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April 1, 2020

Mark D. Marini, Secretary
Department of Public Utilities
One South Station, 5th Floor
Boston, MA 02110

Re: Petition of Massachusetts Electric Company and Nantucket Electric Company, d/b/a National Grid (D.P.U. 15-120), Fitchburg Gas and Electric Light Company d/b/a Unitil (D.P.U. 15-121), and NSTAR Electric Company d/b/a Eversource Energy (D.P.U. 15-122) for Approval by the Department of Public Utilities of Grid Modernization Plans

Dear Secretary Marini:

On behalf of Massachusetts Electric Company and Nantucket Electric Company, each d/b/a National Grid ("National Grid"), Fitchburg Gas and Electric Light Company d/b/a Unitil ("Unitil"), and NSTAR Electric Company d/b/a Eversource Energy ("Eversource") (together the "Companies"), attached please find the Revised Stage 3 Plans for the Grid Modernization Evaluation and the 2019 Grid Modernization Evaluation Report produced by Navigant, a Guidehouse Company, in the above-referenced proceeding.

Sincerely,

Danielle C. Winter

Danielle C. Winter, Esq.

Enclosures

cc: Tina Chin, Hearing Officer
Daniel Licata, Hearing Officer
Greggory Wade, Hearing Officer
D.P.U. 15-120/15-121/15-122 Service Lists

NAVIGANT
A Guidehouse Company

MA Grid Modernization Evaluation

Prepared for:

Massachusetts Electric Distribution Companies

Submitted by:
Navigant, a Guidehouse Company
77 South Bedford Street
Suite 400
Burlington, MA 01803

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guidehouse.com

Reference No.: 209941
March 30, 2020

NAVIGANT
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NAVIGANT
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Study #1 – Monitoring & Control Evaluation Plan

Stage 3 Plan

Prepared for:

Massachusetts Electric Distribution Companies

Submitted by:
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1. INTRODUCTION

The Massachusetts Electric Distribution Companies (EDCs) are making investments in monitoring and control (M&C) on their distribution networks to enable greater levels of automation and to improve reliability. Department preauthorized investment in the M&C investment area are expected to total $49.8M over 2018 to 2020, including $41.0M for Eversource, $8.0M for National Grid, and $750k for Unitil.

1.1 Overall Study Goals

This plan will evaluate the progress and effectiveness of the DPU preauthorized M&C investments for each EDC towards meeting the DPU's grid modernization objectives. Evaluation will focus on the first objective: "(1) optimize system performance by attaining optimal levels of grid visibility, command and control…" Evaluation will also consider the other two objectives: "(2) optimize system demand" and "(3) interconnect and integrate distributed energy resources," given that M&C is a fundamental *enabling* technology for these objectives.

1.2 Research Questions

The research questions and evaluations will be performed on the M&C investments to determine the effectiveness of the M&C equipment to improve reliability and accomplish the DPU grid modernization objectives.

Table 1. Research Questions

Research Questions	IM	PM
1) Are the EDCs progressing in deployment of their M&C investments according to their Grid Modernization Plans?	✓	
2) What factors, if any, are affecting the deployment schedule of M&C equipment?	✓	
3) What is the cost of deploying various types of M&C equipment, including SCADA retrofits, line monitors, microprocessor relays, etc.?	✓	
4) What is the effect of M&C investments on reliability and key reliability metrics, such as SAIDI and SAIFI?		✓

1.3 Evaluation Metrics

Evaluation will leverage the infrastructure metrics and EDC *Stamped Approved* Performance Metrics (PMs) shown in the table below.[1] The Infrastructure Metrics (IMs) are designed to measure the deployment progress against the EDC deployment goals. The Performance Metrics (PMs) intend to measure accurately the improvements in reliability that can be attributed to M&C investments. Navigant will collect data from the EDCs to perform the evaluation. The type of data to be collected is described in **Section 2** below. As part of the evaluation process, Navigant will develop data collection forms in consultation with the EDCs that will be aligned with the metrics calculations and reporting formats defined

[1] DPU Stamp Approved Performance Metrics, July 25, 2019

by the DPU. The forms will be collected semi-annually, and the data will be reported on a per feeder or per substation basis, as appropriate.

In addition, we will work with the EDCs to establish a common definition to assess the "level-of-complete" across their M&C investments, leading up to in-service dates for the various technologies and assets that are part of each EDC investment (see **Section 6** for definitions).

Table 2. Evaluation Metrics

Metric Type	M&C Evaluation Metrics	ES	NG	UTL
IM	System Automation Saturation	✓	✓	✓
IM	Number/Percentage of Circuits with Installed Sensors	✓	✓	✓
IM	Number of Devices Deployed and In-Service*	✓	✓	✓
	Engineering Complete -- Number of Devices			
	Design Complete -- Number of Devices			
	Construction Complete -- Number of Devices			
IM	Cost for Deployment	✓	✓	✓
IM	Deviation Between Actual and Planned Deployment for the Plan Year	✓	✓	✓
IM	Projected Deployment for the Remainder of the Three-Year Term	✓	✓	✓
PM	Grid Modernization Investments' Effect on Outage Duration	✓	✓	✓
PM	Grid Modernization investments' Effect on Outage Frequency	✓	✓	✓
PM	Protective Zone: Average Zone Size per Circuit	✓**		
PM	Customer Minutes of Outage Saved per Circuit			✓
PM	Main Line Customer Minutes of Interruption Saved		✓**	
PM	Case Studies to illustrate how reliability is being improved	✓	✓	✓

IM – infrastructure metric, PM – performance metric.
Bolded metric type field indicates metric is included in the DPU's Stamped, Approved Performance Metrics Order.
*Definitions of the "level-of-complete" stages can be found in Section 6.
** Indicates that metric is focused on ADA investment area, but will be assessed for applicability to M&C given the DPU's interest in understanding how impacts of ADA and M&C might be separately measured.

2. METHODOLOGY

The evaluation will consist of the following major tasks:

- Task 1: Develop Stage 3 Plan includes preparing the evaluation plan (this document) and working with the EDCs to develop a uniform approach to defining the IMs and PMs and the associated baseline.[2]
- Task 2: Collect and Review Data will include agreeing a format for sharing data and semi-annual discussions about the status of the M&C investments.[3]
- Task 3: Complete Analysis includes analyzing the information and synthesizing the feedback from the EDCs from Task 2. We will share our observations in presentations focused on the key findings.
- Task 4: Prepare Evaluation Reports includes a written Draft and Final Reports covering infrastructure metrics and Navigant/Guidehouse assessment of how the investments are proceeding relative to plan, as well as performance metrics and how/if the investments are delivering against the Department's grid modernization objectives.

The Evaluation Team's approach to each task is described in the sub-sections below.

2.1 Task 1. Develop Stage 3 Plan

Navigant/Guidehouse worked with the EDCs to develop the initial, detailed evaluation plan to addressed evaluation requirements for the M&C investment area.

Key activities include:

- Understand planned schedule and investments for each EDC
- Discuss infrastructure and performance metrics
- Understand and accommodate data availability
- Agree on overall evaluation scope, schedule, and budget
- Confirm allocation across EDCs
- Understand the timing and availability of data need for M&C evaluation

Subsequent to the development of the initial Stage 3 Plan, Navigant/Guidehouse worked with the EDCs to adapt this Stage 3 plan to accommodate the schedule of availability for circuit reliability data and to add

[2] Note that this document is an update to the initial Stage 3 Evaluation Plan, which was filed on May 1, 2019, and it incorporates updates based on the Departments Stamped-Approved Performance Metrics, as well as changes necessary to accommodate updates to the EDC deployment schedules and data availability.

[3] The EDCs worked with Navigant/Guidehouse on an initial data collection format and template, which was used to collect evaluation data for the first half of the 2019 program year. Subsequently, the EDCs worked with Navigant/Guidehouse to update the data collection format and template to make the evaluation data collection more efficient and streamlined. This updated template is being used to collect the additional data for the second half of the 2019 program year.

case studies to the Performance Metrics analysis to facilitate better understanding of the impacts of the investments on customer reliability.

Deliverables:

- Initial Stage 3 Evaluation Plan
- Revised Stage 3 Evaluation Plan (this document)[4]

2.2 Task 2. Collect and Review Data

Task 2 consists of collection of evaluation metrics from the EDCs, preliminary data validation, and communication of data collection status. Completion of Task 2 deliverables is contingent upon the on-time delivery of completed data request forms. Data validation will ensure the reported data complies with the metric definitions laid out in the Stage 3 Evaluation Plan, and that the data makes logical sense when compared to the baseline, prior report submissions, and the deployment plan. Anomalous data will be flagged and discussed with EDC personnel.

Navigant provided the EDCs with a Data Request Form that detailed the information required to perform the analysis and evaluation. Navigant is requesting to receive data on a semi-annual basis. In the first half of the year, the completed data request was developed to include any available prior activity and investments. The initial semi-annual data, collected in July 2019, was used to test the data collection process and initially assess the annual results. In the course of this data collection activity, it was determined that a more efficient and detailed data request format could help streamline the data collection process and make it more efficient for future semi-annual data collection activities. Navigant/Guidehouse successfully used this updated data request format to collect data for the 2019 program year in January 2020.

After the review and discussion of the collected data in each semi-annual period, Navigant will share a brief memo reviewing data and observations. A sample of some of the expected data includes:

1. Projected quantities and types of M&C devices to be installed by circuit and substation.
2. Estimated and approved cost for each M&C device to be installed.
3. The number of customers for whom the M&C equipment will improve reliability (customers that benefit)
4. For years 2015, 2016 and 2017, on a circuit level: AVERAGE (‘CKAIDI 2015’+’ CKAIDI Year 2016’+’ CKAIDI Year 2017’) = baseline ‘CKAIDI. EDCs to calculate and provide value.
5. For years 2015, 2016, and 2017, on a circuit level: AVERAGE (‘CKAIFI Year 2015’+’ CKAIFI Year 2016’+’ CKAIFI Year 2017’) = baseline ‘CKAIFI. EDCs to calculate and provide value.
6. CKAIDI for evaluation year n. EDCs to calculate and provide value.
7. CKAIFI for evaluation year n. EDCs to calculate and provide value.
8. *Case study* information such as one-line diagram of the investment circuit, description of reliability improvement example with explanation of the mechanisms employed to achieve the reliability improvement. Case studies will examine the operation and/or use of the M&C technology and

[4] This update is based on learnings from the first year of evaluation, and specifically the timing of availability of circuit level reliability data.

explain in narrative form how they have addressed reliability and efficiency goals. Approximately three case studies will be targeted per EDC to illustrate the range of operations.

9. Engineering Completed date for each M&C device
10. Design Completed date for each M&C device
11. Construction Completed date for each M&C device
12. In service date for each M&C device.
13. Actual final cost to install each M&C device
14. Reason for deviation in schedule and cost between actual and planned deployment for the plan year

We anticipate the EDCs completing and sharing the Data Request Form and files with Navigant. Navigant will have a call with each EDC to review the data provided. Navigant assumes the EDCs will provide complete and accurate information. After the review and discussion, Navigant will share a brief memo summarizing observations.

Deliverables:

- Initial data request form agreed with EDCs
- Semi-annual status memo of QA/QC of Q2 2019 (~10 slides)
- Updated IM data request form to reflect initial learnings and agreed with the EDCs
- Semi-annual IM status memo of QA/QC of Q4 2019 (~10 slides)
- Updated PM data request form to reflect initial learnings and incorporate “case studies” and agreed with EDCs
- Semi-annual PM status memo of QA/QC of 2019 data (~5 slides)
- Semi-annual IM status memo of QA/QC of Q2 2020 (~10 slides)
- Semi-annual IM status memo of QA/QC of Q4 2020 (~10 slides)
- Semi-annual PM status memo of QA/QC of 2020 data (~5 slides)

2.3 Task 3. Complete Analysis

Task 3 consists of in-depth data analysis of the metrics reports and creation of draft results presentations. The basic analysis that Navigant will conduct is prescribed by the infrastructure and performance metrics. The analysis will also explore the research questions outlined in Section 1.2. Navigant’s analysis will actively “follow the data” and explore, describe and visualize any trends, patterns or outcomes impacting the ability to achieve the M&C investment on budget and schedule.

Deliverables:

- Draft presentation of analysis based on 2019 IM data received (~10 slides per EDC)
- Addendum draft presentation will cover PMs
    - draft presentation of analysis of 2019 reliability data (sourced from SQI filing data and other available reliability data) received (~2-3 additional slides per EDC).

  - basic outline and observations for each reliability case study (1 slide each per case-study anticipated. Case studies for PY-19 investments will be limited by investment implementation progress.)
- Draft presentation of analysis based on 2020 IM data received (~10 slides per EDC)
- Addendum draft presentation will cover PMs
  - draft presentation of analysis of 2020 reliability data (sourced from SQI filing data and other available reliability data) received (~2-3 additional slides per EDC).
  - basic outline and observations for each reliability case study (1 slide each per case study anticipated. Three case studies per EDC is anticipated for PY-20 investments.)

2.4 Task 4. Prepare Evaluation Reports

Navigant will prepare two evaluation reports. The first evaluation report will be separated into an initial IM focused delivery and a subsequent PM focused delivery. The IM focused delivery will be completed in Q1 2020 for incorporation into or reference within the EDCs' Annual Reports to be filed on April 1, 2020 (for evaluation year 2019). An addendum to the initial delivery will focus on PMs and case studies, and will be completed by June 2020.

The second evaluation report (for evaluation year 2020, but also covering the previous two years) will be completed in Q2 2021 and will incorporate both IMs and PMs for incorporation into, or reference within, the EDCs' Term Reports.

Outline of Evaluation Report:

- Executive Summary
- Investment description
- Evaluation objectives
- Description of the evaluation approach
- Findings, observations, recommendations (as applicable)
- Appendices with additional work product, for example,
  - Summary of data collected from the EDCs
  - Intermediate analysis outputs
  - Case study results

Deliverables:

- 2019 Draft Evaluation Report covering IMs
- 2019 Final Evaluation Report covering IMs
- 2019 Addendum Draft covering PMs and case studies
- 2019 Addendum Final covering PMs and case studies
- 2020 Draft Evaluation Report covering IMs, PMs, and case studies

- 2020 Final Evaluation Report covering IMs, PMs, and case studies

3. STAFFING

The role of the evaluators will be to carry out the four tasks described in this Stage 3 Evaluation Plan. This team is experienced in both grid modernization and measurement & verification.

Erik Gilbert. Director, Overall Project Manager and M&C Lead. Erik provided subject matter expertise on a number of Massachusetts advanced technology evaluation projects, including National Grid's Worcester Smart Energy Solutions project and Eversource's (NSTAR's) AMR/Dynamic Pricing Smart Grid Pilot. He leads Navigant's Grid Modernization Solutions development and delivery.

Larry Gelbien. Director, Subject Matter Expert for M&C Investment Area. Prior utility executive with 33 years working in Operations and Engineering. Prior VP of Engineering at NSTAR Electric. Area of expertise includes: advanced technology support for the implementation for systems such as DMS, SCADA/RTU Communications, fiber optics, radio, and microwave communications to support business functions. Provides project support for smart grid initiatives in the development of grid modernization strategic roadmaps, regulatory filing support, and tactical implement plans.

Bilhuda Rasheed. Associate Director. Bilhuda supported evaluation of 99 utility grid modernization investments under the Department of Energy Smart Grid Investment Grants Program; and assisted utilities (Eversource and PSEG) and states (New Jersey Board of Public Utilities) with Grid Modernization planning and evaluation.

Taylor Budge. Consultant. Taylor has contributed to a variety of grid modernization efforts for Duke Energy, Tucson Electric Power, and other utilities. She has prior Massachusetts experience leading analyses for Boston's Smart Utilities policy and supporting EM&V work for demand response programs. Taylor has 3.5 years of experience after graduating from Stanford University with a B.S. in Energy, Science & Technology.

Allie Shepard. Consultant, Investment Analyst. Allie supports energy efficiency evaluations and program planning for several utilities. She has prior Massachusetts experience supporting the statewide residential baseline study.   Allie has a S.B. in Chemical Engineering from M.I.T.

Christina Cho. Senior Consultant, M&C Analyst. Christina supports Massachusetts DR Evaluation team and analyzes New England energy policy drivers and initiatives. Also, Christina evaluated energy storage hardware costs and PMs to provide a benchmark for future improvements.

EDC Roles

Navigant requests that each EDC to identify a single point of contact that will complete the data request and be available to meet with us on a semi-annual basis.

4. SCHEDULE

The overall timeline for the evaluation is shown in the Gantt Chart below:

Table 3. Three-Year Schedule

Key Milestone Tasks	2019				2020				2021			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Develop Stage 3 Plan		1A				1B						
2.Collect & Review IM Data		2A	2B	2C	2D		2G		2H			
2. Collect & Review PM Data						2E, 2F				2I		
3. Assess IMs					3A				3C			
3. Assess PMs						3B				3D		
4. Reporting					4A,4B	4C, 4D				4E, 4F		

Milestones:

1A Stage 3 Evaluation Plan (completed)
2A Q2 Data Request Form (completed)
2B Q2 Data Status Memo (completed)
2C Q4 (IM) Data Request Form - Updated (completed-note this spans multiple IAs, but is listed here for reference)
2D Q4 (IM) Data Status Memo (completed)
3A PY'19 (IM) Draft Presentation of Results (completed)
4A PY'19 (IM) Draft Report (completed)
4B PY'19 (IM) Final Report (in-process)
1B Stage 3 Evaluation Plan (updated)
2E Q4 (PM) Data Request Form - Updated
2F Q4 (PM) Data Status Memo
3B PY'19 (PM) Draft Presentation of Results
4C PY'19 (PM) Draft Addendum to Report
4D PY'19 (PM) Final Addendum to Report

2G Q2 (IM) Data Status Memo
2H Q4 (IM) Data Status Memo
3C PY'20 (IM) Draft Presentation of Results
2I Q4 (PM) Data Status Memo
3D PY'20 (PM) Draft Presentation of Results
4E PY'19 (IM+PM) Draft Report
4F PY'19 (IM+PM) Final Report

5. METRIC DEFINITIONS

5.1 Infrastructure Metrics

To create a more accurate representation of deployment progress, and to provide evidence of intermediate progress, the infrastructure metrics regarding number of devices deployed will be reported according to the four steps defined below. There is a sequence of steps that occur prior to the equipment being placed in service, and the project can be considered complete. These steps can be defined generally as: 1) Engineering; 2) Design; 3) Construction; and 4) In-service. Progress can be measured not only as the quantity of units that are installed and in-service (Step 4 complete), but also the quantity of units that have completed design (Step 2) or construction (Step 3). Note that these metrics are not a requirement from the DPU but will allow Navigant to better tell the story of the deployment in the annual reports.

5.1.1 System Automation Saturation

System automation saturation measures customers served by fully automated or partially automated devices. The terms "fully automated" and "partially automated" refer to feeders and substations for which EDCs have attained optimal or partial levels of visibility, command and control, and self-healing capability through automation. The installations will not be limited to the main line infrastructure and will include no-load lines and distribution substation supply ("DSS") lines. The metric is defined below.

System Automation Saturation =
Customers Served / (Fully Automated Device + 0.5*(Partially Automated Device))

Baseline saturation rate will be calculated based on what exists on the EDC systems as of the date the baseline was first calculated. As more automation is installed on EDC systems, both under the GMP and pursuant to other system investment outside of the GMP, the value of this metric will be reduced. The following matrix has been provided as guidance to determine which type of equipment would be considered partially automated, fully automated or included as a sensor.

Table 6. Grid Modernization Devices

Device Type	Sensor	Partial Automation	Full Automation
Recloser SCADA Enablement			X
Padmount Switchgear SCADA Enablement			X
Network Protector SCADA Enablement			X
4kV Circuit SCADA Enablement			X
Microprocessor Relays			X
Feeder Monitors with Communications			X

Substation SCADA Enablement	X

The overall Eversource baseline for this metric is 247, and Eversource has provided circuit-level baselines in Attachment 2 to "ES_Comp_Filing_8-15-18.pdf". Unitil circuit level baselines for each device type are defined in the document "Unitil_Compliance_Report_8-15-18.pdf". National Grid baselines will be incorporated into the first Grid Modernization Annual Report in 2019.

5.1.2 Number/Percentage of Circuits with Installed Sensors

This metric measures the total number of electric distribution circuits with installed sensors which will provide information useful for proactive planning and intervention. The installation of sensors is a key part of the measurement and control investment area and provides the means to enable grid modernization initiatives. Data for calculating this metric will consist of two parts, as defined below:

1. Number of circuits with installed sensors provided as a list of circuits indicating whether the circuit has one or more installed sensors.
2. Quantity of sensors by device type, by circuit

The baseline for this metric will be calculated based on what exists on the EDC systems as of the date the baseline was first calculated. See Table 6 above for devices that have been defined as "sensor" for determining whether a circuit has a sensor. To track intermediate progress, this metric will be reported according to the four deployment phases defined above.

Eversource has an overall baseline of 83% of circuits with installed sensors, and has provided circuit-level baselines in Attachment 2 to "ES_Comp_Filing_8-15-18.pdf". Unitil circuit level baselines for each device type are defined in the document "Unitil_Compliance_Report_8-15-18.pdf". National Grid will be incorporated into the first Grid Modernization Annual Report in 2019.

5.1.3 Number of Devices or Other Technologies Deployed

This metric measures how the EDCs are progressing with their GMPs from an equipment and/or device standpoint. The number of devices installed will be compared to the total number of devices planned by circuit for each investment in each EDC. The following information will be tracked and reported upon per investment at the substation and circuit level where appropriate:

1. Number of devices or other technologies deployed
2. Total number of devices planned
3. Percent – Number of devices installed / total number of devices planned

This information will be provided on an annual basis. Data will be based upon the results at the end of the calendar year. This metric is strictly a grid modernization deployment metric: accordingly, the baseline for this metric necessarily starts at zero to ensure that prior investments are not captured in the baseline. The targets for this metric are the deployment plans defined above. To track intermediate progress, this metric will be reported according to the three "level-of-complete" deployment stages:

1) Engineering Completed: number of devices for which engineering work has been completed. This will track when the circuit and general location of the device has been determined

2) Design Completed: number of devices for which the design work has been completed. This will track when the detailed M&C design has been completed, which would include specific device location and cost estimate.
3) Construction Completed: number of devices for which construction has been completed. This will track when all field construction has been done.

5.1.4 Cost of Deployment

This metric measures the associated costs for the number of devices or technologies installed and is designed to measure how the EDCs are progressing in their grid modernization initiatives. The cost of devices installed will be compared to the total cost of devices planned by circuit for each investment. The following information will be tracked and reported upon per investment at the substation and circuit level where appropriate:

1. Cost of devices or other technologies deployed
2. Total cost of devices deployed
3. Percent – Cost of devices installed / total cost of devices deployed

This information will be provided on an annual basis. Results will be based upon the results at the end of the calendar year. The baseline comparison for this analysis is based upon a combination of the GMPs and any additional detailed design and planning where appropriate. The targets for this metric are the deployment plans defined above. To track intermediate progress, this metric will be reported according to the four deployment phases defined above.

5.1.5 Deviation Between Actual and Planned Deployment for the Plan Year

This metric is designed to measure how the EDCs are progressing on a year-by-year basis. The quantity and cost of devices or technology for each investment will need to be determined and/or updated from the initial GMPs on a year-by-year basis. The quantity and cost of devices or technology installed in a given GMP investment year will be compared on a year-by-year basis and any variations will be quantified and addressed. The following information will be tracked and reported upon per investment at the substation and circuit level where appropriate:

1. Number of devices or technology installed versus plan for a given year
2. Cost of devices or technologies installed versus plan for a given year
3. Reason for discrepancies

This information will be provided on an annual basis. Results will be based upon the results at the end of the calendar year. The metric will be reported at the substation and circuit level where appropriate.

5.1.6 Projected Deployment for the Remainder of the Three-Year Term

This metric is designed to measure how the EDCs are progressing on a year-by-year basis. The metric will compare the revised projected deployment with the original targeted deployment as the EDCs progress in their implementation. The year-by-year investment plan is subject to change based upon the quantity of work completed, the availability of the technology, material lead times, contractor availability, etc. Each year’s revised investment plan will be used as the basis of comparison for the following year’s

GMP work. The following information will be tracked and reported upon per investment at the substation and circuit level where appropriate:

1. Number of devices or technology to be installed the following year
2. Cost of devices or technologies installed the following year

This information will be provided on an annual basis. Results will be based upon the results at the end of the calendar year. The metric will be reported upon at the substation and circuit level where appropriate. The metric will be used as the baseline and target for the following year's work and will be reported on an annual basis.

5.2 Performance Metrics

For M&C investments, the primary impact is on the first DPU objective: "to optimize system performance by attaining optimal levels of grid visibility, command and control". M&C is primarily an enabling investment, however, the additional sensors and control points are expected to improve reliability as well. The performance metrics defined below intend to measure accurately the improvements in reliability that can be attributed to M&C investments.

5.2.1 Grid Modernization Investment Effect on Outage Duration

This metric will compare the experience of customers on circuits with M&C enabled through grid modernization investments as compared to the prior three-year average for the same circuit. This metric is intended to provide insight into how M&C can reduce the duration of outages. This metric will track and report on the following:

1. Circuit level SAIDI for circuits that have M&C enabled in the GMP plan year
2. Three-year average circuit level SAIDI covering years 2015, 2016, and 2017
3. Compare the current year SAIDI with the three-year historic average SAIDI of the circuit

This information will be provided on an annual basis. Results will be based upon the measurement at the end of the calendar year. The metric will use the circuit-level three-year (2015-2017) SAIDI average as the baseline. It will compare the SAIDI results of the plan year to the baseline.

