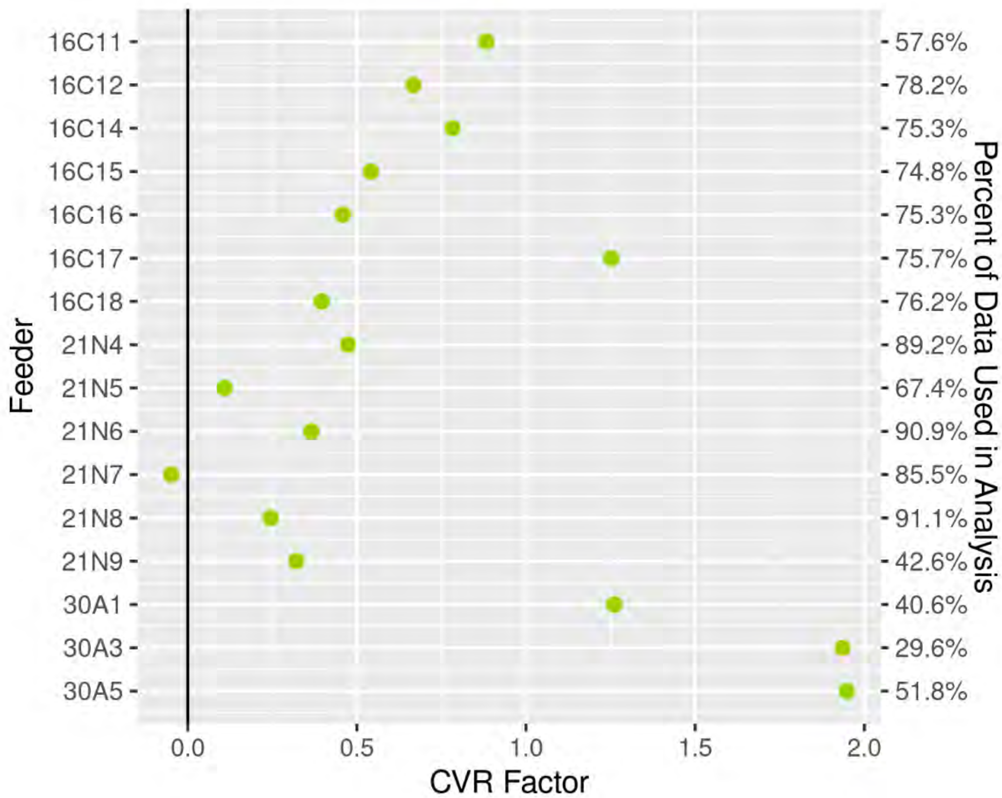
Table 79. Eversource VVO CVR Factor

CVR Factor†
0.60

† The CVR factor provided is the load-weighted average of CVR factors estimated for each feeder. All Podick feeders and Silver feeders 30A2, 30A4, and 30A6 experienced extremely small changes in voltage and have been excluded from overall CVRf calculations due to the outsize effect they have on overall estimates.

Source: Guidehouse analysis

Figure 26. Eversource VVO CVR Factors*



* All Podick feeders and Silver feeders 30A2, 30A4, and 30A6 experienced extremely small changes in voltage and have been excluded from overall CVRf calculations due to the outsize effect they have on overall estimates.

Source: Guidehouse analysis

PM-3: Peak Demand Impact

Guidehouse evaluated the impact of VVO during peak demand periods, defined by ISO-NE as 1:00 p.m. to 5:00 p.m. ET from June 1 to August 31 on non-holiday weekdays. Table 80 details the evaluated peak demand impact across all feeders in absolute and percentage terms.

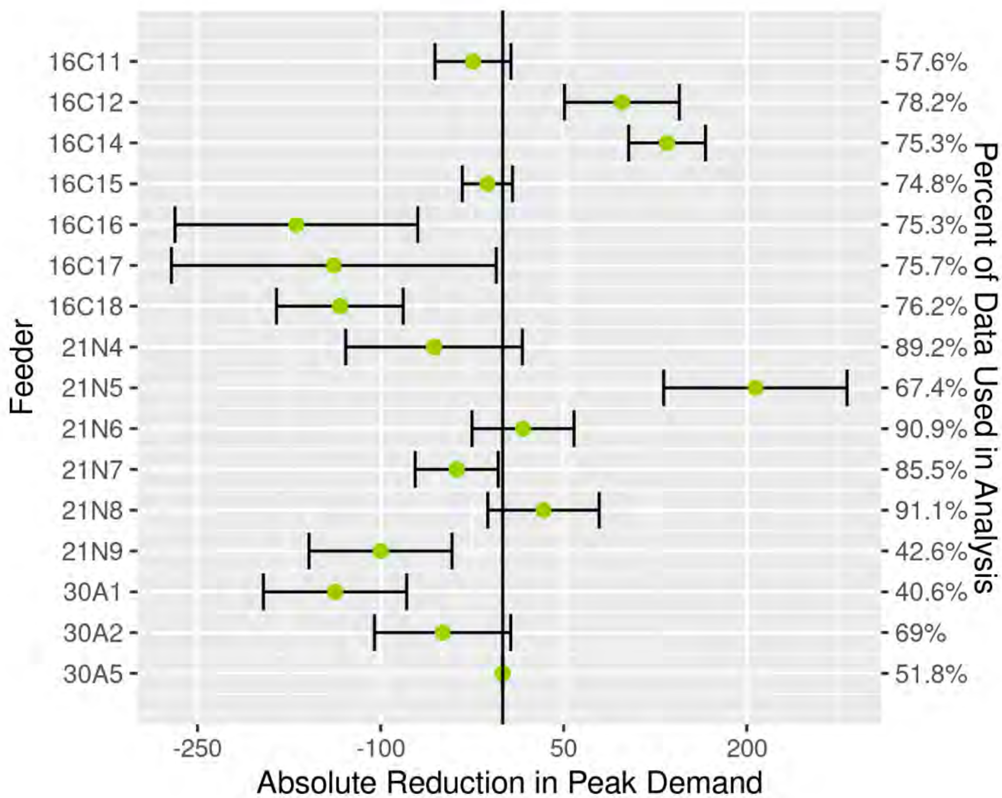
Table 80. Eversource VVO Average Reduction in Peak Demand

Peak Demand Reduction (kW) †	Peak Demand Reduction (%)†
-369 ± 245 kW	-0.70 ± 0.46%

† The percentage peak demand reduction presented in this table is the load-weighted average of percentage peak demand reductions estimated for each feeder. All Podick feeders and Silver feeders 30A3, 30A4, and 30A6 were removed from Peak Demand reduction calculations because they have unreliable standard error estimates.
Source: Guidehouse analysis

Figure 27 indicates the demand reductions measured in kW realized during the peak demand period, defined by ISO-NE as 1:00 p.m. to 5:00 p.m. ET from June 1 to August 31 on non-holiday weekdays. The whiskers overlaid on each feeder's absolute demand reduction estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant. Of the VVO feeders, only feeders 16C12, 16C14, and 21N5 experienced a statistically significant reduction in peak demand. All remaining feeders had an estimated statistically insignificant change in peak demand (7 feeders) or an estimated increase in peak demand (6 feeders).

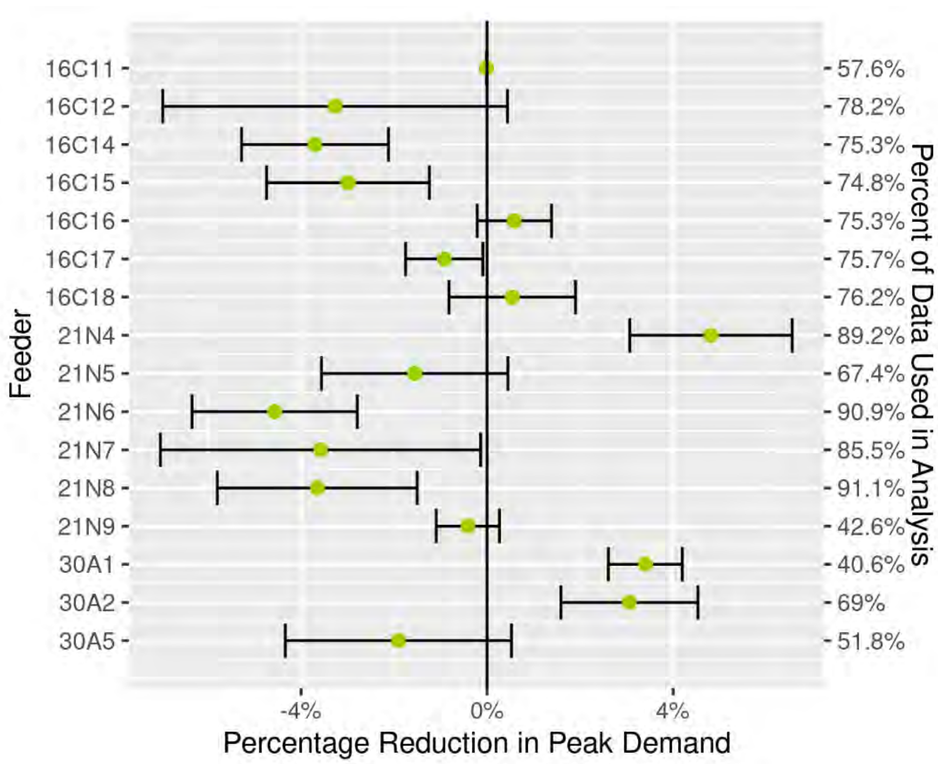
Figure 27. Eversource Reduction in Peak Demand (kW)



Source: Guidehouse analysis Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant.

Figure 28 indicates the percentage load reductions realized during the peak demand period, defined by ISO-NE as 1:00 p.m. to 5:00 p.m. ET from June 1 to August 31 on non-holiday weekdays. The whiskers overlaid on each feeder's percentage demand reduction estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant.

Figure 28. Eversource Reduction in Peak Demand (%)



Source: Guidehouse analysis

Eversource and National Grid saw increases in peak demand between 1:00 p.m. and 5:00 p.m. on non-holiday summer weekdays. This was a finding in both the previous and current evaluations (i.e., PY 2021 and PY 2022). This may be attributable to a number of factors that were present during those hours:

- There is variation in customer types and their relative load contributions depending on the time of day. If feeder load was more heavily comprised of end-uses with constant power load during peak hours as currently defined, a reduction in voltage can be met by a corresponding increase in amperage, which could appear as an increase in MW load at the feeder head-end. For instance, if feeder load was more heavily comprised of commercial or industrial load during those hours, industrial equipment could have actually become more inefficient with a drop in voltage, which could appear as an increase in MW load at the feeder head-end.
- Distribution generation, which has considerable generation during early- to mid-afternoon hours during the summer, may have caused unintended interactions with the VVO scheme.

The period of 1:00 p.m. to 5:00 p.m. for non-holiday summer weekdays was based on ISO-NE's peak demand definition, which was identified in the Stage 3 Evaluation Plan and has been used since the PY 2021 evaluation report. This was intended to be consistent with energy efficiency evaluations. Guidehouse has reviewed other time frames (e.g., 6:00 p.m. to 10:00 p.m.) that better represent the average feeder peaks for those feeders with VVO enabled. However, to be consistent with the Stage 3 Evaluation Plan and prior evaluation reports, this evaluation included the results for the 1:00 p.m. to 5:00 p.m. timeframe. Guidehouse will further explore alternative definitions for peak periods to determine the proper definition moving forward.

PM-4: Distribution Losses

Guidehouse evaluated reduction in distribution losses as a function of VVO during the Spring 2022 – Winter 2022/23 M&V period. Per the Stage 3 Evaluation Plan submitted March 1, 2023, Guidehouse estimated changes in power factor where kW was greater than 75% of annual peak demand.[56] There were several feeders with very little data where kW was greater than 75% of annual peak demand for kVA. These feeders were ultimately removed from the power factor models, as they had fewer than 100 hours of data available for use in regression modeling. Given power factor is an input for the distribution losses equation, these feeders were ultimately removed from the distribution losses calculation. The methodology for calculating the percent reduction in distribution losses is shown in Appendix 5.3B.8.

Table 81 and Figure 29 indicates the estimated percentage change in distribution losses for each Eversource feeder with sufficient data quality.

Table 81. Eversource VVO Distribution Losses

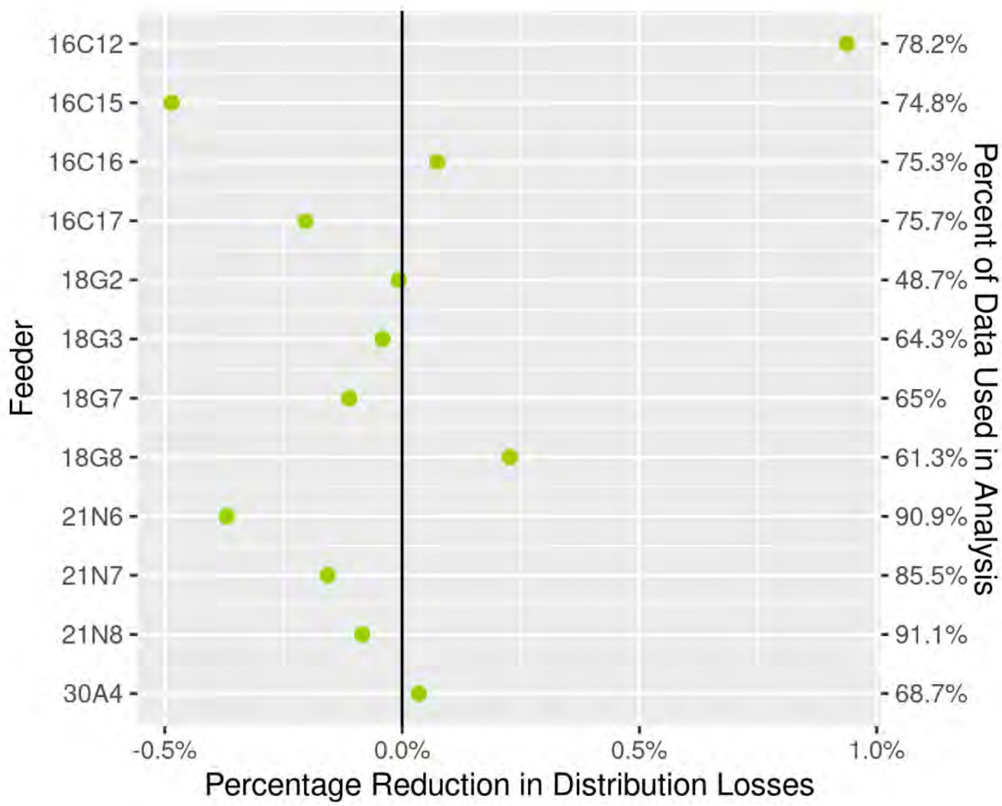
Reduction in Distribution Losses (%)†
0.01%

† The change in distribution losses presented in this table is the load-weighted average of change in distribution losses estimated for each feeder

Source: Guidehouse analysis

[56] This assumes sufficient data being available for use in the analysis for each VVO feeder. For some seasons, including winter, there will be a relatively small number of hours that meet the 75% threshold. Data limitations will limit Guidehouse's ability to conduct analysis for specific feeders or seasons in this case.

Figure 29. Eversource Reduction in Distribution Losses



Source: Guidehouse analysis

PM-5: Power Factor

Guidehouse evaluated the impact on power factor associated with VVO during the Spring 2022 – Winter 2022/23 M&V period. Changes in power factor were analyzed during periods where power was greater than 75% of feeder-specific annual demand. Table 82 details the evaluated change in power factor for each Eversource feeder where clean data existed in sufficient quantity.[57]

Table 82. Eversource VVO Average Hourly Power Factor Change

Change in Power Factor†	Change in Power Factor (%)†
<0.001 ± <0.001	0.06 ± 0.02%

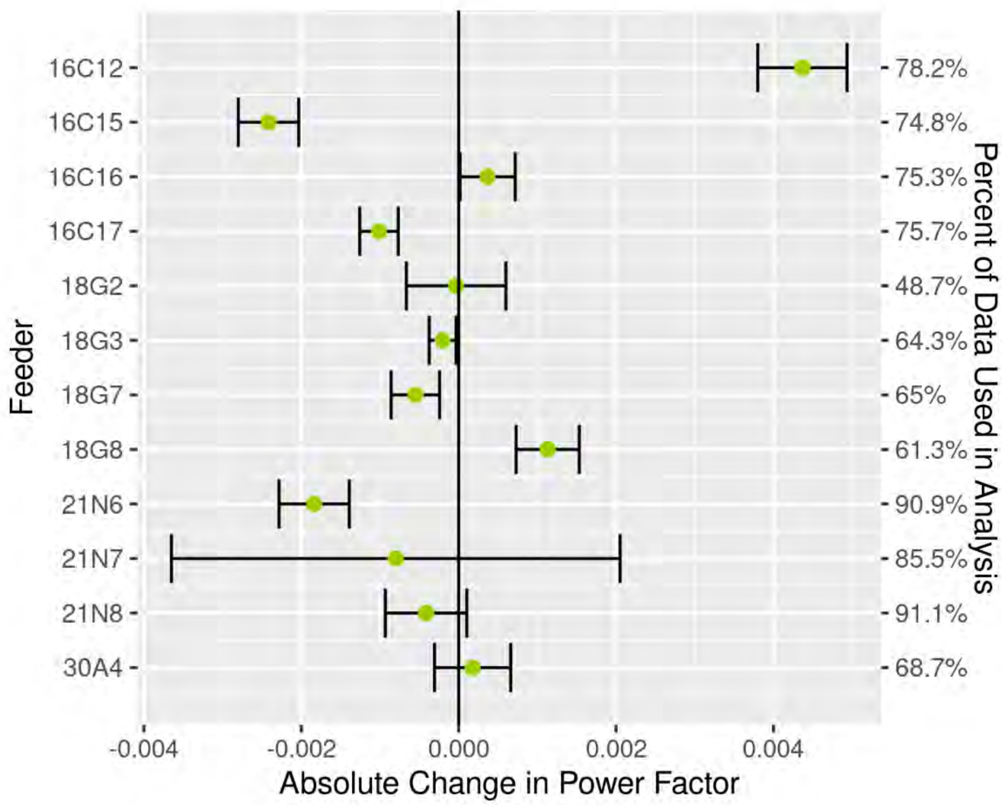
† Power factor changes presented in this table are the load-weighted averages of power factor changes estimated for each feeder
Source: Guidehouse analysis

Figure 30 indicates the change in power factor for each Eversource feeder in absolute terms, with green points indicating each feeder's absolute power factor change. The whiskers overlaid

57 There were some feeders with very little data where kW was greater than 75% of annual peak load for kVA. These feeders were ultimately removed from the power factor models, as they had fewer than 100 hours available for use in regression modeling.

on each feeder's absolute power factor change estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant.

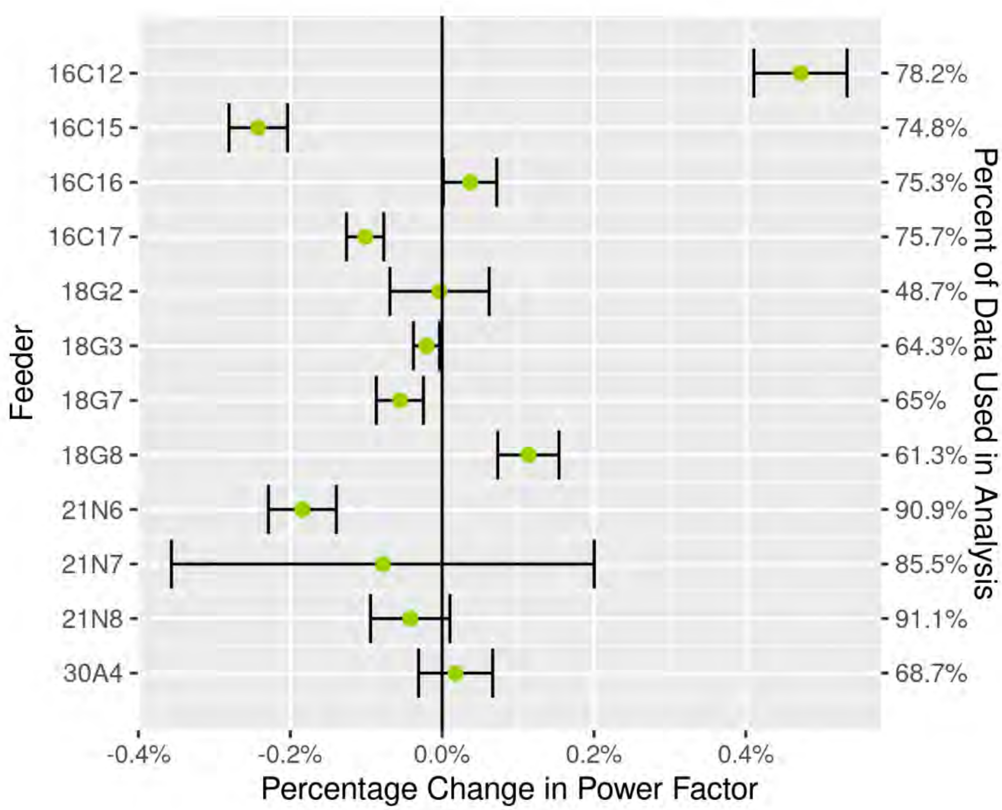
Figure 30. Eversource Absolute Change in Power Factor



Source: Guidehouse analysis

Figure 31 indicates the change in power factor for each Eversource feeder in percentage terms, with green points indicating each feeder's percentage power factor change. The whiskers overlaid on each feeder's percentage power factor change estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant. Most feeders underwent a statistically significant change in power factor, although the changes in power factors were relatively small.

Figure 31. Eversource Percentage Change in Power Factor



Source: Guidehouse analysis

PM-6: GHG Reduction

After evaluating energy savings attributed to VVO, Guidehouse calculated the resulting emissions reductions. For 2022, emissions reductions were determined by to be 0.34 metric tons of emissions per MWh. This was calculated drawing the 2019 value from DPU 18-110 – DPU 18-119, Massachusetts Joint Statewide Electric and Gas Three Year Energy Efficiency Plan for 2019 – 2021, the 2025 value from DPU 21-120 – DPU 21-129, Massachusetts Joint Statewide Electric and Gas Three-Year Energy Efficiency Plan for 2022-2024, and then interpolating the 2022 value from these two sources.[58]

Table 83 provides emissions reductions associated with VVO, with 90% confidence bounds indicated by the ± figure.

[58] 2019 Emissions factors can be found on page 201 of Massachusetts Joint Statewide Electric and Gas Three Year Energy Efficiency Plans for 2019 – 2021 https://ma-eeac.org/wp-content/uploads/Exh.-1-Final-Plan-10-31-18-With-Appendices-no-bulk.pdf. 2025 emissions factors can be found on page 326 of Massachusetts Joint Statewide Electric and Gas Three Year Energy Efficiency Plans for 2022 – 2024 https://ma-eeac.org/wp-content/uploads/Exhibit-1-Three-Year-Plan-2022-2024-11-1-21-w-App-1.pdf

Table 83. Eversource VVO Emissions Reductions

Metric	CO_2
Spring 2022 – Winter 2022/23 Emissions Reduction	299 ± 63 tons

Source: Guidehouse analysis

PM-7: Voltage Complaints

Guidehouse received voltage complaint logs from Eversource to facilitate Performance Metrics analysis. Guidehouse tabulated voltage complaints received by VVO feeder between 2015 and 2022. Discussion below highlights key observations for voltage complaints and compares the count of voltage complaints received during 2022 to the average number of voltage complaints from the 2015–2017 baseline period.

Table 84 summarizes voltage complaints for the Agawam substation. Relative to the average number of voltage complaints per year received prior to when VVO investments were deployed on these feeders (2015 – 2027), 2022 saw no change in voltage complaints relative to baseline at the Agawam substation.

Table 84. Count of Voltage Complaints for Agawam Substation

Number of Voltage Complaints	16C11	16C12	16C14	16C15	16C16	16C17	16C18	Total
Customers*	1,350	80	1,632	1,270	2,563	2,388	3,054	12,337
2015	0	0	2	2	4	2	0	10
2016	0	0	2	0	7	3	2	14
2017	1	0	2	3	7	3	5	21
Baseline†	**1**	**0**	**2**	**3**	**6**	**3**	**3**	**15**
2018	0	0	2	0	3	8	1	**14**
2019	4	0	1	0	5	5	4	**19**
2020	5	3	0	3	6	4	2	**23**
2021	1	0	1	2	7	2	2	**15**
2022	**2**	**1**	**4**	**0**	**1**	**4**	**3**	**15**

* Count of customers served by each feeder was extracted from the 2022 D.P.U 23-30 Report, Appendix B.
† The baseline number of voltage complaints is calculated as the average number of voltage complaints between 2015 and 2017, rounded up to the nearest whole number

Source: Guidehouse analysis

Table 85 summarizes the count of voltage complaints for the Piper substation. Looking at 2015–2017 baseline period, there were 21 voltage complaints received, amounting to 7 voltage complaints per year. Relative to the baseline period, there were 1 fewer voltage complaints reported at the Piper substation in 2022.

Table 85. Count of Voltage Complaints for Piper Substation

Number of Voltage Complaints	21N4	21N5	21N6	21N7	21N8	21N9	Total
Customers*	2,299	829	787	2	557	2,404	6,878
2015	1	1	2	0	0	2	**6**
2016	2	1	0	0	0	3	**6**
2017	4	2	1	0	0	2	**9**
Baseline†	**3**	**2**	**1**	**0**	**0**	**3**	**7**
2018	1	0	0	0	0	3	**4**
2019	2	1	0	0	3	5	**11**
2020	6	3	1	0	0	1	**11**
2022	**2**	**1**	**0**	**0**	**0**	**3**	**6**

* Count of customers served by each feeder was extracted from the 2022 D.P.U 23-30 Report, Appendix B.
† The baseline number of voltage complaints is calculated as the average number of voltage complaints between 2015 and 2017, rounded up to the nearest whole number

Source: Guidehouse analysis

Table 86 summarizes the count of voltage complaints for the Podick substation. Looking at 2015–2017 baseline period, there were 69 voltage complaints received, amounting to 23 voltage complaints per year. Based on voltage complaints data received, a total of 19 voltage complaints were reported along the Podick feeders during 2022, four fewer complaints than observed during the baseline period.

Table 86. Count of Voltage Complaints for Podick Substation

Number of Voltage Complaints	18G2	18G3	18G4	18G5	18G6	18G7	18G8	Total
Customers*	9	2,141	2,347	1,778	1,289	2,226	1,089	10,879
2015	0	3	1	2	1	3	3	**13**
2016	1	1	4	1	2	11	13	**33**
2017	0	0	5	4	3	6	5	**23**
Baseline†	**1**	**1**	**4**	**3**	**2**	**7**	**7**	**23**
2018	0	1	4	6	3	8	14	**36**
2019	0	6	5	8	1	4	3	**27**
2020	0	1	4	11	9	8	6	**39**
2021	0	3	6	7	3	7	5	**31**
2022	**0**	**0**	**2**	**8**	**1**	**3**	**5**	**19**

* Count of customers served by each feeder was extracted from the 2022 D.P.U 23-30 Report, Appendix B.
† The baseline number of voltage complaints is calculated as the average number of voltage complaints between 2015 and 2017, rounded up to the nearest whole number

Source: Guidehouse analysis

Table 87 summarizes the count of voltage complaints for the Silver substation. Looking at 2015–2017 baseline period, there were 45 voltage complaints received, amounting to 16 voltage complaints per year. Based on voltage complaints data received, a total of 13 voltage complaints were reported along the Silver feeders in 2022, three fewer complaints than were observed during the baseline period.

Table 87. Count of Voltage Complaints for Silver Substation

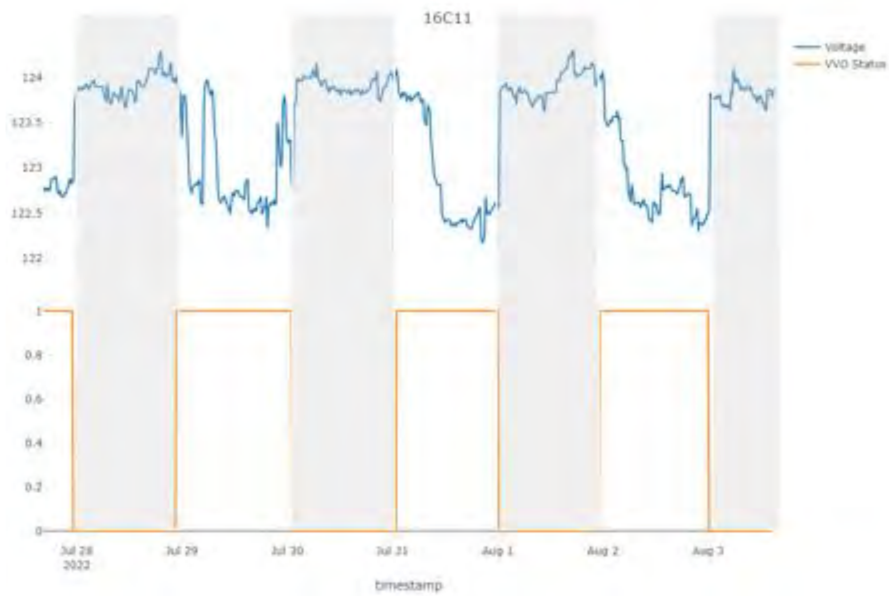
Number of Voltage Complaints	30A1	30A2	30A3	30A4	30A5	30A6	Total
Customers*	2,519	2,286	239	801	1,659	1,007	8,511
2015	2	1	0	1	1	2	**7**
2016	4	5	1	1	2	5	**18**
2017	3	8	2	1	3	3	**20**
Baseline†	**3**	**5**	**1**	**1**	**2**	**4**	**16**
2018	4	2	0	2	0	2	**10**
2019	6	5	1	0	2	3	**17**
2020	5	1	2	4	1	4	**17**
2021	8	3	0	0	1	5	**17**
2022	**7**	**1**	**2**	**1**	**1**	**1**	**13**

* Count of customers served by each feeder was extracted from the 2022 D.P.U 23-30 Report, Appendix B.
† The baseline number of voltage complaints is calculated as the average number of voltage complaints between 2015 and 2017, rounded up to the nearest whole number
‡ Only includes the first quarter of voltage complaints for 2023.
^ The count of voltage complaints in Spring 2022 – Winter 2022/23 contains some of the 2022 voltage complaints and all 2023 voltage complaints presented.
Source: Guidehouse analysis

4.2.2.4 Additional Investigation of Podick and Even-Numbered Silver Feeders

When feeders are undergoing VVO On/Off testing, Guidehouse usually expects to see head-end voltage levels cycling with VVO On/Off status, with voltage levels remaining somewhat higher when VVO is disengaged (e.g., around 124 Volts) and remaining somewhat lower when VVO is engaged (e.g., around 120 Volts). An example of the expected voltage response to VVO is shown in Figure 32 below highlights voltage (in blue) and VVO On/Off status (in orange, where VVO status equal to one corresponds with VVO being engaged) observed for the Agawam 16C substation from July 28, 2022 through August 3, 2022.

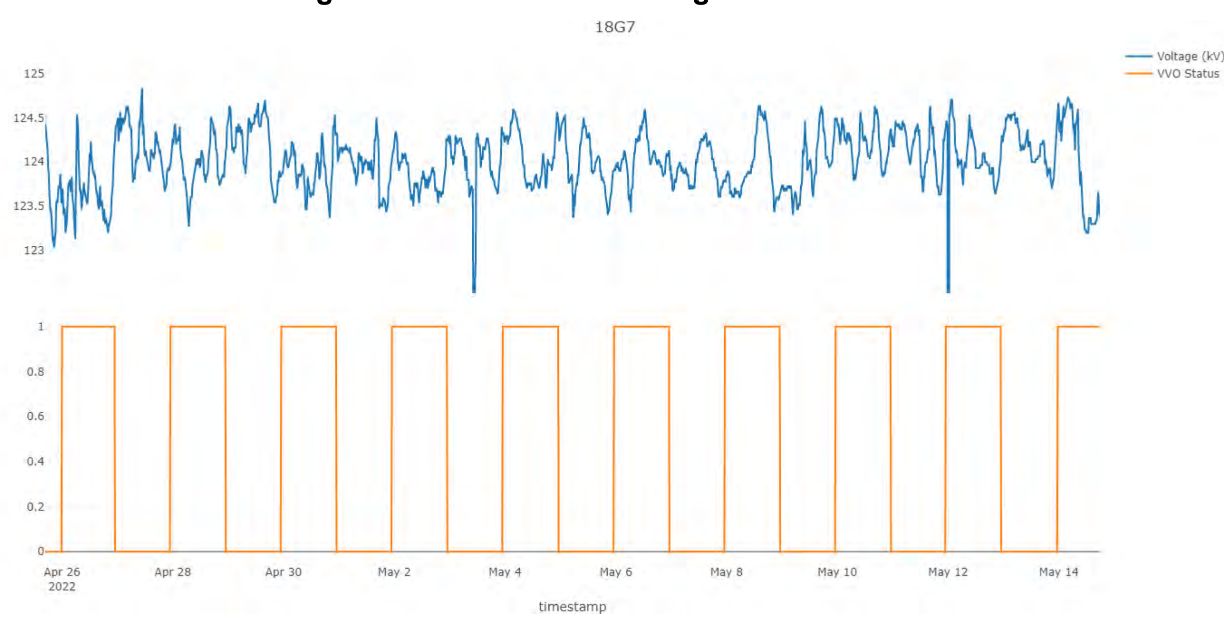
Figure 32. VVO On/Off Testing at Feeder 16C11



Source: Guidehouse analysis

During the process of data QA/QC, Guidehouse discovered that feeders at the Podick and Silver substations did not respond similarly to VVO signals. One such case is presented in Figure 33 for the feeder 18G7, where voltage (in blue) and VVO On/Off status (in orange, where VVO status equal to one corresponds with VVO being engaged) are plotted together for the period spanning April 26, 2022 through May 14, 2022.

Figure 33. VVO On/Off Testing at Feeder 18G7



Source: Guidehouse analysis

Figure 33 illustrates that voltage did not respond as expected during VVO On/Off testing throughout the period spanning April 26, 2022 through May 14, 2022. This was a pattern that was observed throughout much of the Spring 2022 – Winter 2022/23 evaluation period. These patterns were detected regression models and resulted in a minimal estimated impact associated with VVO across numerous feeders (e.g., all Podick 18G feeders and all even-numbered Silver 30A feeders), as VVO was marked as engaged but was not yielding clear voltage benefits. Guidehouse recommends that Eversource continue to investigate what may be driving these voltage patterns and what, if any, changes to the VVO control scheme needs to occur to ensure that VVO is correctly regulating voltage when VVO is engaged.

4.2.2.5 Key Findings and Recommendations

Guidehouse's VVO evaluation findings indicate that VVO allowed Eversource to realize some benefits during the Spring 2022 – Winter 2022/23 M&V period. More specifically:

- Eversource VVO feeders realized 0.41% energy savings and 1.24% voltage reductions when VVO was engaged. Podick feeders realized the least voltage benefits, with almost no change in voltage when VVO was engaged, which may indicate VVO malfunctions occurred. Additionally, Piper 21N4 realized the greatest energy savings, with 2.5% energy savings when VVO was engaged. Lastly, Podick 18G2, 18G8 as well as Silver 30A4 and 30A6 realized the least energy benefits, with a 0.75% increase in energy associated with VVO.
- Eversource VVO feeders experienced a statistically significant increase (0.70%) in peak demand when VVO was engaged. Additionally, Eversource VVO feeders experienced a statistically significant change (0.06%) in power factor when VVO was engaged, which resulted in a minimal decrease in distribution losses (0.01%).

In 2023 and beyond, Guidehouse recommends that Eversource:

- Ensure VVO On/Off testing is running according to plan, with limited pauses to the VVO On/Off testing schedule. Across the VVO feeders, one-quarter to one-half of data points were removed due to extended pauses in VVO On/Off testing. For some feeders, this resulted in the vast majority of provided data to be unusable for components of this evaluation (e.g., for estimation of distribution loss and power factor reductions). Sustained On/Off testing will increase the amount of usable data in the evaluation and improve the ability for Guidehouse to provide a comprehensive evaluation of VVO performance metrics.
- Confirm adjustments to VVO On/Off testing schedule for any VVO feeders prior to implementation. VVO On/Off testing is designed similarly to a Randomized Controlled Trial (RCT), and adjustments to the testing schedule could, potentially, hinder the effectiveness of the testing design and cause biases to evaluation results. Ensuring there is proper balance in the number of VVO on and off hours throughout the evaluation period will allow for Guidehouse to provide a comprehensive and accurate evaluation of VVO performance metrics.
- Continue to investigate how to improve outcomes across VVO feeders. Many feeders underwent no material change in voltage. Correspondingly, energy reduction estimates were small-to-insignificant. These observations may indicate flaws in the VVO control scheme for these feeders. In order to improve VVO performance, Guidehouse recommends that the EDCs continue their efforts to investigate root causes to shortcomings in the VVO control schemes and work with distribution engineers and the

VVO vendors to respond accordingly. If needed, Guidehouse can conduct in-depth case studies at these substations further understand shortcomings in the VVO control scheme.

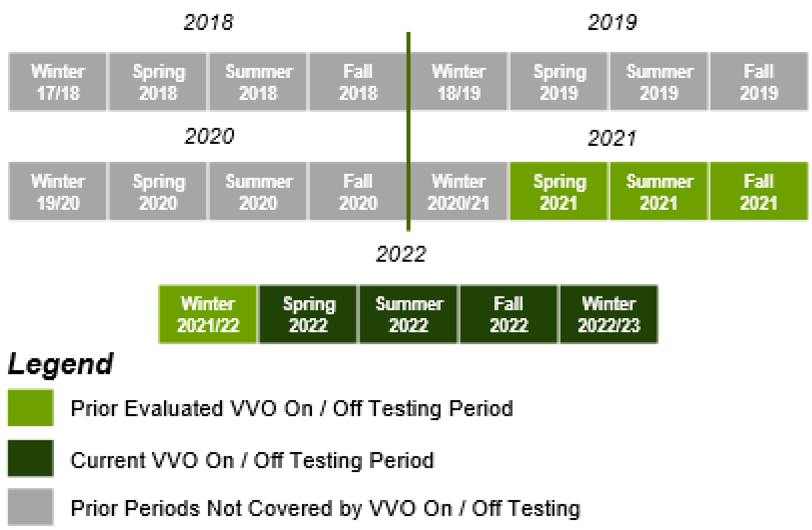
4.2.3 National Grid

This section discusses National Grid's VVO Performance Metrics results following the Spring 2022 – Winter 2022/23 VVO M&V period.

4.2.3.1 Performance Metrics Analysis Timeline

Figure 34 highlights the key Performance Metrics analysis periods for National Grid. The Performance Metrics analysis provided for this report will be focused on results from VVO On/Off testing conducted during Spring 2022 – Winter 2022/23.

Figure 34. National Grid Performance Metrics Analysis Timeline



Source: Guidehouse analysis

4.2.3.2 Evaluation Methodology

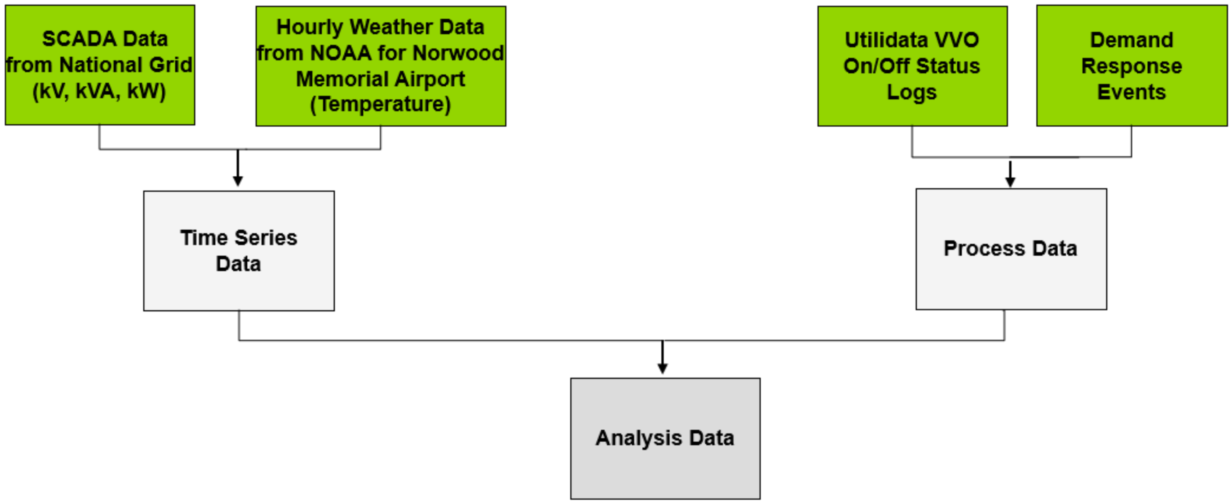
Guidehouse worked with National Grid to collect data necessary to complete the evaluation of VVO Performance Metrics. The sections that follow highlight the analysis data construction, analysis data cleaning, and the analysis approach.

Analysis Data Construction

To assess Performance Metrics, Guidehouse constructed an analysis dataset. This dataset was used in regression modeling to assess changes in multiple outcome variables, such as energy and peak demand. Figure 35 summarizes the data integration process used to construct the analysis dataset for the National Grid Performance Metrics analysis.[59]

[59] Guidehouse receives different data types and structures from the EDCs for estimating impacts across the performance metrics. These differences were minimized as much as possible, but any differences that remain may affect the comparability of performance metrics results across the EDCs.

Figure 35. National Grid Analysis Data Construction Flowchart



Source: Guidehouse

Guidehouse constructed time series and process data to arrive at a final analysis dataset for National Grid Performance Metrics analysis. To construct time series data, the evaluation team first integrated SCADA interval data from National Grid that contained hourly measurements of voltage, real power, and apparent power. The team then integrated hourly dry bulb temperature and hourly cloud cover data from NOAA for Norwood Memorial Airport to arrive at a final time series dataset.[60]

To construct the process data, Guidehouse integrated other VVO system information. Other system information included time-stamped logs of VVO state changes between VVO On (engaged) and Off (disengaged) states from Utilidata, and demand response events during the evaluation period. The time series and process data were then joined to construct a final analysis dataset.

Analysis Data Cleaning

After constructing the analysis dataset, the team conducted data cleaning steps to remove interval data that may bias the estimates of VVO impacts. Table 88 summarizes data observations made by the evaluation team and the resulting data cleaning steps that were executed.

[60] Norwood Memorial Airport was selected due to it having a quality controlled local climatological dataset and due to its being in close proximity to the National Grid substations evaluated this year. Documentation on the NOAA dataset used in this analysis can be found here: https://data.noaa.gov/dataset/dataset/quality-controlled-local-climatological-data-qclcd-publication

Table 88. Data Cleaning Conducted for National Grid Analysis

Data Observation	Data Cleaning Step
Guidehouse identified a handful of periods of repeated, interpolated, and outlier values in kV, kW, and kVA data, as well as periods missing VVO-status data.	Guidehouse removed hours where anomalous data readings were flagged.
Guidehouse identified numerous VVO events that were longer than planned.	To reduce the risk of VVO estimates being biased by imbalance in the sample of VVO On/Off statuses (e.g., overrepresentation of VVO On during winter), Guidehouse removed all VVO events that were three or more days in length (72 hours+).
Even-numbered Maplewood feeders experienced almost no VVO On/Off testing during the evaluation period.	Limited VVO On and Off data streams resulted in the removal of all even-numbered Maplewood feeders from the evaluation of performance metrics.
Due to extensive pauses to VVO On/Off testing, as well as several data outages, there was insufficient data to measure power factor and distribution loss impacts attributed to VVO.	Guidehouse was not able to provide estimates of changes in power factor or distribution losses for any of the substations that underwent VVO On/Off testing during the evaluation period. The power factor and distribution losses results are based on feeders that completed VVO On/Off testing prior to the current evaluation period (i.e., Stoughton).

Source: Guidehouse

Table 89Table 89 indicates the number of hours contained in the analysis dataset for the East Methuen, East Bridgewater, Easton, Maplewood, Stoughton, and West Salem substations. Much of the data removed during data cleaning was due to extended periods over which VVO was engaged or disengaged. Detailed data attrition information is included in Appendix B.10.

Table 89. Count of VVO On, VVO Off, and Removed Hours for National Grid*

Substation	Feeder	VVO On Hours	VVO Off Hours	Hours Removed by Data Cleaning	Spring 2022 – Winter 2022/23 Total
Easton†	92W43	255	235	662	1,152
	92W44	255	235	662	1,152
	92W54	255	235	662	1,152
	92W78	255	235	662	1,152
	92W79	255	235	662	1,152
East Bridgewater	797W1	1,278	1,310	6,172	8,760
	797W19	1,323	1,351	6,086	8,760
	797W20	1,323	1,351	6,086	8,760
	797W23	1,278	1,310	6,172	8,760
	797W24	1,323	1,351	6,086	8,760
	797W29	1,278	1,310	6,172	8,760
	797W42	1,278	1,310	6,172	8,760
East Methuen	74L1	2,362	1,692	4,706	8,760
	74L2	2,008	1,908	4,844	8,760
	74L3	2,362	1,692	4,706	8,760
	74l4	2,008	1,908	4,844	8,760
	74L5	2,362	1,692	4,706	8,760
	74L6	2,008	1,908	4,844	8,760
Maplewood	16W1	1,175	1,137	6,448	8,760
	16W2	152	355	8,253	8,760
	16W3	1,175	1,137	6,448	8,760
	16W4	152	355	8,253	8,760
	16W5	1,175	1,137	6,448	8,760
	16W6	152	355	8,253	8,760
	16W7	1,127	1,092	6,541	8,760
	16W8	152	355	8,253	8,760
West Salem‡	29W1	1,109	1,249	4,209	6,567
	29W2	1,258	1,378	3,931	6,567
	29W3	1,174	1,275	4,118	6,567
	29W4	1,223	1,339	4,005	6,567
	29W5	1,133	1,150	4,284	6,567
	29W6	752	833	4,982	6,567

* Stoughton completed VVO On/Off testing prior to the evaluation period and was not subject to regression analysis to estimate performance metrics.
† Easton began VVO On/Off testing in Winter 2022/23, limiting the total number of possible hours able to be used in the analysis.

‡ West Salem began VVO On/Off testing in Summer 2022, limiting the total number of possible hours able to be used in the analysis.
Source: Guidehouse

Analysis Approach

After the analysis data was constructed and cleaned, Guidehouse conducted regression modeling to assess the impacts of VVO on measured feeder-level energy and voltage. Equation 5-2 and Equation 5-3 in the Appendix summarizes the regression model used to estimate energy and voltage as a function of VVO.

To inform the regression model specification for estimation of energy and voltage as a function of VVO, Guidehouse conducted further inspection of the data to control for exogenous patterns. Table 90 summarizes observations made during this inspection and the resulting data analysis steps that were implemented.

Table 90. Data Analysis Summary for National Grid

Data Observation	Data Analysis Step
Load and voltage data exhibit similar curvature from day-to-day, with load and voltage profiles for any two adjacent days being largely similar	A 24-hour lag of load (for energy models) and voltage (for voltage models) was included as a predictor of load (for energy models) and voltage (for voltage models)
Numerous feeders had a large nominal capacity of connected solar facilities.	Cloud cover and daylight hour data from NOAA were integrated and included in regression analysis to control for hourly generation observed under an array of solar conditions.
Large differences in energy and voltage were observed between most months in the analysis period	Monthly fixed effects were incorporated into regression modeling to capture energy and voltage differences observed across each month.
Numerous feeders were identified with non-residential customers making up a large portion of load, with drops in measured load during holidays and non-business hours.	Day type (i.e., weekday or weekend day) and hour of day fixed effects were incorporated into regression models to capture typical load shapes by day type and control for large drops in demand observed during non-business hours.
Numerous demand response events were called during the Spring 2022 – Winter 2022/23 M&V test period.	Intervals that occurred during demand response events were flagged in the regression analysis to control for changes in energy and voltage associated with demand response events.

Source: Guidehouse

4.2.3.3 Performance Metrics Results

This section summarizes the Performance Metrics results for National Grid. Each of the subsections separately summarize the evaluation results for each performance metric.

PM-1: Baseline

As detailed in the Stage 3 Plan filed December 1, 2020, Guidehouse provides a baseline using data collected when VVO was disabled during the evaluation period, which spans Spring 2022 – Winter 2022/23. Table 91 provides the energy baseline calculated using VVO Off data collected during Spring 2022 – Winter 2022/23.

Table 91. National Grid VVO Energy Baseline

Metric	Baseline Total Energy Use
Baseline Energy	882,631 MWh

Source: Guidehouse analysis

To calculate total baseline energy use, Guidehouse used regression models to first estimate energy savings that occurred for each feeder during Spring 2022 – Winter 2022/23. This resulted in an estimate of how energy use changed as a function of VVO. From there, Guidehouse fitted the model to a case in which VVO was off for the entirety of Spring 2022 – Winter 2022/23 for each VVO feeder, holding all other observable conditions constant (e.g., allowing weather to remain as it actually was when VVO was engaged). Guidehouse then summed this calculated energy usage across all hours and feeders to calculate a baseline total energy use for the Spring 2022 – Winter 2022/23 evaluation period. Baseline energy use is provided by VVO feeder in Appendix 5.3B.11.

PM-2: Energy Savings

Table 92 provides the evaluated energy savings for National Grid for the spring season, summer season, fall season, winter season, and Spring 2022 – Winter 2022/23 overall. The ± figure indicate 90% confidence bounds associated with energy savings estimates.

Table 92. National Grid VVO Net Energy Reduction During Actual VVO On Hours

Season	Net Energy Reduction	
	MWh †	% ‡
Spring^	169 ± 127 MWh	0.37 ± 0.32%
Summer^^	317 ± 92 MWh	1.44 ± 0.44%
Fall^^	569 ± 76 MWh	3.33 ± 0.56%
Winter	533 ± 263 MWh	0.91 ± 0.30%
Spring 2022 – Winter 2022/23 Total†	1,867 ± 302 MWh	0.84 ± 0.15%

† Total energy savings provided for each period is the sum of each feeder's energy savings within that period. Due to model noise, a manual sum of savings across periods may not equal the amount provided in the Total row.
‡ Percentage energy savings provided for each period is the load-weighted average of percentage savings estimated for each feeder.

^Easton and West Salem feeders are excluded from Spring estimate due to not having begun on/off testing.

^^In addition to being excluded from Spring estimate, Easton feeders are also excluded from the Summer and Fall estimates due to not having begun on/off testing.

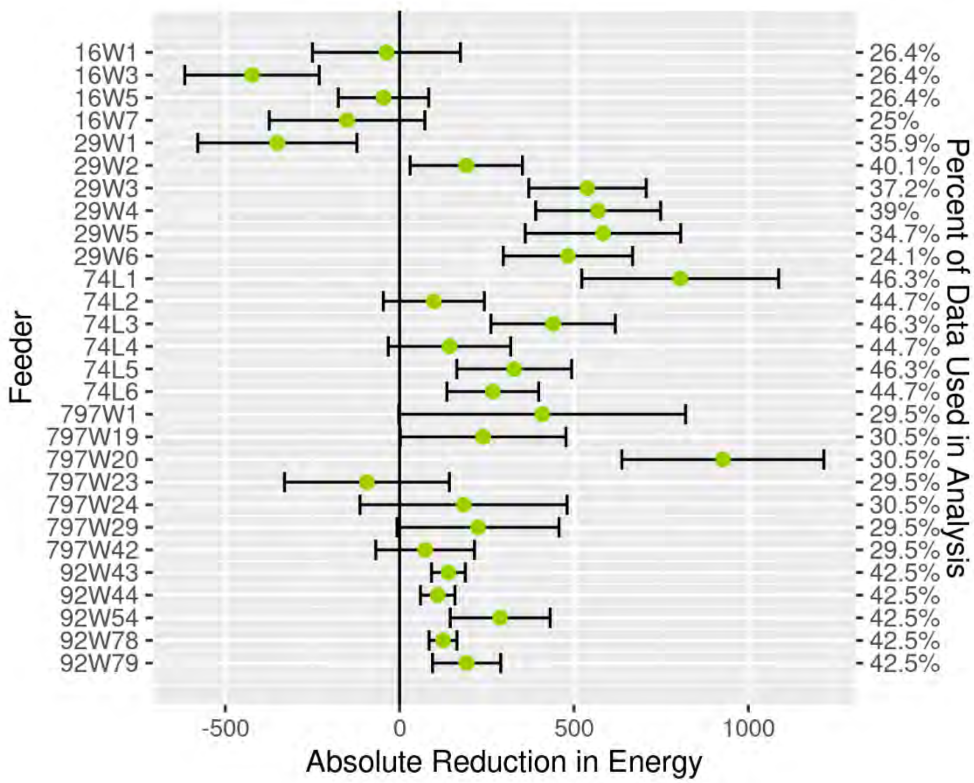
Source: Guidehouse analysis

Regression estimates indicate a statistically significant change in energy use associated with VVO, with 1,867 MWh (0.84%) energy savings realized during the Spring 2022 – Winter 2022/23 M&V period.[61] Regression estimates indicate that there were statistically significant reductions in energy use during all meteorological seasons. The Fall season saw the largest reduction in energy, with a value of 569 MWh, and the Spring saw the smallest reduction in energy, with a value of 169 MWh.