5.2.2 Grid Modernization Investment Effect on Outage Frequency

This metric will compare the experience of customers on circuits with M&C enabled through grid modernization investments as compared to the prior three-year average for the same circuit. This metric is intended to provide insight into how M&C can reduce the frequency of outages. This metric will track and report on the following:

1. Circuit level SAIFI for circuits that have M&C enabled in the GMP plan year
2. Three-year average circuit level SAIFI covering the years 2015, 2016, and 2017
3. Compare the current year SAIFI with the three-year historic average SAIFI of that circuit

This information will be provided on an annual basis. Results will be based upon the results at the end of the calendar year. The metric will use the circuit three-year (2015-2017) SAIFI average as the baseline. Additionally, the baseline will be provided with and without Excludable Major Events along with a summary of the main causes of outages on each feeder. It will compare the SAIFI results of the plan year to the baseline.

5.2.3 Reliability-Related Company-Specific Performance Metrics

In addition, Eversource and Until have defined additional reliability metrics to be measured as described below. National Grid's reliability-related metric is under development.

Eversource Customer Outage Metric

This metric will measure Eversource's progress in sectionalizing circuits into protective zones designed to limit outages to customers located within the zone. The metric will track the average zone size in terms of number of customers interconnected in each protective zone for each circuit and sum of the circuits in Eastern and Western Massachusetts. The metric will use 2018 average zone size by circuit as baseline.

National Grid Reliability-Related Company Specific Performance Metric

Main Line Customer Minutes of Interruption Saved is a metric primarily designed to measure the effectiveness of ADA investments. However, the M&C evaluation will look at leveraging this metric for some of the M&C investments to see if it can provide insight into the performance of these investments and help distinguish between the results of ADA and M&C investments on reliability. This metric will look at:

- Historical customer minutes of interruption for mainline interruptions
- Calendar year customer minutes of interruption for mainline interruptions.

This metric will be examined at the substation and circuit level where M&C investments have been made to understand if it can provide useful information.

Unitil Reliability-Related Company-Specific Performance Metric

This metric will measure customer minutes saving per outage on each feeder. The metric will track and report upon an individual outage basis the following:

1. Time of first notification from AMI to OMS
2. Time of first customer call from IVR to OMS
3. Outage duration
4. Feeder and substation level CAIDI for the years 2015, 2016, and 2017

The number of minutes saved will be calculated using the following equation: (Time of first notification from AMI to OMS) – (Time of first customer call from IVR to OMS). Customer minutes saved is then determined by: number of minutes saved * number of customers affected. The metric will use static three-year average circuit level CAIDI in 2015, 2016, and 2017 for each feeder as baseline. Unitil targets saving an average of 5 minutes per outage.

5.2.4 Case Studies to illustrate how reliability is being improved

The case studies will facilitate understanding of the reliability improvements at select Eversource and National Grid feeder locations. These case studies will examine the impact the M&C investments had on reducing the outage frequency or lengths and will exemplify system outages with explanation of the mechanisms employed and devices used to achieve the reliability improvement.

NAVIGANT
A Guidehouse Company

Study #2 – Communications Evaluation Plan

Stage 3 Plan

Prepared for:

Massachusetts Electric Distribution Companies

Submitted by:
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1. INTRODUCTION

The Massachusetts Electric Distribution Companies (EDCs) are making investments in communications which will be a supporting investment to various grid modernization investments approved by the Department of Public Utilities (DPU). The DPU pre-authorized investments in communications for the three EDCs will total $20.6M over the 2018 to 2020 time period.

The Communications Investment is an enabling technology that will support most, if not all, the preauthorized investments, including Advanced Distribution Automation, Volt VAR Optimization, Advanced Distribution Management Systems, and Monitoring and Control.

The Communications investments proposed by National Grid, Eversource, and Unitil will include a Wide Area Network (WAN) that is proposed to be either fiber optics or a wireless (radio) approach and a Field Area Network (FAN).

1.1 Overall Study Goals

This evaluation process will focus on the progress of deployment and toward the ability of the communication investments to enable the other preauthorized investments to achieve the DPU's grid modernization objectives. The Communications investments are enabling technologies that are necessary to the other investments to enable them to make progress on the DPU objectives. A robust and effective communication network is required for the other preauthorized investments to "(1) optimize system performance (by attaining optimal levels of grid visibility, command and control…," (2) "optimize system demand," and "(3) interconnect and integrate distributed energy resources"[5].

1.2 Research Questions

The below research and evaluations will be performed on the communication investments to determine the progress of deployment of the communication network and the readiness of the investments to support the other preauthorized investments.

Table 1. Evaluation Questions

Evaluation Questions
1) Are the EDCs progressing in deployment of their communications networks according to their Grid Modernization Plans?
2) What factors, if any, are affecting the deployment schedule of communications equipment?
3) What is the cost of deploying various types of communications equipment, including the FAN devices (radio base stations) and WAN (miles of fiber optics cables)?
4) Are the communication investments (WAN and FAN) effective at supporting the other DPU approved investments?

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

1.3 Evaluation Metrics

To perform the evaluation, for year 2019, Eversource and National Grid will leverage the Infrastructure Metrics (IMs) as shown in the table below. For Unitil, in year 2019, the evaluation will be based on the progress to complete the engineering study for a FAN. In year 2020, Unitil will follow the EDC stamped approved IM along with Eversource and National Grid.

Table 2. Evaluation Metrics

Metric Type	Comms Evaluation Metrics[6]	ES	NG	UTL
IM	Number of devices deployed, tested and in-service	✓	✓	✓
	Engineering Completed -- Number of Devices	✓	✓	✓
	Design Completed -- Number of Devices	✓	✓	✓
	Construction Completed -- Number of Devices	✓	✓	✓
IM	Cost for deployment	✓	✓	✓
IM	Deviation between actual and planned deployment for the plan year	✓	✓	✓
IM	Projected deployment for the remainder of the three-year term	✓	✓	✓

IM – infrastructure metric

Section 6 provides a definition for each of the above metrics.

[6] Note: to the degree that the *performance metrics* are modified or augmented during the stakeholder input process, the new metrics will be included in the evaluation plan.

2. METHODOLOGY

Working with each EDC, Guidehouse will define baselines that will be used for the evaluation of the communication investments (WAN and FAN). These baselines will include deployment quantities, schedule, costs, etc., so that the progress along these baselines can be measured.

The following high-level tasks will be executed to perform the evaluation. Details of each task are defined in greater detail in Section 2.

- Task 1: Detailed Communication Evaluation Plan Development (this document) – Reviewed and approved by the EDCs.
- Task 2: Data Request Issued to EDCs – Guidehouse to request specific data on a semi-annual basis and reported on an annual basis and discuss status of communications investments.
- Task 3: Data analysis and presentation – The review and analysis for each metric as well as other evaluation insights and/or recommendations will be developed and presented
- Task 4: Development of Annual Reports – Draft report for EDC review and then a Final report incorporating EDC comments. These will cover infrastructure metrics and Guidehouse assessment of how the investments are proceeding relative to plan, and how/if the investments are delivering against the Department's grid modernization objectives.

The Evaluation Team's approach to each task is described below.

2.1 Task 1. Develop Stage 3 Plan

Guidehouse has worked with the EDCs to develop a detailed evaluation plan that addresses evaluation requirements for the Communications investment area. Key activities include:

- Understand planned schedule and investments for each EDC
- Discuss infrastructure and performance metrics
- Understand and accommodate data availability
- Agree on overall evaluation scope, schedule, and budget
- Confirm allocation across EDCs

Deliverables:

- Initial Stage 3 Evaluation Plan
- Revised Stage 3 Evaluation Plan (this document)
- Subsequent to the development of the initial Stage 3 Plan, Guidehouse worked with the EDCs to adapt this Stage 3 plan to actual experience to date.

2.2 Task 2. Collect and Review Data

Guidehouse provided the EDCs with a Data Request Form that detailed the information required to perform the analysis and evaluation. Guidehouse is requesting to receive the data on a semi-annual basis.

The initial semi-annual data, collected in August 2019, was used to test the data collection process and initially assess the annual results. In the course of this data collection activity, it was determined that a more efficient and detailed data request format could help streamline the data collection process and make future semi-annual data collection activities more efficient. Guidehouse successfully used this updated data request format to collect data for the 2019 program year in January 2020. This semi-annual data will be used to evaluate the annual results.

A sample of some of the expected data will include:

1. By year, the projected quantities of communication devices to be installed.
2. Estimated and approved budget cost for each communication device to be installed.
3. The distance point-to-point for each WAN (miles of fiber, distance of microwave links, etc.).
4. Strategy and pre-planning work completed to date for communications devices
5. Work order design completed for each node.
6. Construction completed date for each node.
7. Testing procedure and date testing was completed for each WAN and/or FAN node.
8. Description of other DPU approved investments using the communications node placed into service.
9. Actual final cost to install each communications node.
10. Deviation in schedule and cost along with the reason for the deviation between actual and planned deployment for the plan year.
11. Projected deployment for the remainder of the three-year term.

We anticipate the EDCs continuing to complete and shares the Data Request Forms and files with Guidehouse. Guidehouse will continue to have discussions with each EDC to review the data provided. Guidehouse assumes the EDCs will provide complete and accurate information. After the review and discussion, Guidehouse shares a brief memo summarizing observations.

Deliverables:

- Initial data request form agreed with EDCs
- Semi-annual status memo of QA/QC of Q2 2019 (~2-3 pages or ~10 slides)
- Updated and streamlined IM data request form agreed with the EDCs
- Semi-annual status memo of QA/QC of Q4 2019 (~2-3 pages or ~10 slides)
- Semi-annual status memo of QA/QC of Q2 2020 (~2-3 pages or ~10 slides)
- Semi-annual status memo of QA/QC of Q4 2020 (~2-3 pages or ~10 slides)

2.3 Task 3. Complete Analysis and Presentation

Guidehouse will conduct the analysis for the evaluation to determine metric performance. Although the basic analysis that Guidehouse will run is designed to be relatively prescribed, the analysis will also explore the research questions outlined in Section 1.2. In other words, Guidehouse's analysis will actively "follow the data" and explore, describe and visualize any trends, patterns, or outcomes impacting the ability to achieve the communications investment on budget and schedule.

We will analyze the available data and incorporate feedback from our prior discussions with the EDCs to answer the research questions identified in Section 1.2. For example, we will assess whether the EDCs are progressing in deployment of their communications networks according to their Grid Modernization Plans, and what factors, if any, are affecting the deployment schedule of communications equipment. We will also explore whether the communication investments (WAN and FAN) are effectively supporting the other DPU-approved investments.

Deliverables:

- Draft presentation of the analysis of 2019 data (~10 slides per EDC)
- Draft presentation of the analysis of 2020 data (~10 slides per EDC)

2.4 Task 4. Prepare Evaluation Reports

Guidehouse will prepare two evaluation reports. The first evaluation report will be completed in Q1 2020 for incorporation into the EDCs' Annual Reports to be filed on April 1, 2020 (for evaluation year 2019). and the second evaluation report will be completed in Q1 2021 (for evaluation year 2020). for incorporation into the EDCs' Term Reports to be filed on April 1, 2021.

Outline of Evaluation Report:

- Executive Summary
- Investment description
- Evaluation objectives
- Description of the evaluation approach
- Findings, observations and recommendations (as applicable)
- Appendices with additional work product, for example:
    - Summary of data collected from the EDCs
    - Intermediate analysis outputs

Deliverables:

- 2019 Draft Evaluation Report
- 2019 Final Evaluation Report
- 2020 Draft Evaluation Report
- 2020 Final Evaluation Report

3. STAFFING

The role of the evaluators will be to carry out the four tasks described in this Stage 3 Evaluation Plan. This team is experienced in both grid modernization and measurement & verification.

Erik Gilbert. Director, Overall Project Manager. Erik leads Guidehouse's Grid Modernization Solutions development and delivery. He provided subject matter expertise on a number of Massachusetts advanced technology evaluation projects, including National Grid's Worcester Smart Energy Solutions project and Eversource's (NSTAR's) AMR/Dynamic Pricing Smart Grid Pilot.

Larry Gelbien. Director in Charge for the communications investment. Prior utility executive with 33 years working in Operations and Engineering. Prior VP of Engineering at NSTAR Electric. Area of expertise includes: advanced technology support for the implementation for systems such as DMS, SCADA/RTU Communications, fiber optics, radio, and microwave communications to support business functions. Provides project support for smart grid Initiatives in the development of grid modernization strategic roadmaps, regulatory filing support, and tactical implement plans. Support the development of standards and initiatives for clients and provides guidance for regulatory agencies for Grid Self-Healing, Demand Response, Advance Metering, and Customer Systems.

Bilhuda Rasheed, Associate Director. Bilhuda supported evaluation of 99 utility grid modernization investments under the Department of Energy Smart Grid Investment Grants Program; and assisted utilities (Eversource and PSEG) and states (New Jersey Board of Public Utilities) with Grid Modernization planning and evaluation.

Allie Shepard. Consultant, Communications Analyst. Allie supports energy efficiency evaluations and program planning for several utilities. She has prior Massachusetts experience supporting the statewide residential baseline study.

EDC Roles

Each EDC has identified a single point of contact that will complete the data request and be available to meet with Guidehouse on a semi-annual basis.

4. SCHEDULE

Table 3 shows, at a high level, the overall three-year schedule.

Table 3. Three-Year Schedule

Key Tasks	2019				2020				2021			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1 Develop Stage 3 Plan		1A				1B						
2 Collect & Review Data		2A	2C	2B	2D		2E		2F			
3 Complete Analysis					3A				3B			
4 Prepare Annual Reports					4A, 4B					4C, 4D		

Milestones:
1A. Initial Stage 3 Evaluation Plan (completed)
1B. Revised Stage 3 Evaluation Plan
2A. Data request form agreed with EDCs (completed)
2B. Data request form updated and agreed with EDCs (completed)
2C. Semi-annual status memo of QA/QC of Q2 2019
2D. Semi-annual status memo of QA/QC of Q4 2019
2E. Semi-annual status memo of QA/QC of Q2 2020
2F. Semi-annual status memo of QA/QC of Q4 2020
3A. Draft presentation of the analysis of 2019 data
3B. Draft presentation of the analysis of 2020 data
4A. 2019 Draft Evaluation Report
4B. 2019 Final Evaluation Report
4C. 2020 Draft Evaluation Report
4D. 2020 Final Evaluation Report

5. METRIC DEFINITIONS

5.1 Infrastructure Metrics

5.1.1 Number of Communication Devices In-Service

These metrics measure how the EDCs are progressing with their communication investment from an equipment and/or device standpoint. As seen in Table 2, these metrics will track progress of the investment from the start of the process through in-service and useful.

1. Number of devices or other communication technologies deployed
2. Total number of devices planned
3. Percent – Number of devices installed / total number of devices planned

This information will be reported to the DPU and stakeholders on an annual basis. Data will be based upon the results at the end of the calendar year. This metric is strictly a grid modernization deployment metric. Accordingly, the baseline for this metric necessarily starts at zero to ensure that prior investments are not captured in the baseline. To track intermediate progress, this metric will be reported according to the three “level-of-complete” deployment stages:

1) Engineering Completed: number of devices for which engineering work has been completed. This will track when the circuit and general location of the device has been determined
2) Design Completed: number of devices for which the design work has been completed. This will track when the detailed Communications design has been completed, which would include specific device location and cost estimate.
3) Construction Completed: number of devices for which construction has been completed. At this stage, the devices are in-service and used and useful. This will track when all field construction has been done.
4) Commissioned: number of devices that are commissioned and operational for Grid Modernization purposes.

5.1.2 Cost to Deploy Communication Equipment

This metric measures the per unit costs for each device (communication nodes or distance of fiber) installed and is designed to measure how the EDCs are progressing in their communication grid modernization investment against cost estimates. The cost of devices installed will be compared to the per unit or per mile cost of equipment planned for each location:

1. Per unit cost of FAN or WAN devices deployed
2. Estimated (budgeted) cost of per unit device planned
3. Percent – Cost of device installed / cost of device planned

This information will be rolled up as an average and reported on an annual basis. Results will be based upon the results at the end of the calendar year.

5.1.3 Deviation Between Actual and Planned Deployment for the Plan Year

This metric is designed to measure how the EDCs are progressing on a year-by-year basis. The quantity and cost of devices or technology for each investment will need to be determined and/or updated from the initial GMPs on a year-by-year basis. The quantity and cost of devices or technology installed in a given GMP investment year will be compared on a year-by-year basis and any variations will be quantified and explained. The following communication investment information will be tracked and reported upon:

1. Number of communication devices, nodes or mile of fiber installed versus plan for a given year
2. Cost of communication devices, nodes of miles of fiber installed versus plan for a given year
3. Reason for discrepancies

This information will be reported on an annual basis. Results will be based upon the results at the end of the calendar year. The metric will be reported on a per location basis.

5.1.4 Projected Deployment for the Remainder of the Three-Year Term

This metric is designed to measure how the EDCs are progressing on a year-by-year basis. The metric will compare the revised projected deployment of communication investments with the original targeted deployment as the EDCs progress in their implementation. The year-by-year investment plan is subject to change based upon the quantity of work completed, the availability of the technology, material lead times, contractor availability, etc. Each year’s revised investment plan will be used as the basis of comparison for the following year’s GMP work. The following information will be reported upon on a per location basis:

1. Number of devices, nodes, or mile of fiber to be installed in the following year
2. Cost of devices or technologies installed in the following year

This information will be reported on an annual basis. Results will be based upon the results at the end of the calendar year. The metric will be reported upon on a per location basis. The metric will be used as the baseline and target for the following year’s work and will be reported on an annual basis.

NAVIGANT
A Guidehouse Company

Study #3 – Advanced Distribution Automation Evaluation Plan

Stage 3 Plan

Prepared for:

Massachusetts Electric Distribution Companies

Submitted by:
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Reference No.: 209941
March 30, 2020

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1. INTRODUCTION

Eversource Energy and National Grid are making investments in Advanced Distribution Automation (ADA). These investments will enable a greater level of automation resulting in improved electric system reliability. The ADA investment for both Electric Distribution Companies (EDCs) is estimated to total $57.4M over the period of 2018 to 2020. The ADA investments for National Grid include $13.4M towards overhead reclosers, and the Eversource investments include $44M toward overhead reclosers, the replacement of underground oil switches, and the enabling of underground 4kV auto-reclosing loops.

1.1 Overall Study Goals

This plan will evaluate the progress and effectiveness of the DPU preauthorized ADA investments for Eversource and National Grid. The ADA projects are expected reduce customer outages and customer minutes of interruption. The evaluation will focus on the ADA investments' impact on "Reducing the Effects of Outages" as part of the DPUs grid modernization objective "(1) optimize system performance (by attaining optimal levels of grid visibility, command and control)."

1.2 Research Questions

The following research questions will help determine the effectiveness of the ADA investments in improving reliability, enabling automatic feeder reconfiguration and FLISR, and accomplishing DPU grid modernization objectives.

Table 1. Evaluation Questions

Evaluation Questions
1) Are the EDCs progressing in deployment of their ADA investments according to their Grid Modernization Plans?
2) What factors, if any, are affecting the deployment schedule of ADA equipment?
3) What is the cost of deploying various types of ADA equipment?
4) What is the effect of ADA investments on reliability and key reliability metrics, such as SAIDI and SAIFI?
5) Is the ADA overhead and underground equipment operating as designed?

1.3 Evaluation Metrics

To perform the evaluation, for year 2019 and 2020, we will leverage the Stamped Approved Infrastructure Metrics (IM) and Performance Metrics (PM) as shown in Table 2.

In addition to the IMs, Guidehouse will track progress using three *level-of-complete* stages to inform the metric that tracks the "number of devices deployed," as shown in the table below. The EDCs will need to provide information on the level-of-complete activity.

Table 2. Evaluation Metrics

Metric Type	ADA Evaluation Metrics[7]	ES	NG
IM	System Automation Saturation	✓	✓
IM	Number of Devices Deployed, Tested and In-Service	✓	✓
	Engineering Completed -- Number of Devices	✓	✓
	Design Completed -- Number of Devices	✓	✓
	Construction Completed -- Number of Devices	✓	✓
IM	Cost for Deployment	✓	✓
IM	Deviation between actual and planned deployment for the plan year	✓	✓
IM	Projected deployment for the remainder of the three-year term	✓	✓
PM	Grid Modernization investments' effect on outage duration	✓	✓
PM	Grid Modernization investments' effect on outage frequency	✓	✓
PM	Numbers of Customers that benefit from GMP-funded Distribution Automation Devices	✓	✓
PM	Protective Zone: Average Zone Size per Circuit	✓	
PM	Main Line Customer Minutes of Interruption Saved		✓
PM	Case Studies to illustrate how reliability is being improved	✓	✓

IM – infrastructure metric, PM – performance metric

Section 6 provides a definition for each of the above metrics.

[7] Note: to the degree that the *performance metrics* are modified or augmented during the stakeholder input process, the new metrics will be included in the evaluation plan.

2. METHODOLOGY

Methodology development leverages the approach proposed by the EDCs in their respective infrastructure metrics filings, joint performance metrics filing as well as those provided by DPU directives. For each EDC, Guidehouse will leverage the baseline definitions that have been agreed across the appropriate dimensions (e.g., deployment timeline and costs, reliability, etc.) so that the progress along these dimensions can be measured quantitatively. The data necessary to perform the evaluation and the expected timing and availability of the data required to meet the necessary analysis and filing timelines is identified at a high level below in this document. The performance metric definitions will be refined as required by the continuing stakeholder process being led by the DPU. The specific data required, and the focus and presentation of analysis results will be refined throughout the evaluation process to ensure that it can measure progress towards the DPU grid modernization objectives mentioned above.

The following high-level tasks will be executed to perform the evaluation.

- Task 1: Develop Stage 3 Plan (this document) – Reviewed and approved by the EDCs and working with the EDCs to develop a uniform approach to defining the IMs and PMs and the associated baseline.[8]
- Task 2: Collect and Review Data – Guidehouse to request specific data on a semi-annual basis and discuss status of ADA investments.
- Task 3: Complete Analysis and Presentation - The review and analysis for each metric as well as other evaluation insights and/or recommendations will be developed and presented.
- Task 4: Prepare Evaluation Reports – Draft report for EDC review and then a Final report incorporating EDC comments. These will cover infrastructure metrics and Guidehouse assessment of how the investments are proceeding relative to plan, as well as performance metrics and how/if the investments are delivering against the Department's grid modernization objectives.

The Evaluation Team's approach for each task is described below.

2.1 Task 1. Develop Stage 3 Plan

Guidehouse has worked with the EDCs to develop the initial detailed evaluation plan addressing evaluation requirements for the ADA investment area. Key activities include:

- Understand planned schedule and investments for each EDC
- Discuss infrastructure and performance metrics
- Understand and accommodate data availability
- Agree on overall evaluation scope, schedule, and budget
- Confirm allocation across EDCs

[8] Note that this document is an update to the initial Stage 3 Evaluation Plan, which was filed on May 1, 2019, and it incorporates updates based on the Departments Stamped-Approved Performance Metrics, as well as changes necessary to accommodate updates to the EDC deployment schedules and data availability.

- Understand the timing and availability of data need for ADA evaluation

Subsequent to the development of the initial Stage 3 Plan, Guidehouse worked with the EDCs to adapt this Stage 3 plan to accommodate the schedule of availability for circuit reliability data and to add case studies to the Performance Metrics analysis to facilitate better understanding of the impacts of the investments on customer reliability.

Deliverables:

- Initial Stage 3 Evaluation Plan
- Revised Stage 3 Evaluation Plan (this document) [9]

2.2 Task 2. Collect and Review Data

Guidehouse provided the EDCs with a Data Request Form that described the information required to perform the analysis and evaluation. Guidehouse is requesting to receive the data on a semi-annual basis.

The initial semi-annual data, collected in August 2019, was used to test the data collection process and initially assess the annual results. In the course of this data collection activity, it was determined that a more efficient and detailed data request format could help streamline the data collection process and make future semi-annual data collection activities more efficient. Guidehouse successfully used this updated data request format to collect data for the 2019 program year in January 2020. This data will be used to develop the results for the annual evaluation and term reports.

A sample of some of the expected data includes:

1. The projected quantities, type of ADA equipment (reclosers, VFI, etc.) to be installed by circuit and substation.
2. Estimated and approved budget for each ADA equipment to be installed.
3. The number of customers for whom the ADA equipment will improve reliability (customers that benefit).
4. For years 2015, 2016 and 2017, on a circuit level: AVERAGE (‘CKAIDI 2015’+’ CKAIDI Year 2016’+’ CKAIDI Year 2017’) = baseline ‘CKAIDI. EDCs to calculate and provide value.
5. For years 2015, 2016, and 2017, on a circuit level: AVERAGE (‘CKAIFI Year 2015’+’ CKAIFI Year 2016’+’ CKAIFI Year 2017’) = baseline ‘CKAIFI. EDCs to calculate and provide value.
6. CKAIDI for evaluation year n. EDCs to calculate and provide value.
7. CKAIFI for evaluation year n. EDCs to calculate and provide value.
8. *Case study* information such as one-line diagram of the investment circuit, description of reliability improvement example with explanation of the mechanisms employed to achieve the reliability improvement. Case studies will examine the operation and/or use of the ADA technology and

[9] This update is based on learnings from the first year of evaluation, and specifically the timing of availability of circuit level reliability data.

explain in narrative form how they have addressed reliability and efficiency goals. Three case studies will be targeted per EDC to illustrate the range of operations.