[61] Calculation uses actual number of VVO On hours spanning the analysis period. Actual VVO On Hours are the number of hours VVO was engaged in the clean analysis data between March 1, 2022 and February 28, 2023.

Figure 36 indicates the net energy reductions for each National Grid feeder in absolute terms (MWh), with green points indicating each feeder's MWh savings. The whiskers overlaid on each feeder's MWh savings estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant. During the Spring 2022 – Winter 2022/23 M&V period, 15 feeders experienced statistically significant reductions in energy. Although included in the aggregate energy impact estimate, Stoughton's individual feeder results are not presented here, as average hourly impacts estimates are unchanged from last year's evaluation.

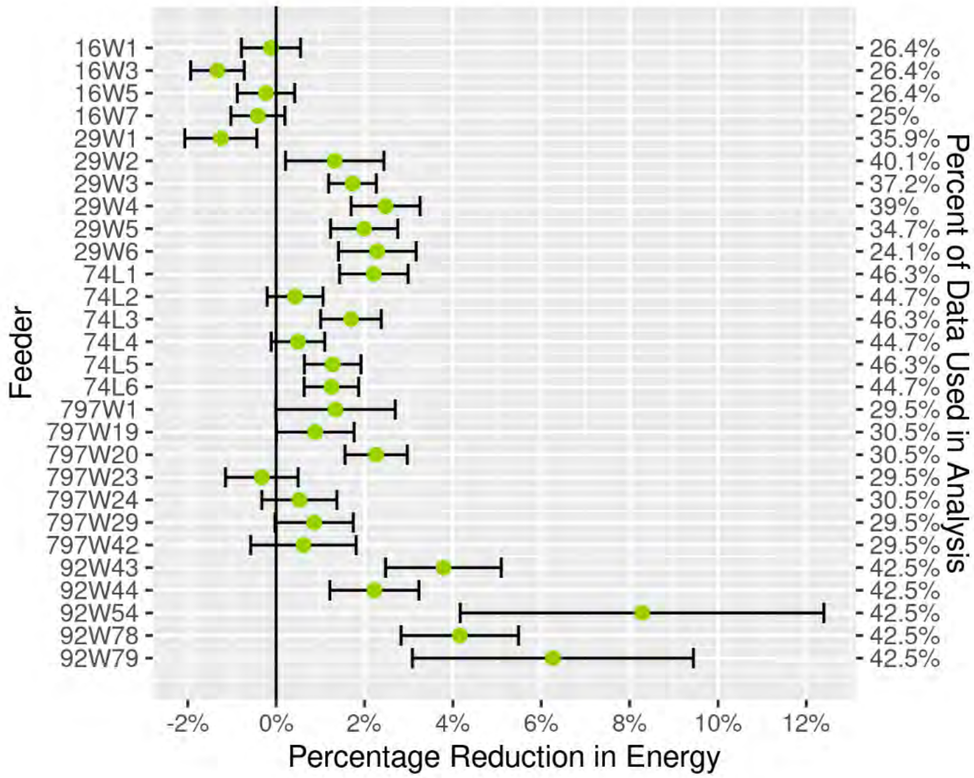
Figure 36. Net Energy Reduction (MWh) for National Grid VVO Feeders*



* Maplewood feeders 16W2, 16W4, 16W6, and 16W8 are removed from the analysis data, as only 5 weeks of On/Off testing took place during the evaluation period. Additionally, Easton feeders only contain estimates from Winter 2023 testing and West Salem feeders only contain estimates from the Summer 2022 – Winter 2023 seasons.
Source: Guidehouse analysis

Figure 37 indicates the net energy reductions for each National Grid feeder in percentage terms, with green points indicating each feeder's percentage MWh savings. The whiskers overlaid on each feeder's percentage MWh savings estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant.

Figure 37. Net Energy Reduction (%) for National Grid VVO Feeders*



* Maplewood feeders 16W2, 16W4, 16W6, and 16W8 are removed from the analysis data, as only 5 weeks of On/Off testing took place during the evaluation period. Additionally, Easton feeders only contain estimates from Winter 2023 testing and West Salem feeders only contain estimates from the Summer 2022 – Winter 2023 seasons.
Source: Guidehouse analysis

To further understand impacts, Guidehouse estimated changes in voltage associated with VVO, Table 93 provides the evaluated voltage reductions for National Grid, with 90% confidence bounds associated with voltage reductions estimates indicated by the ± figure. Regression estimates indicate a statistically significant reduction in voltage associated with VVO, with a 0.08 kV (0.62%) voltage reduction realized during the Spring 2022 – Winter 2022/23 M&V period.

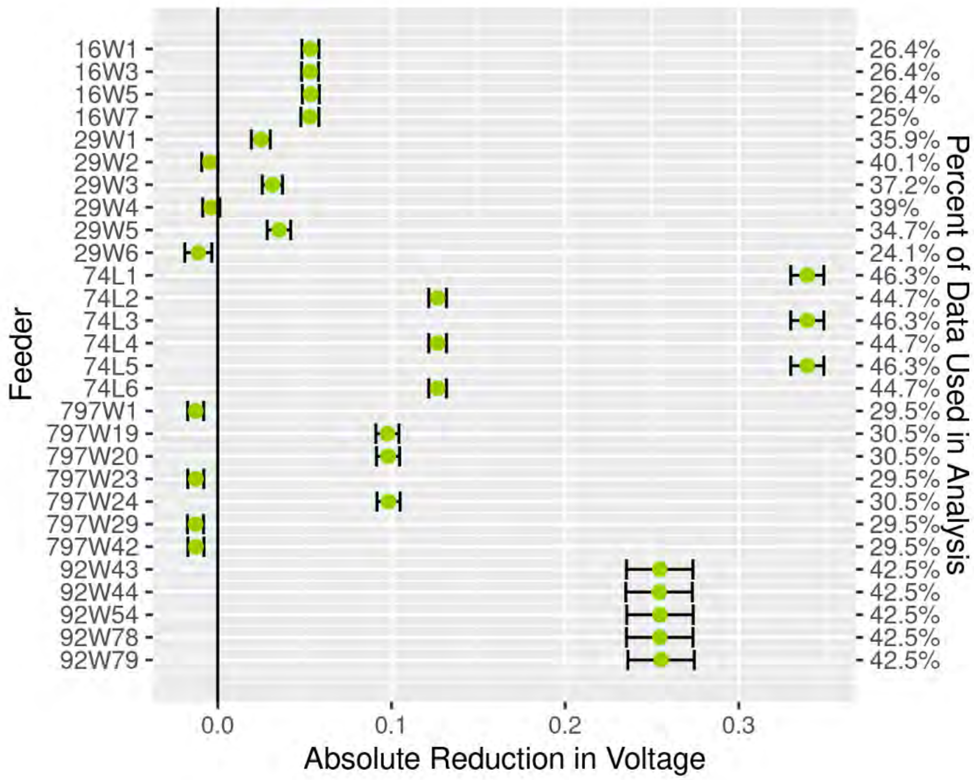
Table 93. National Grid VVO Average Hourly Voltage Reduction*

Average Hourly Reduction (kV)	Average Hourly Reduction (%)
0.08 ± <0.001 kV	0.62 ± 0.01%

* Absolute and percentage voltage reductions provided for each period is the load-weighted average of absolute and percentage voltage reductions estimated for each feeder.
Source: Guidehouse analysis

Figure 38 indicates the average hourly voltage reductions for each National Grid feeder, with green points indicating each feeder's voltage reduction. The whiskers overlaid on each feeder's voltage reduction estimate provide the associated 90% confidence intervals, and the dashed line denotes the weighted average voltage reduction. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant. The majority of feeders experienced a significantly significant average hourly voltage reduction when VVO was engaged.

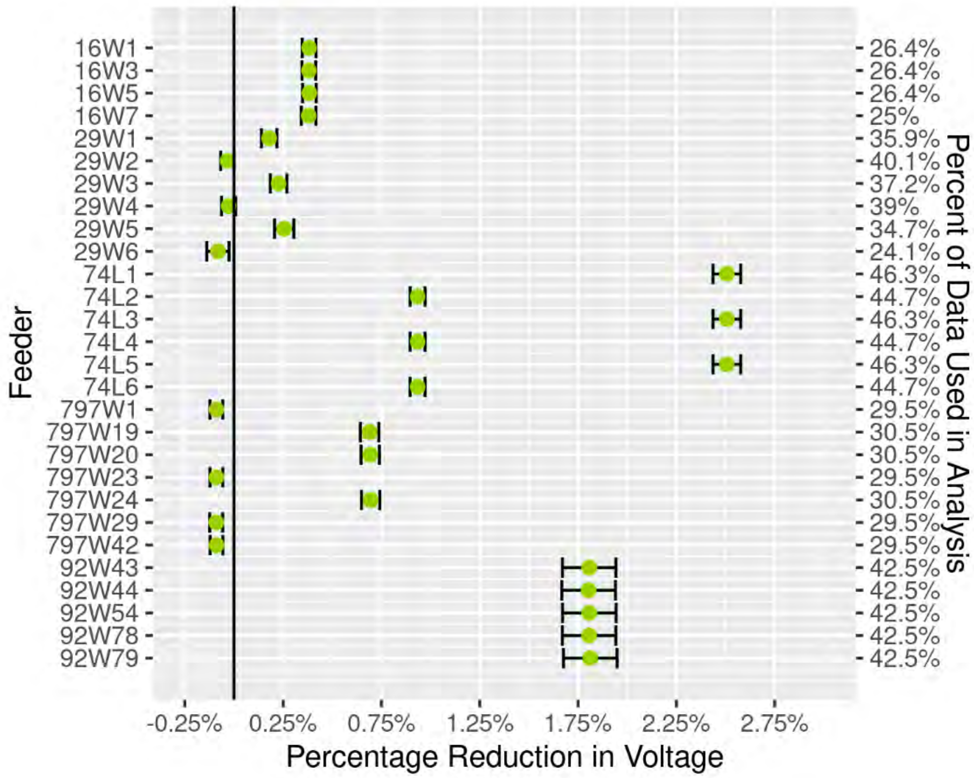
Figure 38. Average Hourly Voltage Reduction (kV) for National Grid VVO Feeders*



* Maplewood feeders 16W2, 16W4, 16W6, and 16W8 are removed from the analysis data, as only 5 weeks of On/Off testing took place during the evaluation period. Additionally, Easton feeders only contain estimates from Winter 2023 testing and West Salem feeders only contain estimates from the Summer 2022 – Winter 2023 seasons.
Source: Guidehouse analysis

Figure 39 indicates the net voltage reductions for each National Grid feeder in percentage terms, with green points indicating each feeder's percentage voltage reduction. The whiskers overlaid on each feeder's percentage voltage reduction estimate provide the 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant. Similar to absolute voltage impacts, the majority of feeders experienced a statistically significant increase in voltage when VVO was enabled.

Figure 39. Average Hourly Voltage Reduction (%) for National Grid VVO Feeders*



* Maplewood feeders 16W2, 16W4, 16W6, and 16W8 are removed from the analysis data, as only 5 weeks of On/Off testing took place during the evaluation period. Additionally, Easton feeders only contain estimates from Winter 2023 testing and West Salem feeders only contain estimates from the Summer 2022 – Winter 2023 seasons.
Source: Guidehouse analysis

Following an estimation of percentage energy savings and percentage voltage reductions attributed to VVO, Guidehouse calculated the associated CVR factors for each feeder. The CVR factor, which is the ratio of percentage energy savings to percentage voltage reductions, can provide an estimate of the percentage energy savings possible with each percent voltage reduction. Equation 5-1 in the Appendix highlights how the CVR factor is calculated using an estimated percentage change in energy and in voltage. Table 94 provides the CVR factor for National Grid.

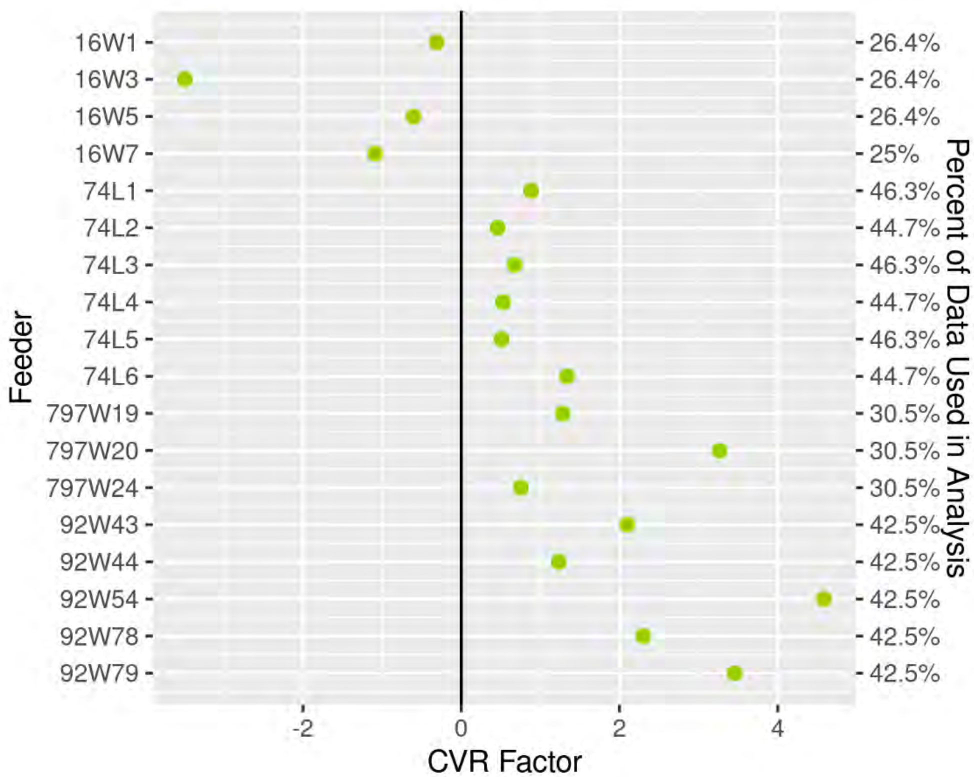
Table 94. National Grid VVO CVR Factor*

CVR Factor
0.36

* Maplewood feeders 16W2, 16W4, 16W6, and 16W8 are excluded from the entire analysis due to poor VVO signal data quality. The CVR factor presented in this table is the load-weighted average of CVR factors for all analysis feeders that experienced a minimum change in voltage of ±0.25% Certain feeders with changes in voltage greater than ±0.25% were also excluded from aggregated CVRf calculations due to highly unstable voltage and energy responses to VVO On / Off testing. Feeders excluded from this calculation are all West Salem 29W feeders and East Bridgewater feeders 797W1, 797W23, 797W23, and 797W42.
Source: Guidehouse analysis

From prior experience evaluating VVO, Guidehouse expects a CVR factor in the neighborhood of 0.80 from a year of VVO M&V testing. Based on evaluation findings, the CVR factor for the Spring 2022 – Winter 2022/23 time period was 0.36. Figure 40 provides the CVR factors for the Spring 2022 – Winter 2022/23 M&V period for each feeder. Although included in the aggregate CVRf estimate, Stoughton's individual feeder results are not presented here, as CVRf estimates are unchanged from last year's evaluation.

Figure 40. National Grid VVO CVR Factors*



* Maplewood feeders 16W2, 16W4, 16W6, and 16W8 are excluded from the entire analysis due to poor VVO signal data quality. The CVR factor presented in this table is the load-weighted average of CVR factors for all analysis feeders that experienced a minimum change in voltage of ±0.25% Certain feeders with changes in voltage greater than ±0.25% were also excluded from aggregated CVRf calculations due to highly unstable voltage and energy responses to VVO On / Off testing. Feeders excluded from this calculation are all West Salem 29W feeders and East Bridgewater feeders 797W1, 797W23, 797W23, and 797W42.

Source: Guidehouse analysis

PM-3: Peak Demand Impact

Guidehouse evaluated the impact of VVO during peak demand, defined by ISO-NE as 1:00 p.m. to 5:00 p.m. ET from June 1 to August 31 on non-holiday weekdays. Not all analysis feeders are included in peak demand impact tables and figures (see footnote below Table 95) Table 95 details the evaluated peak demand impact across all feeders in absolute and percentage terms. Although included in the aggregate peak demand impact, Stoughton's individual feeder results are not presented here, as average hourly impacts estimates are unchanged from last year's evaluation.

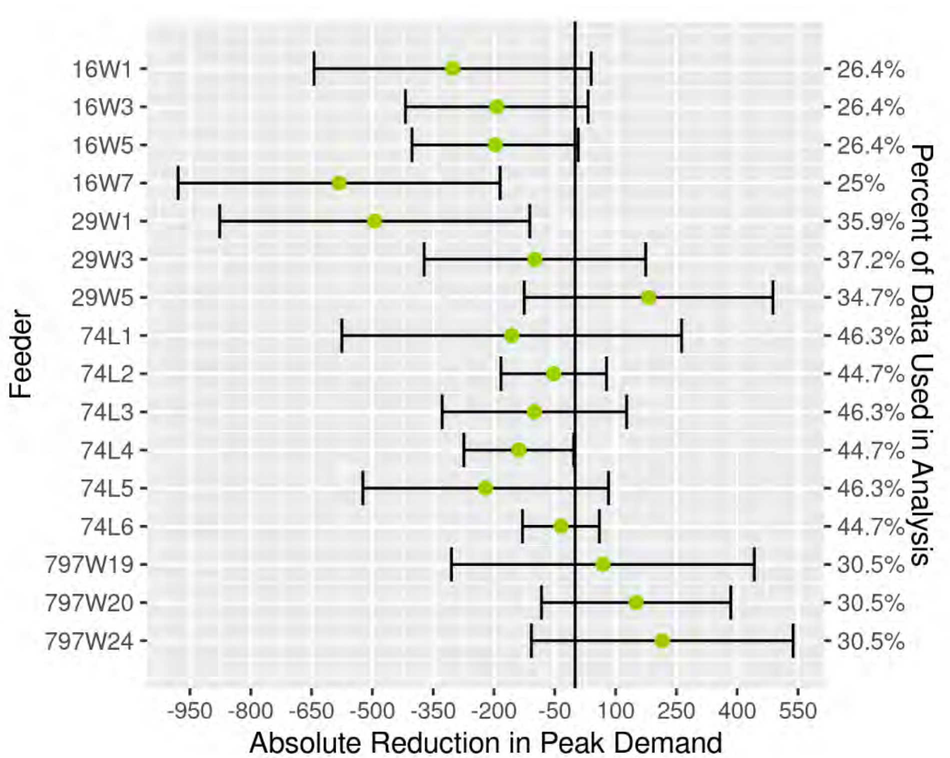
Table 95. National Grid Average Reduction in Peak Demand

Peak Load Reduction (kW)†	Peak Load Reduction (%)†
-2,189 ± 1,173 kW	-2.41 ± 1.28%

† The percentage peak load reduction presented in this table is the load-weighted average of percentage peak load reductions estimated for each feeder. Feeders with statistically insignificant estimates, or those unreliable standard error estimates associated with VVO, are excluded from the estimate of peak demand reductions. These include Maplewood 16W2, 16W4, 16W6, and 16W8, West Salem 29W2, 29W4, 29W6, and East Bridgewater 797W1, 797W23, 797W29, and 797W42.
Source: Guidehouse analysis

Figure 41 indicates the load reductions measured in kW realized during the peak load period, defined by ISO-NE as 1:00 p.m. to 5:00 p.m. ET from June 1 to August 31 on non-holiday weekdays. The whiskers overlaid on each feeder's absolute load reduction estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant. None of the feeders included in the analysis experienced a statistically significant reduction in peak load.

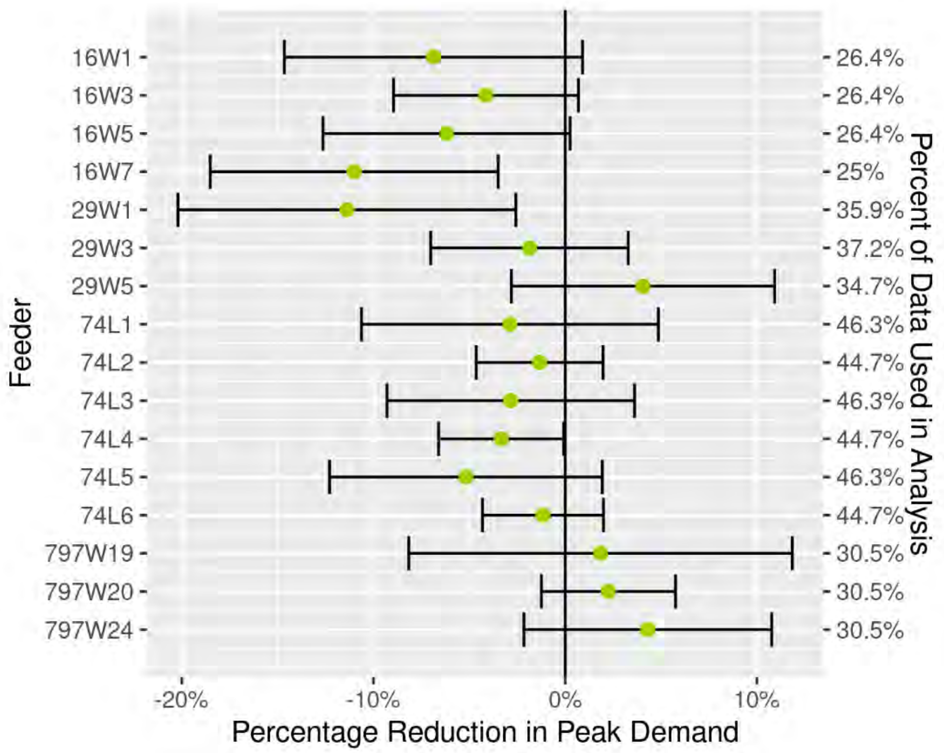
Figure 41. National Grid Reduction in Peak Load (kW)*



* Feeders with statistically insignificant estimates, or those unreliable standard error estimates associated with VVO, are excluded from the estimate of peak demand reductions. These include Maplewood 16W2, 16W4, 16W6, and 16W8, West Salem 29W2, 29W4, 29W6, and East Bridgewater 797W1, 797W23, 797W29, and 797W42.
Source: Guidehouse analysis

Figure 42 indicates the percentage load reductions realized during the peak load period, defined by ISO-NE as 1:00 p.m. to 5:00 p.m. ET from June 1 to August 31 on non-holiday weekdays. The whiskers overlaid on each feeder's percent load reduction estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant.

Figure 42. National Grid Reduction in Peak Demand (%)*



* Feeders with statistically insignificant estimates, or those unreliable standard error estimates associated with VVO, are excluded from the estimate of peak demand reductions. These include Maplewood 16W2, 16W4, 16W6, and 16W8, West Salem 29W2, 29W4, 29W6, and East Bridgewater 797W1, 797W23, 797W29, and 797W42.
Source: Guidehouse analysis

Eversource and National Grid saw increases in peak demand between 1:00 p.m. and 5:00 p.m. on non-holiday summer weekdays. This was a finding in both the previous and current evaluations (i.e., PY 2021 and PY 2022). This may be attributable to a number of factors that were present during those hours:

- There is variation in customer types and their relative load contributions depending on the time of day. If feeder load was more heavily comprised of end-uses with constant power load during peak hours as currently defined, a reduction in voltage can be met by a corresponding increase in amperage, which could appear as an increase in MW load at the feeder head-end. For instance, if feeder load was more heavily comprised of commercial or industrial load during those hours, industrial equipment could have actually become more inefficient with a drop in voltage, which could appear as an increase in MW load at the feeder head-end.

- Distribution generation, which has considerable generation during early- to mid-afternoon hours during the summer, may have caused unintended interactions with the VVO scheme.

The period of 1:00 p.m. to 5:00 p.m. for non-holiday summer weekdays was based on ISO-NE's peak demand definition, which was identified in the Stage 3 Evaluation Plan and has been used since the PY 2021 evaluation report. This was intended to be consistent with energy efficiency evaluations. Guidehouse has reviewed other time frames (e.g., 6:00 p.m. to 10:00 p.m.) that better represent the average feeder peaks for those feeders with VVO enabled. However, to be consistent with the Stage 3 Evaluation Plan and prior evaluation reports, this evaluation included the results for the 1:00 p.m. to 5:00 p.m. timeframe. Guidehouse will further explore alternative definitions for peak periods to determine the proper definition moving forward.

PM-4: Distribution Losses

Guidehouse evaluated reduction in distribution losses as a function of VVO during the Spring 2022 – Winter 2022/23 M&V period. There were some feeders with very little data where kW was greater than 75% of annual peak load for kVA. Given that power factor is an input for the distribution losses equation, these feeders were ultimately removed from the distribution losses calculation, as they had fewer than 100 hours available for use in the regression modeling. The methodology for calculating the percent reduction in distribution losses is shown in Appendix 5.3B.9. Table 96 details the evaluated percentage reduction in distribution losses for each National Grid feeder with sufficient data quality.

Changes in distribution losses could not be estimated for feeders going through VVO On/Off testing during the Spring 2022 – Winter 2022/23 M&V period due to data outages and prolonged pauses to On/Off testing during periods of greater demand. Therefore, the results in Table 96 and Figure 43 only include VVO feeders that completed On/Off testing prior to the Spring 2022 – Winter 2022/23 M&V period (i.e., Stoughton) and informed by last year's estimates.