9. Engineering completed date for ADA equipment.
10. Design completed date for ADA equipment.
11. Construction completed date for each ADA equipment.
12. In Service - testing procedure and date completed for each ADA equipment being placed into service.
13. Actual final Cost to install each ADA equipment.
14. Reason for deviation in schedule and cost between actual and planned deployment for the plan year.
15. Projected deployment for the remainder of the three-year term.
16. Should FLISR be in service during the evaluation period, report on the number of times FLISR automation operated correctly.
17. Should FLISR be in service during the evaluation period, report on the number of times the FLISR operated incorrectly and the cause.

We anticipate the EDCs continuing to complete and share the Data Request Forms and files with Guidehouse. Guidehouse will continue to have discussions with each EDC to review the data provided. Guidehouse assumes the EDCs will provide complete and accurate information. After the review and discussion, Guidehouse shares a brief memo summarizing observations.

Deliverables:

- Initial data request form agreed with EDCs
- Semi-annual status memo of QA/QC of Q2 2019 (~10 slides)
- Updated IM data request form to reflect initial learnings and agreed with the EDCs
- Semi-annual IM status memo of QA/QC of Q4 2019 (~10 slides)
- Updated PM data request form to reflect initial learnings and incorporate “case studies” and agreed with EDCs
- Semi-annual PM status memo of QA/QC of 2019 data (~5 slides)
- Semi-annual IM status memo of QA/QC of Q2 2020 (~10 slides)
- Semi-annual IM status memo of QA/QC of Q4 2020 (~10 slides)
- Semi-annual PM status memo of QA/QC of 2020 data (~5 slides)

2.3 Task 3. Complete Analysis and Presentation

Task 3 consists of in-depth data analysis of the metrics reports and creation of draft results presentations. The basic analysis that Guidehouse will conduct is prescribed by the infrastructure and performance metrics, the analysis will also explore the research questions outlined in Section 1.2. In other words, Guidehouse's analysis will actively "follow the data" and explore, describe and visualize any trends, patterns or outcomes impacting the ability to achieve the ADA investment on budget and schedule.

We will analyze the available data and incorporate feedback from our prior discussions with the EDCs to answer the research questions identified in Section 1.2. For example, we will assess whether the EDCs are progressing in deployment of their ADA equipment according to their Grid Modernization Plans, and what factors, if any, are affecting the deployment schedule and cost. We will also assess the effectiveness of the ADA investments in improving overall reliability.

Deliverables:

- Draft presentation of the analysis of 2019 data (~10 slides per EDC).
- Addendum draft presentation will cover PMs
    - draft presentation of analysis of 2019 reliability data (sourced from SQI filing data and other available reliability data) received (~2-3 additional slides per EDC).
    - basic outline and observations for each reliability case study (1 slide each per case-study anticipated. Case studies for PY-19 investments will be limited by investment implementation progress.)
- Draft presentation of analysis based on 2020 IM data received (~10 slides per EDC)
- Addendum draft presentation will cover PMs
    - draft presentation of analysis of 2020 reliability data (sourced from SQI filing data and other available reliability data) received (~2-3 additional slides per EDC).
    - basic outline and observations for each reliability case study (1 slide each per case study anticipated. Three case studies per EDC is anticipated for PY-20 investments.).

2.4 Task 4. Prepare Evaluation Reports

Guidehouse will prepare two evaluation reports. The 2019 evaluation report will be separated into an initial IM focused delivery and a subsequent PM focused delivery. The IM focused delivery will be completed in Q1 2020 for incorporation into or referenced within the EDCs Annual Report to be filed on April 1, 2020. An addendum to the initial delivery will focus on PMs and case studies, and will be completed by June 2020.

The second evaluation report (for evaluation year 2020, but also covering the previous two years) will be completed in Q2 2021 and will incorporate both IMs and PMs for incorporation into, or reference within, the EDCs' Term Reports.

Outline of Evaluation Report:

- Executive Summary
- Investment description
- Evaluation objectives
- Description of the evaluation approach

- Findings, observations and recommendations (as applicable)
- Appendices with additional work product, for example,
    - Summary of data collected from the EDCs
    - Intermediate analysis outputs
    - Case study results

Guidehouse will share each evaluation report as “draft”. Then incorporate comments and feedback and prepare a final version.

Deliverables:

- 2019 Draft Evaluation Report covering IMs
- 2019 Final Evaluation Report covering IMs
- 2019 Addendum Draft covering PMs and case studies
- 2019 Addendum Final covering PMs and case studies
- 2020 Draft Evaluation Report covering IMs, PMs, and case studies
- 2020 Final Evaluation Report covering IMs, PMs, and case studies

3. STAFFING

The role of the evaluators will be to carry out the four tasks described in this Stage 3 Evaluation Plan. This team is experienced in both grid modernization and measurement & verification.

Erik Gilbert. Director, Overall Project Manager and Area Lead. Erik leads Guidehouse's Grid Modernization Solutions development and delivery. Erik has provided subject matter expertise on a number of Massachusetts advanced technology evaluation projects, including National Grid's Worcester Smart Energy Solutions project and Eversource's (NSTAR's) AMR/Dynamic Pricing Smart Grid Pilot.

Larry Gelbien. Director, DA sponsor and lead deployment of over 1200 automated switches on 100% of overhead circuits at PSEG-LI. Inventor and have two patents for the development of DA. Worked with GE and S&C Electric developing advance auto-sectionalizing and auto-restoration schemes. Recognized by T&D World Magazine and various news releases as a DA SME. Performed DA evaluation work with LILCO (now PSEG-LI) evaluating state-of-the art technology, including overhead switches, reclosers, underground switches, remote terminal units, communication, and DSM for DOE, GE, S&C, MDS, and Microsol to name a few. Evaluated programs, benefits, and equipment interoperability. Massachusetts experience includes several evaluation projects for the DOE SGIG project for NSTAR Electric (now Eversource). This included DA pilot evaluation, Boston network underground monitoring evaluation, AMI pilot evaluation.

Bilhuda Rasheed. Associate Director. Bilhuda supported evaluation of 99 utility grid modernization investments under the Department of Energy Smart Grid Investment Grants Program; and assisted utilities (Eversource and PSEG) and states (New Jersey Board of Public Utilities) with Grid Modernization planning and evaluation.

Allie Shepard. Consultant, ADA Analyst. Allie supports energy efficiency evaluations and program planning for several utilities. She has prior Massachusetts experience supporting the statewide residential baseline study.

<u>EDC Roles</u>

Each EDC has identified a single point of contact that will complete the data request and be available to meet with Guidehouse semi-annually.

4. SCHEDULE

Table 3 shows, at a high level, the overall three-year schedule.

Table 3. Three-Year Schedule

Key Milestone Tasks	2019				2020				2021			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Develop Stage 3 Plan		1A				1B						
2.Collect & Review IM Data		2A	2B	2C	2D		2G		2H			
2. Collect & Review PM Data						2E, 2F				2I		
3. Assess IMs					3A				3C			
3. Assess PMs						3B				3D		
4. Reporting					4A, 4B	4C, 4D				4E, 4F		

Milestones:

1A Stage 3 Evaluation Plan (completed)
2A Q2 Data Request Form (completed)
2B Q2 Data Status Memo (completed)
2C Q4 (IM) Data Request Form - Updated (completed-note this spans multiple IAs, but is listed here for reference)
2D Q4 (IM) Data Status Memo (completed)
3A PY'19 (IM) Draft Presentation of Results (completed)
4A PY'19 (IM) Draft Report (completed)
4B PY'19 (IM) Final Report (in-process)
1B Stage 3 Evaluation Plan (updated)
2E Q4 (PM) Data Request Form - Updated
2F Q4 (PM) Data Status Memo
3B PY'19 (PM) Draft Presentation of Results
4C PY'19 (PM) Draft Addendum to Report
4D PY'19 (PM) Final Addendum to Report

2G Q2 (IM) Data Status Memo
2H Q4 (IM) Data Status Memo
3C PY'20 (IM) Draft Presentation of Results
2I Q4 (PM) Data Status Memo
3D PY'20 (PM) Draft Presentation of Results
4E PY'19 (IM+PM) Draft Report
4F PY'19 (IM+PM) Final Report

5. METRIC DEFINITIONS

The metrics that will be used in the evaluation of the ADA investments are further defined below. These definitions are consistent with those stamped-approved by the DPU.

5.1 Infrastructure Metrics

5.1.1 System Automation Saturation

“System Automation Saturation” is a measurement, calculated by using the number of customers that benefit from a fully automated or partially automated device. As defined by the EDC, the terms “fully automated” and “partially automated” will refer to benefits feeders received by attained optimal or partial, levels of visibility, command and control, and self-healing capability through the ADA investment. It is expected that all ADA equipment, upon being tested and placed into service will be fully automated. If not, it may be classified as partially automated. The following table provides a list of equipment that is expected to be fully automated.

The metric calculation is defined and calculated as follows:

System Automation Saturation =
Customers Served / (Fully Automated Device + 0.5*(Partially Automated Device))

Baseline saturation value will be calculated based on what exists on the EDC systems as of the date the baseline was first calculated. As more automation is installed on EDC systems, both under the GMP and pursuant to other system investment outside of the GMP, the results of this metric will be expected to go down (lower number). Customers that can benefit from multiple devices will be counted as one for purposes of calculating the baseline.

Table 7. ADA Devices

Device Type	Full Automation
Overhead Reclosers/Switches	X
Overhead Reclosers/Switches with Feeder Tie	X
Oil Switch Replacement (New VFI)	X
Vacuum Fault Interrupter (VFI) Retrofit	X

5.1.2 Number of Devices or Other Technologies Deployed

The metric measures how the EDCs are progressing with their GMPs from an equipment and/or device installation standpoint. The number of ADA devices installed will be compared to the total number of devices planned to be installed for each circuit. The following information will be tracked and reported upon for each ADA device at the circuit level and rolled up to the substation level:

1. Number of ADA devices deployed; by circuit
2. Total number of devices planned for the circuit
3. Percent – Number of devices deployed / total number of devices planned

This information will be provided on a semi-annual basis. Data will be based upon the results at the end of the calendar year. This metric is strictly a grid modernization deployment metric: accordingly, the baseline for this metric starts at zero to ensure that prior investments are not captured in the baseline. To track intermediate progress, this metric will be reported according to the three “level-of-complete” deployment stages:

1) Engineering Completed: number of devices for which engineering work has been completed. This will track when the circuit and general location of the device has been determined
2) Design Completed: number of devices for which the design work has been completed. This will track when the detailed ADA design has been completed, which would include specific device location and cost estimate.
3) Construction Completed: number of devices for which construction has been completed. At this stage, the devices are in-service and used and useful. This will track when all field construction has been done.
4) Commissioned: number of devices that are commissioned and operational for Grid Modernization purposes.

5.1.3 Cost for Deployment

This metric measures the associated costs for the devices or technologies installed and is designed to measure how the EDCs are progressing, according to approved budgets. The actual cost of installing a device(s) on a circuit will be compared to the estimated cost for the installation of the device(s). The following information will be tracked and reported upon:

1. Actual cost to deploy ADA devices per circuit
2. Estimated cost for devices deployment per circuit
3. Percent – Cost of devices installed / estimated cost of devices deployed

This information will be provided on an annual basis. Results will be based upon the results at the end of the calendar year. The baseline comparison for this analysis will be based upon a combination of the GMPs and other additional detailed design and planning where appropriate.

5.1.4 Deviation between Actual and Planned Deployment for the Plan Year

This metric is designed to measure how the EDCs are progressing on a year-by-year basis. The quantity and cost of ADA devices or technology installed for the year will be compared to what was planned for each year and any variations will be reported. The following information will be tracked and reported upon at the circuit level and rolled up to the substation level:

1. Number of ADA devices or technology installed for the year versus what was planned for a given year

2. Total actual cost for devices or technologies installed in a given year compared to the total budgetary cost for a given year
3. Reason for discrepancies

This information will be provided on an annual basis. Results will be based upon the results at the end of the calendar year.

5.1.5 Projected Deployment for the Remainder of the Three-Year Term

The metric will compare the revised projected deployment with the original targeted deployment as the EDCs progress in their implementation. The year-by-year investment plan may change based upon the quantity of work completed, the availability of the technology, material lead times, contractor availability, etc. Each year's revised investment plan will be used as the basis of comparison for the following year's GMP work. The following information will be tracked and reported upon for the ADA investment at the circuit level and rolled up to the substation level:

1. Number of devices or technology estimated to be installed the following year(s)
2. Budgetary cost to install devices or technologies in the following year(s)

This information will be provided on an annual basis. Results will be based upon the results at the end of the calendar year. The metric will be reported upon at the circuit level and rolled up to the substation level. The metric will be used as the baseline and target for the following year's work.

5.2 Performance Metrics

The primary benefit is to improve reliability measures by reducing the amount of time customers are without power and reducing number of customers affected by outages. The performance metrics defined below intend to measure accurately the improvements in reliability that can be attributed to ADA investments.

5.2.1 Grid Modernization Investment Effect on Outage Duration

This metric will compare the reliability of the circuits with the ADA investment as compared to the prior three-year average for the same circuit. This metric will provide insight into how ADA can reduce the duration of outages. As set by the MA DPU guidelines, the ADA restoration solutions must restore or avoid customer outage in under the one-minute threshold.

The metric will use a pre-investment baseline of a static three-year average circuit level SAIDI for years 2015, 2016, and 2017 for each circuit. The pre-investment baseline will be calculated by the EDCs with and without Excludable Major Events. The baseline will include a summary of the main causes of outages on each circuit. Based on the baseline, the metric will compare the SAIDI results of the plan year.

This metric will track and report on the following:

1. Circuit level SAIDI for circuits that have ADA installed in the plan year.

2. Three-year average (2015, 2016, 2017) circuit level SAIDI prior to grid modernization investments.
3. Compare the current year circuit SAIDI with the three-year historic average SAIDI of the circuit prior to grid modernization investments.

This information will be provided on an annual basis. Results will be based upon the results at the end of the calendar year. The target for this metric is to have the current year circuit level SAIDI to be less than the baseline.

5.2.2 Grid Modernization Investment Effect on Outage Frequency

This metric will compare the reliability of the circuits with the ADA investment as compared to the prior three-year average for the same circuit. This metric will provide insight into how ADA can reduce the frequency of outages. As set by the MA DPU guidelines, the ADA restoration solutions must restore or avoid customer outages in under the one-minute threshold.

The metric will use a pre-investment baseline of a static three-year average circuit level SAIFI for years 2015, 2016, and 2017 for each circuit. The pre-investment baseline will be calculated by the EDCs with and without Excludable Major Events. Based on the baseline, the metric will compare the SAIFI results of the plan year.

This metric will track and report on the following:

1. Circuit level SAIFI for circuits that have ADA installed in the plan year
2. Three-year average (2015, 2016, 2017) circuit level SAIFI prior to grid modernization investments
3. Compare the current year circuit SAIFI with the three-year historic average SAIFI of the circuit prior to grid modernization investments

This information will be provided on an annual basis. Results will be based upon the results at the end of the calendar year. The target for this metric is to have the current year circuit level SAIFI to be less than the baseline.

5.2.3 Number of Customers that benefit from GMP-funded distribution automation devices

This metric will track the number of customers that benefitted from the installation of ADA devices. This metric will support the objective of optimizing system performance and reducing the duration and number of customers impacted by outage events.

A customer is defined as having benefitted from ADA when their automated zone size is reduced. This metric will track and report the following:

- Circuit number
- Number of customers impacted

The baseline for this metric will start at zero since this will be tracking only the customers that benefit from GMP investments. A table with the type of device, circuit number where installed, and number of customers benefited will be provided to support the tracking of this metric.

5.2.4 Reliability-Related Company-Specific Performance Metrics

In addition, Eversource and Until have defined additional reliability metrics to be measured as described below. National Grid's reliability-related metric is under development.

Eversource Customer Outage Metric

This metric will measure Eversource's progress in sectionalizing circuits into protective zones designed to limit outages to customers located within the zone. The metric will track the average zone size in terms of number of customers interconnected in each protective zone for each circuit and sum of the circuits in Eastern and Western MA. The metric will use 2018 average zone size by circuit as the baseline.

National Grid Reliability-Related Company Specific Performance Metric

Main Line Customer Minutes of Interruption Saved is a metric primarily designed to measure the effectiveness of ADA investments. This metric will look at:

- Historical customer minutes of interruption for mainline interruptions
- Calendar year customer minutes of interruption for mainline interruptions.

5.2.5 Case Studies to illustrate how reliability is being improved

The case studies will examine the impact the ADA investments had on reducing the outage frequency or duration, and will exemplify system outages with explanation of the mechanisms employed and devices used to achieve the reliability improvement.

NAVIGANT
A Guidehouse Company

Study #4 – Volt Var Optimization Evaluation Plan

Stage 3 Plan

Prepared for:

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TABLE OF CONTENTS

1. INTRODUCTION

The Massachusetts Electric Distribution Companies (EDCs) will be making investments to enable volt var optimization (VVO) on selected feeders across their distribution networks. Department preauthorized investment in the VVO investment area are expected to total $25.8m over 2018 to 2020; $13m by Eversource, $10.6m by National Grid and $2.2m by Unitil.

VVO is a solution that optimizes distribution voltage to achieve goals such as reducing energy consumption and demand without the need for customer interaction or participation. The core principle behind VVO is that for many end-use loads, power demand is reduced at voltages in the lower end of their allowable range.

The primary goal of VVO is to reduce circuit demand and energy consumption by flattening and lowering the voltage profile on the circuit 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.

Quantifying VVO impacts requires interval measurements of circuit-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, we recommend that that the EDCs continue a VVO on / off cycling for at least nine months, covering summer, winter, and one of either the spring or fall shoulder seasons. If sufficient pre- and post-period data are available, the impacts of pre-installation line-conditioning can also be measured. The metrics discussed below are all based on a measurement and verification ("M&V") process, which uses statistical analysis to quantify the impacts the VVO system has on the customers it serves.

The VVO investment will first condition feeders, install equipment, and commission software. Once this step is complete, the VVO system will be enabled. The cumulative number of feeders that will reach of these milestones by quarter is provided in Table 1 and Table 2.

Table 1. Number of Feeders with Completed VVO Investments* By EDC

	Fall 2019	Winter 19/20	Spring 2020	Summer 2020	Fall 2020	Winter 20/21
Eversource	0	26	26	26	26	26
National Grid	0	0	6	16	16	16
Unitil	0	0	0	3	6	6

** This includes activities such as phase balancing, VVO device installations, and VVO software commissioning.*
Source: Data provided by EDCs as of January 2020.

Table 2. Cumulative VVO-Enabled Feeders by EDC

	Fall 2019	Winter 19/20	Spring 2020	Summer 2020	Fall 2020	Winter 20/21
Eversource	0	0	26	26	26	26
National Grid	0	0	6	16	16	16
Unitil	0	0	0	0	0	0

Note: Includes feeders for which VVO is enabled and ready for On / Off testing.
Source: Data provided by EDCs as of January 2020.

Eversource installed capacitor banks, regulators, LTC controls and line sensors over 2018 through 2019. Final devices are being deployed across additional substations in Winter 2019/2020. These investments are will cover 26 feeders, all of which will be VVO-enabled by the beginning of Spring 2020.

National Grid began deploying VVO devices at the end of 2019 and will continue to do so through 2020 by adding voltage regulators, capacitor banks, LTC controls, and line voltage monitors. One feeder received initial investments by the end of 2019, with device deployment expected to be complete across all 16 feeders in Summer 2020. All of these feeders are projected to be VVO-enabled and actively controlled by Summer 2020.

Unitil began VVO investments in 2019, and feeders are in the process of being upgraded with capacitor banks, regulators, LTC controls, and line sensors. One substation will have complete VVO device installations by Summer 2020, with two additional substations to have complete installations by Winter 2020/2021. Unitil does not plan to enable active VVO control of these feeders before Winter 2020/2021 because as the VVO device deployment and VVO commissioning is now integrated with ADMS[10].

1.1 Overall Study Goals

This plan will evaluate the progress and effectiveness of the DPU preauthorized VVO investments for each EDC towards meeting the DPU's grid modernization objectives.[11] The evaluation will primarily address the "optimize system demand objective". The evaluation will leverage the infrastructure metrics and EDC *proposed* performance metrics shown in the table below. As the details of the evaluation approach are developed, other metrics may be considered.

1.2 Research Questions

The scope of the VVO measurement and verification (M&V) will include tracking the VVO infrastructure deployment against plan, measuring the energy, peak demand, and greenhouse gas (GHG) impacts of installation VVO devices and operating VVO on the feeders that have been VVO enabled (see Table 3).

Table 3. VVO M&V Objectives and Associated 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?
Energy & Peak Savings by Feeder (VVO Investment*)	• How much energy savings has been realized from VVO investments deployed on VVO-enabled feeders? • How much GHG emissions reduction has been enabled from VVO investments deployed on VVO-enabled feeders?

[10] As Unitil will not be enabling VVO control until December 2020 and SCADA availability is limited during the baseline period, PM analysis for Unitil will be limited to tracking of voltage complaints.

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

VVO M&V Objective	Associated Research Questions
Energy & Peak Savings by Feeder (VVO-operation)	• How much energy savings has been realized from VVO operating on VVO-enabled feeders? • What is the impact on peak load from VVO operating on VVO-enabled feeders? • How much GHG emissions reduction has been enabled from VVO operating on VVO-enabled feeders?
Voltage Complaints	• What is the impact of the VVO-related investments on the number of voltage complaints?

* Device deployment comprises substation- or feeder-level improvements undertaken prior to, but in anticipation of, installing a VVO system. These may include, e.g., reconductoring, phase-balancing, or adding capacitors, regulators, and related equipment.

Table 4 and Table 5 show that each performance metric will be addressed by each stage of the research – VVO investment, and VVO-enabled operation.

Table 4. Performance Metrics by VVO stage

Performance Metrics	VVO Investment**	VVO Operation
PM-2 Energy Savings	✓	✓
PM-3 Peak Demand Savings	✓	✓
PM-4 Loss Reduction		✓
PM-5 Power Factor Improvement		✓
PM-6 GHG Emissions*	✓	✓
PM-7 Voltage Complaints	✓	✓

* Includes customer energy savings (PM-2) and feeder loss reduction (PM-4).
** VVO Investment includes activities such as phase balancing, VVO device installations, and VVO software commissioning.

Table 5. Performance Metrics by EDC

	Eversource	National Grid	Unitil
VVO Investment	✓*	✓	**
VVO-enabled	✓	✓	

* Eversource has indicated hourly data may be available for some, but not all, feeders during the pre-VVO investment period.
** Unitil has indicated that hourly data are not available for constructing the baseline necessary to estimate savings associated with VVO investments. For this reason, only the voltage complaint performance metric will be reported for Unitil.

1.3 Evaluation Metrics

Table 6 shows the key metrics on which the evaluation will report. These include four infrastructure metrics and six performance metrics. The data supporting the infrastructure metrics will be collected and provided to the evaluation team by the EDCs. The evaluation team will collate them and discuss each EDC's progress relative to its planned deployments.

The performance metrics will be based on statistical analyses performed by the evaluation team using data provided by each EDC. These are detailed in Section 5.

Table 6. VVO Evaluation Metrics

Metric 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 three-year term	✓	✓	✓
PM-1	VVO Baseline	✓	✓	
PM-2	VVO Energy Savings	✓	✓	
PM-3	VVO Peak Load Impact	✓	✓	
PM-4	VVO Distribution Losses w/o AMF (Baseline)	✓	✓	
PM-5	VVO Power Factor	✓	✓	
PM-6	VVO – GHG Emissions	✓	✓	
PM-7	Voltage Complaints	✓	✓	✓

* IM = infrastructure metric, PM = performance metric

1.4 Summary of Performance Evaluation Activities

To assess the infrastructure metrics, Navigant will work with each EDC to identify the status of the pre-authorized grid modernization investments. In addition, Navigant will use predictive statistical modeling to assess each feeder's performance, where possible seeking to identify the impact of the deployment of VVO investments and the active VVO control.

The main tasks described within the Stage 3 Plan include:

- Task 1: Detailed Evaluation Plan development (this document) will confirm the specific data available from each EDC including from the pre-deployment period and experimental design (on and off testing) period and confirming the timing of when feeders will be enabled to support VVO.
- Task 2: Data Assimilation and Collection will establish the specific data required for the VVO evaluation and how the data will be transferred to Navigant on a regular basis.
- Task 3: Assessment of infrastructure metrics will compare and contrast the number of devices and cost for the deployment planned for each EDC and what was invested by year.
- Task 4: Data Analytics and Modeling for performance metrics will leverage statistical analyses to assess interval circuit-level demand and reactive power data together with temperature data to develop weather-adjusted load shapes for each VVO-enabled feeder. Recognizing that customer load mix varies seasonally and across feeders, separate estimates will be made on each test feeder for each season for the VVO-on and VVO-off states.
- Task 5: Reporting including an initial presentation with draft results, a written Draft, Final-Draft, and Final report versions. These will support the Annual Reports and Term Report.

2. METHODOLOGY

The evaluation will consist of the following major tasks:

- Task 1. Evaluation Plan
- Task 2. Data Assimilation and Collection
- Task 3: Assess Infrastructure Metrics
- Task 4. Data Analytics and Modeling (Performance Metrics)
- Task 5. Reporting

This section describes the Evaluation Team's approach to each task.

2.1 Task 1. Evaluation Plan

The detailed Evaluation Plan development (this document) will confirm the specific data available from each EDC including from the pre-deployment period and experimental design (on and off testing) period and confirming the timing of when feeders will be enabled to support VVO.

The Stage 3 plan was revised in February of 2020.

The key activities of this task include:

- Understand extent and schedule for the VVO investment for each EDC
- Align on the common terminology that will be used across the EDCs
- Confirm performance metrics definitions can be applied consistently across the EDCs
- Update/refine metric definitions, as necessary
- Identify data elements required for the evaluation and assess their availability across the EDCs
- Agree on the experimental design (e.g., on and off testing during the active VVO control period) and its duration
- Establish protocols for sharing data for the duration of the project
- Agree on the overall evaluation scope
- Agree on the frequency of data collection and analysis to be completed by Navigant
- Agree on the contents of subsequent reports
- Confirm allocation across EDCs

Deliverables:

- Final Stage 3 Evaluation Plan
- Revised Stage 3 Evaluation Plan (this document)

2.2 Task 2. Data Assimilation and Collection

During this task Navigant will work with the EDCs to confirm the data required and available for completing the VVO evaluation. In addition, this section describes when the EDCs will share data with Navigant for further analysis, which is described in Task 3.

The data request will identify the specific data fields and when they will be needed from the EDCs. The final data request will incorporate the feedback of the EDCs and will include the schedule the team will work toward achieving.

We anticipate that data necessary to perform the evaluation will come from multiple sources: EDC data such as SCADA and/or sensor data and NOAA weather and/or climate data. Table 7 describes the data types and measurement frequencies required to implement the Evaluation, Measurement, and Verification (EM&V) protocol.

Table 7. Data Required for VVO Evaluation

Data Type	Data	Source
EDC System information	• Feeder characteristics (e.g., rated primary voltage, rated capacity, feeder length, # customers (res, com, ind, etc.), load factor (ratio of average load to peak load), ZIP code or town number of capacitors, number of regulators • Distributed generation information (e.g., type, size, installation date, feeder) • Demand response events (time-stamped log of any system-wide DR (or similar) events, for example: ISO-NE DR, EDC direct load control programs, EDC behavioral DR programs) • Operational changes (time-stamped log of changes to substation and feeders away from normal operating state (temporary or permanent), and power outages) • Voltage-related complaints based on voltage perturbation (e.g., high voltage, low voltage, flicker), duration (e.g., multiple days, sporadic)	EDC
Deployment information	• Description of voltage control devices • Voltage control devices installed by feeder • Cost of deployment by EDC	EDC
Time series data (hourly)	• Feeder head-end (voltage, current, apparent power, reactive power, power factor) • Distributed generation (gross generation) energy data for large facilities (e.g., >100 kW)	EDC
VVO system information	• Time-stamped log of VVO state changes between on and off states and any other VVO modes	EDC
Weather data	• Hourly temperature data from selected weather stations	NOAA

As part of Task 2, we will provide you with a separate document listing the specific fields, keyed to field headers or labels from the sample data files and one-line diagrams you have already supplied. We will work with you to securely transfer the historical data (e.g., annual 2017) and the required test data following each of the seasonal test periods (e.g., summer 2020, autumn 2020, winter 2020-2021). We assume relevant data will start to be shared seasonally with the Navigant team.

Upon receipt of each dataset, Navigant will perform QA/QC. The QA/QC includes checks to confirm each PM-related dataset can be incorporated within the regression analysis. Examples of the QA/QC include:

- Time series data cover each feeder receiving VVO investments and include variables needed to facilitate analysis of performance metrics, including voltage and real power; 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)
- Interval data have been provided for large distributed generation facilities
- Voltage complaints data have been received for each feeder receiving VVO investments and are at an adequate level of detail for analysis (for instance, sufficient information regarding voltage perturbation)

After PM-related data are received at the end of every season, Navigant will provide a summary of the QA/QC in a status update memo that will be provided to the EDCs that confirms receipt of the datasets and indicates quality.

In addition, Navigant will receive IM-related data from the EDCs every six months. Different QA/QC steps will be taken to ensure the quality of this data. Examples of the QA/QC include:

- Determining completeness of actual versus planned investments, deployment costs
- Flagging presence of variance in actual versus planned investments
- Checking actual versus planned deployment schedules for missingness or inconsistencies.

After IM-related data are received every six months, Navigant will provide a summary of the QA/QC in a status update memo that will be provided to the EDCs that confirms receipt of the datasets and indicates quality. In addition, at the end of every calendar year, Navigant will provide a summary of the QA/QC encompassing the entire calendar year in a status update memo for infrastructure metrics only.

Although Navigant will perform this QA/QC for both PM- and IM-related data, we assume that the data provided to Navigant by the EDCs will not require additional back and forth. Additional iteration will require modifications to scope and budget.

Deliverables:

- Data request specific to each EDC
- Summary of the QA/QC review associated with the PMs by season (assumes 6 seasons)
- Summary of the QA/QC review associated with the IMs by half-year (assumes 4 periods)

2.3 Task 3: Assess Infrastructure Metrics

Annually, assess the progress of the EDCs towards enabling VVO on their feeders. This task entails:

- Ensuring alignment of infrastructure metrics with the VVO investment
- Establishing the baseline as it relates to the VVO investment
- Obtaining and understanding planned VVO investments by EDC
- Interviewing a representative from each EDC to understand the status of the VVO investments
- Preparing a summary presentation that describes our understanding of the year's VVO investment relative to the baseline and plan (to be completed as inputs to the 2019 Evaluation Report and 2020 Evaluation Report)

We will work with the EDCs to establish a common description of asset types, for example:

- Line voltage control device – this can include capacitor banks or line regulators
- Substation voltage control device – LTCs
- Line sensors – Feeder head and end-of-line
- VVO software – standalone or integrated with ADMS

In addition, we will work with the EDCs to establish a common definition to assess the "level-of-complete" across their VVO and other Grid Modernization investments. See Section 5 for definitions.
These definitions will be utilized for the infrastructure metrics, described below, that will be discussed in the Annual Reports filed in 2020 (includes investments in 2018 and 2019) and 2021 (includes investments in 2018, 2019 and 2020).

Deliverables for Task 3:

- Draft PowerPoint of Infrastructure Metrics in advance of 2019 Evaluation Report
- Draft PowerPoint of Infrastructure Metrics in advance of 2020 Evaluation Report

2.4 Task 4. Data Analysis & Modeling for Performance Metrics

We will assess impacts of deployment of VVO investments and of active VVO control of VVO-enabled feeders. In order to estimate impacts associated with the VVO-enabled state, Navigant recommends that the VVO on / off period covers at least nine-months spanning winter, summer, and either the fall or spring shoulder.

Deployment of VVO investments and completion of VVO system commissioning is not expected to be completed until the Spring of 2020 for Eversource and National Grid. As a result, VVO on / off testing is not expected to begin until Spring 2020 for Eversource and Summer 2020 for National Grid. Given this, on / off testing will be continuing through at least winter of 2020/2021 at minimum to obtain at least one summer and one winter season. The Eversource on/off testing will include Spring 2020, Summer 2020, Fall 2020, and Winter 2020/21 and the National Grid on/off testing will include Summer 2020, Fall 2020, and Winter 2020/21. Thus, no performance metrics will be evaluated ahead of the 2019 Evaluation Report, as data will be insufficient at that time. Instead, Navigant will provide the PM analysis for the 2020

Evaluation Report, where there should be sufficient data spanning the pre- and post-VVO investment time periods and sufficient VVO on / off testing data.

The key task includes completing an analysis of the QA/QC'd data collected during Task 2 to:

- Establish hourly profiles of pre-VVO-enabled feeders by season for each feeder for the following characteristics: voltage; true power; apparent power or reactive power; power factor
- Establish hourly profiles VVO-on by season for each feeder for the following characteristics: voltage; true power; apparent power or reactive power; power factor
- Establish hourly profiles VVO-off by season for each feeder for the following characteristics: voltage; true power; apparent power or reactive power; power factor

These hourly profiles will then be compared to assess the impact of the deployment of VVO investment and of VVO-enabled feeders.

- VVO investment: compare VVO-off to pre-VVO
- VVO-enabled: compare VVO-on to VVO-off

The comparison would be completed by feeder and by season, as well as annually. Seasons will be defined as:

- Winter: December, January, and February
- Spring: March, April, and May
- Summer, June, July, and August
- Fall: September, October, and November

We will perform our evaluation at the level of aggregation permitted by the data obtained from the EDCs' SCADA systems: at either the transformer or (preferably) the feeder level. We will develop power and voltage models trained to all data from each test period (i.e., the period during which the control state alternates on a day-on/day-off schedule), and then use these empirical models to simulate annualized profiles under VVO-on and VVO-off scenarios. The impacts will be measured as the summed difference between the two simulations.

The basic form of the models Navigant will use to estimate VVO impacts on real power, reactive power, or voltage on a given feeder or transformer[12] in a specific test period will be:

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

where:

- i, t, and p index the feeder/transformer, time interval, and test period (i.e., summer, autumn, winter), respectively;
- $X_{i,t,p}$ is the interval load – in MW units in the case of real power, |MVAR| in the case of reactive power – or voltage on feeder/transformer i at time t in period p. Interval power should be measured at the substation, while voltage will be measured as the load-weighted average of

[12] If telemetry data are available by feeder we will perform a separate analysis for each feeder; otherwise, the analysis will be performed by transformer.

interval voltage readings from the AMI meters of the connected customer service points on feeders (if any) where reliable AMI voltage data are available, or at the substation otherwise;

- *load-shape elements* refers to model components designed to capture the underlying time-varying patterns observed in the data, including hour of day, week of year, day of year, weekend, elapsed days since Jan 1, 2017, and holidays;
- *weather features* refers to the weather components included in the model, including heating and cooling degree-days, normalized heat build-up, and various lagged values of these features;
- *feeder characteristics* refers to static (or infrequently-changing) characteristics of each VVO-enabled feeder, such as average or typical load mix (by customer type), conductor miles, geographic location, load factor, most recent annual peak, rated load, rated primary voltage, number of capacitor banks and regulators;
- *VVO status* refers to whether the VVO controls are engaged or disengaged during time interval t;
- *Events* comprises a set of binary flags indicating whether time interval t falls during an event that temporarily affects feeder load, such as a DR event, outage, or temporary load-shifting;
- *VVO Investment* refers to whether time interval t falls before, during, or after the VVO investments have been deployed; and
- ΔLRs comprises a set of binary flags indicating when a given load-regime change has occurred.

Deliverables from Task 4:

- Draft PowerPoint of Performance Metrics for 2020 Annual Report[13]

2.5 Task 5. Reporting

By the time we start preparing the annual evaluation reports, the EDCs will be well-aware of our approach, findings, and recommendations through the presentations delivered in Task 3 and Task 4. During this task we will prepare a draft evaluation report (MS Word) and incorporate feedback in a final evaluation report (MS Word). The evaluation reports will include the following sections:

- Executive Summary
- Investment description
- Evaluation objectives
- Description of the evaluation approach
- Analysis of infrastructure metrics
- Analysis of performance metrics
- Findings & Recommendations
- Appendices with additional work product, for example,
  - Summary of data collected from the EDCs
  - Intermediate analysis outputs

[13] The EDCs have requested complete an assessment of the VVO Performance Metrics in support of the 2020 Annual Reports.

Deliverables:

- Draft 2019 Evaluation Report (IM only) (Word)
- Final 2019 Evaluation Report (IM only) (Word)
- Draft 2020 Evaluation Report (IM and PM) (Word)
- Final 2020 Evaluation Report (IM and PM) (Word)

3. STAFFING

The role of the evaluation team will be to carry out the tasks described in this Stage 3 Evaluation Plan. This team is experienced in VVO evaluation having completed similar engagements at other US utilities.

Erik Gilbert. Director, Overall Project Manager. Erik provided subject matter expertise on a number of Massachusetts advanced technology evaluation projects, including National Grid's Worcester Smart Energy Solutions project and Eversource's (NSTAR's) AMR/Dynamic Pricing Smart Grid Pilot. He leads Navigant's Grid Modernization Solutions development and delivery.

Steven Tobias, Director. Steven leads impact and process evaluation of Massachusetts DR programs; manages the ongoing Smart Energy Solutions evaluation; manages the VVO evaluation of National Grid's Clifton Park VVO demonstration. Also leads studies to assess benefits and costs of electric and distribution investments (e.g., distribution automation, superconductors) and customer technologies (e.g., solar + energy storage). He has 14 years of experience; B.S. and M.S. degrees from MIT.

Paul Higgins, Associate Director, VVO Area Lead. Paul leads measurement and verification (M&V) of energy savings and demand reductions of VVO installations for Commonwealth Edison, Pacific Gas & Electric, Tucson Electric, and Potomac Edison. He also leads the impact and process evaluations of Commonwealth Edison Small Business and Public Small Facilities programs. He has 23 years of experience; B.A. degrees from University of California, M.S. degree from Tulane University, both in Economics.

Ethan Young, Managing Consultant, Lead Data Scientist. Ethan participates in data analytics for M&V of Commonwealth Edison and Ameren Illinois VVO installations. He is currently leading VVO and CVR analysis for two major utilities. He has experience in evaluation spanning behavioral programs, smart thermostats, and demand response. Ethan has 2.5 years of experience after graduating from the University of Wisconsin Madison with a Ph.D. in Agricultural & Applied Economics.

Jennifer Ma, Senior Consultant, Senior Data Scientist. Jen participates in data analytics for M&V of MA Grid Mod and Clifton Park VVO installations. Jen supports VVO by focusing on capturing efficiencies with improved data management and QAQC. She has 2.5 years of experience after graduating from the University of Virginia with a B.S. in Chemical Engineering.

Taylor Burdge, Consultant, Data Scientist. Taylor has contributed to a variety of grid modernization efforts for Duke Energy, Tucson Electric Power, and other utilities. She has prior Massachusetts experience leading analyses for Boston's Smart Utilities policy and supporting EM&V work for demand response programs. Taylor has 3.5 years of experience after graduating from Stanford University with a B.S. in Energy, Science & Technology.

<u>EDC Roles</u>
Navigant requests that each EDC identify a single point of contact that will complete the data requests and be available to meet with us quarterly.

4. SCHEDULE

Table 8 shows, at a high level, the overall schedule for the VVO evaluation.

Table 8. VVO Evaluation Schedule

Key Tasks	2019				2020				2021	
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
1. Develop Stage 3 Plan	A				A1					
2. Collect & Review IM Data		B	C		E		K		N	
2. Collect & Review PM Data					D	I J	L	M	P	
3. Assess IMs					F				O	
4. Analysis for PMs										Q
5. Reporting					G H					R S

Milestones:
A. Final Stage 3 Evaluation Plan
A1. Revised Stage 3 Evaluation Plan
B. Data request form agreed with EDCs
C. H1 2019 IM QA/QC Memo
D. Fall 2019 PM QA/QC Memo
E. H2 2019 IM QA/QC Memo
F. Draft PowerPoint of 2019 analysis (IMs)
G. 2019 Draft Evaluation Report
H. 2019 Final Evaluation Report
I. Winter 2019/20 PM QA/QC Memo
J. Spring 2020 PM QA/QC Memo
K. H1 2020 IM QA/QC Memo
L. Summer 2020 PM QA/QC Memo
M. Fall 2020 PM QA/QC Memo
N. H2 2020 IM QA/QC Memo
O. Draft PowerPoint of 2020 analysis (IMs)
P. Winter 2020/21 PM QA/QC Memo
Q. Draft PowerPoint of 2020 analysis (PMs)
R. 2020 Draft Evaluation Report
S. 2020 Final Evaluation Report

5. METRIC DEFINITIONS

5.1 Infrastructure Metrics

IM-4. Number of Devices or other technologies deployed

The number of VVO-related devices installed by substation and/or circuit by calendar year will be compared to the total number of devices planned by substation and/or circuit over 2018 to 2020. The comparison will yield a percent – number of devices installed[14] / total number of devices planned.

Table 11. Number of Devices

EDC	Feeder	Preauthorized Device Type	2018 (Actual)	2019 (Actual)	2020 (Actual)	Planned Total (2018-20)	Percent as of Year
A	123	AAA	#	#	#	#	%
A	123	BBB	#	#	#	#	%
A	123	CCC	#	#	#	#	%
A	124	AAA	#	#	#	#	%
A	124	BBB	#	#	#	#	%
A	124	CCC	#	#	#	#	%

The “level-of-complete” deployment stages are defined as follows:

1) Engineering Completed: number of devices for which engineering work has been completed. This will track when the circuit and general location of the device has been determined
2) Design Completed: number of devices for which the design work has been completed. This will track when the detailed VVO design has been completed, which would include specific device location and cost estimate.
3) Construction Completed: number of devices for which construction has been completed. This will track when all field construction has been done.

IM-5. Cost for deployment

The cost of VVO-related devices installed by substation and/or circuit by calendar year will be compared to the total cost of devices planned by substation and/or circuit over 2018 to 2020. The comparison will yield a percent – cost for VVO-related devices / total planned cost for VVO.

[14] Beyond deployment of VVO investments and VVO enabled status, incorporating a “level of complete” for VVO investments may be appropriate. This may take the form of engineered, designed, constructed. Currently, this detail is not included in the scope of the Stage 3 Plan.

Table 12. Cost for Deployment

EDC	Feeder	Asset Type	2018 (Actual)	2019 (Actual)	2020 (Actual)	Planned Total (2018-20)	Percent as of Year
A	123	AAA	$	$	$	$	%
A	123	BBB	$	$	$	$	%
A	123	CCC	$	$	$	$	%
A	124	AAA	$	$	$	$	%
A	124	BBB	$	$	$	$	%
A	124	CCC	$	$	$	$	%

IM-6. Deviation between actual and planned deployment for the plan year
IM-7. Projected deployment for the remainder of the three-year term

The deviation between actual and planned deployment will focus on which feeders are VVO-enabled feeders by calendar year and season and compare to the plan.

Table 13. Deployment Status

EDC	Feeder	Anticipated Commission Date	Actual Commission Date	Status*
A	123	MM / DD / YYYY	MM / DD / YYYY	
A	124	MM / DD / YYYY	MM / DD / YYYY	
A	125	MM / DD / YYYY	MM / DD / YYYY	

* Status can be: planning, design, construction, device deployment complete, VVO commissioning in process, or VVO enabled.

At the company level, provide the deviation between actual and planned cumulative VVO-enabled feeders by calendar year.

Table 14. Feeder Deployment

	2018	2019	2020	2018-20
Actual	#	#	#	#
Planned	#	#	#	#
Revised in 2020	#	#	#	#
Revised in 2021	#	#	#	#
% Actual of Revised	%	%	%	%

At the company level, provide the deviation between actual and planned cumulative VVO investment by calendar year.

Table 15. VVO Investment

	2018	2019	2020	2018-20
Actual	$	$	$	$
Planned	$	$	$	$
Revised in 2020	$	$	$	$
Revised in 2021	$	$	$	$
% Actual of Revised	%	%	%	%

5.2 Performance Metrics

PM-1. VVO Baseline

Two “baselines” concepts are relevant for evaluating VVO impacts: one based on data collected during the year prior to any VVO installation work is performed, and the other based on post-install data during the time the feeder is operated in VVO-off mode. The former is used only to measure the impacts of any VVO deployment steps undertaken in preparation for, or as part of, the VVO installation. These effects are measured by comparing the pre-install baseline to the VVO-off post-install baseline. The latter is used to measure the impacts of VVO when it is operating, which are captured by comparing the post-install VVO-off profile to the post-install VVO-on profile. The pre-VVO conditions will inform the impact of the deployment of VVO investments and the VVO-off state will inform the impact of VVO-on state.

Navigant recommends nine months at a minimum of data to include summer, winter and either spring or fall to sufficiently capture the seasonal changes to customer loads.

PM-2. VVO Energy Savings

Once VVO is enabled on the feeder, and after the completion of the on / off testing, Navigant would assess the energy impact of the VVO-on state. To determine energy savings associated with the VVO-on state, Navigant will compare an effective annual load shape based on the VVO-off and VVO-on states. Navigant will also assess the impact of the deployment of VVO investments. Navigant will determine savings associated with deployment of VVO investments by comparing a post-investment, VVO-off state effective annual load shape to energy data collected one year prior to the deployment of VVO investments. Navigant will also compare the post-investment, VVO-off state to the baseline annual energy delivered for 2015, 2016, and 2017.

Data permitting, Navigant will report annual energy savings and energy savings for four additional periods, which are defined as

- Winter Peak Energy kWh: 7 AM – 11 PM, weekdays except holidays, October to May
- Winter Off-Peak Energy kWh savings: 11 PM – 7 AM weekdays, all day weekends and holidays, October to May
- Summer Peak Energy kWh savings: 7 AM – 11 PM, weekdays except holidays, June to September

- Summer Off-Peak Energy kWh savings: 11 PM – 7 AM weekdays, all day weekends and holidays, June to September

Navigant will recommend an approach when feeders are conditioned or enabled for a partial year.

PM-3. VVO Peak Load Impact

Navigant plans to assess the peak load impact by utilizing the ISO-NE definition of the summer on-peak period, which is 1:00 to 5:00 pm ET from June 1 to August 31 on non-holiday weekdays. Navigant will generate an estimate of peak load impacts using estimated hourly demand reductions during peak hours for all feeders receiving VVO-related investments. Navigant will coordinate with the EDCs on the definition of peak hours, to ensure the intended reporting of peak demand reductions. Once estimated, feeder-level peak demand reductions will be aggregated to a single estimated demand reduction attributed to VVO. Navigant will also identify a pre-investment baseline of annual peak load by feeder and substation for the years 2015, 2016, and 2017.

PM-4. VVO Distribution Losses w/o AMF (Baseline)

Navigant will calculate VVO distribution losses using hourly data for real and reactive power. Similar to the assessment of energy savings, Navigant will develop an estimate of distribution losses under VVO-on by comparing distribution losses between the VVO-on and VVO-off states after the deployment of VVO investments have been completed. Navigant will also assess the impact of the deployment of VVO investments on distribution losses by comparing real and reactive power data collected during the post-investment, VVO-off state to data collected one year prior to deployment of VVO investments.

PM-5. VVO Power Factor

Navigant will leverage the annualized hourly profile of power factors and take a simple average of the hours that correspond to power that is >75% of the feeder's peak annual demand.

The EDCs will then use the feeder averages to generate a system power factor performance, weighted by the peak demand of each respective circuit. Results will be provided under both the VVO-off state and the VVO-on state once VVO-on/off testing has been completed to inform a baseline.

PM-6. VVO – GHG Emissions

Navigant will determine the GHG emissions reduction as a function of the aggregate change in energy attributed to the VVO investment on each feeder and GHG emissions factors provided in each EDC's most recent 2019 - 2021 Three-Year Energy Efficiency Plans.

PM-7. VVO – Voltage Complaints

Navigant plans to examine customer complaint data received from each EDC to categorize voltage-related complaints based on voltage perturbation (e.g., high voltage, low voltage, flicker) and duration (e.g., multiple days, sporadic). If an EDC did not historically track voltage complaints by feeder, Navigant does not plan to analyze this metric[15].

In the analysis of voltage complaints, Navigant will first provide a voltage complaint baseline, equal to the average annual number of voltage complaints spanning 2015 through 2017. To the extent that voltage complaint and resolution data and necessary identifiers are available, voltage complaints will be mapped to specific feeders. Navigant will then tally cases in which voltage-related complaints were made for each feeder during core stages, including (1) before VVO-device deployment, (2) during device deployment, and (3) after device deployment and when VVO is enabled. Navigant will then assess whether there are any differences in the count and type of voltage complaints between each of the stages. Based on the categorization, Navigant will track the count of voltage-related complaints received over time to determine whether there are any shifts in the number of complaints associated with the VVO-related investments.

[15] As detailed in their June 6, 2019 Revised Performance Metrics ("Revised Filing") filed consistent with certain Department directives, the EDCs noted that, prior to the requirement to track and report on whether VVO investments could potentially contribute to customer complaints, the EDCs were not required to track customer voltage complaints by feeder (Revised Filing at 19-20). Going forward, the Companies intend to specifically track customer voltage complaints to determine if VVO investments led to the voltage condition giving rise to the customer complaint (id. at 20-21).

Study #5 – Workforce Management Evaluation Plan

Stage 3 Plan

Prepared for:

Massachusetts Electric Distribution Companies

Submitted by:
Navigant Consulting, Inc.
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Reference No.: 209941
March 30, 2020

TABLE OF CONTENTS

1. INTRODUCTION

Through the pre-authorized investments, the MA Electric Distribution Companies (EDCs) will be making changes to internal systems and processes to improve the customer experience and increase efficiency. In addition, Unitil is specifically investing in software to improve the efficiency and effectiveness of its damage assessment process during major storms.