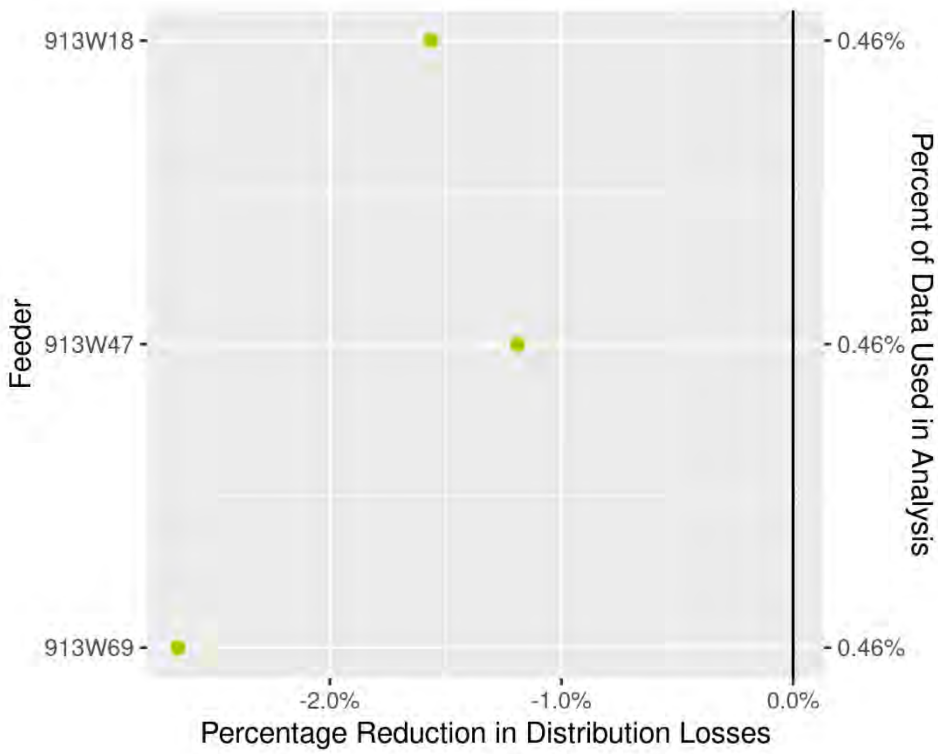
Table 96. National Grid Reduction in Distribution Losses

Reduction in Distribution Losses (%)*
-1.95%

* The change in distribution losses presented in this table is the load-weighted average of reduction in distribution losses estimated for each feeder.
Source: Guidehouse analysis

Figure 43 indicates the percentage reduction in distribution losses.

Figure 43. National Grid Reduction In Distribution Losses (%)*



* Changes in power factor and distribution losses could not be estimated for substations going through VVO On/Off testing during Spring 2022 through Winter 2022/23 due to data quality issues. Results presented for these metrics are based off of VVO substations that completed VVO On/Off testing prior to this evaluation period. For this evaluation period, the only substation to conclude On/Off testing is Stoughton.

Source: Guidehouse analysis

PM-5: Power Factor

Guidehouse evaluated the impact on power factor associated with VVO during the Spring 2022 – Winter 2022/23 M&V period. Changes in power factor were analyzed during periods where power was greater than 75% of feeder-specific annual demand. Table 97 details the evaluated change in power factor for each National Grid feeder with sufficient data quality.[62]

Changes in power factor could not be estimated for feeders going through VVO On/Off testing during the Spring 2022 – Winter 2022/23 M&V period due to data outages and prolonged pauses to On/Off testing during periods of greater demand. Therefore, the results in Table 97 and Figure 44 only include VVO feeders that completed On/Off testing prior to the Spring 2022 – Winter 2022/23 M&V period (i.e., Stoughton) and informed by last year's estimates.

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[62] There were some feeders with very little data where kW was greater than 75% of annual peak load for kVA. These feeders were ultimately removed from the power factor models, as they had fewer than 100 hours available for use in regression modeling.

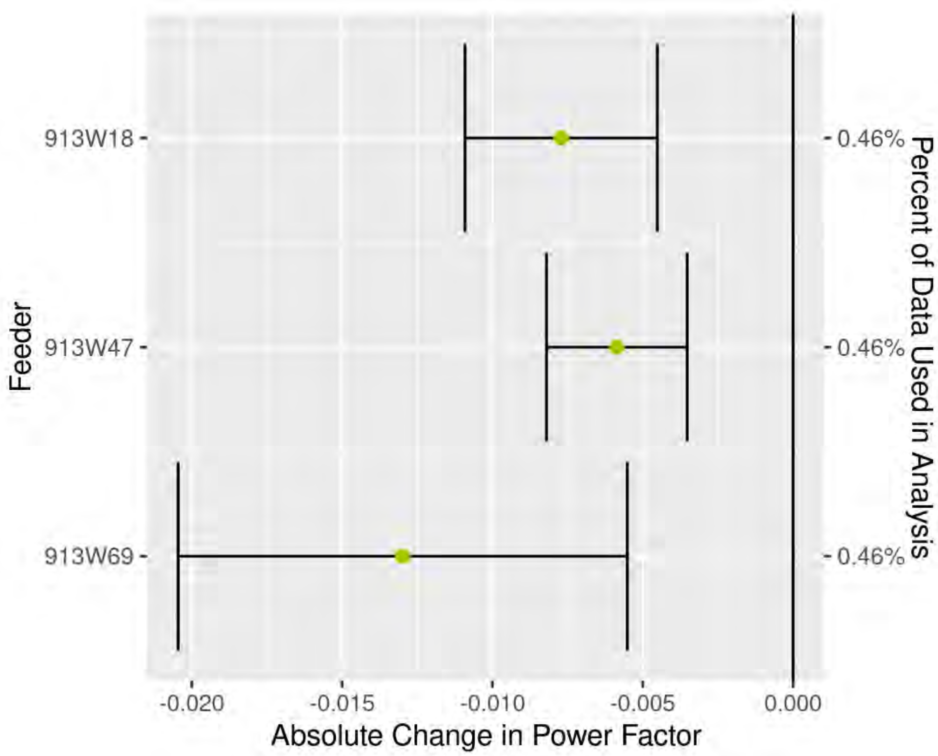
Table 97. National Grid VVO Average Hourly Power Factor Change*

Change in Power Factor	Change in Power Factor (%)
-0.01 ± 0.002	-0.96 ± 0.20%

* Power factor change presented in this table is the load-weighted average of power factor changes estimated for each feeder.
Source: Guidehouse analysis

Figure 44 indicates the change in power factor for each National Grid feeder in absolute terms, with green points indicating each feeder's absolute power factor change. The whiskers overlaid on each feeder's absolute power factor change estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant.

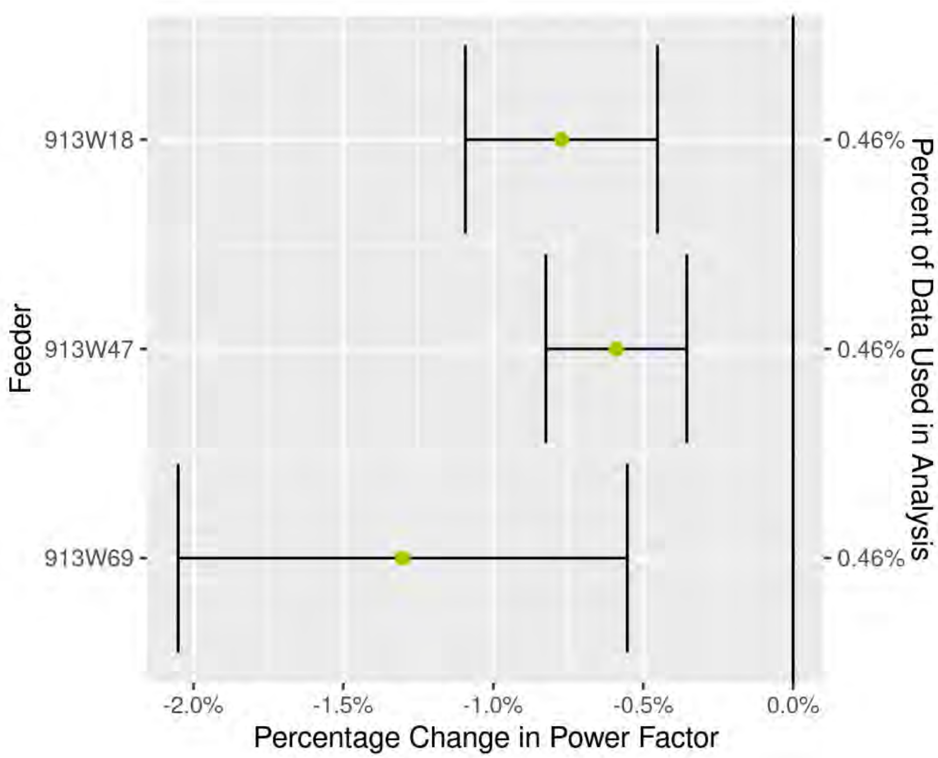
Figure 44. National Grid Absolute Change in Power Factor*



* Changes in power factor and distribution losses could not be estimated for substations going through VVO On/Off testing during Spring 2022 through Winter 2022/23 due to data quality issues. Results presented for these metrics are based off VVO substations that completed VVO On/Off testing prior to this evaluation period. For this evaluation period, the only substation to conclude On/Off testing is Stoughton.
Source: Guidehouse analysis

Figure 45 indicates the change in power factor for each National Grid feeder in percentage terms, with green points indicating each feeder's percentage power factor change. The whiskers overlaid on each feeder's percentage power factor change estimate provide the associated 90% confidence intervals. Where the confidence interval crosses the zero line, results may be interpreted as statistically insignificant.

Figure 45. National Grid Percentage Change in Power Factor*



* Changes in power factor and distribution losses could not be estimated for substations going through VVO On/Off testing during Spring 2022 through Winter 2022/23 due to data quality issues. Results presented for these metrics are based off of VVO substations that completed VVO On/Off testing prior to this evaluation period. For this evaluation period, the only substation to conclude On/Off testing is Stoughton.

Source: Guidehouse analysis

PM-6: GHG Emissions

After evaluating energy savings attributed to VVO, Guidehouse calculated the resulting emissions reductions. For 2022, emissions reductions were determined by to be 0.34 metric tons of emissions per MWh. This was calculated drawing the 2019 value from DPU 18-110 – DPU 18-119, Massachusetts Joint Statewide Electric and Gas Three Year Energy Efficiency Plan for 2019 – 2021, the 2025 value from DPU 21-120 – DPU 21-129, Massachusetts Joint Statewide Electric and Gas Three-Year Energy Efficiency Plan for 2022-2024, and then interpolating the 2022 value from these two sources.[63]

Table 98 provides emissions reductions associated with VVO, with 90% confidence bounds indicated by the ± figure.

[63] 2019 Emissions factors can be found on page 201 of Massachusetts Joint Statewide Electric and Gas Three Year Energy Efficiency Plans for 2019 – 2021 https://ma-eeac.org/wp-content/uploads/Exh.-1-Final-Plan-10-31-18-With-Appendices-no-bulk.pdf. 2025 emissions factors can be found on page 326 of Massachusetts Joint Statewide Electric and Gas Three Year Energy Efficiency Plans for 2022 – 2024 https://ma-eeac.org/wp-content/uploads/Exhibit-1-Three-Year-Plan-2022-2024-11-1-21-w-App-1.pdf

Table 98. National Grid VVO Emissions Reductions During Actual VVO On Hours

Metric	CO_2
Spring 2022 – Winter 2022/23 Emissions Reduction	645 ± 103 tons

Source: Guidehouse analysis

PM-7: Voltage Complaints

Guidehouse received voltage complaint logs from National Grid to facilitate Performance Metrics analysis. Guidehouse tabulated voltage complaints received by VVO feeder between 2016 and Q1 2023, as well as the Spring 2022 – Winter 2022/23 M&V period.[64] Discussion below highlights key observations for voltage complaints, comparing the count of voltage complaints received during Spring 2022 – Winter 2022/23 to the average number of voltage complaints from the 2016–2017 baseline period.

Table 99 summarizes voltage complaints for the Easton substation. Looking at 2016–2017 baseline period,[65] there were about 15 voltage complaints per year. Based on voltage complaints data received, a total of 12 voltage complaints were reported along the Easton feeders during 2022, slightly below the baseline period average number of complaints per year.

Table 99. Count of Voltage Complaints for Easton

Number of Voltage Complaints	92W43	92W44	92W54	92W78	92W79	Total
Customers*	1,973	1,779	2,284	1,993	1,655	**9,684**
Baseline†	**0**	**3**	**4**	**3**	**5**	**15**
2022	**1**	**2**	**4**	**2**	**3**	**12**

* Count of customers served by each feeder and the baseline number of voltage complaints was extracted from the 2022 D.P.U 23-30 Report, Appendix 22-25.

Source: Guidehouse analysis

Table 100 summarizes voltage complaints for the East Bridgewater substation. Looking at 2016–2017 baseline period, there were about 25 voltage complaints per year. Based on voltage complaints data received, a total of 25 voltage complaints were reported along the East Bridgewater feeders during 2022, representing no change from the baseline period average number of complaints per year.

[64] Since 2016 is the earliest date at which voltage complaints data are available, Guidehouse limited its summary of voltage complaints to January 1, 2016 through February 28, 2023.

[65] Guidehouse presents a comparison of complaints between the 2016–2017 period and winter 2020/21 M&V period. For new VVO feeders that begin receiving VVO investments beginning in 2021, Guidehouse recommends that a 3-year moving average (i.e. 2019–2021) be used instead of an average for the time period spanning 2016 through 2017, as conditions in 2016 through 2017 may not accurately reflect baseline conditions immediately preceding deployment of VVO investments.

Table 100. Count of Voltage Complaints for East Bridgewater

Number of Voltage Complaints	797W1	797W19	797W20	797W23	797W24	797W29	797W42	**Total**
Customers*	2,821	2,563	1,717	2,650	2,583	2,338	1,239	**15,911**
Baseline†	**7**	**1**	**5**	**1**	**5**	**3**	**4**	**25**
2022	**4**	**2**	**5**	**5**	**7**	**2**	**0**	**25**

* Count of customers served by each feeder and the baseline number of voltage complaints was extracted from the 2022 D.P.U 23-30 Report, Appendix 22-25.
Source: Guidehouse analysis

Table 101 summarizes voltage complaints for the East Methuen substation. Voltage complaints vary considerably across years and VVO feeders, ranging from 14 complaints in 2019 to 35 complaints in 2016. Looking at 2016–2017 baseline period, there were 59 voltage complaints received, amounting to about 30 voltage complaints per year. Based on voltage complaints data received, a total of 15 voltage complaints were reported along the East Methuen feeders during 2022, 50% below the baseline period average number of complaints per year.

Table 101. Count of Voltage Complaints for East Methuen Substation

Number of Voltage Complaints	74L1	74L2	74L3	74L4	74L5	74L6	Total
Customers*	3,088	1,574	3,355	1,609	3,162	1,781	**14,569**
2016	2	5	10	7	9	2	**35**
2017	8	1	5	2	6	2	**24**
Baseline†	**5**	**3**	**8**	**5**	**8**	**2**	**30**
2018	3	0	2	3	5	3	**16**
2019	5	0	2	2	3	2	**14**
2020	1	1	7	3	2	2	**16**
2021	3	0	2	1	3	1	**10**
2022	**2**	**3**	**7**	**1**	**1**	**1**	**15**

* Count of customers served by each feeder was extracted from the 2022 D.P.U 23-30 Report, Appendix 22-25.
† The baseline number of voltage complaints is calculated as the average number of voltage complaints between 2016 and 2017, rounded up to the nearest whole number
Source: Guidehouse analysis

Table 102 summarizes voltage complaints for the Maplewood substation. Voltage complaints vary considerably across years and VVO feeders, ranging from 20 complaints in 2016 to 50 complaints in 2019. Looking at 2016–2017 baseline period, there were 51 voltage complaints received, amounting to about 26 voltage complaints per year. Based on voltage complaints data received, a total of 41 voltage complaints were reported along the Maplewood feeders during the 2022, above the baseline period average number of complaints per year.

Table 102. Count of Voltage Complaints for Maplewood Substation

Number of Voltage Complaints	16W1	16W2	16W3	16W4	16W5	16W6	16W7	16W8	Total
Customers*	3,683	4,674	3,352	1,131	1,710	5,627	3,891	3,427	**27,495**
2016	4	3	0	2	3	4	2	2	**20**
2017	6	3	2	0	5	6	4	5	**31**
Baseline†	**5**	**3**	**1**	**1**	**4**	**5**	**3**	**4**	**26**
2018	6	3	1	4	1	6	6	7	**34**
2019	7	10	5	3	1	8	6	10	**50**
2020	6	7	4	4	3	10	6	8	**48**
2021	2	7	0	1	1	4	3	3	**21**
2022	**3**	**6**	**0**	**3**	**0**	**7**	**4**	**18**	**41**

* Count of customers served by each feeder was extracted from the 2022 D.P.U 23-30 Report, Appendix 22-25.
† The baseline number of voltage complaints is calculated as the average number of voltage complaints between 2016 and 2017, rounded up to the nearest whole number

Source: Guidehouse analysis

Table 103 summarizes voltage complaints for the Stoughton substation. Voltage complaints vary considerably across years and VVO feeders, ranging from 3 complaints in 2021 to 32 complaints in 2019. Looking at 2016–2017 baseline period, there were 52 voltage complaints received, amounting to about 26 voltage complaints per year. Based on voltage complaints data received, a total of 22 voltage complaints were reported along the Stoughton feeders during the 2022, below the baseline period average number of complaints per year

Table 103. Count of Voltage Complaints for Stoughton Substation

Number of Voltage Complaints	913W17	913W18	913W43	913W47	913W67	913W69	Total
Customers*	1,350	1,504	2,132	1,796	755	3,603	**11,140**
2016	2	7	5	5	2	11	**32**
2017	1	8	5	1	1	4	**20**
Baseline†	**2**	**8**	**5**	**3**	**2**	**8**	**26**
2018	8	1	6	0	1	7	**23**
2019	4	3	4	2	0	1	**14**
2020	3	3	3	6	6	3	**24**
2021	1	2	0	0	0	0	**3**
2022	**0**	**3**	**7**	**6**	**2**	**4**	**22**

* Count of customers served by each feeder was extracted from the 2022 D.P.U 23-30 Report, Appendix 22-25.
† The baseline number of voltage complaints is calculated as the average number of voltage complaints between 2016 and 2017, rounded up to the nearest whole number

Source: Guidehouse analysis

Table 104 summarizes voltage complaints for the West Salem substation. Looking at 2016–2017 baseline period, there were 41 voltage complaints per year. Based on voltage complaints data received, a total of 23 voltage complaints were reported along the West Salem feeders during 2022, quite below the baseline period average number of complaints per year.

Table 104. Count of Voltage Complaints for West Salem Substation

Number of Voltage Complaints	29W1	29W2	29W3	29W4	29W5	29W6	Total
Customers*	3,788	1,653	4,286	2,700	2,915	1,426	16,768
Baseline†	**16**	**4**	**8**	**1**	**9**	**3**	**41**
2022	**9**	**1**	**5**	**3**	**3**	**2**	**23**

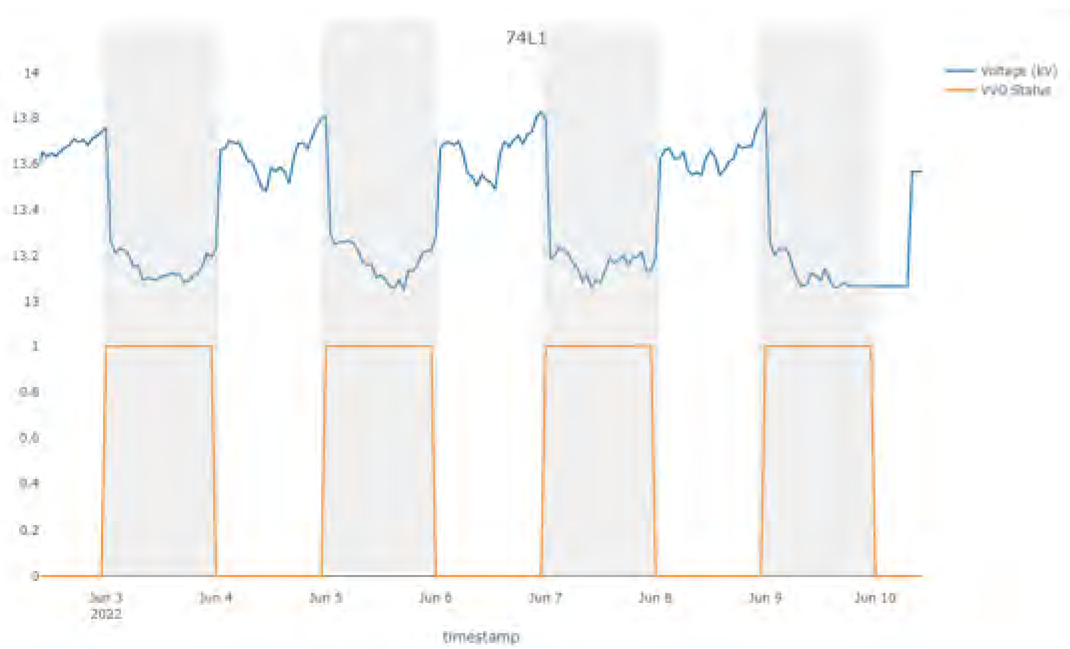
* Count of customers served by each feeder and the baseline number of voltage complaints was extracted from the 2022 D.P.U 23-30 Report, Appendix 22-25.

Source: Guidehouse analysis

4.2.3.4 Additional Investigation of West Salem Feeders

When feeders are undergoing VVO On/Off testing, Guidehouse usually expects to see head-end voltage levels cycling with VVO On/Off status, with voltage levels remaining somewhat higher when VVO is disengaged (e.g., 13.8 Volts) and remaining somewhat lower when VVO is engaged (e.g., 13.2 Volts). An example of the expected voltage response to VVO is shown in Figure 46 below highlights voltage (in blue) and VVO On/Off status (in orange, where VVO status equal to one indicates VVO is engaged) observed for the feeder 74L1 from June 3, 2022 through June 10, 2022.

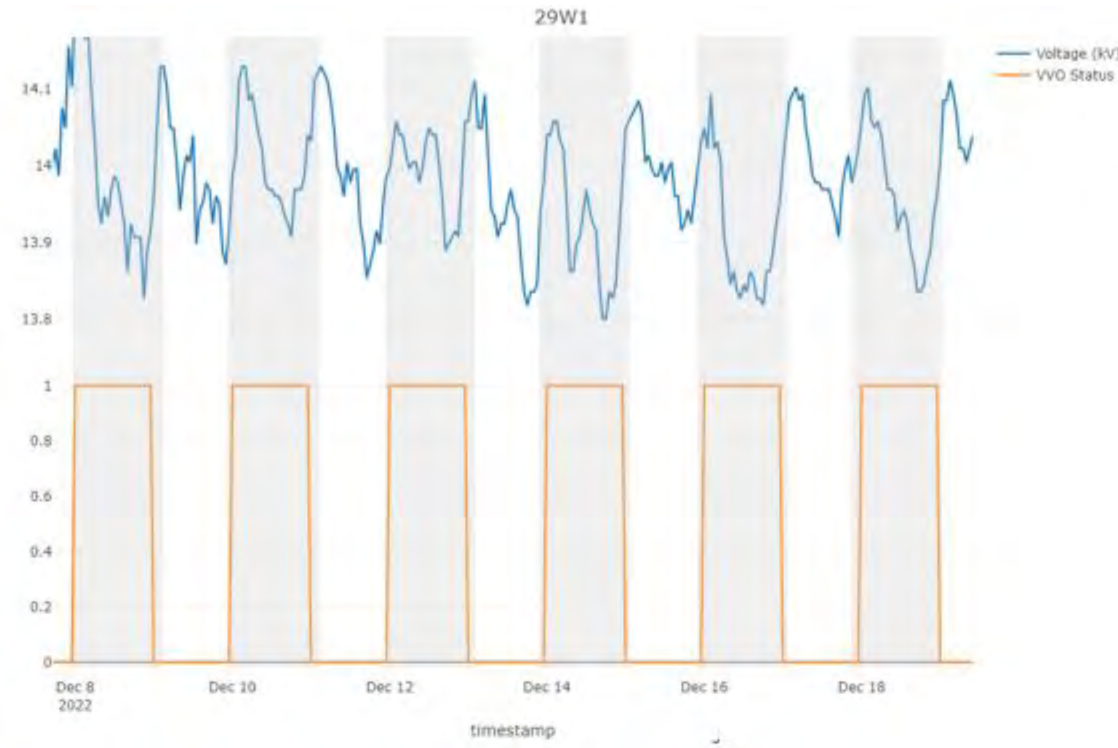
Figure 46. VVO On/Off Testing at Feeder 74L1



Source: Guidehouse analysis

However, Guidehouse has identified additional cases for feeders at the East Bridgewater, Maplewood, and West Salem substations where VVO signals did not correspond with reductions in voltage. One such case is presented in Figure 47 for the feeder 29W1, where voltage (in blue) and VVO On/Off status (in orange, where VVO status equal to one indicates VVO is engaged) are plotted together for the period spanning December 8, 2022, through December 18, 2022.

Figure 47. VVO On/Off Testing at Feeder 29W1



Source: Guidehouse analysis

Figure 47 illustrates that voltage did not fluctuate as expected during VVO On/Off testing throughout the period spanning December 8, 2022, through December 18, 2022. This reduced assessed impacts of VVO across numerous feeders (e.g., feeders at the East Bridgewater, Maplewood, and West Salem substations), as VVO was marked as engaged but was not yielding clear voltage benefits. Guidehouse recommends that National Grid investigate what may be driving these voltage patterns and what, if any, changes to VVO need to occur to ensure that VVO is correctly regulating voltage when VVO is engaged.

4.2.3.5 Key Findings and Recommendations

Guidehouse's VVO evaluation findings indicate that VVO allowed National Grid to realize energy savings and voltage reductions during the Spring 2022 – Winter 2022/23 M&V period. More specifically:

- National Grid VVO feeders realized 0.84% energy savings and 0.62% voltage reductions when VVO was engaged. East Methuen 74L1, 74L3, and 74L5 feeders realized greatest energy and voltage benefits, with 2.5% voltage reduction when VVO was engaged.
- National Grid VVO feeders experienced a statistically significant increase (2.41%) in peak demand when VVO was engaged. In addition, insufficient data during periods of higher demand limited the number of feeders for which Guidehouse could estimate changes in power factor and distribution losses associated with VVO.

In 2023 and beyond, Guidehouse recommends that National Grid:

- Ensure VVO On/Off testing is running according to plan, with limited pauses to the VVO On/Off testing schedule. Across the VVO feeders, one-quarter to one-half of data points were removed due to extended pauses in VVO On/Off testing. For some feeders, this resulted in the vast majority of provided data to be unusable for components of this evaluation (e.g., for estimation of distribution loss and power factor reductions). Sustained On/Off testing will increase the amount of usable data in the evaluation and improve the ability for Guidehouse to provide a comprehensive evaluation of VVO performance metrics.
- Confirm adjustments to VVO On/Off testing schedule for any VVO feeders prior to implementation. VVO On/Off testing is designed similarly to a Randomized Controlled Trial (RCT), and adjustments to the testing schedule could, potentially, hinder the effectiveness of the testing design and cause biases to evaluation results. Ensuring there is proper balance in the number of VVO on and off hours throughout the evaluation period will allow for Guidehouse to provide a comprehensive and accurate evaluation of VVO performance metrics.
- Continue to investigate how to improve outcomes across VVO feeders. Many feeders underwent no material change in voltage. Correspondingly, energy reduction estimates were small-to-insignificant. These observations may indicate flaws in the VVO control scheme for these feeders. In order to improve VVO performance, Guidehouse recommends that the EDCs continue their efforts to investigate root causes to shortcomings in the VVO control schemes and work with distribution engineers and the VVO vendors to respond accordingly. If needed, Guidehouse can conduct in-depth case studies at these substations further understand shortcomings in the VVO control scheme.