1.1 Overall Study Goals

This evaluation plan describes a Unitil-focused assessment of their Mobile Damage Assessment implementation and a Grid Modernization Workforce survey, for National Grid and Unitil, that will evaluate the progress and effectiveness of the DPU preauthorized investments towards improving workforce and asset management, which is considered a benefit associated with the DPU's three objectives for grid modernization.[16]

Since the workforce management (WFM) investment is specific to Unitil, certain infrastructure metrics will only apply to Unitil. To assess the overall impact of the pre-authorized investments on National Grid's and Unitil's workforce, we will also identify research questions and metrics that that will be assessed via an online survey of employees.

1.2 Evaluation Metrics and Research Questions

Table 1 contains proposed metrics for evaluating the impact of the grid modernization investments on workforce management. Metrics associated with the progress of Unitil's rollout of the Mobile Damage Assessment are specific to Unitil. Metrics to assess the broader influence of National Grid and Unitil investments on their workforce are also proposed.

Table 1. 2019 - 2021 WFM Evaluation Metrics

Type	WFM Evaluation Metrics	ES	NG	UTL
IM	Number of devices or other technologies deployed[17]			✓
IM	Cost for deployment			✓
	Employee awareness & engagement in Grid Modernization		✓	✓

*IM – infrastructure metric

In addition to the metrics outlined above, the evaluation would look to inform the following qualitative research questions:

[16] DPU Order, May 10, 2018, p.105. Previously the DPU had listed "improve workforce and asset management" as a stand-alone objective for grid modernization, but in its May 10, 2018 Order it eliminated this as a stand-alone objective, stating it considered improved workforce and asset management as a benefit associated with the other three grid modernization objectives.

[17] Unitil's Mobile Damage Assessment will be a software rollout.

Table 2. 2019 - 2021 WFM Survey Evaluation Qualitative Research Questions

Grid Modernization Workforce Survey Research Questions	ES	NG	UTL
How engaged are employees with the company's grid modernization initiatives?		✓	✓
How has the company's investments changed the nature of interactions with customers?		✓	✓
How has the company's grid modernization investments increased employee efficiency and productivity?		✓	✓

1.3 Summary of Evaluation Activities

The following high-level tasks will be executed to perform the evaluation.

- Task 1: Detailed Evaluation Plan development (this document) will confirm the key attributes of the Unitil Mobile Damage Assessment, confirm the types of questions that would be included in the employee survey, and the survey fielding and analysis process.

- Task 2: Unitil WFM Metrics Tracking includes developing a data collection form. Data from Unitil will be collected and reviewed twice, once as of June 30, 2020 (serving as the baseline for the Mobile Damage Assessment) and once as of December 31, 2020. Unitil Employee Case Studies will include the selection of 2-3 specific employees whose storm-related job functions have been positively impacted by the Mobile Damage Assessment during 2020. Case studies will profile selected employees' damage assessment during storms and how these have changed over time.

- Task 3: Grid Modernization Workforce Survey includes designing and fielding an online survey. We envision working with National Grid and Unitil to develop questions for an online survey that are common across the two EDCs with EDC-specific branding.[18] The survey will be fielded in 2019 to establish a baseline and again in early 2021.

- Task 4: Reporting includes a written Draft and Final versions of the Unitil-specific memo covering the Mobile Damage Assessment investment and a memo explaining the Grid Modernization Workforce Survey and findings. These memos will support the 2018-2020 Term Report.

These are described in more detail in the following section.

[18] The online employee survey could seek to identify what percent of employees by job category are aware of and familiar with the company's grid modernization investments, through questions such as: 1) Are you aware of the company's Grid Mod investments?; 2) Are you aware of the benefits of the company's Grid Modernization investments?; and 3) Have you completed a task that was changed because of the company's Grid Modernization Investments?.

2. METHODOLOGY

This section describes Navigant's approach to each task. The tasks are summarized in the table below and described in more detail in subsequent sections.

Table 3. 2019 - 2021 Evaluation Activities

Task	Activities	2019	2020	2021
Task 1. WFM Evaluation Planning	Stage 3 Plan development	✓		
Task 2. Unitil WFM Metrics Tracking	Define metrics		✓	
	Develop collection form		✓	
	Develop case study interview guide		✓	
	Collect & summarize data		✓	
	Identify 2-3 employees for case study		✓	
	Complete case study interviews		✓	*
Task 3. Grid Modernization Workforce Survey	Develop survey	✓		
	Field & administer survey	✓		✓
	Analyze & share survey results	✓		✓
Task 4. Reporting	Unitil-specific memo			✓
	Grid Modernization Workforce survey memo			✓

*Note: The timeline for Task 2 assumes the Mobile Damage Assessment software is commissioned early in 2020 and is used for a major storm during 2020. If there are delays or no major storms, the timeline for completing case studies will be shifted into early 2021.

2.1 Task 1. WFM Evaluation Planning

Navigant will work with the National Grid and Unitil to develop a detailed evaluation plan that addresses evaluation requirements for the workforce management investment area. Key activities include:

- Understand schedule and investment for Mobile Damage Assessment for Unitil
- Confirm infrastructure metrics for evaluating the Mobile Damage Assessment
- Agree on Grid Modernization Workforce survey design
- Agree on overall evaluation scope, schedule, and budget
- Confirm allocation across National Grid and Unitil

Based on the latest understanding of the timeline for the Mobile Damage Assessment solution and updates to other evaluation plans, revise the WFM Stage 3 Plan in early 2020.

Deliverables:

- Stage 3 Evaluation Plan
- Revised Stage 3 Evaluation Plan (this document)

Table 4. 2019 - 2021 Task 1 Activities

Task	Activities	2019	2020	2021
Task 1. WFM Evaluation Planning	Stage 3 Plan development	✓		
Task 1. Revised WFM Evaluation Planning	Stage 3 Plan development		✓	

2.2 Task 2. Unitil WFM Metrics Tracking

Navigant will coordinate with Unitil to determine the metrics to track to evaluate progress in the Mobile Damage Assessment deployment. Potential metrics to track include:

- Number of devices or other technologies deployed[19]
- Cost for deployment

Once the metrics of interest have been confirmed, Navigant will develop a data collection form to capture the relevant attributes of the Mobile Damage Assessment investment. Unitil will identify the most appropriate staff member to complete the form and Navigant will distribute the form to this individual via email once in Q2 2020 and again in Q4 2020. Navigant will include in its Unitil-specific evaluation memo a summary of the Mobile Damage Assessment investment over time and the situations when the investment was utilized.

In addition, Navigant will work with Unitil to identify storm response activities at Unitil that have benefited the most from the Mobile Damage Assessment and select 2-3 specific employees to participate in case study interviews within a month of a storm event. The case study will profile selected employees' damage assessment responsibilities during storms and how these have changed with the investment.

Table 5. 2019 - 2021 Task 2 Activities

Task	Activities	2019	2020	2021
Task 2. Unitil WFM Metrics Tracking	Define metrics		✓	
	Develop collection form		✓	
	Develop case study interview guide		✓	
	Collect & summarize data		✓	
	Identify 2-3 employees for case study		✓	
	Complete case study interviews		✓	*

*Note: The timeline for Task 2 assumes the Mobile Damage Assessment software is commissioned early in 2020 and is used for a major storm during 2020. If there are delays or no major storms, the timeline for completing case studies could be shifted into 2021.

Deliverables:

- Data collection form and case study interview guide and process
- Summary of progress through June 30, 2020 (one-page synopsis)
- Summary of progress through December 30, 2020 (one-page synopsis)
- Share case study interview notes

[19] Unitil's Mobile Damage Assessment will be a software rollout.

2.3 Task 3. Grid Modernization Workforce Survey

Navigant will field a Grid Modernization Workforce survey in early 2019 and again in early 2021 to assess how the pre-authorized Grid Modernization investments changed the workforce at National Grid and Unitil. The surveys would focus on employee awareness of the Grid Modernization investments and engagement.

Navigant will develop a web-based workforce survey and coordinate administration of the survey to employees of National Grid who might be engaged with, support or benefit from Grid Modernization for the Massachusetts Electric and Nantucket Electric operating companies, and to Unitil employees, in 2019 and 2021.[20] After administering the surveys, Navigant will analyze and summarize the results. Following the 2021 survey, the analysis will include a comparison of the differences in employee awareness and perceptions, workforce efficiency, and satisfaction related to their company's grid modernization investments compared to the 2019 survey. Task 3 activities are summarized in the table below.

Table 6. 2019 - 2021 Task 3 Activities

Task	Activities	2019	2020	2021
Task 3. Grid Modernization Workforce Survey	Develop survey	✓		
	Field & administer survey	✓		✓
	Analyze & share survey results	✓		✓

The table below outlines the characteristics of the survey effort.

Table 7. Grid Modernization Workforce Survey Characteristics

Survey Characteristics	Explanation
Frequency	Initial workforce survey in Q2 2019; second workforce survey in Q1 2021
Study Group(s)	Employees of National Grid and Unitil with non-gas focused job functions
Survey Mode	Online
Implementation Method(s)	Navigant sends survey links in invitation with EDC-specific branding or Navigant provides links to EDCs and EDCs send invites
Survey Quota/Sample Size	Send to all non-gas employees for National Grid and all employees for Unitil[21]

The workforce survey activities are detailed in the figure below.

[20] The survey will have the similar questions for National Grid and Unitil, although the response options for certain questions will be specific to National Grid or Unitil (e.g., office location). The same formatting will be used, but the introduction email will be tailored for National Grid and Unitil.

[21] For Unitil, Navigant will remove employees with self-reported gas-related job functions after fielding the survey.

Figure 1. Survey Approach and Schedule

Pre-Fielding Preparation
- Analysis plan to ensure data collected aligns with EDCs research needs ***(Q2 2019)***
- Fielding plan to ensure fielding approach is efficient and maximizes response rate ***(Q2 2019)***
- Survey instrument development ***(Q2 2019)***
- Survey instrument iteration with EDCs ***(Q2 2019)***
- Survey programming and testing; iteration ***(Q2 2019)***

Fielding
- Survey fielding ***(Q2 2019 and Q1 2021)***

Post-Fielding Analysis
- Data cleaning, recoding and analysis ***(Q2 2019 and Q1 2021)***
- Share findings ***(Q2 2019 and Q1 2021)***
- Comparison of 2019 and 2021 results ***(Q1 2021)***

Navigant will work with National Grid and Unitil to develop a survey instrument that captures key information needed to assess the impact of the companies' grid modernization investments on employee awareness and efficiency.

Navigant has outlined several illustrative questions in the table below.

Table 8. Illustrative Workforce Survey Questions

Topic	Example Questions
Employee Awareness and Perceptions	• Are you aware of the company's [planned] Grid Modernization investments? • Are you aware of the benefits of the company's Grid Modernization investments? • What benefits have you observed from the company's Grid Modernization investments, if any? • Provide an example of how the grid modernization investments have changed the way you interact with customers
Workforce Efficiency	• Has the way you do your job been affected by the company's Grid Modernization Investments? • Provide an example of how the Grid Modernization investments have changed the way you do your job.

Deliverables:

- Survey instrument
- Programmed and fielded survey in 2019
- Programmed and fielded survey in 2021
- Share findings from the analysis of the 2019 survey (PowerPoint summary)
- Share findings from the analysis of the 2021 survey (PowerPoint summary)

2.4 Task 4. Reporting

Navigant will prepare a Unitil-specific evaluation memo focused on the Mobile Damage Assessment and a Grid Modernization Workforce Survey evaluation memo that shares the results of the employee survey.

The Mobile Damage Assessment evaluation memo for Unitil will:

- Discuss the technology and when it is used
- Explain timeline of investment & investment ($)
- Describe a case study for one storm event

The Grid Modernization Workforce Survey evaluation memo will:

- Identify evaluation objectives
- Discuss change management activities at National Grid and Unitil, as learned via surveys
- Explain overall approach & methodology (e.g., on-line surveys, surveys fielded in 2019 & 2021, number of responses for each cycle for National Grid and Unitil)
- Summarize results of the survey for National Grid and Unitil

Table 9. 2019 - 2021 Task 4 Activities

Task	Activities	2019	2020	2021
Task 4. Reporting	Prepare Mobile Damage Assessment memo			✓
	Prepare Grid Modernization Workforce Survey memo			✓

Deliverables:

- Draft Mobile Damage Assessment memo as input to the Unitil Term Report
- Final Mobile Damage Assessment memo as input to the Unitil Term Report
- Draft Grid Modernization Workforce Survey memo as input to National Grid’s and Unitil’s Term Report
- Final Grid Modernization Workforce Survey memo as input to National Grid’s and Unitil’s Term Report

3. STAFFING

The following Navigant staff are expected to be the primary support for this evaluation. Additional staff may be used to augment various tasks or capabilities as needed.

Erik Gilbert. Director, Overall Project Manager. Erik leads Navigant's Grid Modernization Solutions development and delivery. He provided subject matter expertise on a number of Massachusetts advanced technology evaluation projects, including National Grid's Worcester Smart Energy Solutions project and Eversource's (NSTAR's) AMR/Dynamic Pricing Smart Grid Pilot.

Steven Tobias, Director, WFM Area Lead
Leads the Massachusetts DR evaluations for Navigant, which includes impact and process evaluation components and manages the ongoing Smart Energy Solutions (SES) Evaluation at National Grid. Also, significant experience understanding Grid Modernization activities gained through completing BCAs of distribution automation, energy storage, and other utility and customer technologies.

Nicole Buccitelli, Managing Consultant, WFM Manager
Nicole manages evaluations of EE and DR program processes and customer experience for utility clients. For example, she currently manages residential and SMB DR program process evaluations for Cape Light Compact and Eversource (MA), respectively, and the Con Ed C&I EE process evaluations.

Christina Cho, Senior Consultant, WFM Analyst
Supports Massachusetts DR Evaluation team and analyzes New England energy policy drivers and initiatives. Also, evaluated energy storage hardware costs and PMs to provide a benchmark for future improvements.

Unitil and National Grid Roles
Navigant requests that Unitil appoint a point of contact for transmitting data and facilitating case study interviews. Navigant also requests that National Grid and Unitil identify a point of contact to coordinate the fielding of the workforce surveys.

4. SCHEDULE

The overall timeline for the evaluation is shown in the Gantt Chart below:

Table 10. Three-Year Schedule

Key Tasks	2019				2020				2021			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1 WFM Evaluation Planning		A			A1							
2 Unitil WFM Metrics Tracking						B			C	D		
3 Grid Mod Workforce Survey		E, F	G						H I			
4 Reporting										J, K L, M		

Milestones:
A. Evaluation Plan; **A1**. Revised Evaluation Plan
B. Data collection form, case study guide, and process agreed
C. Summary of 2020 progress as of December 31, 2020 (one-page synopsis)
D. Case interview notes
E. Survey instrument
F. Programmed and fielded survey in 2019
G. Share findings from the analysis of 2019 survey (PowerPoint)
H. Programmed and fielded survey in 2021
I. Share findings from the analysis of 2021 survey (PowerPoint)
J,K. Mobile Damage Assessment evaluation memo (draft, then final) (Word)
L,M. Grid Modernization Workforce Survey memo (draft, then final) (Word)

A detailed schedule for Task 3 from March through May 2019 is shown below.

Table 11. Task 3 2019 Schedule

Activities for Task 3	March 2019					April 2019				May 2019				
	1	8	15	22	29	5	12	19	26	3	10	17	24	31
1 Analysis plan														
2 Fielding plan														
3 Invitation email development														
4 Survey instrument development							E							
5 Survey instrument review														
6 Survey programming and testing									F					
7 Survey fielding														
8 Analysis of survey responses														
9 Share findings (PowerPoint summary)														G

Task 2 assumes the Mobile Damage Assessment will be deployed during 2020. Milestone D are related milestones are dependent on this deployment schedule and whether a storm occurs during that time period.

NAVIGANT
A Guidehouse Company

Study #6 – Advanced Distribution Management System and Advanced Load Flow Evaluation Plan

Stage 3 Plan

Prepared for:

Massachusetts Electric Distribution Companies

Submitted by:
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Reference No.: 209941
March 30, 2020

NAVIGANT
A Guidehouse Company

Study #6 – Advanced Distribution Management System and Advanced Load Flow Evaluation Plan

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1. INTRODUCTION

This plan will evaluate the progress and effectiveness of the DPU preauthorized *Advanced Distribution Management Systems (ADMS)* for the MA EDCs, and *Advanced Load Flow* (ALF) investments for Eversource only, towards meeting the DPU's grid modernization objectives.[22]

ADMS, which can include supervisory control and data acquisition (SCADA), outage management system (OMS), distribution management system (DMS), and advanced applications including operational power flow, volt-var optimization (VVO), and fault location isolation and service restoration (FLISR), is a software platform investment and is fundamental to a modernized grid. The capabilities of ADMS are key to delivering on all three of the DPU's Grid Modernization objectives, supported by the ability to control devices for system optimization, provide support for advanced distribution automation (ADA) and VVO, and serve as an enabling platform to support a high penetration of distributed energy resources (DERs).

The pre-authorized ADMS investments across the EDCs in the 2018 to 2020 timeframe are summarized in the following table.

Table 1. ADMS Investments

EDCs	Description
Eversource	Planning for ADMS and implementation of ALF
National Grid	Implementation of DMS and integration w/ SCADA
Unitil	Planning for ADMS

ALF investments are typically tightly coupled with ADMS investments, and Eversource is the only EDC with a separate investment plan for ALF.

1.1 Overall Study Goals

This evaluation plan will evaluate the progress and effectiveness of the DPU preauthorized ADMS and ALF investments for each EDC towards meeting the DPU's grid modernization objectives.[23] Evaluation will be developed to understand and measure these investments' contribution to meeting all three DPU objectives: "(1) optimize system performance (by attaining optimal levels of grid visibility, command and control…", "(2) optimize system demand", and "(3) interconnect and integrate distributed energy resources."

ADMS is a fundamental *enabling* technology that has the potential to significantly enhance the utility's ability to meet these objectives. ALF is a fundamental *enabling* technology for all three of the DPU's objectives by enabling improved modeling of the distribution system's current and future states. In addition, ALF is tightly coupled with the ADMS investment for Eversource in that the GIS and Other System data clean-up components of ALF enable the ability to perform engineering load flow in CYME, but also are necessary for the operational load flow, and other ADMS functions, in their future ADMS investment.

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

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

The key goals of the ADMS and ALF evaluation plan are the following:

- Ensure flexibility across EDCs relative to their specific investment implementation plans (scope and schedule) for the ADMS investment
- Assess either the native implementation or integration of key ADMS components
    - Supporting native ADMS DSCADA, integrated distribution SCADA component of energy management systems (EMS), or integrated distribution component of SCADA
    - Supporting native ADMS OMS, integrated OMS, or no integration of OMS in the 2018-2020 timeframe
- Assess data cleanup of GIS and Other Systems data[24] for ADMS and ALF
- Measure progress towards achieving engineering load flow capability supporting DER interconnection supported by the ALF investment

1.2 Research Questions

Navigant has established these research questions in the ADMS and ALF domain to establish a connection between each EDC's ADMS and ALF implementation and the DPU's criteria for value to customers.

The key research questions addressed in this plan are:

- How do the ADMS and ALF investments align with optimizing system performance, optimizing system demand, and enabling interconnection and integration of DER?
- What is each EDC's specific investment plan strategy for ADMS and ALF implementation (components and timeframes) during the pre-authorized investment period, 2018-2020?
- What does each EDC plan to leverage as a baseline ADMS and ALF application / component stack? (GIS, PI Historian, DSCADA, OMS, CYME, Other Systems, and/or other)
- What does each EDC plan to do related to ADMS functionality, including operational load flow, VVO, FLISR, and DERMS?
- What does each EDC plan to do related to ALF functionality, including static analysis, semi-automated analysis, and fully automatic analysis?
- What is the specific timing of ADMS implementation, integration with supporting systems, and data cleanup in GIS and Other Systems?
- What is the specific timing of ALF investment components including GIS data cleanup, Other System data cleanup, and CYME implementation?

1.3 Evaluation Metrics

The metrics for tracking ADMS and ALF are:

---

[24] ADMS investment that are filed including GIS and Other System data cleanup

- **Company Infrastructure Metrics**: The EDCs will implement project deviation tracking along with projecting ADMS and ALF (Eversource only) deployment over the entire 3-year period.
- **Performance Metrics**: The EDCs have proposed to score and then count the number of substations with fully implemented and successful ADMS power flow analysis and the number of circuits with the specified control functions implemented. For ALF, Eversource has proposed a metric designed to demonstrate progress towards the final completion of a fully automated modelling tool.

Table 2. ADMS Evaluation Metrics

Type	ADMS Evaluation Metrics	ES	NG	UTL
IM	Deviation between actual and planned deployment for the plan year	✓	✓	
IM	Projected deployment for the remainder of the three-year term	✓	✓	
PM	Increase in circuits and substations with DMS power flow and control capabilities	✓	✓	
PM	Control functions implemented by circuit and substation	✓	✓	
	DMS implementation (planning, procurement, development, deployment, go-live)	✓	✓	✓
	DSCADA implementation or integration (planning, procurement, development, deployment, go-live)	✓	✓	✓
	OMS implementation or integration (planning, procurement, development, deployment, go-live)	✓	✓	✓
	Cleanup of GIS data by circuit, substation, and region		✓	
	Cleanup of Other Data by circuit, substation, and region		✓	

Note: Potential metrics in the future would be to assess the implementation and functionality of ADMS advanced applications such as VVO and FLISR.

The ALF evaluation will leverage the infrastructure metrics and EDC approved performance metrics shown in the table below. As the details of the evaluation approach are developed, other metrics may be considered, examples of which are included in the following table:

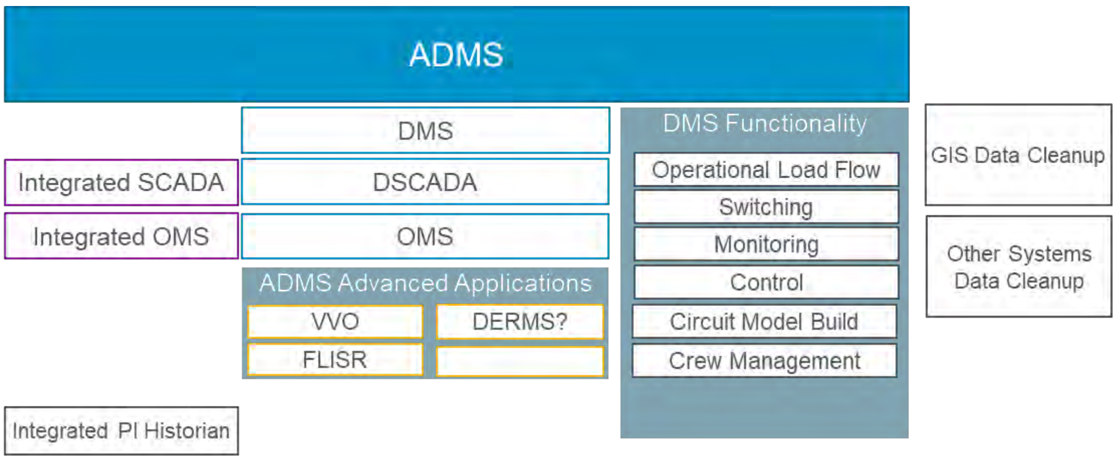
Table 3. ALF Evaluation Metrics

Type	ALF Evaluation Metrics	ES	NG	UTL
IM	Deviation between actual and planned deployment for the plan year	✓		
IM	Projected deployment for the remainder of the three-year term	✓		
PM	Advanced Load Flow – Percent Milestone Completion	✓		
	Data cleanup of GIS and Other Systems by circuit, substation, sub-region, and region	✓		
	Use of load flow tools for engineering (e.g., CYME, Synergi) by % of service territory	✓		
	% of region and sub-region using automated scripting on a monthly basis	✓		
	Use of near-real time system telemetry in load-flow analysis	✓		
	% of DG interconnection requests that leverage Advanced Load Flow investment	✓		
	Comparison of reduction in average DG interconnection request between ALF-enabled vs. non-ALF enabled feeders	✓		

*IM – infrastructure metric, PM – performance metric

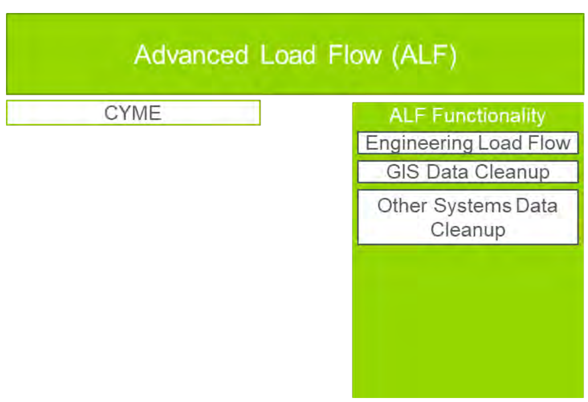
A picture of ADMS context is shown below in **Figure 1**. This diagram shows the normal native and integrated components of ADMS along with a functionality stack related to the DMS component of ADMS. The components and functionality shown below are foundational to the current industry status of ADMS and serve as the consistent picture for evaluation of ADMS at the EDC.

Figure 1. ADMS Evaluation Components & Functionality



A picture of ALF context is shown below in **Figure 2**. This diagram shows CYME and a functionality stack related to the data cleanup component of ALF. The components and functionality shown below are foundational to the current industry status of ALF and serve as the consistent picture for evaluation of ALF at Eversource.

Figure 2. ALF Evaluation Components and Functionality



1.4 Summary of Evaluation Activities

The ADMS evaluation will be based upon implementation of ADMS components and then progression of functional realization of the ADMS at each EDC. This ADMS evaluation framework is flexible and componentized to enable it to be applied to each EDC given the differences in ADMS strategy, ADMS implementation plan, and pre-existing ADMS components.[25]

The ALF investment supports the integration of DERs into the network from a regional, substation group, substation, and feeder level through CYME and in the future will provide necessary and required information to the ADMS investment. Tying the actual interconnection process duration to the ALF modeling of each region is complex and dependent upon many other variables, but ALF is a prerequisite for reducing the interconnection process duration and meeting the DPU’s goal of enabling interconnection and integration of DERs. The cost and complexity of performing this evaluation to “connect the dots” between ALF and the integration of DERs into the electrical network will be reviewed.

[25] A different Stage 3 Plan discusses Eversource’s ALF investment.

2. METHODOLOGY

Evaluation of the ADMS and ALF investments consists of four main tasks:

- Task 1. Evaluation Plan
- Task 2. Collect and Review Data
- Task 3. Complete Analysis and Presentation
- Task 4. Reporting

The first task is the stage 3 plan development consisting of defining overall study goals and metric identification. This task also includes a round of plan refinement and coordination with the EDCs prior to finalization. Data collection, task 2, will then occur on a semi-annual basis and include written data requests, each EDC providing the data, and Navigant conducting follow-up data review meetings. At the end of the year and following the data collection tasks, Navigant will analyze the data, task 3, producing a year-end draft presentation for each EDC to review in preparation for the reporting task. Following the yearly analysis review meetings with the EDCs, Navigant will provide an interim draft report, and incorporate feedback into a final evaluation report. The evaluation reports will be provided to the EDC for incorporation into filings or reports to the DPU.

This section describes the Evaluation Team's approach to each task.

2.1 Task 1. Evaluation Plan

Navigant will develop the Evaluation Plan for the ADMS and ALF investments that will include a prescriptive approach to data collection, analysis, and reporting including integrated management of the overall evaluation. The evaluation plan development includes defining overall study goals, metric identification, and is followed by plan refinement after review and coordination with the EDCs.

This task includes working with the EDCs to begin to develop a uniform approach to defining the IMs and PMs and the associated baselines. The evaluation plan development also includes the following:

- Understand planned schedule and investments for each EDC
- Define overall study goals
- Discuss and confirm metrics
- Understand data availability
- Review and refine evaluation plan
- Confirm allocation across EDCs

Deliverables:

- Final Stage 3 Evaluation Plan
- Revised Stage 3 Evaluation Plan (this document)

2.2 Task 2. Collect and Review Data

The data collection task includes defining details on the specific data to be collected, the timing of data collection, and designated owners at each EDC of the data (only Eversource for ALF data). Data collection coordination including scheduling and status reporting is included in the scope of this task. The objective of this task is to collect planning and cost information as well as data to track enabled power flow and control capabilities at regular intervals from each EDC based on the approved Evaluation Plan.

In general, because of the strategy of evaluation based upon implementation of ADMS components and then progression of functional realization of each EDCs' ADMS, the data will help identify progress each EDC has made in establishing the functionality of the ADMS starting with foundational prerequisites, basic ADMS software, integration of OMS and DSCADA components, data clean-up, enablement of functionality includes load flow on a circuit and substation basis, and advanced functionality including potentially including VVO, FLISR, and DERMS.

For Eversource's ALF investment, the data will help identify Eversource's progress toward establishing the functionality of the ALF starting with foundational pre-requisites, basic CYME software, integration of CYME to GIS and Other Systems, and data clean-up in both GIS and Other Systems.

The objective of this task is to collect baseline and periodic planning and cost information as well as data to track enabled power flow and control capabilities at regular intervals from each EDC based on the approved Evaluation Plan. This data collection task for ADMS and ALF includes:

- Defining specific data to be collected during the baseline assessment and then during the semi-annual reviews
    - Current state of prerequisite application components
    - Number of substations and circuits
    - Timing of integrations to GIS, Other Systems, and OMS / DSCADA if in the solution context
    - Status of engineering load flow analysis, automation, and advanced applications on each circuit
- Creation of data requests to each EDC for the baseline, semi-annual data collection, and year-end collection periods with specific owners at each EDC and clearly defined timeframes
- Preparing for data review meetings associated with the baseline, semi-annual data collection, and year-end collections to validate the data provided, ask additional questions, and get supporting or ancillary data if needed
- Summarizing findings from review meetings in brief memos

Deliverables:

- Memo (MS Word) defining specific types of data to be collected to support creation of evaluation baseline and data anticipated to be needed to support semi-annual reviews and year-end analysis and reporting.
- Semi-annual status memo of QA/QC of Q2 2019 (~10 slides)
- Semi-annual status memo of QA/QC of Q4 2019 (~10 slides)

- Semi-annual status memo of QA/QC of Q2 2020 (~10 slides)
- Semi-annual status memo of QA/QC of Q4 2020 (~10 slides)

2.3 Task 3. Complete Analysis and Presentation

The analysis task (Task 3. Complete Analysis and Presentation) will take data obtained in Task 2. Collect and Review Data, prepare a baseline, assess progress against the baseline in each functional area, and produce metrics and graphics for use in subsequent reporting on a yearly basis. This task will produce an interim output that will be presented in MS Power Point to the EDCs enabling a valuable feedback and correction cycle. Analysis coordination including scheduling and status reporting will be included as part of this task.

Task 3 will include analysis of the task 2 data and the following steps:

- Prepare a baseline,
- Determine progression against the baseline in functional areas, and
- Produce metrics and graphics for reporting.

Deliverables:

- Draft presentation of the analysis of 2019 data (~10 slides per EDC)
- Draft presentation of the analysis of 2020 data (~10 slides per EDC)

2.4 Task 4. Prepare Evaluation Reports

The reporting task (Task 4. Prepare Evaluation Reports) will take as input the output of the analysis task (Task 3. Complete Analysis and Presentation) combined with feedback from the EDCs and prepare the annual evaluation report (MS Word). Navigant will prepare two evaluation reports. The first evaluation report will be completed in Q1 2020 (for evaluation year 2019). for incorporation into the EDCs Annual Report to be filed on April 1, 2020, and the second evaluation report will be completed in Q1 2021 (for evaluation year 2020). for incorporation into the EDCs Term Report to be filed on April 1, 2021. The evaluation reports will address both infrastructure and performance metrics as they relate to ADMS and ALF. A draft report will be shared with the EDCs and their feedback will be incorporated in the final report.

Outline of Evaluation Report:

- Executive Summary
- Investment description
- Evaluation objectives
- Description of the evaluation approach
- Findings
- Recommendations
- Appendices with additional work product, for example:

  - Summary of data collected from the EDCs
  - Intermediate analysis outputs

Deliverables:

- 2019 Draft Evaluation Report
- 2019 Final Evaluation Report
- 2020 Draft Evaluation Report
- 2020 Final Evaluation Report

3. STAFFING

The team of experts leading and supporting the evaluation of the ADMS and ALF Investment Areas is described below. Navigant also leverages a deep bench of consultants with proven experience leading relevant studies, who support this core team.

Erik Gilbert. Director, Overall Project Manager. Erik provided subject matter expertise on a number of Massachusetts advanced technology evaluation projects, including National Grid's Worcester Smart Energy Solutions project and Eversource's (NSTAR's) AMR/Dynamic Pricing Smart Grid Pilot. He leads Navigant's Grid Modernization Solutions development and delivery.

Omar Dickenson. Associate Director, ADMS and ALF Project Lead. Omar brings 10 years of experience in all aspects of ADMS and ALF from development of software to vendor selection to implementation. He also has experience with Eversource planning their OT/IT Smart Grid investment strategy including ADMS and ALF.

Sam Crawford. Associate Director, Analyst. Sam supported development and evaluation of utility and state EE and DSM programs; assisted MA utilities (National Grid and Eversource) and state organizations (MassCEC) with strategy and program development for Grid Modernization efforts, including energy storage and microgrids.

Mina Healey. Senior Consultant, Analyst. Mina researched ADMS and ALF vendor offerings and supported development of implementation plans for Duke Energy, Eversource, and other utilities. She also has prior Massachusetts experience supporting MA EE evaluation activities and MA Clean Energy Center's Microgrid Feasibility Assessment program.

Taylor Burdge. Consultant, Analyst. Taylor has contributed to a variety of grid modernization efforts for Duke Energy, Tucson Electric Power, and other utilities. She has prior Massachusetts experience leading analyses for Boston's Smart Utilities policy and supporting EM&V work for demand response programs.

EDC Staffing

Navigant requests that each EDC identify a single point of contact that will complete the data request and be available to meet with us semi-annually.

4. SCHEDULE

The overall timeline and schedule for the evaluation in shown in the Gantt chart below. Key milestone deliverables are marked with letters and are described below the chart.

Table 4. Three-Year Schedule

Key Tasks	2019				2020				2021			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1 Develop Stage 3 Plan		A										
2 Collect & Review Data		B	C		D		E		F			
3 Complete Analysis					G				H			
4 Prepare Annual Reports					I, J					K, L		

Milestones:

A. Final Stage 3 Evaluation Plan
B. Data request form agreed with EDCs
C. Semi-annual status memo of QA/QC of Q2 2019
D. Semi-annual status memo of QA/QC of Q4 2019
E. Semi-annual status memo of QA/QC of Q2 2020
F. Semi-annual status memo of QA/QC of Q4 2020
G. Draft presentation of the analysis of 2019 data
H. Draft presentation of the analysis of 2020 data
I. 2019 Draft Evaluation Report
J. 2019 Final Evaluation Report
K. 2020 Draft Evaluation Report
L. 2020 Final Evaluation Report

Guidehouse

Massachusetts Electric Distribution Companies

Massachusetts Grid Modernization Program Year 2019 Evaluation Report

Monitoring and Control

April 1, 2020

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Disclaimer

This report was prepared by Guidehouse Inc, for the Massachusetts Electric Distribution Companies. The work presented in this report represents Guidehouse's professional judgment based on the information available at the time this report was prepared. Guidehouse is not responsible for the reader's use of, or reliance upon, the report, nor any decisions based on the report. GUIDEHOUSE MAKES NO REPRESENTATIONS OR WARRANTIES, EXPRESSED OR IMPLIED. Readers of the report are advised that they assume all liabilities incurred by them, or third parties, as a result of their reliance on the report, or the data, information, findings and opinions contained in the report.

1.0 Executive Summary

1.1 Introduction

As a part of the Grid Modernization Plan, the Massachusetts electric distribution companies (EDCs) are investing to enable monitoring and control (M&C) on selected circuits across their distribution networks. These investments are intended to enhance grid visibility and control capabilities to increase reliability and provide other grid and customer benefits.

This evaluation focuses on the progress and effectiveness of the Department of Public Utilities (DPU) preauthorized M&C investments for each EDC toward meeting the DPU's grid modernization objectives for Program Year (PY) 2019. The focus of this evaluation is on M&C infrastructure metrics.

1.2 M&C Evaluation Process

As part of the Grid Modernization Plans (GMPs), the DPU requires a formal evaluation process (including an evaluation plan and evaluation studies) for the EDCs' preauthorized grid modernization plan investments. Guidehouse (formerly Navigant Consulting, Inc.)[1] is completing the evaluation to ensure a uniform statewide approach and to facilitate coordination and comparability. The evaluations' objective is to measure the progress made toward the achievement of DPU's grid modernization objectives. The evaluation uses the DPU-established infrastructure metrics (IMs) and performance metrics (PMs) to meet the DPU's evaluation objectives. Additional information about these metrics is provided in Section 2.1.3

Table 1 illustrates the key infrastructure metrics and performance metrics relevant for the M&C evaluation by EDC. Additional information about these metrics is provided in Section 4.

Table 1. M&C Evaluation Metrics

Type	M&C Evaluation Metrics	ES	NG	UTL
IM	System Automation Saturation*	✓	✓	✓
IM	Number and Percent of Circuits with Installed Sensors*	✓	✓	✓
IM	Number of Devices or Other Technologies Deployed and In Service	✓	✓	✓
IM	Cost for Deployment	✓	✓	✓
IM	Deviation Between Actual and Planned Deployment for the Plan Year	✓	✓	✓
IM	Projected Deployment for the Remainder of the 3-Year Term	✓	✓	✓

[1] Guidehouse LLP completed its acquisition of Navigant Consulting, Inc, in October of 2019. The two brands are now combined as one Guidehouse.

Type	M&C Evaluation Metrics	ES	NG	UTL
PM	Grid Modernization Investments' Effect on Outage Durations	✓	✓	✓
PM	Grid Modernization Investments' Effect on Outage Frequency	✓	✓	✓
PM	Protective Zone: Average Zone Size per Circuit**	✓		
PM	Customer Minutes of Outage Saved per Circuit**			✓
PM	Main Line Customer Minutes of Interruption Saved**		✓	

Source: Stamp Approved Performance Metrics, July 25, 2019.
** Metric calculation is EDC responsibility*
*** Metrics primarily apply to ADA, but will be completed for M&C as well given interest in understanding how to separately measure the impacts of these two investment areas.*

1.3 Data Management

Guidehouse worked with the EDCs to collect data to complete the M&C 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 M&C evaluation for PY 2019. Further detail on each of the data sources is provided in Section 3.1.

Table 2. M&C Data Sources

Data Source	Description
2018 Grid Modernization Plan Annual Report[2,3,4]	Contains planned device deployment and cost information from each EDC's Supplement to the 2018 GMP Annual Report.[5,6,7] Data were used as references to track progress against the GMP targets and are referred as the "EDC Plan" in summary tables and graphs throughout this report.
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. Planned device deployment information and estimated spend for PY2020 was provided at the circuit-level or substation-level.

Source: Guidehouse

[2] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-120
[3] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-122
[4] Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-121
[5] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Supplement to the 2018 Grid Modernization Plan Annual Report. Submitted to Massachusetts DPU on January 31, 2020 as part of D.P.U. 15-120
[6] NSTAR Electric Company d/b/a Eversource Energy, Supplement to the 2018 Grid Modernization Plan Annual Report. Submitted to Massachusetts DPU on January 31, 2020 as part of D.P.U. 15-120
[7] Fitchburg Gas and Electric Light Company d/b/a Unitil, Supplement to the 2018 Grid Modernization Plan Annual Report. Submitted to Massachusetts DPU on January 31, 2020 as part of D.P.U. 15-120

Guidehouse reviewed all data provided upon receipt of requested data and conducted a detailed QA/QC of data inputs used in analysis of infrastructure metrics and performance metrics. These QA/QC steps include checks to confirm each of the required data inputs are accounted for and appropriate to be incorporated into analysis. Additional information about the QA/QC process is covered in Section 3.2.

1.4 Findings & Recommendations

Guidehouse's M&C evaluation has confirmed that all EDCs are progressing towards their M&C plans at varying paces with catch-up plans in place to meet 2018-2020 targets. Table 3 summarized the infrastructure metrics results for each EDC's M&C investment area through PY 2019.

Table 3. 2019 Infrastructure Metrics Summary

Infrastructure Metrics		Parameter	Progress thru. PY2019		
			Eversource[8]	National Grid	Unitil[9]
2018-2020 Original Plan[10]		Devices	436	180	10
		Spend	$41.0 million	$3.96 million	$960,000
2018-2020 Revised Plan[11]		Devices	452	177	10
		Spend	$49.8 million	$3.6 million	$997,000
IM-3	Number of Devices/ Technologies Deployed	# Commissioned	195	5	1
		% Commissioned	43%	2.8%	10%
IM-4	Cost for Deployment	Total Spend	$26 million	$201,000	$238,000
		% Spend	52%	5.6%	24%
IM-5	Deviation Between Actual and Planned Deployment	% On Track (Devices)	76%	6.3%	25%
		% On Track (Spend)	84%	11.4%	30%
IM-6	Projected Deployment in PY2020	# Projected	257	172	9
		Spend Projected	$23.8 million	$3.6 million	$759,000

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Actual spending in PY2019 was less than anticipated for all EDCs. Eversource and Unitil's revised 2018-2020 estimated total spend is higher than originally anticipated while National Grid's revised 2018-2020 estimated spend is lower than originally anticipated. Figure 1 differentiates between the original planned spend per the 2018 GMP Annual Report and the actual/updated projected spend based on the EDC data provided.

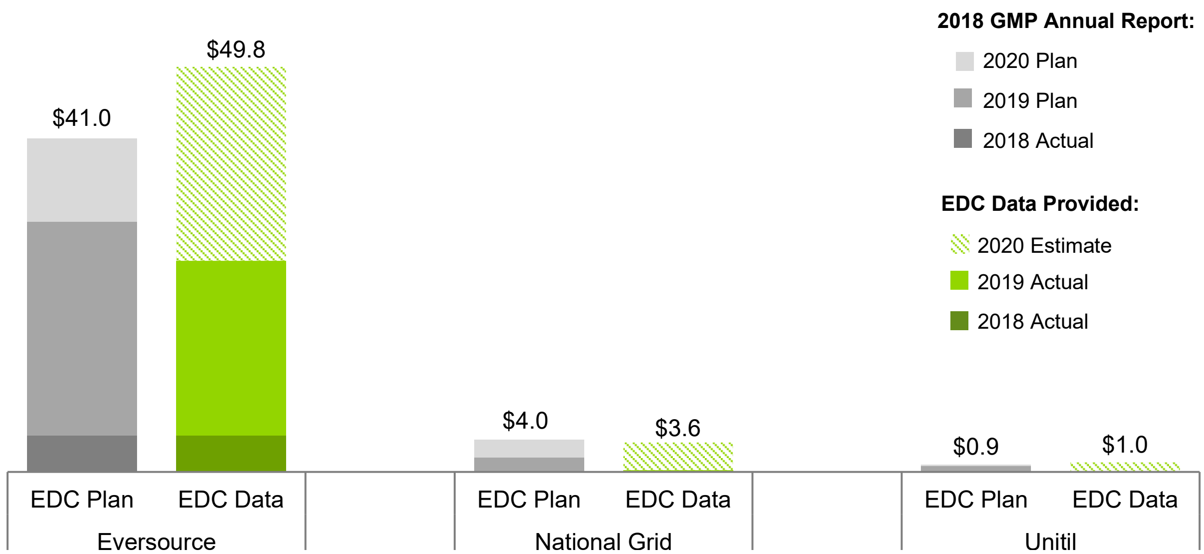
[8] Device-related counts and percentages include all device types aggregated together.

[9] Device-related counts and percentages include circuits with substation SCADA retrofit.

[10] Based on the 2018 GMP Annual Report Appendix 1 filed January 31, 2020.

[11] Based on the EDC data provided through PY 2019.

Figure 1. M&C Planned vs. Actual Spend (2018 – 2020, $M)



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Table 4 summarizes key findings related Guidehouse's M&C evaluation for each EDC.

Table 4. EDC-Specific M&C Findings

EDC	Summary of Findings
Eversource	• Majority of progress and spending to date has focused on microprocessor relays • Progress and spending in PY2019 was slightly behind the original projection because of challenges with the completing the final commissioning for devices. • Many devices planned for PY 2020 are already in the construction or design phase. • The revised 2018-2020 total estimated spending for M&C investments ($49.8 million) is now 20% higher than the original estimate ($41 million) because of higher unit costs for implementing microprocessor relays and 4 kV SCADA and a decision by Eversource to increase funding to this investment area.
National Grid	• PY2019 progress was focused on planning with most deployment now occurring in PY2020. • Vendor lead times delayed feeder monitor deployment progress in PY2019. • A large shipment of sensors was received in late 2019; therefore, National Grid expects to make up the delayed PY2019 progress in PY2020 to meet the original 2018-2020 target. • The revised 2018-2020 total estimated spending ($3.6 million) is now 11% lower than the original estimate ($4.0 million) due to lower unit costs.
Unitil	• Issues with vendor data accessibility has delayed the completion of Phase 1 for OMS/AMI integration; however, Unitil anticipates making up progress in PY2020 to meet the original 2018-2020. • Substation SCADA retrofit required more work than originally planned, delaying the final commissioning planned for PY 2019 to PY 2020. • The revised 2018-2020 total estimated spending ($997,000) is 4% higher than the original estimate ($960,000).

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Guidehouse also submits the following recommendations for EDC consideration in program year 2020:

- Guidehouse should work with the EDCs to implement an updated data collection template and format, using experience gained during the Q2'19 data collection process, to streamline data collection and make the process more efficient.[12]
- EDCs should work with Guidehouse to develop a "case-study approach" to understanding reliability impacts due to M&C investments, and help distinguish between how impacts are attributed to M&C vs ADA where these investments are deployed on same circuit.
- National Grid should consider updating the asset intake process so that equipment ordered for the Grid Modernization Program are clearly identified as assigned/allocated to the GMP program. This may help prevent equipment from being diverted from inventory for other uses within the utility.
- In the future, the EDCs could consider a more sophisticated statistical approach to assessing the reliability impacts of M&C investments. Such techniques require more outage data collection (e.g., outage cause), feeder characteristics (e.g., length, customers, location), equipment installed (e.g., number and type of reclosers), knowledge of other activities (e.g. timing of vegetation trimming), integration with weather data (e.g., hourly wind speed and direction) for feeders that receive the M&C investment and those that do not, but promise more insight on whether the M&C investments are yielding reliability improvements in MED and non-MED situations. This type of approach is more complex and requires additional data collection and more analysis, but it could control for weather and other factors effecting reliability.

[12] Note, the data collection template and format update has already been implemented, as the EDCs and Guidehouse agreed that this was appropriate and would make future data collection and data QA/QC process more efficient.

2.0 Introduction to Massachusetts Grid Modernization

A brief background to the Grid Modernization Evaluation process is provided below in this section along with an overview of the Monitoring & Control (M&C) investment area and specific M&C evaluation objectives. These are provided for context when reviewing the subsequent sections that address the specific evaluation process and findings.

2.1 Massachusetts Grid Modernization Plan Background

On May 10, 2018, the Massachusetts Department of Public Utilities (DPU) issued its Order[13] regarding the individual Grid Modernization Plans (GMPs) filed by the three Massachusetts electric distribution companies (EDCs): Eversource, National Grid, and Unitil.[14,15] 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. These preauthorized GMP investments will advance the achievement of DPU's grid modernization objectives:

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

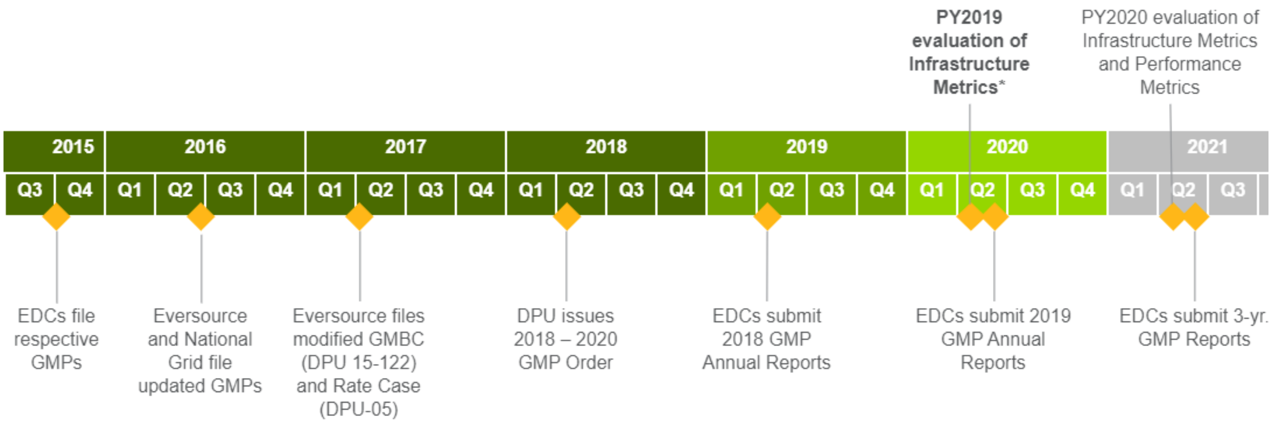
As part of the GMPs, the DPU determined that a formal evaluation process for the preauthorized GMP investments, including an evaluation plan and studies, was necessary to help ensure that the benefits are maximized and achieved with greater certainty. Figure 2 highlights the filing background and timeline of the GMP order and the evaluation process.

[13] Massachusetts D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 (Grid Modernization) Order issued May 10, 2018

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

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

Figure 2. MA Grid Modernization Timeline (by Program Year)



Source: Guidehouse review of the DPU orders and GMP process
** Performance metrics will be included in an addendum report (target date June 2020).*

In addition, 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)

This report focuses on the M&C investment area. Similarly, structured evaluation reports have been developed for each of the other investment areas.

2.1.1 Investment Areas

Table 5 summarizes the preauthorized GMP investments.

Table 5. Overview of Investment Areas

Investment Area	Description	Goal/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
Advanced Distribution Automation (ADA)	Isolation of outage events with automated backup for 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

Investment Area	Description	Goal/Objective
Advanced Distribution Management Systems/Advanced Load Flow (ADMS and ALF)	New capabilities in real-time system control with investments in developing accurate system models and enhancing SCADA and outage management systems to control devices for system optimization and provide support for distribution automation and VVO with high penetration of distributed energy resources (DER)	Enables high penetration of DER by supporting the ability to control devices for system optimization, ADA, and VVO
Communications/IoT (Comms)	Fiber middle mile and field area communications systems	Enables the full benefits of grid modernization devices to be realized
Workforce Management (WFM)	Investments 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

The Massachusetts preauthorized budget for grid modernization varies by investment area and EDC. Eversource has 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 is $82.2 million, with ADMS and ALF representing over 50% ($48.4 million). Unitil's preauthorized budget is $5.5million and VVO makes up 40% ($2.2 million). Table 6 shows the budget for each investment area by EDC. Note that the DPU added flexibility to these budgets based on changing technologies and circumstances. For example, EDCs can shift funds across the different preauthorized investments if a reasonable explanation for these shifts is supplied.