5. Key Findings and Recommendations

The subsections that follow present key findings for VVO Infrastructure Metrics, VVO Performance Metrics, and recommendations for the VVO investment area for each of the EDCs.

5.1 Key Findings for VVO Infrastructure Metrics

Guidehouse's review of Eversource's VVO progress on Term 1 revealed that Eversource was approximately on-track with planned spend and deployment outlined in their *2021 GMP Term Report*. However, some spend and deployment remain in order to complete activities from Term 1. Key findings related to Eversource's progress include:

Device Deployment

- Eversource made headway on deploying 2021 investments in 2022, with Capacitor Banks and Grid Monitoring Line Sensors comprising the bulk of deployed devices. Eversource exceeded plans (25 devices) for Capacitor Banks, as refinements made during the planning and design process placed more priority on Capacitor Banks, less on Regulators, for VVO operation. At the close of 2022, Eversource was awaiting delivery of 3 ordered VVO Regulators from its vendor. Line Sensor and Micro-capacitor deployment also fell short of plans.

Total Spend

- Eversource made substantial progress on PY 2021 work that was planned for 2022. Total spend through the end of 2022 was approximately on track with plans for all device types, with total spend on VVO ($16.87M) being slightly below planned spend ($17.23M) laid out for Term 1.

VVO Enablement

- Eversource completed deployment of VVO at four of its six Term 1 plan substations (Agawam, Piper, Podick, and Silver) by the end of 2021, and conducted On/Off testing at these substations throughout 2022. Eversource stopped VVO On/Off testing on these four substations in May 2023, transitioning towards leaving VVO in its enabled state moving forward. Meanwhile, the Gunn and Oswald substations will be VVO enabled in 2023, with On/Off testing to begin shortly thereafter.

PY 2022's VVO Infrastructure Metrics findings show that the EDCs are at varying stages in VVO deployment for Term 2. Details pertaining to device deployment progress, total spend, and VVO enablement progress are shown below:

Device Deployment:

- Eversource did not meet VVO deployment goals for PY 2022. Eversource progress on VVO investments targeted for 2022 through 2025 was comprised of progressing engineering/design work for all VVO device types, as well as planning for future VVO deployments, while awaiting DPU decisions on continued VVO investment for 2022 through 2025. Given limited deployment on Term 2 investments in 2022, Eversource has adjusted plans for the remainder of Term 2, with the majority of deployment and spend activity projected to occur in 2024 and 2025. At the technology-level, planned deployment has declined for Regulators, Line Sensors, and Microcapacitors, and planned Capacitor Bank deployment has increased slightly. Capacitor Bank deployment has been revised upwards to reflect refinements made during the planning and design process.

- National Grid conducted less deployment than initially planned in PY 2022. A late-2022 DPU decision on preauthorizing 2022 through 2025 investment activity, resource constraints, and vendor lead times were all key contributors to this outcome. In response to lower-than-expected deployment in 2022, National Grid has accelerated its deployment timeline for 2023 through 2025. National Grid has also adjusted total deployment plans for numerous device types, increasing projected deployment for Capacitor Banks, Line Sensors, and LTC Controls, while reducing projected deployment for Regulators. National Grid cites that these revisions are primarily due to the VVO planning work that has been conducted since the 2022-2025 GMP was filed.
- Unitil deployment was below plans for 2022, with variation by technology. Unitil was on-track with deployment of VVO Capacitor Banks and Line Sensors in 2022, deploying 100% and 210% of planned units, respectively. However, deployment was under plans for Regulators and LTC Controls. Lower deployment than plans for these technologies may be attributed to Unitil's efforts to resolve LTC radio and control issues and cancelation of 4 deployments that were found to be unnecessary. Unitil has adjusted deployment plans for the remainder of Term 2 to conduct most deployment during 2023 and 2025. Additionally, Unitil has reduced its planned deployments of VVO Regulators and Capacitor Banks, as Unitil reassessed deployment plans and determined there were fewer Regulator and Capacitor Bank deployments needed than initially planned. Work in 2024 will be limited to material orders in preparation for construction work at the Beech Street substation.

Total Spend:

- Eversource spend on Term 2 investments amounted to $0.04M, short of the $8.70M that was initially planned for 2022. Given limited deployment and spend on Term 2 investments in 2022, as well as ongoing vendor delays in fulfilling material orders, Eversource has adjusted plans for the remainder of Term 2. In 2023, Eversource will be conducting additional design work, submitting material orders, and, when material orders are received, deploying VVO investments. Eversource has projected that most spend activity will occur in 2024 and 2025.
- National Grid spend on VVO was below plans for 2022. The majority of spend occurred on Capacitor Banks, while spend on Regulators and Line Sensors was well below plans. Lower-than-anticipated spend on Line Sensors can, in part, be attributed to National Grid's previous line sensor vendor discontinuing their selected model. For VVO Regulators, vendor delays in fulfilling material orders was a key contributor to lower spend than initially planned. In response to its 2022 experience with Line Sensors and Regulators, National Grid has begun to increase diversification of vendors that it sources materials from.
- Unitil spend on VVO was below initial plans. Unitil met 48% of its planned spend for Regulators. Spend and deployment of all other devices met or exceeded initial plans. Spend plans for the remainder of Term 2 have been revised downwards across all device types. Reduced spend on Regulators and Capacitor Banks can be attributed to a reduction in the units that Unitil plans to deploy, as well as lower than expected costs for deployment of Regulators. Reduced spend on LTC Controls and Line Sensors may be tied to process efficiencies implemented in 2022 that brought unit costs below plans. Most spend is

planned for 2023 and 2025, with work in 2024 limited to material orders in preparation for construction work at the Beech Street substation.

VVO Enablement:

- For its Term 2 substations, Eversource is currently in the VVO Investment phase, and is conducting engineering / design work for the selected substations. Eversource anticipates completing deployment during 2024 and 2025. Once VVO investments are deployed, Eversource plans to conduct VVO On/Off testing, with testing start dates ranging from July 2024 through July 2025. Once VVO On/Off testing has begun, Eversource anticipates conducting this testing for 9 – 12 months to collect one summer, one winter, and one shoulder season of testing data.
- National Grid conducted VVO On/Off testing at its East Methuen and Maplewood Term 1 substations throughout 2022. Among its Term 2 substations, National Grid conducted On/Off testing at the East Bridgewater substation throughout 2022, as VVO deployment was completed at the substation in 2021. Additionally, National Grid completed VVO deployment at the Easton and West Salem substations and began VVO On/Off for these substations in winter 2022/23 and spring 2022, respectively. National Grid projects that it will complete VVO deployment and enable VVO at its remaining Term 2 substations in 2023.
- Unitil completed VVO deployment for its Term 1 substation (Townsend) in 2021, enabling VVO on December 1, 2021, and On/Off testing is expected to begin in spring 2023. Among its Term 2 substations, Unitil completed deploying VVO investments at the Summer Street substation and enabled VVO in December 2022, with VVO On/Off testing projected to begin at the substation in December 2023. Lunenburg and West Townsend are currently receiving VVO investments and Unitil plans to enable VVO at the substations in January and November 2024, respectively. Unitil then plans to conduct On/Off testing at the substations beginning in December 2024. For its remaining substations, Unitil is currently conducting planning and engineering/design work for its Beech Street, Pleasant Street, and Princeton Road substations. These substations are expected to be enabled after the close of Term 2 in 2026 and 2027.

5.2 Key Findings for VVO Performance Metrics

Findings from the evaluation of Performance Metrics indicate that VVO allowed Eversource and National Grid to realize energy savings and voltage reductions during the Spring 2022 – Winter 2022/23 M&V period. It can be difficult to compare the results from Performance Metrics analysis between Eversource and National Grid. For example, there are differences in the granularity of telemetry (e.g., 15-minute versus 1 hour), data quality at different times of the year. As such, data cleaning can cause certain portions of the M&V period to be represented more for one EDC than the other. Additionally, there are numerous differences in DG penetration, customer types, and geographic areas served by Eversource and National Grid feeders that limit the ability to directly compare Eversource and National Grid VVO outcomes. Key Findings from the evaluation of Performance Metrics are as follows:

- During the Spring 2022 – Winter 2022/23 M&V period, Eversource's Agawam, Piper, Podick, and Silver substations realized 879 MWh (0.41%) energy savings and 1.52 V (1.24%) voltage reduction associated with VVO. The CVR Factor, which provides an estimate of energy savings possible with voltage reductions, was 0.60. During the same

M&V period, National Grid's East Methuen, East Bridgewater, Easton, Maplewood, Stoughton, and West Salem substations realized 1,867 MWh (0.84%) energy savings and 0.08 kV (0.62%) voltage reduction associated with VVO. National Grid's CVR factor was 0.36.

- Eversource energy savings of 879 MWh yielded a 299 short ton reduction of CO_2 emissions. National Grid energy savings of 1,867 MWh yielded a 645 short ton reduction in CO_2 emissions.
- Eversource and National Grid VVO feeders experienced a minimal benefit associated with peak load, power factor, and distribution losses. Eversource VVO feeders experienced a statistically significant increase (0.70%) in peak load, a statistically significant decrease (0.06%) in power factor, and a minimal decrease in distribution losses when VVO was engaged. National Grid VVO feeders experienced a statistically significant increase in peak load of 2.41%, a small decrease (0.43%) in power factor, and a minimal increase in distribution losses when VVO was engaged.
- For Eversource, a total of 53 voltage complaints were received from customers connected to the Agawam, Piper, Podick, and Silver VVO feeders during the Spring 2022 – Winter 2022/23 M&V period. This is a 13% decrease relative to the baseline number of voltage complaints measured between 2015 and 2017 (61 complaints). For National Grid, a total of 136 voltage complaints were received from customers connected to the East Methuen, East Bridgewater, Maplewood, West Salem, and Stoughton VVO feeders during the period. This is a 16% decrease relative to the average voltage complaints per year received between 2016 – 2017. For both EDCs, there is not sufficient evidence to support changes in voltage complaints being attributed to VVO.

5.3 Recommendations

In 2023 and beyond, Guidehouse recommends that Eversource and National Grid:

- Ensure VVO On/Off testing is running according to plan, with limited pauses to the VVO On/Off testing schedule. Across the VVO feeders, one-quarter to one-half of data points were removed due to extended pauses in VVO On/Off testing. For some feeders, this resulted in the vast majority of provided data to be unusable for components of this evaluation (e.g., for estimation of distribution loss and power factor reductions). Sustained On/Off testing will increase the amount of usable data in the evaluation and improve the ability for Guidehouse to provide a comprehensive evaluation of VVO performance metrics.
- Confirm adjustments to VVO On/Off testing schedule for any VVO feeders prior to implementation. VVO On/Off testing is designed similarly to a Randomized Controlled Trial (RCT), and adjustments to the testing schedule could, potentially, hinder the effectiveness of the testing design and cause biases to evaluation results. Ensuring there is proper balance in the number of VVO on and off hours throughout the evaluation period will allow for Guidehouse to provide a comprehensive and accurate evaluation of VVO performance metrics.
- Continue to investigate how to improve outcomes across VVO feeders. Many feeders across the EDCs underwent no material change in voltage. Correspondingly, energy reduction estimates were small-to-insignificant. These observations may indicate flaws in the VVO control scheme for these feeders. In order to improve VVO performance, Guidehouse recommends that the EDCs continue their efforts to investigate root causes to

shortcomings in the VVO control schemes and work with distribution engineers and the VVO vendors to respond accordingly. If needed, Guidehouse can conduct in-depth case studies at these substations further understand shortcomings in the VVO control scheme.

Appendix A. Additional Feeder Characteristics by EDC

A.1 Eversource Additional Feeder Characteristics

Table A-1. Additional Eversource Feeder Characteristics

Substation	Feeder	Avg Customer Loading (kVA/customer)	Customer Density (customer/mi.)	Load Density (MVA/mi.)	DG Penetration (DG MW/MVA)
Term 1 Feeders					
Agawam (13.8 kV)	16C11	7.11	55	0.39	0.23
	16C12	146.25	13	1.84	0.17
	16C14	7.17	105	0.76	0.02
	16C15	9.45	113	1.06	0.01
	16C16	4.56	115	0.52	0.22
	16C17	4.02	81	0.33	0.13
	16C18	3.37	145	0.49	0.08
Piper (13.8 kV)	21N4	5.26	69	0.37	0.14
	21N5	14.60	56	0.82	0.02
	21N6	14.87	52	0.78	0.05
	21N7	7,000	0	2.90	0.00
	21N8	21.72	63	1.38	0.01
	21N9	5.32	101	0.54	0.08
Podick (13.8 kV)	18G2	1,589	2	3.18	0.00
	18G3	5.98	57	0.34	0.08
	18G4	4.69	67	0.32	0.52
	18G5	5.79	44	0.26	0.22
	18G6	7.84	34	0.27	0.36
	18G7	4.63	35	0.16	1.13
	18G8	11.39	23	0.27	0.70
Silver (13.8 kV)	30A1	5.68	68	0.38	0.11
	30A2	5.60	187	1.05	0.03
	30A3	48.95	20	0.99	0.43
	30A4	13.73	74	1.01	0.03
	30A5	7.05	77	0.55	0.08
	30A6	8.04	51	0.41	0.28
Gunn (23 kV)	15A1	5.79	40	0.23	0.19
	15A2	8.49	97	0.83	0.22
	15A3	4.47	39	0.17	0.60
	15A5	5.31	110	0.58	0.11
Oswald (23 kV)	30B5	6.13	72	0.44	0.33
	30B7	8.33	23	0.19	0.88
Term 2 Feeders					
Amherst	17K1	2.47	85	0.21	2.62

Substation	Feeder	Avg Customer Loading (kVA/customer)	Customer Density (customer/mi.)	Load Density (MVA/mi.)	DG Penetration (DG MW/MVA)
(13.8 kV)	17K2	2.25	40	0.09	0.85
	17K3	2.22	110	0.25	0.21
	17K4	4.17	117	0.49	0.93
	17K5	4.45	57	0.25	0.15
	17K6	5.63	65	0.36	0.53
	17K7	1.45	76	0.11	0.26
	17K8	2.20	48	0.11	0.65
Breckwood (13.8 kV)	20A11	N/A	0	1.59	0.00
	20A12	2.73	88	0.24	0.09
	20A13	2.31	149	0.34	0.23
	20A14	3.08	88	0.27	0.37
	20A21	2.86	96	0.27	0.23
	20A22	2.59	127	0.33	0.18
	20A23	2.39	100	0.24	0.20
	20A31	2.70	105	0.28	0.07
	20A32	2.27	119	0.27	0.35
	20A33	3.38	130	0.44	0.18
	20A34	3.12	85	0.26	0.35
	20A35	2.74	101	0.28	0.23
Cross Road (13.2 kV)	2-522-522	3.54	26	0.09	1.13
	2-523-523	2.72	27	0.07	0.72
	2-524-524	1.61	16	0.03	0.99
	2-525-525	1,652	1	1.40	1.21
	2-528-528	N/A	0	0.06	0.50
Cumberland (13.8 kV)	22B1	6.10	26	0.16	0.29
	22B2	2.64	102	0.27	0.20
	22B3	3.21	38	0.12	0.89
	22B4	3.15	50	0.16	1.26
	22B5	2.00	17	0.03	3.70
	22B6	N/A	0	0.77	0.00
	22B7	3.08	24	0.07	0.38
	22B8	N/A	125	N/A	N/A
Doreen	19A1	1.32	68	0.09	0.64

Substation	Feeder	Avg Customer Loading (kVA/customer)	Customer Density (customer/mi.)	Load Density (MVA/mi.)	DG Penetration (DG MW/MVA)
(23 kV)	19A2	1.47	76	0.11	0.42
	19A3	18.18	11	0.21	1.34
	19A4	28.13	27	0.75	1.11
	19A5	4.50	43	0.20	0.38
	19A6	1,367	1	0.75	0.43
	19A7	1.36	133	0.18	0.18
	19A8	1.14	134	0.15	0.28
Duxbury (4.16 kV)	3-24A-34J1	21.21	47	1.00	0.03
	3-24A-34J2	51.73	56	2.92	0.00
	3-24A-35J1	20.51	33	0.68	0.01
	3-24A-35J2	N/A	0	0.00	N/A
Franconia (13.8 kV)	22H11	N/A	0	0.00	N/A
	22H12	4.18	63	0.26	0.32
	22H13	4.32	61	0.26	0.10
	22H14	2.63	113	0.30	0.10
	22H15	2.05	180	0.37	0.12
	22H16	2.00	181	0.36	0.15
	22H17	3.26	88	0.29	0.07
	22H18	4.24	333	1.41	0.01
Industrial Park (13.2 kV)	2-101-101	348.02	6	2.01	0.26
	2-102-102	6.52	51	0.33	1.02
	2-102-608	3.06	47	0.14	0.30
	2-103-103	340.14	2	0.73	0.85
	2-104-104	3.87	83	0.32	0.39
	2-105-105	3.13	119	0.37	0.22
	2-106-106	1,498	2	3.35	0.00
	2-106-160	1.13	82	0.09	0.64
	2-106-161	2.90	84	0.24	0.31
	2-107-107	12.51	17	0.22	2.05
	2-108-108	N/A	0	0.29	1.19
	2-151-151	312.09	5	1.51	0.90
	2-152-152	N/A	0	3.69	0.00
Mashpee (22.8 kV)	4-71-455	2.13	36	0.08	0.58
	4-71-71	1,538	42	64.40	0.00
	4-77B-456	3.48	44	0.15	0.14
	4-77B-77B	41.32	39	1.61	0.00
Montague	21C1	4.87	25	0.12	0.93

Substation	Feeder	Avg Customer Loading (kVA/customer)	Customer Density (customer/mi.)	Load Density (MVA/mi.)	DG Penetration (DG MW/MVA)
(13.8 kV)	21C2	6.93	45	0.31	1.27
	21C3	N/A	0	0.00	N/A
	21C4	3.97	111	0.44	0.17
	21C5	2.01	33	0.07	0.22
	21C6	1.82	102	0.19	8.68
	21C7	1.98	25	0.05	0.44
	21C8	3.04	44	0.13	3.02
Orchard (13.8 kV)	27A10	2.00	125	0.25	1.52
	27A11	4,600	1	2.90	0.00
	27A12	767	4	2.96	1.66
	27A13	3.80	163	0.62	0.79
	27A14	N/A	0	1.85	0.00
	27A15	200	0	0.02	0.00
	27A16	N/A	0	1.66	0.00
	27A17	N/A	0	1.69	0.00
	27A4	2.92	105	0.31	0.21
	27A5	8.16	42	0.34	0.43
	27A6	2.39	162	0.39	0.67
	27A7	3.63	98	0.36	0.16
Wareham (22.8 kV)	3-85-85	6.39	32	0.21	0.41
	3-85-928	5.74	29	0.17	1.34
	3-85-957	3.55	24	0.09	0.26
	3-86-966	5.88	42	0.24	0.59

Note: Values presented in this table were published on April 24, 2023 and are reflective of data collected through the end of 2022.
Source: Guidehouse analysis of 2022 GMP Term Report, Appendix 1 filed April 24, 2023. EDCs provided distributed generation data.

A.2 National Grid Additional Feeder Characteristics

Table A-2. Additional National Grid Feeder Characteristics

Substation	Feeder	Avg Customer Loading (kVA/customer)	Customer Density (customer/mi.)	Load Density (MVA/mi.)	DG Penetration (DG MW/MVA)
Term 1 Feeders					
East Methuen (13.2 kV)	74L1	6.04	80	0.48	0.31
	74L2	6.17	94	0.58	0.09
	74L3	3.39	171	0.58	0.17
	74L4	5.94	186	1.10	0.12
	74L5	3.47	58	0.20	0.12
	74L6	6.80	211	1.43	0.06

Substation	Feeder	Avg Customer Loading (kVA/customer)	Customer Density (customer/mi.)	Load Density (MVA/mi.)	DG Penetration (DG MW/MVA)
Stoughton (13.8 kV)	913W17	9.38	95	0.90	0.14
	913W18	6.75	127	0.86	0.07
	913W43	6.30	67	0.42	0.11
	913W47	8.08	112	0.90	0.04
	913W67	17.79	60	1.07	0.07
	913W69	3.73	114	0.43	0.12
Maplewood (13.8 kV)	16W1	3.28	212	0.70	0.11
	16W2	2.09	432	0.90	0.11
	16W3	3.78	248	0.94	0.05
	16W4	11.20	146	1.64	0.07
	16W5	7.20	254	1.83	0.08
	16W6	2.25	238	0.54	0.16
	16W7	3.26	272	0.89	0.15
	16W8	3.70	217	0.80	0.15
Term 2 Feeders					
East Bridgewater (13.8 kV)	797W1	5.19	79	0.41	0.10
	797W19	5.66	68	0.38	0.19
	797W20	8.21	55	0.45	0.05
	797W23	5.47	64	0.35	0.12
	797W24	5.62	48	0.27	0.10
	797W29	6.21	63	0.39	0.19
	797W42	11.38	58	0.66	0.14
East Dracut (13.8 kV)	75L1	3.20	183	0.58	0.10
	75L2	4.21	67	0.28	0.10
	75L3	5.21	46	0.24	0.18
	75L4	28.65	44	1.27	0.02
	75L5	2.73	190	0.52	0.11
	75L6	7.93	58	0.46	0.08
Easton	92W43	5.15	71	0.36	0.11

Substation	Feeder	Avg Customer Loading (kVA/customer)	Customer Density (customer/mi.)	Load Density (MVA/mi.)	DG Penetration (DG MW/MVA)
(13.8 kV)	92W44	7.55	68	0.51	0.10
	92W54	4.45	68	0.30	0.78
	92W78	6.24	52	0.33	0.07
	92W79	7.51	69	0.52	0.43
Melrose (13.8 kV)	25W1	7.82	85	0.66	0.19
	25W2	10.18	74	0.75	0.06
	25W3	15.41	84	1.30	0.07
	25W4	2.58	217	0.56	0.10
	25W5	3.24	193	0.63	0.11
West Salem (13.8 kV)	29W1	3.31	162	0.54	0.19
	29W2	6.80	105	0.71	0.06
	29W3	2.90	281	0.81	0.11
	29W4	4.16	152	0.63	0.19
	29W5	3.53	244	0.86	0.13
	29W6	8.88	83	0.74	0.10
Westboro (13.8 kV)	312W1	5.56	75	0.42	0.16
	312W2	71.03	21	1.46	0.24
	312W3	6.81	72	0.49	0.09
	312W4	4.79	48	0.23	0.40
	312W5	29.88	31	0.93	0.07

Note: Values presented in this table were published on April 24, 2023 and are reflective of data collected through the end of 2022.
Source: Guidehouse analysis of 2022 GMP Term Report, Appendix 1 filed April 24, 2023 EDCs provided distributed generation data.

A.3 Unitil Additional Feeder Characteristics

Table A-3. Additional Unitil Feeder Characteristics

Substation	Feeder	Avg Customer Loading (kVA/customer)	Customer Density (customer/mi.)	Load Density (MVA/mi.)	DG Penetration (DG MW/MVA)
Term 1 Feeders					
Townsend (13.8 kV)	15W15	8,844	6	55.20	0.00
	15W16	5.76	36	0.21	0.35
	15W17	15.41	50	0.77	0.36
Term 2 Feeders					
Summer Street (13.8 kV)	40W38	137.28	110	15.16	0.05
	40W39	24.93	46	1.14	0.21
	40W40	6.06	86	0.52	0.23
	40W42	4.98	153	0.76	0.20
Lunenburg	30W30	6.44	31	0.20	0.32

Substation	Feeder	Avg Customer Loading (kVA/customer)	Customer Density (customer/mi.)	Load Density (MVA/mi.)	DG Penetration (DG MW/MVA)
(13.8 kV)	30W31	6.01	37	0.22	0.94
West Townsend (13.8 kV)	39W18	6.63	38	0.25	0.00
	39W19	5.72	22	0.12	0.00

Note: Values presented in this table were published on April 24, 2023 and are reflective of data collected through the end of 2022.
Source: Guidehouse analysis of 2022 GMP Term Report, Appendix 1 filed April 24, 2023 EDCs provided distributed generation data.

Appendix B. Detailed Information for Performance Metrics Analysis

B.1 Conservation Voltage Reduction Factor

One informative metric associated with VVO is the conservation voltage reduction (CVR) factor, which reveals the percentage of energy savings that can be expected for each percentage of voltage reduction. Equation 5-1 highlights how the CVR factor is calculated using an estimated percentage change in energy and percentage change in voltage.

Equation 5-1. CVR Factor Calculation

$$CVRf = \frac{\%\Delta\, Energy}{\%\Delta\, Voltage}$$

B.2 Regression Methodology for Estimating VVO-Related Energy and Voltage Changes

For feeders going through VVO On/Off testing during the Spring 2022 – Winter 2022/23 M&V period, Guidehouse conducted regression modeling to assess the impacts of VVO on measured feeder-level real power and voltage. To estimate the impact of VVO on feeder-level real power and voltage observed during the Spring 2022 – Winter 2022/23 M&V period, Guidehouse estimated a regression model of real power and a regression model of voltage for each individual feeder. Equation 5-2 and Equation 5-3[66] summarizes the regression model specification used to estimate real power and voltage as a function of VVO.

Equation 5-2. Regression Model of Energy and Voltage

$$\begin{aligned}\{kW_{it}, V_{it}\} = {} & \beta_1 lagged\,\{kW_{it}, V_{it}\} + \beta_2 Spring_{it} + \beta_3 Summer_{it} + \beta_4 Fall_{it} + \beta_5 Winter_{it} \\ & + \beta_6 VVO_{it} * Spring_{it} + \beta_7 VVO_{it} * Summer_{it} + \beta_8 VVO_{it} * Fall_{it} + \beta_9 VVO_{it} \\ & * Winter_{it} + \beta_{10} Daylight_{it} + \sum_{wknd=1}^{2} \beta_{11wknd} * \tau_{wknd} + \sum_{m=1}^{12} \beta_{12m} * \tau_m \\ & + \sum_{wknd,h=1}^{48} \beta_{13wknd,h} * \tau_{wknd,h} + \sum_{h=1}^{24} \beta_{14h} * \tau_h * Cloud_{it} * Daylight_{it} \\ & + \sum_{h=1}^{24} \beta_{15h} * \tau_h * HDH_{it} + \sum_{h=1}^{24} \beta_{16h} * \tau_h * CDH_{it} + \beta_{17} DR\, Flag_t + \varepsilon_{it}\end{aligned}$$

[66] Given that the Easton substation did not start VVO On/Off testing until Winter 2022/23, Guidehouse ran a separate model to estimate energy and voltage changes for this substation that does not include seasonal terms (e.g., Spring, Summer, Fall, and Winter).