Table 6. 2018-2020 GMP Preauthorized Budget, $M

Investment Areas	Eversource	National Grid	Unitil	Total
ADA	$44.0	$13.4	N/A	**$57.4**
ADMS/ALF	$17.0	$48.4	$0.7	**$66.1**
Comms	$18.0	$1.8	$0.8	**$20.6**
M&C	$41.0	$8.0	$0.75	**$49.8**
VVO	$13.0	$10.6	$2.2	**$25.8**
WFM			$1.0	**$1.0**
2018-2020 Total	$133	$82.2	$5.5	**$220.7**

Source: DPU Order, May 10, 2018

This report covers the Program Year (PY) 2019 evaluation of infrastructure metrics and focuses on the M&C investment area. The following subsection discusses these investment areas in greater detail.

2.1.2 Evaluation Goal and Objectives

The DPU requires a formal evaluation process (including an evaluation plan and evaluation studies) for the EDCs' preauthorized GMP investments. Guidehouse (formerly Navigant Consulting, Inc.)[16] is completing the evaluation to ensure a uniform statewide approach and to facilitate coordination and comparability. The evaluation's objective is to measure the progress made toward the achievement of DPU's grid modernization objectives. The evaluation uses the DPU-established infrastructure metrics and performance metrics to help determine if the investments are meeting the DPU's GMP objectives.

2.1.3 Metrics for Evaluation

The DPU-required evaluation involves infrastructure metrics and performance metrics for each investment area.

2.1.3.1 Infrastructure Metrics

Infrastructure metrics were designed to evaluate the deployment of the GMP investments. Table 7 summarizes the infrastructure metrics.

Table 7. Infrastructure Metrics Overview

Metric		Description	Applicable IAs	Metric Responsibility
IM-1	**System Automation Saturation**	Measures the quantity of customers served by fully or partially automated devices.	M&C, ADA	EDC
IM-2	**Number and Percent of Circuits with Installed Sensors**	Measures the total number of circuits with installed sensors which will provide information useful for proactive planning and intervention.	M&C	EDC
IM-3	**Number of Devices Deployed and In Service**	Measures how the EDC is progressing with its GMP from an equipment and/or device standpoint.	All IAs	Evaluator
IM-4	**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-5	**Deviation Between Actual and Planned Deployment for the Plan Year**	Measures how the EDC is progressing under its GMP on a year-by-year basis.	All IAs	Evaluator
IM-6	**Projected Deployment for the Remainder of the Three-Year Term**	Compares the revised projected deployment with the original target deployment as the EDC implements its EDC.	All IAs	Evaluator

Source: Guidehouse review of infrastructure metric filings

[16] Guidehouse LLP completed its acquisition of Navigant Consulting, Inc, in October of 2019. The two brands are now combined as one Guidehouse.

2.1.3.2 Performance Metrics

Table 8 summarizes the performance metrics, which are used to evaluate the performance of all the GMP investments. Several of these metrics that pertain specifically to the M&C investments are discussed within this report. They will be quantified in a subsequent addendum and as part of the PY 2019 evaluation reporting process.

Table 8. Performance Metrics Overview

Metric	Applicable IAs
VVO Baseline	VVO
VVO Energy Savings	VVO
VVO Peak Load Impact	VVO
VVO Distribution Losses without AMF (Baseline)	VVO
VVO Power Factor	VVO
VVO – GHG Emissions	VVO
Voltage Complaints	VVO
Increase in Substations with DMS Power Flow and Control Capabilities	ADMS/ ALF
Control Functions Implemented by Circuit	ADMS/ ALF
Numbers of Customers that benefit from GMP funded Distribution Automation Devices	ADA
Grid Modernization investments' effect on outage durations	M&C, ADA
Grid Modernization investments' effect on outage frequency	M&C, ADA
Advanced Load Flow – Percent Milestone Completion	ADMS/ ALF
Protective Zone: Average Zone Size per Circuit*	M&C, ADA
Customer Minutes of Outage Saved per Circuit	M&C
Main Line Customer Minutes of Interruption Saved*	M&C, ADA

Source: Stamp Approved Performance Metrics, July 25, 2019.
** Note that these metrics primarily apply to ADA, but will be completed for M&C as well given interest in understanding how to separately measure the impacts of these two investment areas.*

2.2 Monitoring and Control (M&C) Investment Area Overview

As a part of the grid modernization efforts, the EDCs are making investments to advance their M&C capabilities and enhance network visibility. These M&C investments contribute to optimized system performance, higher reliability, and DER integration. As identified in the May 1, 2019 Grid Modernization annual reports filed by the EDCs, the M&C investments are planned to total to $45.9 million over 2018 to 2020: $41 million by Eversource, $4 million by National Grid, and $0.9 million by Unitil. The following subsection discusses EDC-specific approaches to M&C.

2.2.1 EDC Approach to M&C

Each EDC has a unique approach to their M&C investment area. Eversource and Unitil are focused on expanding SCADA on substations and distribution networks, while National Grid is focused on deploying feeder monitors on its distribution network. Unitil has an additional investment focused on integrating its advance metering infrastructure (AMI) data with its outage management system (OMS).

Table 9 defines the devices and technologies deployed as part of M&C. Specifics related to each EDCs' goals and objectives for their M&C investment area are discussed in Section 5.0.

Table 9. Devices and Technologies Deployed Under M&C Investment

EDC	Device/Investment Type	Description
Eversource	Microprocessor relays	Include advance overcurrent protection, pushbutton controls for the breakers, safety Hot Line Tagging, reclosing, breaker failure, and under-frequency load-shedding schemes.
	Recloser SCADA	Addition of communications capability so the device can be centrally monitored and controlled from the dispatch center.
	4 kV Circuit Breaker SCADA	Provides real-time visibility of loading conditions on the underground circuits that are among the most heavily loaded on Eversource's distribution system.
	Padmount Switch SCADA	Addition of a radio package to enable communications and central monitoring.
	Network Protector SCADA	Provide real-time network load data
National Grid	Feeder Monitors	Installation of interval power monitoring devices on feeders where National Grid currently does not have distribution information.
Unitil	Substation SCADA	The installation and interconnection of a SCADA terminal unit at the site, the establishment of communications between the terminal unit and the remotely located SCADA Master system, and the associated programming to implement desired functions.
	AMI-OMS Integration	The deployment of software that analyzes AMI status changes and relevant data points, detects suspect outages, and reports them as such to the OMS.

Source: Guidehouse

2.3 M&C Evaluation Objectives

This evaluation focuses on the progress and effectiveness of the DPU preauthorized M&C investments for each EDC toward meeting the DPU's grid modernization objectives. Table 10 illustrates the key infrastructure metrics and performance metrics relevant for the M&C evaluation.

Table 10. M&C Evaluation Metrics

Type	M&C Evaluation Metrics	ES	NG	UTL
IM	System Automation Saturation*	✓	✓	✓
IM	Number and Percent of Circuits with Installed Sensors*	✓	✓	✓
IM	Number of Devices or Other Technologies Deployed and In Service	✓	✓	✓
IM	Cost for Deployment	✓	✓	✓
IM	Deviation Between Actual and Planned Deployment for the Plan Year	✓	✓	✓
IM	Projected Deployment for the Remainder of the 3-Year Term	✓	✓	✓
PM	Grid Modernization Investments' Effect on Outage Durations	✓	✓	✓

Type	M&C Evaluation Metrics	ES	NG	UTL
PM	Grid Modernization Investments' Effect on Outage Frequency	✓	✓	✓
PM	Protective Zone: Average Zone Size per Circuit**	✓		
PM	Customer Minutes of Outage Saved per Circuit**			✓
PM	Main Line Customer Minutes of Interruption Saved**		✓	
PM	Case Study***	✓	✓	✓

** Denotes that generating the metrics is EDC responsibility*
*** Metrics primarily apply to ADA, but will be completed for M&C as well given interest in understanding how to separately measure the impacts of these two investment areas.*
****Case Studies will be added as a metric to facilitate understanding of the effectiveness of the investments toward improving customer reliability and to help distinguish improvements due to each specific investment area.*
Source: Guidehouse Stage 3 Evaluation Plan

The EDCs provided the data supporting the infrastructure metrics to the evaluation team. Guidehouse presents results from analysis of infrastructure metrics data in Section 5.0. The performance metrics analyses will be based on reliability and case study data from the EDCs and will be provided in a subsequent addendum to this report.[17] The case studies will facilitate understanding of the reliability improvements at select Eversource and National Grid feeder locations. These case studies will examine the impact the M&C investments had on reducing the outage frequency or lengths and will exemplify system outages with explanation of the mechanisms employed and devices used to achieve the reliability improvement.

Table 11 summarizes the M&C measurement and verification (M&V) objectives and associated research questions. The scope of the M&C evaluation includes tracking the M&C infrastructure deployment against the plan and evaluating the impact on system reliability.

Table 11. M&C M&V Objectives and Associated Research Questions

Associated Research Questions	IM	PM[18]
1) Are the EDCs progressing in deployment of their M&C investments according to their GMPs?	✓	
2) What factors, if any, are affecting the deployment schedule of M&C equipment?	✓	
3) What is the cost of deploying various types of M&C equipment, including SCADA retrofits and microprocessor relays?	✓	
4) What is the effect of M&C investments on key reliability metrics, such as SAIDI and SAIFI.		✓

Source: Guidehouse M&C Evaluation Plan

[17] The reliability data required for two of the M&C performance metrics will not be available for analysis until March 2020, which was not enough time to include by the April 1st 2020 filing date for this 2019 Program Year Evaluation Report. An explanation of the need for this timing was provided in response to DPU IR EP-1-1 Attachment A. This timing will lead to the performance metrics being evaluated in an addendum that will be released later in 2020.

[18] This report focuses on IMs. PM evaluation will be provided as an addendum to this report.

3.0 M&C Data Management

Guidehouse worked with the EDCs to collect data to complete the M&C evaluation and the assessment of infrastructure metrics. The subsections that follow highlight data sources and data QA/QC processes followed by Guidehouse to complete the evaluation and calculate the infrastructure metrics. Information is also included about data for the performance metrics for completeness.

3.1 Data Sources

Guidehouse used a consistent methodology (across investment areas and EDCs) for evaluating and illustrating EDC progress toward the GMP metrics. The subsections that follow summarize each of the data sources used to evaluate infrastructure metrics.

3.1.1 2018 Grid Modernization Plan Annual Report

Guidehouse used the planned device deployment and cost information from each EDCs' 2018 GMP Annual Reports, which were filed on May 1, 2019. Additional deployment metrics, progress, cost, and plan details for the 2018 program year were also provided in each EDC's Annual Report Appendix 1, filed on January 31, 2020.[19] These filings served as the sources for planning data in this report[20] and are referred collectively as the EDC "Plan" for each EDC in summary tables and figures throughout this report.

Table 12 provides a legend of the different planned and actual quantities reviewed and specifies the color/shade used to represent each in the remainder of the report.

Table 12. Deployment Categories Used for the EDC Plan

Representative Color	Data	Description
	2020 Plan	Projected 2020 unit deployment/ total spend
	2019 Plan	Estimated 2019 unit deployment/ total spend
	2018 Actual	Actual reported unit deployment and spend in 2018

Source: EDCs' 2018 GMP Annual Report Appendix 1 filed July 31, 2020

3.1.2 EDC PY2019 Device Deployment Data Template

Guidehouse collected device deployment data using standardized data collection templates (e.g., the All Device Deployment workbook file) for all EDCs in January –

[19] The Appendix 1 filings were submitted after the specific required format was determined by the DPU.

[20] See section 6 for specific details regarding 2018 GMP Annual Report data used for each EDC.

February 2019. The data collected provides an update of planned and actual deployment, in dollars and device units, at the end of PY2019. Data from this source are referred to as "EDC Data" in summary tables and figures throughout the report. Table 13 summarizes the date of file version receipt used for the evaluation.

Table 13. All Device Deployment Data File Versions for Analysis

EDC	File Version
Eversource	Received 1/22/2020
National Grid	Received 2/11/2020
Unitil	Received 1/20/2020

Source: Guidehouse

Since the receipt of these file versions, several data updates and corrections were discovered through the evaluation process. These revisions were received after the file versions shown in Table 13; however, they were included in Guidehouse's analysis.

The EDC device deployment data (collected primarily 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 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 were also collected. Planned device deployment information and estimated spend for PY2020 was provided at the most granular level (circuit or substation) where available. Table 14 summarizes the categories used for the revised planned and actual deployment and spend from the EDC Data and specifies the color used to represent each in the remainder of the report.[21]

Table 14. EDC Device Deployment Data

Representative Color	Data	Description
Device Deployment Data		
	2020 Plan	Remaining units planned for 2020 where work has not yet started
	2020 Design	Units in the design phase and will be commissioned in 2020
	2020 Construction	Units under construction and will be commissioned in 2020
	2019 Commissioned	Units in service and commissioned in 2019
	2018 Commissioned	Units in service and commissioned in 2018

[21] Eversource provided year-end total actual and planned devices commissioned and spend data. This aggregated data varied slightly from the work order data provided because of nuance's in Eversource's work order accounting methodologies. Guidehouse used the aggregated total data for the 2019 and 2018 commissioned units and spend data. Work order data was used to capture progress towards their updated 2020 plan (per the aggregated year-end total data).

Representative Color	Data	Description
Spend Data		
	2020 Estimate	Additional cost anticipated in 2020
	2019 Actual	All actual spend that occurred in 2019
	2018 Actual	All actual spend that occurred in 2018

Source: Guidehouse analysis

3.1.3 M&C Data for Performance Metrics

Table 15 summarizes the data inputs that are required for performance metrics analysis. Performance metrics will be evaluated in an addendum report. For the M&C investment area, data will be provided by the EDCs or sourced from their annual Service Quality Index (SQI) filings. Information must be provided at the circuit-level for the all circuits receiving M&C investments.

Table 15. Data Required for Performance Metrics Evaluation

PM Evaluation	EDC	Data Required
Effect on outage duration	All	• Baseline circuit average interruptions duration index (CKAIDI)[22] • Evaluation year CKAIDI
Effect on outage frequency	All	• Baseline circuit average interruptions frequency index (CKAIFI)[23] • Evaluation year CKAIFI
Customer Impact	All	• The number of customers for whom the M&C equipment will improve reliability (customers that benefit)
Effect on average protective zone*	ES	• Customers per zone per circuit before and after investment
Effect on customer minutes of outage saved	UTL	• Number of CMI reduced per circuit (from OMS and AMI data) and number of customers on each circuit
Effect on main line customer minutes of interruption	NG	• Number of main line CMI reduced per circuit based on OMS and system data
Case Studies	All	• One-line diagrams, available data on specific outage(s), interview with technical and/or operations staff to understand technology use

** Evaluation primarily applies to ADA, but will be completed for M&C as well given interest in understanding how to separately measure the impacts of these two investment areas.*
Source: Guidehouse Stage 3 M&C Evaluation Plan

[22] For years 2015, 2016, and 2017, on a circuit level for all circuits receiving M&C investments: AVERAGE (‘CKAIDI 2015’+’ CKAIDI Year 2016’+’ CKAIDI Year 2017’) = baseline ‘CKAIDI’

[23] For years 2015, 2016, and 2017, on a circuit level for all circuits receiving M&C investments: AVERAGE (‘CKAIFI 2015’+’ CKAIFI Year 2016’+’ CKAIFI Year 2017’) = baseline ‘CKAIFI’

3.2 Data QA/QC Process

Guidehouse reviewed all data provided for infrastructure metrics analysis upon receipt of requested data. The following sections detail the data QA/QC process.

3.2.1 Infrastructure Metrics Data QA/QC

To ensure accuracy, Guidehouse conducted a high-level 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., circuit information provided in the wrong field)
- Missing or incomplete information
- Large variation in the unit cost of commissioned devices
- Variance in the January 1 through June 30, 2019 data provided last year, and the work order-level data provided for PY2019
- Variance between the aggregated year-end total information and work order-level data (applicable to Eversource only)
- Differences between 2018 GMP Annual Report (filed May 1, 2019) and actual deployment and spend from our PY 2019 data collection

During the QAQC process, some inconsistencies were noted between the 2018 GMP Annual Report filing (submitted May 1, 2019) and the Annual Report Appendix 1 filing (submitted January 31, 2020) for two EDCs.[24] Also, one EDC identified calculation or conceptual adjustments that would be required in their Appendix 1 filings.[25] These items are described at various points in the report below or otherwise noted in figure or table notes or in footnotes where appropriate. These inconsistencies did not adversely affect the evaluation results.

3.2.2 Performance Metrics Data QA/QC

The QA/QC of performance metrics (to be provided in the June 2020 Addendum report) will include checks to confirm each of the required data inputs can be incorporated within the performance metrics analysis. This review will include the following criteria:

- Baseline data was calculated correctly
- Reliability data is complete and was provided for the appropriate circuits

[24] Unitil submitted updated information from their Appendix 1 filing, which was not available in time for the evaluation analysis. Additionally, Eversource excluded the 2018 to 2019 “carry-over” units in their 2019 planned unit totals within the Appendix 1 filing.

[25] Eversource’s planned 2020 cost breakdown by device type in the Annual Report Appendix 1 filing (submitted January 31, 2020) requires adjustment.

- The CKAIDI and CKAIFI metrics are within the expected range, and any outliers have been verified by the EDCs
- EDC specific reliability data based on Stamped Approved Metrics definitions
- Discussion with appropriate personnel to validate the specific operation and corresponding benefits developed in any case studies.

Data irregularities discovered during this process are being discussed with the EDCs and explained within the Performance Metrics addendum report.

4.0 M&C Evaluation Process

This section presents a high-level overview of the Guidehouse methodologies for the evaluation of infrastructure and performance metrics.

This M&C evaluation is focused on infrastructure metrics for PY 2019, as data required for the performance metrics is not yet available. Performance metrics (including case studies) for PY 2019 will be evaluated in an addendum to this report.

4.1 Infrastructure Metrics Analysis

Guidehouse annually assesses the progress of each of the EDCs toward enabling M&C devices and technologies on their feeders. Table 16 highlights the infrastructure metrics that were evaluated and their associated calculation parameters.

Table 16. M&C Infrastructure Metrics Overview

IM	Metric	Calculation Parameters
IM-3	**Number of devices or other technologies deployed**	# Devices – *total number of devices that have been commissioned, are in the construction phase, and are in the design phase*
		% Devices Deployed – *percent of the total planned devices over the 3-year period that have been commissioned*
IM-4	**Cost for Deployment**	Total Spend – *total spend through PY2019, regardless of whether the device has been commissioned*
		% Spend – *percent of the total estimated spend over the 3-year GMP period*
IM-5	**Deviation Between Actual and Planned Deployment for the Plan Year**	% On Track (Devices) – *devices commissioned through PY2019 divided by the devices planned for commission through PY2019*
		% On Track (Spend) – *actual spend through PY2019 divided by the planned spend through PY2019*
IM-6	**Projected Deployment in PY2020[26]**	# Devices– *How many devices remain to be commissioned in PY2020*
		Spend Remaining – *How much spend is estimated for PY2020*

Source: Guidehouse

Section 5.0 provides the results from the evaluation of infrastructure metrics. To evaluate infrastructure metrics Guidehouse:

[26] DPU-approved metric is titled "Project Deployment for Remainder of the 3-Year Term." Since 2020 is the last year of the 3-year team, Guidehouse abbreviated the metric for simplicity.

- Reviewed the EDC data provided with the EDCs to ensure the information provided accurately reflected their progress through PY2019 (see Section 3.2, "Data QA/QC Process")
- Interviewed representatives from each EDC to understand the status of the M&C investments, including:
    - Updates to their planned M&C investments
    - Reasons for deviation between actual and planned deployment and spend

4.2 Performance Metrics Analysis

Performance metrics will be evaluated for each of the three EDCs, focusing on the reliability metrics (CKAIDI and CKAIFI) at the circuit level. Table 17 describes the performance metrics that will be evaluated in the PY 2020 Addendum (target June 2020) and again for PY 2020.

Table 17. M&C Performance Metrics Overview

Performance Metrics	EDC	Description
Grid Modernization investments' effect on outage durations	All	Provides insight into how M&C investments can reduce outage durations (CKAIDI). Compares the experience of customers on GMP M&C-enabled circuits as compared to the previous three-year average for the same circuit.
Grid Modernization investments' effect on outage frequency	All	Provides insight into how M&C investments can reduce outage frequencies (CKAIFI). Compares the experience of customers on M&C-enabled circuits as compared to the prior three-year average for the same circuit.
Protective Zone: Average Zone Size per Circuit*	ES	Measures Eversource's progress in sectionalizing circuits into protective zones designed to limit outages to customers located within the zone.
Customer Minutes of Outage Saved per Circuit*	UTL	Tracks time savings from faster AMI outage notification than customer outage call, leading to faster outage response and reduced customer minutes of interruption.
Main Line Customer Minutes of Interruption Saved*	NG	Measures the impact of M&C investments on the customer minutes of interruption (CMI) for main line interruptions. Compares the CMI of GMP M&C-enabled circuits to the previous three-year average for the same circuit.
Case Studies	All	Provide insight into the impact that the M&C investments had on reducing the outage frequency or lengths and will exemplify system outages with explanation of the mechanisms employed and devices used to achieve the reliability improvement.

** Metrics primarily apply to ADA, but will be completed for M&C as well given interest in understanding how to separately measure the impacts of these two investment areas.*
Source: Stamp Approved Performance Metrics, July 25, 2019.

5.0 Deployment Progress and Findings

Guidehouse presents findings from the infrastructure metrics analysis for the M&C investment area in the following subsections.

5.1 Statewide Comparison

This section discusses the anticipated scope of M&C investments relative to the number of feeders and customers in Massachusetts, and summarizes the deployment progress and findings across all three EDCs.

5.1.1 Anticipated Impact on Massachusetts

As part of the 2018-2020 GMP, M&C technology deployment is anticipated on 341 feeders (10% of all EDC feeders) serving 421,700 customers (15% of all EDC customers). Table 18 highlights the anticipated impact by EDC. The number of cities and towns that contain feeders with planned M&C investments include:

- Eversource: 37
- National Grid: 45
- Unitil: 3

Table 18. Number of Feeders and Customers Covered by M&C Investments

M&C Impact	Eversource		National Grid		Unitil		Total	
	Feeders	Customers	Feeders	Customers	Feeders	Customers	Feeders	Customers
System-Wide Total	2,234	1,397,000	1,114	1,320,000	45	29,900	3,393	2,746,900
2018-20 Plan	270	255,000	177	254,118	10	9,800	341	421,700
% System Total	7.2%	12.8%	15.2%	17.9%	22.2%	32.8%	10.1%	15.4%

Source: Guidehouse analysis of 2018 GMP Annual Report Appendix 1

5.1.2 Infrastructure Metrics Results

Table 19 summarizes the infrastructure metrics results for each EDC's M&C investment area through PY2019. Guidehouse's M&C evaluation has confirmed that all EDCs are progressing towards their M&C plans, at varying paces; some EDCs have catch-up plans in place to meet 2018-2020 targets.

Table 19. 2019 Infrastructure Metrics Summary

Infrastructure Metrics		Parameter	Progress thru. PY2019		
			Eversource[27]	National Grid	Unitil[28]
2018-2020 Original Plan[29]		Devices	436	180	10
		Spend, $M	$41.0 million*	$3.96 million	$960,000
2018-2020 Revised Plan[30]		Devices	452	177	10
		Spend, $M	$49.8 million	$3.6 million	$997,000
IM-3	Number of Devices/ Technologies Deployed	# Commissioned	195	5	1
		% Commissioned	43%	2.8%	10%
IM-4	Cost for Deployment	Total Spend	$26 million	$201,000	$238,000
		% Spend	52%	5.6%	24%

[27] Device-related counts and percentages include all device types aggregated together.

[28] Device-related counts and percentages include circuits with substation SCADA retrofit.

[29] Based on the 2018 GMP Annual Report Appendix 1 filed January 31, 2020.