Where:

$i, t, h, wknd, and\ m$	index feeder, time-interval, each of the 24 hours of the day, weekend, and month of year respectively.
kW_{it}	is real power (kW) measured at feeder i at time t.
V_{it}	is voltage (V) measured at feeder i at time t.
$lagged\ kW_{it}$	is real power (kW) measured at feeder i at time $t-24$. The corresponding coefficient, β_1, captures the degree to which any given hour *t's* real power is correlated with real power 24 hours prior.
$lagged\ V_{it}$	is voltage (V) measured at feeder i at time $t-24$. The corresponding coefficient, β_2, captures the degree to which hour *t* voltage is correlated with voltage 24 hours prior.
$Spring_{it}$	is an indicator equal to 1 when feeder i at time t falls within March 1 through May 31, 2022. The corresponding coefficient β_2 captures the average real power and voltage observed during the Spring season.
$Summer_{it}$	is an indicator equal to 1 when feeder i at time t falls within June 1 through August 31, 2022. The corresponding coefficient β_3 captures the average real power and voltage observed during the Summer season.
$Fall_{it}$	is an indicator equal to 1 when feeder i at time t falls within September 1 through November 30, 2022. The corresponding coefficient β_4 captures the average real power and voltage observed during the Fall season.
$Winter_{it}$	is an indicator equal to 1 when feeder i at time t falls within December 1, 2022 through February 28, 2023. The corresponding coefficient β_5 captures the average real power and voltage observed during The Winter season.
VVO_{it}	is an indicator equal to 1 when VVO is engaged for feeder i at time t. The coefficient β_6 captures the average hourly impact of VVO on real power or voltage during the Spring season; the coefficient β_7 captures the average hourly impact of VVO on real power or voltage during the Summer season; the coefficient β_8.captures the average hourly impact of VVO on real power or voltage during the Fall season; and the coefficient β_9 captures the average hourly impact of VVO on real power or voltage during the Winter season. A combination of $\beta_6, \beta_7, \beta_8, \text{and } \beta_9$ captures the average hourly impact of VVO on real power or voltage during the entire analysis period.
$Daylight_{it}$	is an indicator equal to 1 when feeder i at time t falls within a daylight hour. The coefficient β_{10} captures the average real power or voltage

observed during daylight hours when distributed solar facilities are producing electricity.

τ_{wknd} are fixed effects for a weekday or weekend. The corresponding β_{11wknd} coefficients capture the average daily real power or voltage for a weekday or weekend.

τ_m are fixed effects for each month m. The corresponding β_{12m} coefficients capture the average monthly real power or voltage for each month of the Spring 2022 – Winter 2022/23 analysis period.

$\tau_{wknd,h}$ are hourly fixed effects for each weekday or weekend $wknd$ and each hour of day h combination. The corresponding $\beta_{13wknd,h}$ coefficients capture the average real power or voltage for each weekday or weekend and hour of day combination.

τ_h are hourly fixed effects for each hour of day h. The corresponding β_{14h} coefficients capture the average hourly real power or voltage for each hour across the Spring 2022 – Winter 2022/23 analysis period.

$Cloud_{it}$ is a categorical variable denoting hourly cloud cover conditions recorded by NOAA, intended to control for distributed solar generation connected to VVO feeders. Cloud cover multiplied by $Daylight_{it}$ and τ_h forces the regression model to provide an estimate of real power or voltage associated with distributed solar during each daylight hour. The coefficient β_{14h} captures this average real power or voltage observed during daylight hours when distributed solar facilities are producing electricity.

CDH_{it} are cooling degree-hours (CDH), base 65°F, for feeder i at time t to capture the impacts of temperature on cooling load for each hour of day h. The corresponding coefficients β_{15h} captures the impact of CDH on real power or voltage for each hour of day h.

HDH_{it} are heating degree-hours (CDH), base 65°F, for feeder i at time t to capture the impacts of temperature on heating load for each hour of day h. The corresponding coefficients β_{16h} captures the impact of HDH on real power or voltage for each hour of day h.

$DR\ Flag_t$ is an indicator equal to 1 when a demand response event occurred at time t. The coefficient β_{17} captures the average hourly impact of VVO on real power or voltage during the demand response events.

ϵ_{it} is an error term for feeder i at time t and captures unexplained variation in real power or voltage.

Equation 5-3. Regression Model of Energy and Voltage (Easton Substation)

$$\{kW_{it}, V_{it}\} = \beta_1 lagged\ \{kW_{it}, V_{it}\} + \beta_2 VVO_{it} + \beta_3 Daylight_{it} + \sum_{wknd=1}^{2} \beta_{4wknd} * \tau_{wknd} + \sum_{m=1}^{12} \beta_{5m} * \tau_m + \sum_{wknd,h=1}^{48} \beta_{6wknd,h} * \tau_{wknd,h} + \sum_{h=1}^{24} \beta_{7h} * \tau_h * Cloud_{it} * Daylight_{it} + \sum_{h=1}^{24} \beta_{8h} * \tau_h * HDH_{it} + \sum_{h=1}^{24} \beta_{9h} * \tau_h * CDH_{it} + \beta_{10} DR\ Flag_t + \epsilon_{it}$$

Where:

$i, t, h, wknd, and\ m$	index feeder, time-interval, each of the 24 hours of the day, weekend, and month of year respectively.
kW_{it}	is real power (kW) measured at feeder i at time t.
V_{it}	is voltage (V) measured at feeder i at time t.
$lagged\ kW_{it}$	is real power (kW) measured at feeder i at time $t - 24$.
$lagged\ V_{it}$	is voltage (V) measured at feeder i at time $t - 24$.
VVO_{it}	is an indicator equal to 1 when VVO is engaged for feeder i at time t. β_2 captures the average hourly impact of VVO on real power or voltage while Easton was going through VV On/Off testing.
$Daylight_{it}$	is an indicator equal to 1 when feeder i at time t falls within a daylight hour. The coefficient β_3 captures the average real power or voltage observed during daylight hours when distributed solar facilities are producing electricity.
τ_{wknd}	are fixed effects for a weekday or weekend. The corresponding β_{4wknd} coefficients capture the average daily real power or voltage for a weekday or weekend.
τ_m	are fixed effects for each month m. The corresponding β_{5m} coefficients capture the average monthly real power or voltage for each month while Easton was going through VVO On/Off testing.
$\tau_{wknd,h}$	are hourly fixed effects for each weekday or weekend $wknd$ and each hour of day h combination. The corresponding $\beta_{6wknd,h}$ coefficients

	capture the average real power or voltage for each weekday or weekend and hour of day combination.
τ_h	are hourly fixed effects for each hour of day h. The corresponding β_{7h} coefficients capture the average hourly real power or voltage for each hour while Easton was going through VVO On/Off testing.
$Cloud_{it}$	is a categorical variable denoting hourly cloud cover conditions recorded by NOAA, intended to control for distributed solar generation connected to VVO feeders. Cloud cover multiplied by $Daylight_{it}$ and τ_h forces the regression model to provide an estimate of real power or voltage associated with distributed solar during each daylight hour. The coefficient β_{8h} captures this average real power or voltage observed during daylight hours when distributed solar facilities are producing electricity.
CDH_{it}	are cooling degree-hours (CDH), base 65°F, for feeder i at time t to capture the impacts of temperature on cooling load for each hour of day h. The corresponding coefficients β_{9h} captures the impact of CDH on real power or voltage for each hour of day h.
HDH_{it}	are heating degree-hours (CDH), base 65°F, for feeder i at time t to capture the impacts of temperature on heating load for each hour of day h. The corresponding coefficients β_{10h} captures the impact of HDH on real power or voltage for each hour of day h.
$DR\ Flag_t$	is an indicator equal to 1 when a demand response event occurred at time t. The coefficient β_{17} captures the average hourly impact of VVO on real power or voltage during the demand response events.
ϵ_{it}	is an error term for feeder i at time t and captures unexplained variation in real power or voltage.

B.3 Methodology for Estimating VVO Energy Savings for Feeders that Completed On/Off Testing

For the VVO substations that completed VVO On/Off testing prior to the Spring 2022 – Winter 2022/23 M&V period, Guidehouse did not estimate energy impacts using a regression methodology. Instead, Guidehouse estimated energy impacts using energy impact estimates from the most-recent period (i.e., Spring 2021 – Winter 2021/22) in which the substation conducted VVO On/Off testing. For the Spring 2022 – Winter 2022/23 evaluation period, there was only one National Grid substation that completed VVO On/Off testing, which included 6 feeders.

To estimate energy savings, Guidehouse conducted the following four steps:

1. Calculated average hourly energy demand per feeder and peak energy period (i.e., Summer Peak, Summer Off-Peak, Winter Peak, Winter Off-Peak) while VVO was turned off during the current M&V period (i.e., Spring 2022 – Winter 2022/23)

2. Calculated the total number of hours where VVO was turned on per feeder and peak energy period (i.e., Summer Peak, Summer Off-Peak, Winter Peak, Winter Off-Peak) during the current M&V period (i.e., Spring 2022 – Winter 2022/23)

3. Calculated estimated average hourly energy reductions for each feeder for each peak energy period. This was calculated by taking the product of (a) percent energy reductions estimates per peak energy period from Spring 2021 – Winter 2021/22 (the last period where the feeder conducted VVO On/Off testing), and (b) average hourly energy demand per feeder and peak energy period (i.e., Summer Peak, Summer Off-Peak, Winter Peak, Winter Off-Peak) while VVO was turned off during the current evaluation period (i.e., Spring 2022 – Winter 2022/23).

4. Calculated the weighted average hourly energy reductions per feeder. This weighted average was calculated based on the total number of hours where VVO was turned on per feeder and peak energy period (e.g., Summer Peak, Summer Off-Peak, Winter Peak, Winter Off-Peak) during the current evaluation period (i.e., Spring 2022 – Winter 2022/23).

Once weighted average hourly energy reductions were calculated for each of these feeders, Guidehouse multiplied these values by the total number of hours where VVO was turned on per feeder during the current M&V period (i.e., Spring 2022 – Winter 2022/23) to generate total energy reduction estimates per feeder during the Spring 2022 – Winter 2022/23 M&V period.

B.4 Regression Methodology for Estimating VVO-Related Peak Load Changes

Equation 5-4 summarizes the regression model specification used to estimate peak load as a function of VVO for the feeders that went through VVO On/Off testing during the Spring 2022 – Winter 2022/23 M&V period.

Equation 5-4. Regression Model of Peak Load

$$Peak_{it} = \beta_1 VVO_{it} + \sum_{d=1}^{7} \beta_{2d} * \tau_d + \sum_{h=1}^{24} \beta_{3h} * \tau_h * Cloud_{it} + \beta_4 CDH_{it} + \beta_5 HDH_{it} + \beta_6 DR\ Flag_t + \epsilon_{it}$$

Where:

i, t, h, d	index feeder, time-interval, each of the 24 hours of the day, and day of week respectively.
$Peak\ kW_{it}$	is peak load (kW) measured at feeder i at time t.
VVO_{it}	is an indicator equal to 1 when VVO is engaged for feeder i at time t. The coefficient β_1 captures the average hourly impact of VVO on peak load during the entire analysis period.
τ_d	are fixed effects for each day of the week d. The corresponding β_{2d} coefficients capture the average daily peak load for each day of the week.
τ_h	are hourly fixed effects for each hour h. The corresponding β_{4h} coefficients capture the average hourly peak load across the Spring 2022 – Winter 2022/23 analysis period.
$Cloud_{it}$	is a categorical variable denoting hourly cloud cover conditions recorded by NOAA, intended to control for distributed solar generation connected to VVO feeders. Cloud cover multiplied by τ_h forces the regression model to provide an estimate of peak load associated with distributed solar during each peak load hour of the day. The coefficient β_{3h} captures this average peak load observed during daylight hours when distributed solar facilities are producing electricity.
CDH_{it}	are cooling degree-hours (CDH), base 65°F, for feeder i at time t to capture the impacts of temperature on cooling load. The corresponding coefficient β_4 captures the impact of CDH on peak load.
HDH_{it}	are heating degree-hours (HDH), base 65°F, for feeder i at time t to capture the impacts of temperature on heating load. The corresponding coefficient β_5 captures the impact of HDH on peak load.
$DR\ Flag_t$	is an indicator equal to 1 when a demand response event occurred at time t. The coefficient β_6 captures the average hourly impact of VVO on real power or voltage during the demand response events.
ϵ_{it}	is an error term for feeder i at time t and captures unexplained variation in peak load.

B.5 Methodology for Estimating VVO-Related Peak Load Changes for Feeders that Completed On/Off Testing

For the feeders that did not undergo VVO On/Off testing during the Spring 2022 – Winter 2022/23 evaluation period, Guidehouse calculated estimated peak load changes by taking the product of (a) average hourly energy per feeder during peak load period that occurred Spring 2022 – Winter 2022/23 while VVO was turned off and (b) the estimated percentage reduction in peak load percentage from the last period where the feeder underwent VVO On/Off testing. For the Spring 2022 – Winter 2022/23 evaluation period, there was only one National Grid substation that completed VVO On/Off testing, which included 6 feeders.

B.6 Regression Methodology for Power Factor

Equation 5-5 summarizes the regression model specification used to estimate power factor as a function of VVO for the feeders that went through VVO On/Off testing during the Spring 2022 – Winter 2022/23 M&V period.

Equation 5-5. Regression Model of Power Factor

$$PF_{it} = \beta_1 VVO_{it} + \sum_{d=1}^{7} \beta_{2d} * \tau_d + \sum_{h=1}^{24} \beta_{3h} * \tau_h * Cloud_{it} + \beta_4 HDH_{it} + \beta_5 CDH_{it} + \beta_6 DR\ Flag_t + \epsilon_{it}$$

Where:

i, t, h, d	index feeder, time-interval, each of the 24 hours of the day, and day of week respectively.
PF_{it}	is power factor measured at feeder i at time t.
VVO_{it}	is an indicator equal to 1 when VVO is engaged for feeder i at time t. The coefficient β_1 captures the average hourly impact of VVO on power factor during the entire analysis period.
τ_d	are fixed effects for each day of the week d. The corresponding β_{2d} coefficients capture the average daily power factor for each day of the week.
τ_h	are hourly fixed effects for each hour h. The corresponding β_{3h} coefficients capture the average hourly power factor across the Spring 2022 – Winter 2022/23 analysis period.
$Cloud_{it}$	is a categorical variable denoting hourly cloud cover conditions recorded by NOAA, intended to control for distributed solar generation connected to VVO feeders. Cloud cover multiplied by $Daylight_{it}$ and τ_h forces the regression model to provide an estimate of power factor associated with distributed solar during each daylight hour. The

	coefficient β_{3h} captures this average power factor observed during daylight hours when distributed solar facilities are producing electricity.
HDH_{it}	are heating degree-hours (HDH), base 65°F, for feeder i at time t to capture the impacts of temperature on heating load. The corresponding coefficient β_4 captures the impact of HDH on power factor.
CDH_{it}	are cooling degree-hours (CDH), base 65°F, for feeder i at time t to capture the impacts of temperature on cooling load. The corresponding coefficient β_5 captures the impact of CDH on power factor.
$DR\ Flag_t$	is an indicator equal to 1 when a demand response event occurred at time t. The coefficient β_6 captures the average hourly impact of VVO on power factor during the demand response events.
ϵ_{it}	is an error term for feeder i at time t and captures unexplained variation in power factor.

B.7 Methodology for Estimating VVO-Related Power Factor Changes for Feeders that Completed On/Off Testing

For the feeders that did not go through VVO On/Off testing during the Spring 2022 – Winter 2022/23 evaluation period, Guidehouse leveraged the estimates for power factor change from the last period where the feeder went through VVO On/Off testing. Power factor change estimates provided last year were interpreted as the average hourly impact of VVO on power factor for each feeder. Given that power factor is not affected based on the number of hours when VVO is On, the results from when the feeder underwent VVO On/Off testing applied to when the feeder completes VVO On/Off testing as well. For the Spring 2022 – Winter 2022/23 evaluation period, there was only one National Grid substation that completed VVO On/Off testing, which included 6 feeders.

B.8 Distribution Losses Methodology

Guidehouse evaluated change in distribution losses as a function of VVO during the Spring 2022 – Winter 2022/23 M&V period. To estimate the impact of VVO on feeder-level distribution losses, Guidehouse used a distribution losses equation for each individual feeder.[67] Equation 5-6 summarizes the equation used to estimate the change in distribution losses as a function of VVO for the VVO feeders that went through VVO On/Off testing during the Spring 2022 – Winter 2022/23 M&V period.

Equation 5-6. Distribution Losses Equation

$$\%\ Loss\ Reduction = 100 - 100\left(\frac{PF_{VVO\ Off}}{PF_{VVO\ On}}\right)^2$$

[67] https://www.nepsi.com/resources/calculators/loss-reduction-with-power-factor-correction.htm

Where:

$PF_{VVO\ Off}$	Power factor when VVO is in the disengaged state.
$PF_{VVO\ On}$	Power factor when VVO is in the engaged state.

B.9 Methodology for Estimating VVO-Related Distribution Loss Changes for Feeders that Completed On/Off Testing

For the feeders that did not undergo VVO On/Off testing during the Spring 2022 – Winter 2022/23 evaluation period, Guidehouse leveraged the estimates for distribution losses change from the last period where the feeder went through VVO On/Off testing. Given that distribution losses estimates provided were in percentage terms, the metric is unitless and is not affected based on the number of hours when VVO is On. As such, the results from when the feeder went through VVO On/Off testing can be applied to when the feeder completes VVO On/Off testing as well. For the Spring 2022 – Winter 2022/23 evaluation period, there was only one National Grid substation that completed VVO On/Off testing, which included 6 feeders.

B.10 Overall Data Attrition from Data Cleaning

The tables in this section provide a detailed summary of data attrition from cleaning steps applied to analysis datasets. Detailed data attrition results are provided separately by EDC and substation.

B.10.1 Eversource

Table B-1. Count of Quarter-Hours Remaining by Data Cleaning Step for Agawam

Data Cleaning Step	16C11	16C12	16C14	16C15	16C16	16C17	16C18
Initial Dataset (Spring 2022 – Winter 2022/23)	**35,040**	**35,040**	**35,040**	**35,040**	**35,040**	**35,040**	**35,040**
1. Remove Long Events	4,629	4,629	6,756	6,756	6,756	6,755	6,755
2. Remove Interpolated	6,460	1,398	1,050	1,089	1,093	890	886
3. Remove Repeated	2,789	844	487	541	442	178	204
4. Remove Outliers	982	654	308	358	295	620	421
Final Dataset	20,180	27,515	26,439	26,296	26,454	26,597	26,774
Observations Removed	**14,860**	**7,525**	**8,601**	**8,744**	**8,586**	**8,443**	**8,266**

Source: Guidehouse analysis

Table B-2. Count of VVO On, VVO Off, and Removed Quarter-Hours for Agawam

Number of Quarter-Hours	16C11	16C12	16C14	16C15	16C16	16C17	16C18
VVO On *Weekday*	7,076	9,302	9,142	9,104	9,178	9,185	9,333
VVO On *Weekend*	2,889	3,769	3,984	3,980	3,960	4,059	4,050
VVO Off *Weekday*	7,473	10,722	9,845	9,766	9,875	9,844	9,974
VVO Off *Weekend*	2,741	3,721	3,467	3,445	3,440	3,508	3,416
Removed	14,860	7,525	8,601	8,744	8,586	8,443	8,266
Spring 2022 – Winter 2022/23 Total	35,040	35,040	35,040	35,040	35,040	35,040	35,040

Source: Guidehouse analysis

Table B-3. Count of Quarter-Hours Remaining by Data Cleaning Step for Piper

Data Cleaning Step	21N4	21N5	21N6	21N7	21N8	21N9
Initial Dataset (Spring 2022 – Winter 2022/23)	**35,040**	**35,040**	**35,040**	**35,040**	**35,040**	**35,040**
1. Remove Long Events	1,912	1,912	1,912	1,912	1,912	1,912
2. Remove Interpolated	950	7,216	796	924	832	1,537
3. Remove Repeated	316	1,708	189	273	156	880
4. Remove Outlier	534	596	242	1,897	179	15,742
Final Dataset	31,328	23,608	31,901	30,034	31,961	14,969
Observations Removed	**3,712**	**11,432**	**3,139**	**5,006**	**3,079**	**20,071**

Source: Guidehouse analysis

Table B-4. Count of VVO On, VVO Off, and Removed Quarter-Hours for Piper

Number of Quarter-Hours	21N4	21N5	21N6	21N7	21N8	21N9
VVO On *Weekday*	11,016	8,607	11,183	10,978	11,211	5,220
VVO On *Weekend*	4,823	3,778	4,921	4,574	4,914	2,350
VVO Off *Weekday*	11,322	8,292	11,473	10,559	11,530	5,570
VVO Off *Weekend*	4,167	2,931	4,324	3,923	4,306	1,829
Removed	3,712	11,432	3,139	5,006	3,079	20,071
Spring 2022 – Winter 2022/23 Total	35,040	35,040	35,040	35,040	35,040	35,040

Source: Guidehouse analysis

Table B-5. Count of Quarter-Hours Remaining by Data Cleaning Step for Podick

Data Cleaning Step	18G2	18G2	18G4	18G5	18G6	18G7	18G8
Initial Dataset (Spring 2022 – Winter 2022/23)	**35,040**	**35,040**	**35,040**	**35,040**	**35,040**	**35,040**	**35,040**
1. Remove Long Events	0	0	0	0	0	0	0
2. Remove Interpolated	8,448	8,448	8,448	8,448	8,769	8,769	8,769
3. Remove Repeated	4,557	1,727	956	1,357	6,277	1,651	545
4. Remove Outliers	2,942	920	361	676	3,667	781	256
Final Dataset	18,822	23,352	24,688	23,931	15,810	23,010	21,511
Observations Removed	**16,218**	**11,688**	**10,352**	**11,109**	**19,230**	**12,030**	**13,529**

Source: Guidehouse analysis

Table B-6. Count of VVO On, VVO Off, and Removed Quarter-Hours for Podick

Number of Quarter-Hours	18G2	18G3	18G4	18G5	18G6	18G7	18G8
VVO On *Weekday*	6,903	8,561	8,951	8,702	5,809	8,659	7,787
VVO On *Weekend*	3,143	3,834	4,123	3,977	2,622	3,751	3,452
VVO Off *Weekday*	6,415	8,006	8,387	8,133	5,049	7,532	7,346
VVO Off *Weekend*	2,361	2,951	3,227	3,119	2,330	3,068	2,926
Removed	16,218	11,688	10,352	11,109	19,230	12,030	13,529
Spring 2022 – Winter 2022/23 Total	35,040	35,040	35,040	35,040	35,040	35,040	35,040

Source: Guidehouse analysis

Table B-7. Count of Quarter-Hours Remaining by Data Cleaning Step for Silver

Data Cleaning Step	30A1	30A2	30A3	30A4	30A5	30A6
Initial Dataset (Spring 2022 – Winter 2022/23)	**35,040**	**35,040**	**35,040**	**35,040**	**35,040**	**35,040**
1. Remove Missing VVO Status	0	0	0	0	0	0
2. Remove Long Events	14,147	3,564	14,147	3,564	14,147	3,564
3. Remove Interpolated	5,843	5,507	8,371	6,415	1,133	7,576
4. Remove Repeated	567	1,151	1,501	274	663	1,253
5. Remove Outliers	243	611	119	635	884	799
Final Dataset	**14,240**	**24,207**	**10,902**	**24,152**	**18,213**	**21,848**
Observations Removed	**20,800**	**10,833**	**24,138**	**10,888**	**16,827**	**13,192**

Source: Guidehouse analysis

Table B-8. Count of VVO On, VVO Off, and Removed Quarter-Hours for Silver

Number of Quarter-Hours	30A1	30A2	30A3	30A4	30A5	30A6
VVO On *Weekday*	4,660	8,150	3,396	8,025	6,051	7,144
VVO On *Weekend*	1,934	3,512	1,606	3,250	2,600	3,136
VVO Off *Weekday*	5,608	9,264	4,516	9,467	7,129	8,447
VVO Off *Weekend*	2,038	3,281	1,384	3,410	2,433	3,121
Removed	20,800	10,833	24,138	10,888	16,827	13,192
Spring 2022 – Winter 2022/23 Total	35,040	35,040	35,040	35,040	35,040	35,040

Source: Guidehouse analysis

B.10.2 National Grid

Table B-9. Count of Hours Remaining by Data Cleaning Step for Easton

Data Cleaning Step	92W43	92W44	92W54	92W78	92W79
Initial Dataset (Spring 2022 – Winter 2022/23)	**1,152**	**1,152**	**1,152**	**1,152**	**1,152**
1. Remove Missing VVO Status	0	0	0	0	0
2. Remove Long Events	661	661	661	661	661
3. Remove Interpolated	1	1	1	1	1
4. Remove Repeated	0	0	0	0	0
5. Remove Outliers	0	0	0	0	0
Final Dataset	490	490	490	490	490
Observations Removed	**662**	**662**	**662**	**662**	**662**

Source: Guidehouse analysis

Table B-10. Count of VVO On, VVO Off, and Removed Hours for Easton

Number of Hours	92W43	92W44	92W54	92W78	92W79
VVO On *Weekday*	159	159	159	159	159
VVO On *Weekend*	96	96	96	96	96
VVO Off *Weekday*	235	235	235	235	235
VVO Off *Weekend*	0	0	0	0	0
Removed	662	662	662	662	662
Spring 2022 – Winter 2022/23 Total	1,152	1,152	1,152	1,152	1,152

Source: Guidehouse analysis

Table B-11. Count of Hours Remaining by Data Cleaning Step for East Bridgewater

Data Cleaning Step	797W1	797W19	797W20	797W23	797W24	797W29	797W42
Initial Dataset (Spring 2022 – Winter 2022/23)	**8,760**	**8,760**	**8,760**	**8,760**	**8,760**	**8,760**	**8,760**
1. Remove Missing VVO Status	2,670	2,670	2,670	2,670	2,670	2,670	2,670
2. Remove Long Events	3,502	3,363	3,363	3,502	3,363	3,502	3,502
3. Remove Interpolated	0	53	53	0	53	0	0
4. Remove Repeated	0	0	0	0	0	0	0
5. Remove Outliers	0	0	0	0	0	0	0
Final Dataset	2,588	2,674	2,674	2,588	2,674	2,588	2,588
Observations Removed	6,172	6,086	6,086	6,172	6,086	6,172	6,172

Source: Guidehouse analysis

Table B-12. Count of VVO On, VVO Off, and Removed Hours for East Bridgewater

Number of Hours	797W1	797W19	797W20	797W23	797W24	797W29	797W42
VVO On *Weekday*	968	1,012	1,012	968	1,012	968	968
VVO On *Weekend*	310	311	311	310	311	310	310
VVO Off *Weekday*	969	1,045	1,045	969	1,045	969	967
VVO Off *Weekend*	341	306	306	341	306	341	343
Removed	**6,172**	**6,086**	**6,086**	**6,172**	**6,086**	**6,172**	**6,172**
Spring 2022 – Winter 2022/23 Total	8,760	8,760	8,760	8,760	8,760	8,760	8,760

Source: Guidehouse analysis

Table B-13. Count of Hours Remaining by Data Cleaning Step for East Methuen

Data Cleaning Step	74L1	74L2	74L3	74L4	74L5	74L6
Initial Dataset (Spring 2022 – Winter 22/23)	**8,760**	**8,760**	**8,760**	**8,760**	**8,760**	**8,760**
1. Remove Missing VVO Status	2,670	2,670	2,670	2,670	2,670	2,670
2. Remove Long Events	2,005	2,155	2,005	2,155	2,005	2,155
3. Remove Interpolated	28	16	28	16	28	16
4. Remove Repeated	3	3	3	3	3	3
5. Remove Outliers	0	0	0	0	0	0
Final Dataset	4,054	3,916	4,054	3,916	4,054	3,916
Observations Removed	**4,706**	**4,844**	**4,706**	**4,844**	**4,706**	**4,844**

Source: Guidehouse analysis

Table B-14. Count of VVO On, VVO Off, and Removed Hours for East Methuen

Number of Hours	74L1	74L2	74L3	74L4	74L5	74L6
VVO On *Weekday*	1,789	1,529	1,789	1,529	1,789	1,529
VVO On *Weekend*	573	479	573	479	573	479
VVO Off *Weekday*	1,268	1,441	1,268	1,441	1,268	1,441
VVO Off *Weekend*	424	467	424	467	424	467
Removed	4,706	4,844	4,706	4,844	4,706	4,844
Spring 2022 – Winter 2022/23 Total	8,760	8,760	8,760	8,760	8,760	8,760

Source: Guidehouse analysis

Table B-15. Count of Hours Remaining by Data Cleaning Step for Maplewood

Data Cleaning Step	16W1	16W2	16W3	16W4	16W5	16W6	16W7	16W8
Initial Dataset (Spring 2022 – Winter 2022/23)	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760
1. Remove Missing VVO Status	2,670	2,670	2,670	2,670	2,670	2,670	2,670	2,670
2. Remove Long and Short Events	3,778	5,583	3,778	5,583	3,778	5,583	3,778	5,583
3. Remove Interpolated	0	0	0	0	0	0	91	0
4. Remove Repeated	0	0	0	0	0	0	2	0
5. Remove Outliers	0	0	0	0	0	0	0	0
Final Dataset	2,312	507	2,312	507	2,312	507	2,219	507
Observations Removed	**6,448**	**8,253**	**6,448**	**8,253**	**6,448**	**8,253**	**6,541**	**8,253**

Source: Guidehouse analysis

Table B-16. Count of VVO On, VVO Off, and Removed Hours for Maplewood

Number of Hours	16W1	16W2	16W3	16W4	16W5	16W6	16W7	16W8
VVO On *Weekday*	947	128	947	128	947	128	923	128
VVO On *Weekend*	228	24	228	24	228	24	204	24
VVO Off *Weekday*	885	331	885	331	885	331	864	331
VVO Off *Weekend*	252	24	252	24	252	24	228	24
Removed	6,448	8,253	6,448	8,253	6,448	8,253	6,541	8,253
Spring 2022 – Winter 2022/23 Total	**8,760**	**8,760**	**8,760**	**8,760**	**8,760**	**8,760**	**8,760**	**8,760**

Source: Guidehouse analysis

Table B-17. Count of Hours Remaining by Data Cleaning Step for West Salem

Data Cleaning Step	29W1	29W2	29W3	29W4	29W5	29W6
Initial Dataset (Spring 2022 – Winter 2022/23)	6,576	6,576	6,576	6,576	6,576	6,576
1. Remove Missing VVO Status	2,831	2,838	2,833	2,833	2,829	2,797
2. Remove Long Events	1,387	1,102	1,294	1,181	1,464	2,194
3. Remove Interpolated	0	0	1	1	1	1
4. Remove Repeated	0	0	1	0	0	0
5. Remove Outliers	0	0	0	0	0	0
Final Dataset	2,358	2,636	2,449	2,562	2,283	1,585
Observations Removed	**4,218**	**3,940**	**4,127**	**4,014**	**4,293**	**4,991**

Source: Guidehouse analysis

Table B-18. Count of VVO On, VVO Off, and Removed Hours for West Salem

Number of Hours	29W1	29W2	29W3	29W4	29W5	29W6
VVO On *Weekday*	879	982	898	970	856	604
VVO On *Weekend*	230	276	276	253	277	148
VVO Off *Weekday*	1,056	1,139	1,059	1,123	980	755
VVO Off *Weekend*	193	239	216	216	170	78
Removed	4,218	3,940	4,127	4,014	4,293	4,991
Spring 2022 – Winter 2022/23 Total	**6,576**	**6,576**	**6,576**	**6,576**	**6,576**	**6,576**

Source: Guidehouse analysis

B.11 Detailed Performance Metrics Results

This section details feeder-specific performance metrics estimates for the Spring 2022 – Winter 2022/23 period by VVO feeder. Results are provided separately by EDC.

B.11.1 Eversource

Table B-19. Eversource Performance Metrics Results by Feeder

Feeder	Energy Baseline (MWh)	Net Energy Reduction (MWh)* †	Voltage Reduction (V)	CVRf	Peak Load Reduction (kW)	Distribution Loss Reduction (%)	Power Factor Change	GHG Reductions (CO2) †
16C11	7,502	16 ± 5	2.58 ± 0.03	0.9	-24 ± 31	--	-	5 ± 2
16C12	24,627	34 ± 7	2.27 ± 0.02	0.7	98 ± 47	0.94	0.004 ± 0.001	12 ± 2
16C14	22,558	23 ± 5	1.41 ± 0.02	0.8	135 ± 31	-	-	8 ± 2
16C15	19,560	14 ± 3	1.4 ± 0.02	0.5	-13 ± 21	-0.49	-0.002 ± <0.001	5 ± 1
16C16	35,182	21 ± 7	1.42 ± 0.02	0.5	-169 ± 99	0.07	<0.001 ± <0.001	7 ± 3
16C17	24,679	41 ± 8	1.42 ± 0.02	1.3	-138 ± 133	-0.2	-0.001 ± <0.001	14 ± 3
16C18	19,286	10 ± 5	1.43 ± 0.02	0.4	-133 ± 52	-	-	3 ± 2
18G2	2,990	-4 ± 1	0.25 ± 0.03	-5.2	-12 ± 7	-0.01	<0.001 ± 0.001	-1 ± 0
18G3	17,621	-4 ± 7	0.16 ± 0.02	-1.3	27 ± 121	-0.04	<0.001 ± <0.001	-1 ± 2
18G4	13,742	-11 ± 14	0.16 ± 0.02	-5.3	137 ± 170	-	-	-4 ± 5
18G5	15,869	-1 ± 13	0.16 ± 0.02	-0.3	-4 ± 176	-	-	0 ± 5
18G6	16,257	-5 ± 14	0.58 ± 0.05	-0.6	-8 ± 121	-	-	-2 ± 5
18G7	10,485	-5 ± 20	0.35 ± 0.03	-1.4	-425 ± 283	-0.11	-0.001 ± <0.001	-2 ± 7
18G8	29,110	-37 ± 22	0.37 ± 0.03	-3.7	-172 ± 168	0.23	0.001 ± <0.001	-12 ± 8
21N4	19,606	23 ± 6	2.71 ± 0.03	0.5	-56 ± 72	-	-	8 ± 2
21N5	32,160	10 ± 2	2.95 ± 0.03	0.1	207 ± 74	-	-	3 ± 1
21N6	16,074	16 ± 3	2.92 ± 0.03	0.4	17 ± 42	-0.37	-0.002 ± <0.001	5 ± 1
21N7	29,070	-4 ± 8	2.92 ± 0.03	0	-38 ± 34	-0.16	-0.001 ± 0.003	-1 ± 3
21N8	38,995	26 ± 7	2.92 ± 0.03	0.2	33 ± 46	-0.08	<0.001 ± 0.001	9 ± 2
21N9	24,009	22 ± 5	3.07 ± 0.05	0.3	-100 ± 58	-	-	7 ± 2

Feeder	Energy Baseline (MWh)	Net Energy Reduction (MWh)* †	Voltage Reduction (V)	CVRf	Peak Load Reduction (kW)	Distribution Loss Reduction (%)	Power Factor Change	GHG Reductions (CO2) †
30A1	26,590	26 ± 19	0.84 ± 0.03	1.3	-137 ± 59	-	-	9 ± 6
30A2	12,956	14 ± 4	0.14 ± 0.02	8.2	-49 ± 56	-	-	5 ± 1
30A3	19,086	37 ± 24	1.11 ± 0.36	1.9	-92 ± 464	-	-	13 ± 8
30A4	16,111	-11 ± 9	0.15 ± 0.02	-4.8	-232 ± 91	0.04	<0.001 ± <0.001	-4 ± 3
30A5	4,544	6 ± 2	0.73 ± 0.02	1.9	0 ± 0	-	-	2 ± 1
30A6	26,324	-14 ± 5	0.16 ± 0.02	-3.4	-286 ± 580	-	-	-5 ± 2
Overall*	524,992	879 ± 184	1.52 ± 0.01	-0.18	-1,435 ± 903	0.01%	<0.001± <0.001	299 ± 63

* Overall energy savings is the sum of each feeder's energy savings, and due to model noise, a manual sum of savings across periods may not equal the amount provided in the Total row. Overall voltage reductions and CVR factors provided are load-weighted averages of these estimates provided for each feeder. Aggregate CVRf value presented here is the load-weighted average of every feeder-specific CVRf estimate for which there was enough data to estimate CVRf. This differs from the inclusion criteria applied to aggregate CVRf values presented in *Table* Table 79 and Table 94. Similarly, aggregate peak load reduction is the load-weighted average of every feeder-specific peak load reduction estimate for which there was enough data to estimate peak load reduction. This differs from the inclusion criteria applied to aggregate peak load reduction values presented in *Table* Table 80 and Table 95.
† Calculation uses actual number of VVO On hours spanning the analysis period. Actual VVO On Hours are the number of hours VVO was engaged between March 1, 2022 and February 28, 2023.

Source: Guidehouse analysis

B.11.2 National Grid

Table B-20. National Grid Performance Metrics Results by Feeder*

Feeder	Energy Baseline (MWh)	Net Energy Reduction (MWh)†‡	Voltage Reduction (kV)	CVRf	Peak Load Reduction (kW)	Distribution Loss Reduction (%)	Power Factor Change	GHG Reductions (CO2)‡
16W1	30,699	-4 ± 24	0.05 ± <0.001	-0.3	-302 ± 334	-	-	-1 ± 8
16W3	31,288	-48 ± 22	0.05 ± <0.001	-3.5	-193 ± 220	-	-	-16 ± 7
16W5	19,329	-5 ± 15	0.05 ± <0.001	-0.6	-197 ± 200	-	-	-2 ± 5
16W7	35,103	-17 ± 25	0.05 ± 0.01	-1.1	-582 ± 388	-	-	-6 ± 9
29W1	37,577	-53 ± 35	0.02 ± 0.01	-7	-494 ± 378	-	-	-18 ± 12
29W2	19,272	29 ± 24	<0.001 ± <0.001	-40	-236 ± 218	-	-	10 ± 8
29W3	41,240	82 ± 26	0.03 ± 0.01	7.6	-99 ± 271	-	-	28 ± 9
29W4	30,585	87 ± 27	<0.001 ± <0.001	-90	-240 ± 250	-	-	29 ± 9
29W5	38,941	89 ± 34	0.04 ± 0.01	7.8	182 ± 305	-	-	30 ± 12
29W6	28,225	73 ± 28	-0.01 ± 0.01	-28.1	50 ± 194	-	-	25 ± 10
74L1	35,699	92 ± 32	0.34 ± 0.01	0.9	-156 ± 415	-	-	31 ± 11
74L2	22,748	11 ± 17	0.13 ± 0.01	0.5	-53 ± 129	-	-	4 ± 6
74L3	25,622	50 ± 20	0.34 ± 0.01	0.7	-100 ± 225	-	-	17 ± 7
74L4	28,739	16 ± 20	0.13 ± 0.01	0.5	-139 ± 135	-	-	6 ± 7
74L5	25,151	38 ± 19	0.34 ± 0.01	0.5	-220 ± 300	-	-	13 ± 6
74L6	21,148	31 ± 15	0.13 ± 0.01	1.3	-35 ± 94	-	-	10 ± 5
797W1	29,904	47 ± 47	-0.01 ± <0.001	-15	-	-	-	16 ± 16
797W19	26,886	27 ± 27	0.1 ± 0.01	1.3	69 ± 368	-	-	9 ± 9
797W20	40,544	106 ± 33	0.1 ± 0.01	3.3	151 ± 230	-	-	36 ± 11
797W23	28,363	-11 ± 27	-0.01 ± <0.001	3.6	-	-	-	-4 ± 9
797W24	34,820	21 ± 34	0.1 ± 0.01	0.8	215 ± 318	-	-	7 ± 12
797W29	25,735	26 ± 27	-0.01 ± <0.001	-9.5	-	-	-	9 ± 9
797W42	11,706	8 ± 16	-0.01 ± <0.001	-6.9	-	-	-	3 ± 6
913W17	12,900	9 ± 12	-	-	9 ± 103	-	-	3 ± 4
913W18	12,851	16 ± 9	-	-	-18 ± 73	-1.6	-0.008 ± 0.003	5 ± 3

Feeder	Energy Baseline (MWh)	Net Energy Reduction (MWh)†‡	Voltage Reduction (kV)	CVRf	Peak Load Reduction (kW)	Distribution Loss Reduction (%)	Power Factor Change	GHG Reductions (CO2)‡
913W43	13,940	15 ± 16	-	-	-55 ± 134	-	-	5 ± 5
913W47	15,213	14 ± 11	-	-	-51 ± 89	-1.2	-0.006 ± 0.002	5 ± 4
913W67	5,523	4 ± 6	-	-	-18 ± 50	-	-	1 ± 2
913W69	23,391	14 ± 20	-	-	-102 ± 164	-2.7	-0.013 ± 0.007	5 ± 7
92W43	26,146	122 ± 42	0.25 ± 0.02	2.1	-	-	-	41 ± 14
92W44	36,938	95 ± 43	0.25 ± 0.02	1.2	-	-	-	32 ± 15
92W54	24,153	250 ± 124	0.25 ± 0.02	4.6	-	-	-	85 ± 42
Overall†	882,631	1,867 ± 302	0.08 ± <0.001	-6.64	-2,615 ± 1,234	-1.95	-0.01 ± 0.002	645 ± 103

* A value of "-" for any one season has been provided for feeders without sufficient data in that specific season.

† Overall energy savings is the sum of each feeder's energy savings, and due to model noise, a manual sum of savings across periods may not equal the amount provided in the Total row. Overall voltage reductions and CVR factors provided are load-weighted averages of these estimates provided for each feeder. Aggregate CVRf value presented here is the load-weighted average of every feeder-specific CVRf value for which there was enough data to estimate CVRf. This differs from the inclusion criteria applied to aggregate CVRf values presented in Table and Table 94. Similarly, aggregate peak load reduction is the load-weighted average of every feeder-specific peak load reduction estimate for which there was enough data to estimate peak load reduction. This differs from the inclusion criteria applied to aggregate peak load reduction values presented in Table and Table 95.

‡ Calculation uses actual number of VVO On hours spanning the analysis period. Actual VVO On Hours are the number of hours VVO was engaged between March 1, 2022 and February 28, 2023.

Source: Guidehouse analysis

B.12 Feeder MW Percent of Peak MVA

This section details feeder-specific comparisons of feeder demand in the clean analysis data and feeder annual peak MVA. Each table details each feeder's average demand during the entire analysis period, average demand during the summer peak period,[68] and annual peak MVA.[69] The average feeder demand during the entire analysis period and during the summer peak period are then compared to annual peak MVA by taking the ratio of these values to annual peak MVA. Results are provided separately by EDC.

B.12.1 Eversource

Table B-21. Eversource Feeder MW Percent of Peak MVA by Feeder

Feeder	Average MW (Spring 2022 – Winter 2022/23†)	Average MW (Summer Peak‡)	Annual Peak MVA¶	Average MW Percent of Peak MVA (Spring 2022 – Winter 2022/23)	Average MW Percent of Peak MVA (Summer Peak)
16C11	0.84	1.33	5.8	14%	23%
16C12	2.80	3.15	4.4	64%	72%
16C14	2.56	3.90	6.3	41%	62%
16C15	2.22	3.05	4.1	54%	74%
16C16	4.00	4.70	7.4	54%	64%
16C17	2.79	3.90	7.0	40%	56%
16C18	2.19	2.97	6.3	35%	47%
18G2	0.34	0.33	0.5	68%	66%
18G3	2.01	1.77	4.0	50%	44%
18G4	1.58	-0.15	4.7	34%	-3%
18G5	1.81	0.75	5.8	31%	13%
18G6	1.85	1.53	5.0	37%	31%
18G7	1.19	-1.26	4.5	26%	-28%
18G8	3.33	2.07	7.5	44%	28%
21N4	2.23	3.61	6.8	33%	53%
21N5	3.67	4.18	8.4	44%	50%
21N6	1.83	3.07	4.3	43%	71%
21N7	3.32	4.11	4.8	69%	86%
21N8	4.44	5.67	6.8	65%	83%
21N9	2.73	3.41	6.4	43%	53%
30A1	3.03	3.75	6.8	45%	55%
30A2	1.47	1.52	8.8	17%	17%
30A3	2.16	3.35	7.8	28%	43%

[68] Summer peak is defined in this evaluation as 1:00 p.m. to 5:00 p.m. ET from June 1 to August 31 on non-holiday weekdays.

[69] Annual peak MVA was drawn from 2022 GMP Term Report, Appendix 1 filed April 24, 2023.

Feeder	Average MW (Spring 2022 – Winter 2022/23†)	Average MW (Summer Peak‡)	Annual Peak MVA¶	Average MW Percent of Peak MVA (Spring 2022 – Winter 2022/23)	Average MW Percent of Peak MVA (Summer Peak)
30A4	1.84	4.17	4.6	40%	91%
30A5	0.52	0.48	4.4	12%	11%
30A6	3.01	2.72	5.5	55%	49%

† Calculations are based off of clean analysis data.
‡ Summer peak is defined in this evaluation as 1:00 p.m. to 5:00 p.m. ET from June 1 to August 31 on non-holiday weekdays.
¶ Annual peak MVA was drawn from 2022 GMP Term Report, Appendix 1 filed April 24, 2023.
Source: Guidehouse analysis

B.12.2 National Grid

Table B-22. National Grid Feeder MW Percent of Peak MVA by Feeder

Feeder	Average MW (Spring 2022 – Winter 2022/23*)	Average MW (Summer Peak†)	Annual Peak MVA‡	Average MW Percent of Peak MVA (Spring 2022 – Winter 2022/23)	Average MW Percent of Peak MVA (Summer Peak)
16W1	3.58	4.66	9.6	37%	49%
16W2	3.76	-	8.6	44%	-
16W3	3.65	4.83	7.6	48%	64%
16W4	2.57	-	9.2	28%	-
16W5	2.27	3.37	5.7	40%	59%
16W6	4.82	-	14.3	34%	-
16W7	4.13	-	10.9	38%	-
16W8	3.55	-	9.6	37%	-
29W1	4.30	4.70	10.7	40%	44%
29W2	2.19	2.89	6.0	37%	48%
29W3	4.68	5.36	10.3	45%	52%
29W4	3.43	3.60	8.2	42%	44%
29W5	4.43	4.36	10.5	42%	42%
29W6	3.18	4.09	6.8	47%	60%
74L1	4.11	5.59	12.1	34%	46%
74L2	2.60	3.95	6.7	39%	59%
74L3	2.94	3.63	8.2	36%	44%
74L4	3.29	4.20	6.6	50%	64%
74L5	2.91	4.49	10.7	27%	42%
74L6	2.42	3.00	5.0	48%	60%
797W1	3.45	3.72	10.4	33%	36%
797W19	3.10	3.91	8.3	37%	47%
797W20	4.63	6.80	9.7	48%	70%
797W23	3.30	4.20	9.7	34%	43%

Feeder	Average MW (Spring 2022 – Winter 2022/23*)	Average MW (Summer Peak†)	Annual Peak MVA‡	Average MW Percent of Peak MVA (Spring 2022 – Winter 2022/23)	Average MW Percent of Peak MVA (Summer Peak)
797W24	3.98	5.11	9.7	41%	53%
797W29	2.98	3.70	8.3	36%	45%
797W42	1.35	1.78	8.3	16%	21%
913W17	2.06	2.60	5.5	37%	47%
913W18	2.07	2.69	4.6	45%	58%
913W43	2.28	3.38	7.1	32%	48%
913W47	2.48	3.41	5.8	43%	59%
913W67	0.90	1.22	3.0	30%	41%
913W69	3.82	5.64	9.9	39%	57%
92W43	3.03	-	7.1	39%	-
92W44	4.23	-	9.0	43%	-
92W54	2.78	-	7.3	47%	-
92W78	2.39	-	7.9	38%	-
92W79	2.48	-	6.4	30%	-

† Calculations are based off of clean analysis data.
‡ Summer peak is defined by ISO-NE as 1:00 p.m. to 5:00 p.m. ET from June 1 to August 31 on non-holiday weekdays.
¶ Annual peak MVA was drawn from 2022 GMP Term Report, Appendix 1 filed April 24, 2023.
Source: Guidehouse analysis

B.13 VVO Energy Savings and Voltage Reductions by Season

At the request of Eversource, in this section Guidehouse provides energy savings and voltage reductions attributed to VVO for each season from Spring 2022 through Winter 2022/23. Each table provides the energy savings and voltage reductions, and the associated 90 percent confidence bounds. A value of “-“ for any one season has been provided for feeders without sufficient data in that specific season. Estimates are provided by feeder for Eversource and National Grid separately.

B.13.1 Eversource

Table B-23. Eversource Energy Savings by Feeder and Season

Feeder*	Spring 2022		Summer 2022		Fall 2022		Winter 2022/23	
	MWh†‡	%¶	MWh†‡	%¶	MWh†‡	%¶	MWh†‡	%¶
16C11	6.9 ± 8.9	1.5 ± 1.9	23.9 ± 8.4	2.2 ± 0.8	-15.2 ± 8.0	-1.8 ± 0.9	54.6 ± 9.9	7.8 ± 1.4
16C12	-34.3 ± 11.7	-1.8 ± 0.6	46.8 ± 14.9	1.6 ± 0.5	85.8 ± 14.1	2.9 ± 0.5	29.4 ± 14.2	1.0 ± 0.5
16C14	16.5 ± 5.4	1.7 ± 0.6	65.1 ± 9.2	2.2 ± 0.3	-12.9 ± 9.7	-0.5 ± 0.4	15.8 ± 8.9	0.6 ± 0.3
16C15	7.6 ± 3.1	0.9 ± 0.4	25.9 ± 5.2	1.0 ± 0.2	9.2 ± 5.5	0.4 ± 0.2	7.8 ± 5.0	0.3 ± 0.2
16C16	-7.6 ± 8.6	-0.7 ± 0.8	42.8 ± 14.7	1.0 ± 0.3	-2.5 ± 15.8	-0.1 ± 0.3	44.5 ± 14.4	0.9 ± 0.3
16C17	-27.4 ± 9.8	-3.1 ± 1.1	58.1 ± 16.7	1.7 ± 0.5	-3.4 ± 17.7	-0.1 ± 0.6	123.8 ± 16.7	3.8 ± 0.5
16C18	4.9 ± 5.3	0.7 ± 0.7	36.2 ± 8.9	1.3 ± 0.3	-4.8 ± 9.4	-0.2 ± 0.4	1.6 ± 8.7	0.1 ± 0.3
18G2	-3.7 ± 1.6	-0.9 ± 0.4	6.1 ± 1.8	2.9 ± 0.8	-7.2 ± 1.8	-2.5 ± 0.6	-7.4 ± 1.8	-2.3 ± 0.6
18G3	-18.9 ± 12.5	-0.9 ± 0.6	73.3 ± 13.2	5.2 ± 0.9	-22.4 ± 12.3	-1.3 ± 0.7	-23.4 ± 13.1	-1.0 ± 0.6
18G4	-27.2 ± 25.8	-1.9 ± 1.8	100.8 ± 24.7	11.2 ± 2.7	-58.5 ± 24.9	-4.3 ± 1.8	-37.7 ± 26.8	-1.7 ± 1.2
18G5	-38.3 ± 24.9	-2.2 ± 1.4	100.3 ± 23.7	7.1 ± 1.7	-64.5 ± 24.4	-4.4 ± 1.7	18.3 ± 26.1	0.8 ± 1.2
18G6	-42.6 ± 23.7	-2.3 ± 1.3	11.9 ± 22.5	0.6 ± 1.2	0.4 ± 29.2	0.0 ± 1.8	27.9 ± 28.6	2.0 ± 2.1
18G7	-14.2 ± 35.4	-1.5 ± 3.6	60.6 ± 37.4	5.8 ± 3.6	-49.0 ± 34.5	-5.0 ± 3.5	-7.5 ± 34	-0.5 ± 2.2
18G8	-99.6 ± 38.7	-2.6 ± 1.0	110.9 ± 38.1	3.2 ± 1.1	-73.2 ± 37.7	-2.6 ± 1.4	-	-
21N4	-4.4 ± 12.1	-0.2 ± 0.6	69.8 ± 12.3	2.3 ± 0.4	4.6 ± 12.9	0.2 ± 0.6	31.7 ± 12.2	1.3 ± 0.5
21N5	1.0 ± 4.7	0.0 ± 0.1	81.3 ± 6.2	2.2 ± 0.2	-4.6 ± 5.1	-0.1 ± 0.1	-4.8 ± 4.4	-0.1 ± 0.1
21N6	12.8 ± 6.8	0.7 ± 0.4	43.6 ± 7.0	1.9 ± 0.3	-7.4 ± 7.3	-0.4 ± 0.4	19.2 ± 6.8	1.0 ± 0.3
21N7	8.9 ± 17.1	0.3 ± 0.5	24.8 ± 16.9	0.7 ± 0.5	-91.8 ± 17.9	-2.6 ± 0.5	45.1 ± 18.4	1.2 ± 0.5
21N8	38.9 ± 13.9	0.8 ± 0.3	62.8 ± 14.1	1.3 ± 0.3	9.6 ± 14.9	0.2 ± 0.3	0.2 ± 13.9	0.0 ± 0.3
21N9	6.2 ± 13.5	0.2 ± 0.5	76.8 ± 10.2	2.5 ± 0.3	-20.1 ± 11.7	-0.7 ± 0.4	13.1 ± 12.3	0.4 ± 0.4

Feeder*	Spring 2022		Summer 2022		Fall 2022		Winter 2022/23	
	MWh†‡	%¶	MWh†‡	%¶	MWh†‡	%¶	MWh†‡	%¶
30A1	-	-	10.7 ± 26.8	0.3 ± 0.8	47.3 ± 25.0	1.9 ± 1.0	-103.9 ± 66.7	-5.4 ± 3.5
30A2	9.9 ± 8.1	1.1 ± 0.9	63.0 ± 9.7	4.3 ± 0.7	-3.7 ± 7.6	-0.2 ± 0.4	2.3 ± 6.2	0.1 ± 0.4
30A3	-	-	22.6 ± 122	1.4 ± 7.5	-64.3 ± 28.5	-3.9 ± 1.7	191.0 ± 30.2	9.5 ± 1.5
30A4	-51.2 ± 16.2	-3.1 ± 1.0	16.6 ± 16.6	0.6 ± 0.6	-20.4 ± 14.9	-1.6 ± 1.2	131.9 ± 38.9	11.5 ± 3.4
30A5	-	-	-0.7 ± 2.4	-0.2 ± 0.6	7.3 ± 2.4	1.5 ± 0.5	7.8 ± 1.9	2.0 ± 0.5
30A6	-26.4 ± 9.5	-0.9 ± 0.3	22.7 ± 15.3	0.8 ± 0.5	-29.4 ± 9.6	-1.0 ± 0.3	1.1 ± 8.1	0.0 ± 0.3
Overall*	-282 ± 81	-0.6 ± 0.2	1,257 ± 151	2.1 ± 0.3	-391 ± 93	-0.7 ± 0.2	582 ± 11	1.1 ± 0.3

† Total energy savings provided for each period is the sum of each feeder's energy savings within that period. Due to model noise, a manual sum of savings across periods may not equal the amount provided in the Total row.
‡ Calculation uses actual number of VVO On hours spanning the analysis period. Actual VVO On Hours are the number of hours VVO was engaged in the raw analysis data between March 1, 2022 and February 28, 2023.
¶ Percentage energy savings provided for each period is the load-weighted average of percentage savings estimated for each feeder.
Estimates with a "-" represent a feeder/season for which there was not enough useable data to estimate impacts.
Source: Guidehouse analysis

Table B-24. Eversource Voltage Reductions by Feeder and Season*

Feeder	Spring 2022		Summer 2022		Fall 2022		Winter 2022	
	V	%	V	%	V	%	V	%
16C11	0.00 ± 0.08	0.00 ± 0.07	2.64 ± 0.05	2.14 ± 0.04	2.87 ± 0.05	2.32 ± 0.04	3.44 ± 0.07	2.80 ± 0.05
16C12	-0.03 ± 0.05	-0.02 ± 0.04	2.55 ± 0.05	2.06 ± 0.04	2.78 ± 0.04	2.24 ± 0.03	2.99 ± 0.05	2.42 ± 0.04
16C14	1.84 ± 0.07	1.49 ± 0.06	1.80 ± 0.05	1.45 ± 0.04	0.93 ± 0.04	0.75 ± 0.04	1.41 ± 0.05	1.14 ± 0.04
16C15	1.82 ± 0.07	1.47 ± 0.06	1.81 ± 0.05	1.46 ± 0.04	0.92 ± 0.04	0.74 ± 0.03	1.39 ± 0.04	1.12 ± 0.04
16C16	1.86 ± 0.07	1.50 ± 0.06	1.81 ± 0.05	1.47 ± 0.04	0.92 ± 0.04	0.74 ± 0.03	1.40 ± 0.04	1.13 ± 0.04
16C17	1.85 ± 0.07	1.50 ± 0.06	1.82 ± 0.05	1.47 ± 0.04	0.90 ± 0.04	0.73 ± 0.03	1.45 ± 0.05	1.17 ± 0.04
16C18	1.83 ± 0.07	1.48 ± 0.06	1.83 ± 0.05	1.48 ± 0.04	0.93 ± 0.04	0.76 ± 0.03	1.41 ± 0.04	1.15 ± 0.04
18G2	-0.01 ± 0.05	0.00 ± 0.04	1.48 ± 0.09	1.23 ± 0.07	0.12 ± 0.07	0.10 ± 0.06	-0.01 ± 0.07	-0.01 ± 0.06
18G3	0.01 ± 0.03	0.01 ± 0.03	1.05 ± 0.05	0.87 ± 0.04	0.03 ± 0.04	0.02 ± 0.03	-0.03 ± 0.04	-0.02 ± 0.03
18G4	0.01 ± 0.03	0.01 ± 0.03	0.89 ± 0.05	0.74 ± 0.04	0.02 ± 0.04	0.01 ± 0.03	-0.02 ± 0.04	-0.02 ± 0.03
18G5	0.00 ± 0.03	0.00 ± 0.03	0.88 ± 0.05	0.73 ± 0.04	0.03 ± 0.04	0.03 ± 0.03	-0.01 ± 0.04	-0.01 ± 0.03
18G6	0.09 ± 0.08	0.07 ± 0.07	1.58 ± 0.09	1.28 ± 0.07	0.10 ± 0.13	0.08 ± 0.10	0.03 ± 0.19	0.02 ± 0.15
18G7	0.06 ± 0.04	0.05 ± 0.04	1.26 ± 0.05	1.01 ± 0.04	0.01 ± 0.05	0.01 ± 0.04	0.09 ± 0.08	0.07 ± 0.06
18G8	0.07 ± 0.05	0.06 ± 0.04	1.06 ± 0.05	0.86 ± 0.04	0.01 ± 0.05	0.01 ± 0.04	-	-
21N4	2.51 ± 0.05	2.03 ± 0.04	2.48 ± 0.06	2.01 ± 0.05	2.65 ± 0.05	2.14 ± 0.04	3.18 ± 0.06	2.58 ± 0.05
21N5	2.73 ± 0.06	2.22 ± 0.05	3.31 ± 0.08	2.71 ± 0.07	2.75 ± 0.06	2.24 ± 0.05	3.15 ± 0.06	2.57 ± 0.05
21N6	2.69 ± 0.05	2.18 ± 0.04	2.75 ± 0.05	2.23 ± 0.04	3.01 ± 0.05	2.44 ± 0.04	3.22 ± 0.05	2.61 ± 0.04
21N7	2.67 ± 0.05	2.16 ± 0.04	2.73 ± 0.06	2.22 ± 0.04	3.01 ± 0.05	2.43 ± 0.04	3.30 ± 0.06	2.68 ± 0.05
21N8	2.71 ± 0.05	2.20 ± 0.04	2.73 ± 0.05	2.21 ± 0.04	3.00 ± 0.05	2.43 ± 0.04	3.21 ± 0.05	2.60 ± 0.04
21N9	3.00 ± 0.11	2.43 ± 0.09	3.01 ± 0.09	2.44 ± 0.07	3.13 ± 0.09	2.53 ± 0.07	3.14 ± 0.10	2.55 ± 0.08
30A1	-	-	0.58 ± 0.04	0.47 ± 0.03	0.99 ± 0.03	0.80 ± 0.03	1.54 ± 0.15	1.25 ± 0.12
30A2	0.07 ± 0.03	0.06 ± 0.02	0.37 ± 0.04	0.30 ± 0.03	0.12 ± 0.03	0.10 ± 0.03	0.08 ± 0.03	0.07 ± 0.03
30A3	-	-	2.81 ± 1.96	3.39 ± 2.37	1.08 ± 0.41	0.89 ± 0.34	0.80 ± 0.71	0.65 ± 0.58
30A4	0.08 ± 0.03	0.06 ± 0.02	0.27 ± 0.03	0.22 ± 0.03	0.12 ± 0.03	0.10 ± 0.03	0.15 ± 0.1	0.12 ± 0.08
30A5	-	-	0.57 ± 0.04	0.46 ± 0.03	1.05 ± 0.04	0.85 ± 0.03	0.43 ± 0.05	0.35 ± 0.04
30A6	0.08 ± 0.03	0.07 ± 0.03	0.53 ± 0.06	0.43 ± 0.05	0.18 ± 0.04	0.15 ± 0.03	0.07 ± 0.04	0.06 ± 0.03
Overall*	1.43 ± 0.01	1.16 ± 0.01	1.85 ± 0.05	1.40 ± 0.02	1.13 ± 0.01	1.53 ± 0.07	1.57 ± 0.02	1.28 ± 0.03

* Overall kV and percent voltage savings provided for each period is the load-weighted average of kV and percent savings estimated for each feeder.
Estimates with a "-" represent a feeder/season for which there was not enough useable data to estimate impacts.
Source: Guidehouse analysis

B.13.2 National Grid

Table B-25. National Grid Energy Savings by Feeder and Season

Feeder	Spring 2022		Summer 2022		Fall 2022		Winter 2022/23	
	MWh*†	%	MWh*†	%	MWh*†	%	MWh*†	%
16W1	-18.2 ± 18.7	-1.0 ± 1.0	35.8 ± 13.7	3.8 ± 1.4	-31.7 ± 13.1	-7.7 ± 3.2	1.6 ± 11.9	0.2 ± 1.2
16W3	-35.9 ± 17.0	-1.9 ± 0.9	23.8 ± 12.5	2.6 ± 1.4	-34.7 ± 11.9	-7.8 ± 2.7	-16.7 ± 10.8	-1.6 ± 1.1
16W5	-20.3 ± 11.4	-1.8 ± 1.0	21.9 ± 8.4	3.6 ± 1.4	-11.6 ± 8.0	-3.9 ± 2.7	1.1 ± 7.3	0.2 ± 1.1
16W7	-33.2 ± 20.1	-1.6 ± 1.0	29.0 ± 13.9	2.5 ± 1.2	-22.4 ± 13.3	-4.2 ± 2.5	-0.1 ± 12.3	0.0 ± 1.1
29W1	**West Salem did not undergo testing in Spring 2022**		-94.7 ± 22.7	-5.4 ± 1.3	34.6 ± 21.0	4.4 ± 2.7	9.1 ± 57.4	0.2 ± 1.1
29W2			-35.3 ± 21.3	-2.7 ± 1.6	27.5 ± 15.9	6.5 ± 3.8	98.0 ± 43.1	3.8 ± 1.7
29W3			33.0 ± 19.9	1.4 ± 0.8	46.4 ± 14.9	5.3 ± 1.7	53.3 ± 41.4	1.0 ± 0.8
29W4			6.1 ± 22.5	0.3 ± 1.2	55.6 ± 17.4	8.5 ± 2.6	115.5 ± 47.4	2.6 ± 1.1
29W5			53.9 ± 26.4	2.1 ± 1.0	33.3 ± 18.9	3.8 ± 2.1	38.2 ± 49.9	1.0 ± 1.3
29W6			17.7 ± 15.0	1.4 ± 1.2	16.1 ± 11.8	2.6 ± 1.9	70.9 ± 34.3	3.6 ± 1.7
74L1	40.9 ± 43.4	1.3 ± 1.3	40.2 ± 27.0	1.9 ± 1.3	96.9 ± 24.6	9.7 ± 2.5	64.7 ± 91.8	1.1 ± 1.6
74L2	-37.2 ± 28.5	-1.5 ± 1.1	34.9 ± 19.2	1.7 ± 0.9	17.7 ± 13.4	3.4 ± 2.6	-7.3 ± 67.5	-0.2 ± 1.5
74L3	23.7 ± 27.4	1.0 ± 1.2	33.7 ± 17	2.4 ± 1.2	51.4 ± 15.5	8.3 ± 2.5	10.1 ± 57.9	0.2 ± 1.3
74L4	-25.4 ± 34.6	-0.8 ± 1.0	1.2 ± 23.3	0.0 ± 0.9	59.8 ± 16.3	8.2 ± 2.2	-15.4 ± 81.8	-0.3 ± 1.6
74L5	-5.4 ± 25.3	-0.2 ± 1.1	36.3 ± 15.7	2.3 ± 1.0	46.3 ± 14.3	7.5 ± 2.3	9.7 ± 53.5	0.2 ± 1.3
74L6	5.7 ± 25.9	0.2 ± 1.1	28.6 ± 17.4	1.5 ± 0.9	33.8 ± 12.2	6.4 ± 2.3	-6.2 ± 61.4	-0.1 ± 1.4
797W1	-12.3 ± 49.1	-0.5 ± 2.0	17.8 ± 25.8	4.2 ± 6.1	28.5 ± 23.1	5.2 ± 4.2	88.5 ± 104.7	1.6 ± 1.9
797W19	53.6 ± 34.2	2.5 ± 1.6	-12.8 ± 18.5	-1.2 ± 1.7	30.5 ± 15.2	5.4 ± 2.7	-18.9 ± 24.9	-1.1 ± 1.4
797W20	166.0 ± 41.7	4.8 ± 1.2	19.7 ± 22.6	1.2 ± 1.3	21.2 ± 18.5	2.4 ± 2.1	1.2 ± 30.4	0.1 ± 1.3
797W23	15.4 ± 28.1	0.6 ± 1.1	8.0 ± 14.7	1.8 ± 3.4	9.4 ± 13.2	1.9 ± 2.6	-166.5 ± 60.1	-3.8 ± 1.4
797W24	28.8 ± 42.8	1.0 ± 1.5	-2.5 ± 23.1	-0.2 ± 1.6	40.9 ± 19.0	5.8 ± 2.7	-38.2 ± 31.2	-1.8 ± 1.5
797W29	16.6 ± 27.7	0.8 ± 1.3	14.0 ± 14.5	3.6 ± 3.7	17.2 ± 13.0	3.6 ± 2.7	-46.2 ± 59.1	-1.1 ± 1.4
797W42	6.4 ± 16.9	0.7 ± 1.8	6.5 ± 8.9	3.5 ± 4.7	2.4 ± 7.9	1.2 ± 4.0	-9.9 ± 36.1	-0.5 ± 1.8
92W43	**Easton did not undergo testing in Spring – Fall 2022**						48.6 ± 16.8	3.8 ± 1.3
92W44							38.0 ± 17.2	2.2 ± 1.0
92W54							100.1 ± 49.6	8.3 ± 4.1

Feeder	Spring 2022		Summer 2022		Fall 2022		Winter 2022/23	
	MWh*†	%	MWh*†	%	MWh*†	%	MWh*†	%
92W78							43.2 ± 13.8	4.2 ± 1.3
92W79							66.7 ± 33.8	6.3 ± 3.2
Overall*	169 ± 127	0.4 ± 0.3	317 ± 92	1.4 ± 0.4	569 ± 76	3.3 ± 0.6	533 ± 263	0.9 ± 0.3

* Total energy savings provided for each period is the sum of each feeder's energy savings within that period. Due to model noise, a manual sum of savings across periods may not equal the amount provided in the Total row.
† Calculation uses actual number of VVO On hours spanning the analysis period for each feeder. Actual VVO On Hours are the number of hours VVO was engaged in the raw analysis data during each feeder's testing period within the Spring 2022 – Winter 2023 evaluation period.

Source: Guidehouse analysis

Table B-26. National Grid Voltage Reductions by Feeder and Season

Feeder	Spring 2022		Summer 2022		Fall 2022		Winter 2022/23	
	kV	%	kV	%	kV	%	kV	%
16W1	0.03 ± 0.01	0.24 ± 0.04	0.03 ± 0.01	0.21 ± 0.09	0.02 ± 0.02	0.18 ± 0.13	0.13 ± 0.01	0.90 ± 0.07
16W3	0.03 ± 0.01	0.24 ± 0.04	0.03 ± 0.01	0.20 ± 0.09	0.02 ± 0.02	0.17 ± 0.13	0.13 ± 0.01	0.89 ± 0.07
16W5	0.03 ± 0.01	0.24 ± 0.04	0.03 ± 0.01	0.20 ± 0.09	0.02 ± 0.02	0.17 ± 0.13	0.13 ± 0.01	0.90 ± 0.07
16W7	0.03 ± 0.01	0.25 ± 0.05	0.03 ± 0.01	0.21 ± 0.09	0.02 ± 0.02	0.17 ± 0.13	0.12 ± 0.01	0.88 ± 0.07
29W1	**West Salem did not undergo testing in Spring 2022**		0.03 ± 0.01	0.20 ± 0.06	0.04 ± 0.02	0.29 ± 0.11	0.02 ± 0.01	0.12 ± 0.05
29W2			0.00 ± 0.01	0.02 ± 0.05	-0.02 ± 0.01	-0.12 ± 0.09	-0.01 ± 0.01	-0.05 ± 0.05
29W3			0.02 ± 0.01	0.16 ± 0.07	0.09 ± 0.02	0.64 ± 0.12	0.02 ± 0.01	0.15 ± 0.06
29W4			0.01 ± 0.01	0.04 ± 0.06	-0.02 ± 0.01	-0.13 ± 0.10	-0.01 ± 0.01	-0.05 ± 0.05
29W5			0.03 ± 0.01	0.20 ± 0.06	0.07 ± 0.02	0.53 ± 0.12	0.03 ± 0.01	0.19 ± 0.09
29W6			0.01 ± 0.01	0.04 ± 0.08	-0.02 ± 0.01	-0.12 ± 0.11	-0.03 ± 0.01	-0.24 ± 0.11
74L1	0.34 ± 0.01	2.54 ± 0.08	0.40 ± 0.02	2.93 ± 0.12	0.30 ± 0.02	2.19 ± 0.18	0.31 ± 0.02	2.30 ± 0.12
74L2	0.13 ± 0.01	0.97 ± 0.05	0.12 ± 0.01	0.92 ± 0.05	0.13 ± 0.01	0.93 ± 0.10	0.12 ± 0.01	0.88 ± 0.07
74L3	0.34 ± 0.01	2.54 ± 0.08	0.40 ± 0.02	2.93 ± 0.12	0.30 ± 0.02	2.19 ± 0.18	0.31 ± 0.02	2.30 ± 0.12
74L4	0.13 ± 0.01	0.97 ± 0.05	0.12 ± 0.01	0.92 ± 0.05	0.13 ± 0.01	0.93 ± 0.10	0.12 ± 0.01	0.88 ± 0.07
74L5	0.34 ± 0.01	2.54 ± 0.08	0.40 ± 0.02	2.93 ± 0.12	0.30 ± 0.02	2.19 ± 0.18	0.31 ± 0.02	2.30 ± 0.12
74L6	0.13 ± 0.01	0.97 ± 0.05	0.12 ± 0.01	0.92 ± 0.05	0.13 ± 0.01	0.93 ± 0.10	0.12 ± 0.01	0.88 ± 0.07
797W1	-0.03 ± 0.01	-0.20 ± 0.04	-0.08 ± 0.02	-0.53 ± 0.17	-0.03 ± 0.01	-0.23 ± 0.10	0.05 ± 0.01	0.37 ± 0.06
797W19	0.15 ± 0.01	1.05 ± 0.07	0.05 ± 0.01	0.35 ± 0.09	0.11 ± 0.02	0.81 ± 0.12	0.07 ± 0.01	0.47 ± 0.08
797W20	0.15 ± 0.01	1.05 ± 0.07	0.05 ± 0.01	0.35 ± 0.09	0.12 ± 0.02	0.81 ± 0.12	0.07 ± 0.01	0.47 ± 0.08
797W23	-0.03 ± 0.01	-0.20 ± 0.04	-0.08 ± 0.02	-0.54 ± 0.17	-0.03 ± 0.01	-0.23 ± 0.10	0.05 ± 0.01	0.37 ± 0.06
797W24	0.15 ± 0.01	1.05 ± 0.07	0.05 ± 0.01	0.35 ± 0.09	0.11 ± 0.02	0.81 ± 0.12	0.07 ± 0.01	0.47 ± 0.08
797W29	-0.03 ± 0.01	-0.21 ± 0.04	-0.08 ± 0.02	-0.54 ± 0.17	-0.03 ± 0.01	-0.23 ± 0.10	0.05 ± 0.01	0.37 ± 0.06
797W42	-0.03 ± 0.01	-0.21 ± 0.04	-0.07 ± 0.02	-0.53 ± 0.17	-0.03 ± 0.01	-0.23 ± 0.10	0.05 ± 0.01	0.37 ± 0.06
92W43	**Easton did not undergo testing in Spring – Fall 2022**						0.25 ± 0.02	1.81 ± 0.14
92W44							0.25 ± 0.02	1.80 ± 0.14
92W54							0.25 ± 0.02	1.81 ± 0.14
92W78							0.25 ± 0.02	1.81 ± 0.14

Feeder	Spring 2022		Summer 2022		Fall 2022		Winter 2022/23	
	kV	%	kV	%	kV	%	kV	%
92W79							0.26 ± 0.02	1.81 ± 0.14
Overall*	0.12 ± 0.00	0.84 ± 0.02	0.56 ± 0.02	0.22 ± 0.01	0.08 ± 0.00	0.58 ± 0.03	0.12 ± 0.00	0.86 ± 0.02

* kV and percent voltage savings provided for each period is the load-weighted average of kV and percent savings estimated for each feeder.
Source: Guidehouse analysis

B.14 Seasonal Data Attrition from Data Cleaning

This section details data attrition from data cleaning for each season from Spring 2022 through Winter 2022/23. Tables provide the number of observations received, then the observations remaining after data cleaning by season and by feeder. Tables are provided separately by EDC.

B.14.1 Eversource

Table B-27. Eversource Data Attrition by Feeder and Season

	Spring 2022		Summer 2022		Fall 2022		Winter 2022/23	
Feeder	Obs* Received	Obs Remaining	Obs Received	Obs Remaining	Obs Received	Obs Remaining	Obs Received	Obs Remaining
16C11	8,828	2,544	8,832	5,907	8,736	6,890	8,640	4,835
16C12	8,828	5,014	8,832	6,803	8,736	7,843	8,640	7,851
16C14	8,828	3,131	8,832	7,029	8,736	8,215	8,640	8,060
16C15	8,828	3,020	8,832	7,064	8,736	8,162	8,640	8,046
16C16	8,828	3,144	8,832	7,118	8,736	8,142	8,640	8,046
16C17	8,829	3,167	8,832	7,195	8,736	8,378	8,640	7,853
16C18	8,829	3,150	8,832	7,143	8,736	8,324	8,640	8,153
18G2	8,828	6,847	8,832	3,141	8,736	4,328	8,640	4,502
18G3	8,828	8,102	8,832	3,557	8,736	5,862	8,640	5,827
18G4	8,828	8,246	8,832	4,290	8,736	6,102	8,640	6,046
18G5	8,828	8,069	8,832	4,189	8,736	5,863	8,640	5,806
18G6	8,828	6,222	8,832	5,679	8,736	2,573	8,640	1,332
18G7	8,828	8,018	8,832	5,655	8,736	5,908	8,640	3,425
18G8	8,828	8,341	8,832	6,689	8,736	6,106	8,640	0
21N4	8,828	8,142	8,832	7,201	8,736	7,959	8,640	8,022
21N5	8,828	6,528	8,832	3,513	8,736	6,296	8,640	7,267
21N6	8,828	8,338	8,832	7,239	8,736	8,015	8,640	8,305
21N7	8,828	7,945	8,832	7,225	8,736	7,918	8,640	6,942
21N8	8,828	8,361	8,832	7,325	8,736	8,022	8,640	8,249
21N9	8,829	2,823	8,832	4,535	8,736	4,116	8,640	3,491
30A1	0	0	8,832	5,714	8,736	8,097	8,640	425
30A2	8,828	7,338	8,832	4,491	8,736	6,012	8,640	6,362
30A3	0	0	8,832	726	8,736	7,475	8,640	2,697
30A4	8,828	8,498	8,832	7,156	8,736	7,416	8,640	1,078
30A5	0	0	8,832	5,913	8,736	7,606	8,640	4,690
30A6	8,828	7,707	8,832	2,744	8,736	5,723	8,640	5,670

* Refers to observations
Source: Guidehouse analysis

B.14.2 National Grid

Table B-28. National Grid Data Attrition by Feeder and Season

	Spring 2022		Summer 2022		Fall 2022		Winter 2022/23	
Feeder	Hours Received	Hours Remaining	Hours Received	Hours Remaining	Hours Received	Hours Remaining	Hours Received	Hours Remaining
16W1	2,208	1,167	2,208	406	2,185	199	2,160	540
16W2	2,208	60	1,777	0	1,337	0	2,160	447
16W3	2,208	1,167	2,208	406	2,185	199	2,160	540
16W4	2,208	60	1,777	0	1,337	0	2,160	447
16W5	2,208	1,167	2,208	406	2,185	199	2,160	540
16W6	2,208	60	1,777	0	1,337	0	2,160	447
16W7	2,208	1,074	2,208	406	2,185	199	2,160	540
16W8	2,208	60	1,777	0	1,337	0	2,160	447
29W1	0	0	2,208	835	2,185	374	2,160	1,149
29W2	0	0	2,208	1,085	2,184	415	2,160	1,136
29W3	0	0	2,208	952	2,186	359	2,160	1,138
29W4	0	0	2,208	998	2,184	415	2,160	1,149
29W5	0	0	2,208	1,178	2,184	413	2,160	692
29W6	0	0	2,208	714	2,185	414	2,160	457
74L1	2,208	1,578	2,208	811	2,185	382	2,160	1,283
74L2	2,208	1,568	2,208	1,310	2,185	381	2,160	657
74L3	2,208	1,578	2,208	811	2,185	382	2,160	1,283
74L4	2,208	1,568	2,208	1,310	2,185	381	2,160	657
74L5	2,208	1,578	2,208	811	2,185	382	2,160	1,283
74L6	2,208	1,568	2,208	1,310	2,185	381	2,160	657
797W1	2,208	1,429	2,208	168	2,185	360	2,160	631
797W19	2,208	939	2,208	641	2,185	381	2,160	713
797W20	2,208	939	2,208	641	2,185	381	2,160	713
797W23	2,208	1,429	2,208	168	2,185	360	2,160	631
797W24	2,208	939	2,208	641	2,185	381	2,160	713
797W29	2,208	1,429	2,208	168	2,185	360	2,160	631
797W42	2,208	1,429	2,208	168	2,185	360	2,160	631
92W43	0	0	0	0	0	0	1,152	490
92W44	0	0	0	0	0	0	1,152	490
92W54	0	0	0	0	0	0	1,152	490
92W78	0	0	0	0	0	0	1,152	490
92W79	0	0	0	0	0	0	1,152	490

Source: Guidehouse analysis