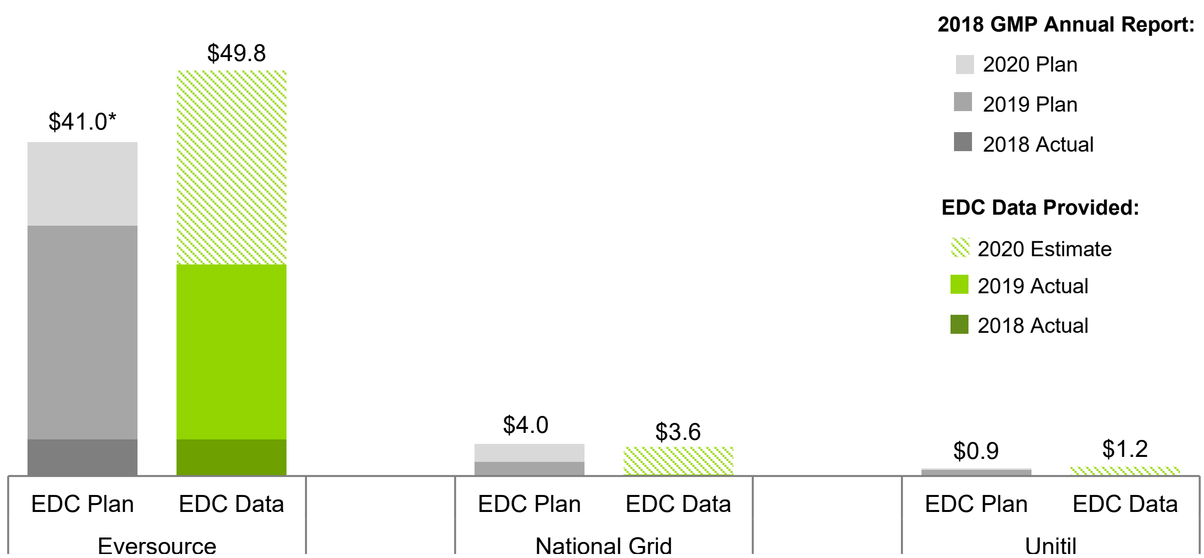
[30] Based on the EDC data through PY 2019 provided for the evaluation.

Infrastructure Metrics		Parameter	Progress thru. PY2019		
			Eversource[27]	National Grid	Unitil[28]
IM-5	Deviation Between Actual and Planned Deployment	% On Track (Devices)	76%	6.3%	25%
		% On Track (Spend)	84%	11.4%	30%
IM-6	Projected Deployment in PY2020	# Projected	257	172	9
		Spend Projected	$23.8 million	$3.4 million	$759,000

** Eversource adjustment to $40.7M. See discussion Section 5.2 for details.*
Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Actual spending in PY2019 was less than anticipated for all EDCs. Eversource and Unitil's revised 2018-2020 estimated spend is higher than originally anticipated while National Grid's revised 2018-2020 estimated spend is lower than originally anticipated. Figure 3 differentiates between the original planned spend per the 2018 GMP Annual Report and the actual/updated projected spend based on the EDC data provided.

Figure 3. M&C Planned vs. Actual Spend (2018 – 2020, $M)



** Eversource adjustment to $40.7M. See discussion Section 5.2 for details.*
Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data.

5.2 Eversource

This section discusses Eversource's M&C investment progress through PY 2019 and projected PY 2020 progress compared to the 2018 GMP Annual Report.

5.2.1 Overview of GMP Deployment Plan

Eversource's M&C investment area goals and objectives include:

- Increasing the amount of data that are being collected by the existing SCADA system for enhanced analytical capabilities (e.g., load flow analysis)

- Increasing reliability by enabling crew dispatch to remotely isolate faulted cable sections, restoring power to customers

To achieve these goals, Eversource is expanding SCADA on their distribution network. Table 20 details the technologies and devices that are being implemented as part of Eversource's M&C investment area.

Table 20. Eversource M&C Devices and Technologies

Device/Investment Type		Description
Microprocessor relays		Include advance primary overcurrent protection, pushbutton controls for the breakers, safety Hot Line Tag, reclosing, breaker failure, and under-frequency load-shedding schemes.
SCADA	**Recloser SCADA**	Addition of communications capability so the device can be centrally monitored and controlled from the dispatch center.
	4 kV Circuit Breaker SCADA	ADA that provides real-time visibility of loading conditions on the underground circuits that are among the most heavily loaded on Eversource's distribution system.
	Padmount Switch SCADA	Addition of a radio package to enable communications and central monitoring.
	Network Protector SCADA	Provide real-time network load data and remote-control capability.

Source: Guidehouse

Eversource's 2018 Annual Report Appendix 1 filing was used as the primary data source for the actual and plan information presented below. Guidehouse has determined some inconsistences between the Annual Report information and the data in Appendix 1, and Eversource has suggested additional changes to the some of the Appendix 1 data. While these issues did not adversely affect the evaluation results, we have included notes on the tables and figures below to point them out. These include: the number of planned units for 2019 has been adjusted to accurately reflect Eversource's actual plan as discussed in the 2018 GMP Annual Report[31] dollar value adjustments for 2020 planned spend; total 2018 through 2020 planned spend are indicated in table notes where applicable.[32]

[31] Eversource excluded the 2018 to 2019 "carry-over" units in their 2019 planned unit totals within the 2018 GMP Annual Report Appendix 1 filing (submitted January 31, 2020). Information in their Appendix 1 filing was taken directly from Table S2-4 of their 2018 Annual Report (filed May 1, 2019), and does not include the units shown in Table 5 of the Annual Report. These units must be added to the 2019 planned units shown in Table S2-4 to accurately reflect Eversource's 2019 planned unit deployment.

[32] Additionally, Eversource has suggested that the planned 2020 cost breakdown by device type in the Annual Report Appendix 1 filing requires adjustment, and Eversource supplied updated cost breakdown data for evaluation purposes. Guidehouse has compared this updated data against the original Appendix 1 file and has noted this in places in the evaluation report.

5.2.2 M&C Investment Progress through PY 2019

Eversource's M&C investment area made significant progress across all technologies through PY 2019. Devices have been commissioned across all M&C technologies, except network protector SCADA where devices were installed but pending final commissioning. In addition, Eversource made significant progress preparing for PY 2020 deployment, with many devices in the construction and design stage. The total spend through PY 2019 was $26 million and the revised 2018-2020 projected total spend is now $49.8 million. Microprocessor relays make up the largest share, with 70% of the spend through PY 2019 and 84% of the 2018-2020 projected total spend. Table 21 shows Eversource's M&C progress through December 31, 2019 (PY 2019) based on the data received in the All Device Deployment data workbook.

Table 21. Eversource M&C Deployment Progress

Technology	Actual through PY2019		PY2019 Progress towards PY2020 Plan		2018 - 2020 Revised Plan	
	Commiss-ioned Units	Accrued Cost, $M	Construction	Design	Commiss-ioned Units	Accrued Cost, $M
Microprocessor Relay	97	$18.4	24	51	193	$33.1
4kV Circuit Breaker SCADA	16	$4.2	0	12	55	$11.1
Network Protector SCADA	0	$0.9	83	0	83	$2.0
Padmount Switch SCADA	44	$0.7	4	22	62[33]	$1.0
Recloser SCADA	34	$1.9	5	8	37[34]	$2.5
Total	**195**	**$26.0**	**116**	**93**	**430**	**$49.8**

Source: Guidehouse analysis of EDC Data

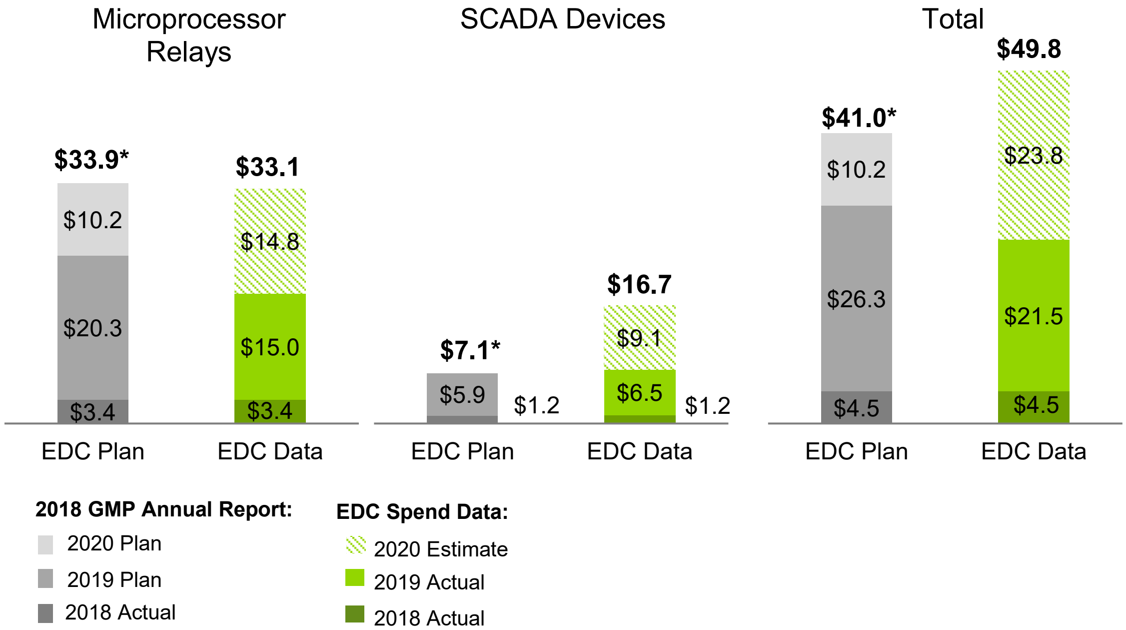
Figure 4 highlights the 2018-2020 planned and actual spend for microprocessor relays and SCADA devices (4 kV circuit breaker SCADA, network protector SCADA, padmount switch SCADA, and recloser SCADA) separately and aggregated together.[35] Spending on M&C investments was lower than planned in PY 2019; however, the total estimated spend for 2018-2020 is now higher than originally planned.

[33] Of the 26 devices that are currently in construction or design, Eversource has confirmed that at least 18 will be commissioned. Additional locations will be designed to ensure goal completion in the event some planned locations are not suitable.

[34] Of the 13 devices that are currently in construction or design, Eversource has confirmed that at least 3 will be commissioned. Additional locations will be designed to ensure goal completion in the event some planned locations are not suitable.

[35] Microprocessor relays are discussed separately from the SCADA devices because they make up the largest share of the overall spending for M&C, and investment in the relays is fundamentally different from the SCADA upgrades being done in the other categories.

Figure 4. Eversource Planned vs. Actual Spend Comparison (2018-2020, $M)



** Eversource has suggested that this 2018 GMP Annual Report Appendix 1 value be adjusted to $40.7M. With this adjustment, the corresponding values for the chart would be: microprocessor relays -- $27.3M, SCADA devices -- $13.4M.*
Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 222 presents a year-over-year comparison of Eversource's planned, actual, and revised PY 2020 planned spend for microprocessor relays and SCADA devices over from 2018 to 2020.

Table 22. Eversource Planned vs. Actual Year-over-Year Spend Comparison (2018-2020, $M)

Spend, $M	2018	2019	2020	2018-2020
Microprocessor Relays				
Actual Progress	$3.4	$15.0	-	-
EDC Original Plan[36]	$3.4	$20.3	$10.2*	$33.9*
% EDC Actual / EDC Plan	-	74%	-	-
EDC Revised Plan[37]	$3.4	$15.0	$14.8	$33.1
% EDC Revised Plan / EDC Plan	-	-	144%	98%
SCADA Devices				
Actual Progress	$1.2	$6.5	-	-
EDC Original Plan	$1.2	$5.9	$0.0*	$7.1*
% EDC Actual / EDC Plan	-	109%	-	-

[36] Based on 2018 GMP Annual Report Appendix 1 (filed January 31, 2020).

[37] Based on the EDC's updated projections for PY2020.

Spend, $M	2018	2019	2020	2018-2020
EDC Revised Plan	$1.2	$6.5	$9.1	$16.7
% EDC Revised Plan / EDC Plan	-	-	100%	235%
Total				
Actual Progress	$4.5	$21.5	-	-
EDC Original Plan	$4.5	$26.3	$10.2*	$41.0*
% EDC Actual / EDC Plan	-	82%	-	-
EDC Revised Plan	$4.5	$21.5	$23.8	$49.8
% EDC Revised Plan / EDC Plan	-	-	233%	121%

** Eversource has suggested that these 2018 GMP Annual Report Appendix 1 values be adjusted as follows: 2018-2020 totals for microprocessor relays-- $27.3M, SCADA devices-- $13.4M, total--$40.7M; 2020 values for microprocessor relays-- $18.2M, SCADA devices-- $9.0M, total--$27.2M. Note that under these adjustments, the percentages would vary somewhat as well.*
Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Eversource spent $21.5 million in PY 2019, 18% lower than the $26.3 million originally planned. This was caused primarily by delayed microprocessor relay final commissioning due to unforeseen conditions and complexity as well as a very tight execution schedule. Spending on microprocessor relay deployment was 26% below the original estimate ($15 million compared to $20.3 million). Some of this shift was caused by increased spending on SCADA devices. Spending on SCADA devices was 9% higher than originally planned ($6.5 million compared to $5.9 million).

Projected spending for PY 2020 is now more than double the original estimate due to shifting delayed PY 2019 microprocessor relay deployment into PY 2020, an increase in SCADA device deployments planned for PY 2020, as well as increased microprocessor relay and 4kV SCADA unit costs. Eversource now anticipates spending $14.8 million on microprocessor relays and $9.1 million on SCADA devices throughout PY 2020. As a result of these increases, Eversource now estimates spending $49.8 million from 2018 to 2020, 21% higher than originally estimated in the 2018 GMP Annual Report. These additional funds for M&C investment were allocated by Eversource from the original Communications investment area budget in accordance with the DPU's allowance for shifting funds among investment areas.

Table 23 presents the infrastructure metrics results through PY 2019 for each investment type related to Eversource's M&C investment area.

Table 23. Eversource PY2019 Infrastructure Metrics for M&C Technologies

IM	Metric	Parameter	Progress through PY 2019					
			Micro-process-or Relays	SCADA				Total
				4 kV Circuit Breaker	Network Protector	Pad-mount Switch	Recloser	
IM-3	Number of Devices Deployed	# Deployed	97	16	0	44	34	191
		% Deployed	51%	29%	0%	63%	72%	43%
IM-4	Cost for Deployment	Total Spend, $M	$18.4	$4.2	$0.9	$0.7	$1.9	$26.0
		% Spend	55%	37%	44%	73%	73%	52%

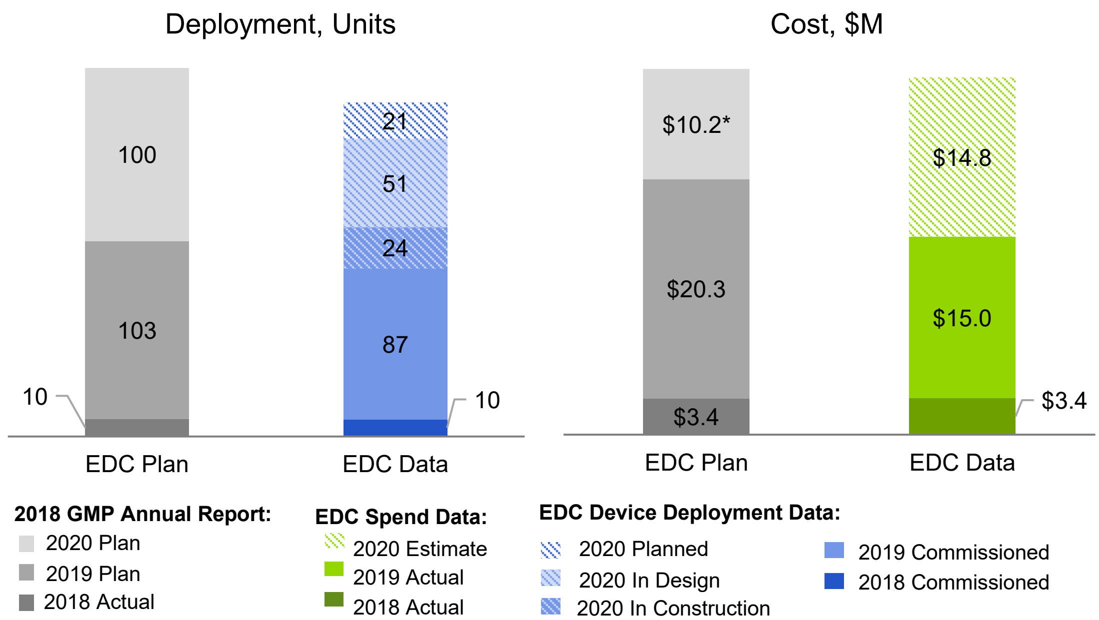
IM	Metric	Parameter	Progress through PY 2019					
			Micro-processor Relays	SCADA				Total
				4 kV Circuit Breaker	Network Protector	Pad-mount Switch	Recloser	
IM-5	Deviation Between Actual and Planned Deployment	% On Track (Devices)	88%	76%	0%	100%	117%	76%
		% On Track (Spend)	78%	167%	40%	178%	93%	84%
IM-6	Projected Deployment in PY 2020	# Devices	96	39	83	18	3	239
		Spend, $M	$14.8	$7.0	$1.1	$0.3	$0.7	$23.8

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

5.2.2.1 Microprocessor Relays

Figure 5 shows Eversource's planned versus actual microprocessor relay deployment progress totaled over the 2018-2020 period.

Figure 5. Eversource Microprocessor Relay Comparison (2018-2020)



** Eversource has suggested that the 2018 GMP Annual Report Appendix 1 value for 2020 planned spending be adjusted to $3.6M.*
Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 24 presents a year-over-year comparison of Eversource's planned, actual, and revised PY2020 plan microprocessor relay deployment from 2018 to 2020.

Table 24. Eversource Planned vs. Actual Microprocessor Relay Comparison

Microprocessor Relays	2018	2019	2020	2018-2020
Deployment Progress				
EDC Actual Progress	10	87	-	-
EDC Original Plan[38]	10	103	100	213
% EDC Actual / EDC Plan	-	84%	-	-
EDC Revised Plan[39]	10	87	96	193
% EDC Revised Plan / EDC Plan	-	-	96%	91%
Spend, $M				
EDC Actual Progress	$3.4	$15.0	-	-
EDC Original Plan	$3.4	$20.3	$10.2*	$33.9*
% EDC Actual / EDC Plan	-	74%	-	-
EDC Revised Plan	$3.4	$15.0	$14.8	$33.1
% EDC Revised Plan / EDC Plan	-	-	144%**	98%**

** Eversource has suggested that these 2018 GMP Annual Report Appendix 1 values be adjusted as follows: 2020 planned spend: $3.6M, total spend: $27.3M.*
*** If these adjustments are used, the percentages will vary.*
Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Microprocessor relay deployment in PY 2019 was 16% lower than originally planned in the 2018 GMP Annual Report. In PY 2019, 87 devices were commissioned compared to the 100 devices originally planned.[40] This was caused by delays in the final commissioning of devices after construction due to unforeseen conditions and a very tight construction schedule.

Although device deployment was slightly behind the original plan for PY 2019, Eversource made significant progress toward its PY 2020 deployment plans with 24 devices in construction and 51 devices in design at the end of PY 2019. Eversource now estimates commissioning 96 devices in PY 2020, four less than the 100 units originally planned. The total estimated microprocessor relay deployment for the 2018-2020 period is now 193 units, 10% lower than the 213 units originally planned in the 2018 GMP Annual Report.

Although the 2018-2020 microprocessor relay deployment is 10% lower than originally planned, the estimated unit cost of $172,000 is 8% higher than the $161,000 originally anticipated in the 2018 GMP Annual Report.[41] As a result, the 2018-2020 total estimated spending ($33.1 million) is 2% below the original estimate in the 2018 GMP Annual Report ($33.9 million).[42]

[38] Based on 2018 GMP Annual Report Appendix 1 (filed January 31, 2020) with carry-over units added.

[39] Based on the EDC's updated projections for PY2020.

[40] Eversource's corrected original planned deployment may have been 103 units.

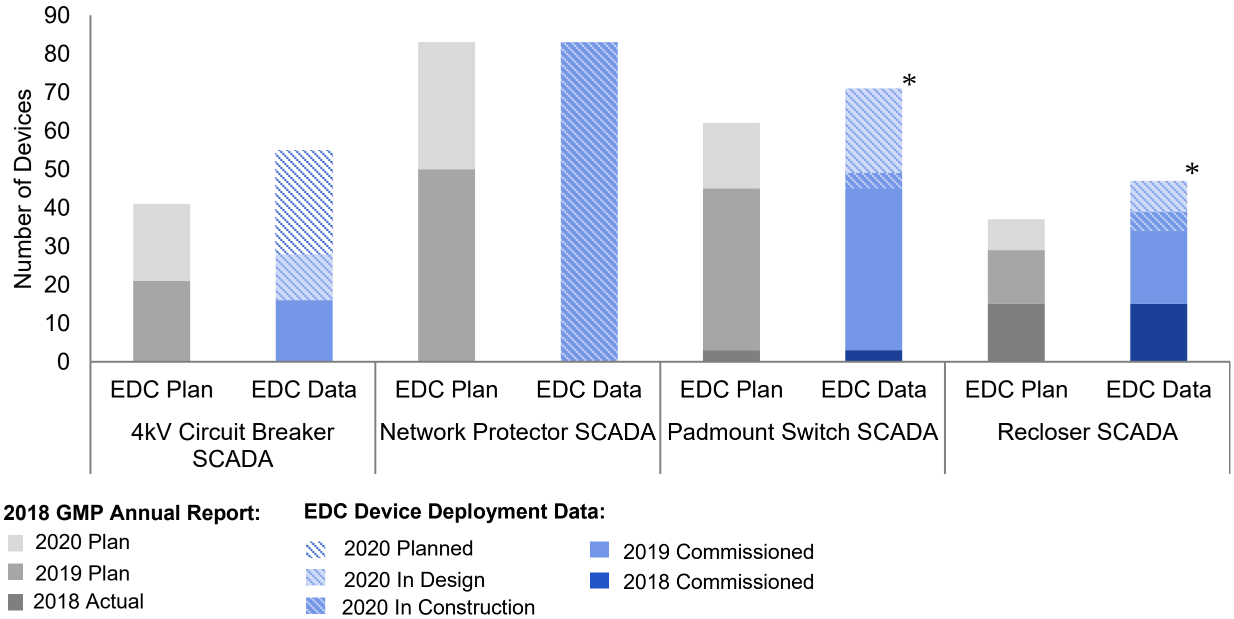
[41] Eversource's corrected original estimated unit cost may have been $128,000/unit.

[42] Eversource's corrected original estimated spend may have been $27.3M.

5.2.2.2 SCADA Devices

Figure 6 shows Eversource's planned versus actual SCADA device deployment progress by technology type over the 2018-2020 period.

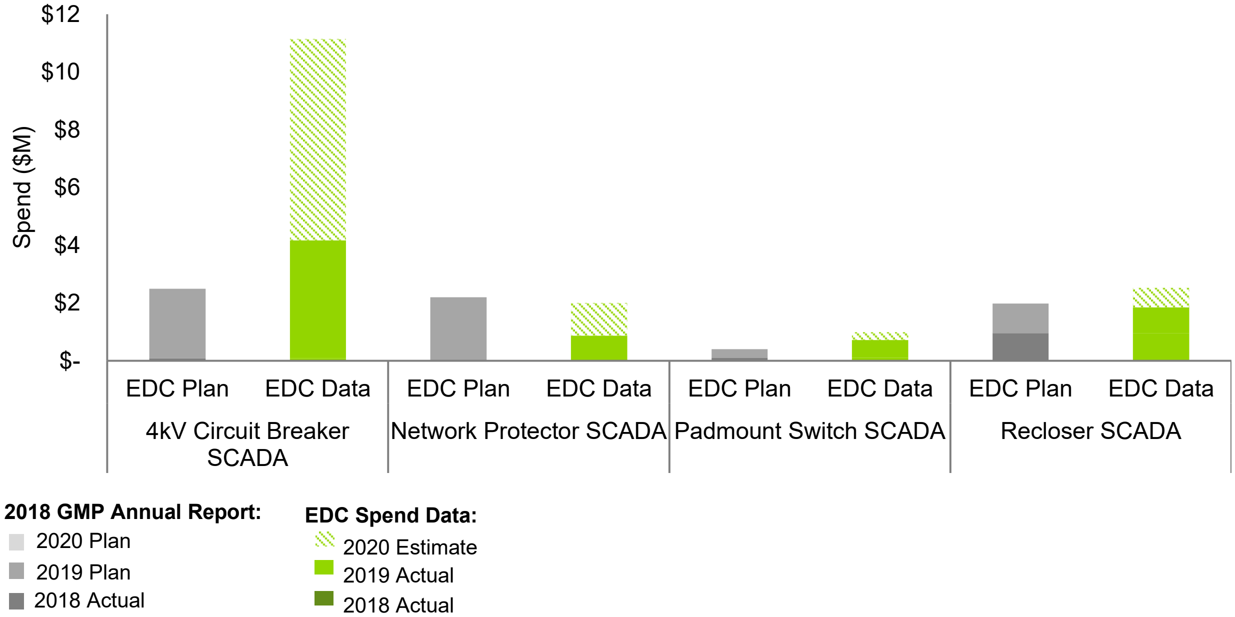
Figure 6. Eversource SCADA Device Deployment Comparison (2018-2020)



** For padmount switch SCADA and recloser SCADA, there are more devices that are in the design/ construction phase than Eversource anticipates commissioning by 2020. Eversource is using this approach as a planning technique for the contingency that some devices fall out of eligibility for full commissioning, so there will still be enough designed/ constructed devices to commission the full number planned for in its GMP. Eversource's 2018 - 2020 total deployment plan still aligns with the 2018 GMP Annual Report.*
Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Figure 7 shows Eversource's planned versus actual SCADA device spend by technology type over the 2018-2020 period.

Figure 7. Eversource SCADA Device Spend Comparison (2018 – 2020, $M)*



** Suggested adjustments to the 2018 GMP Annual Report Appendix 1 values shown in the figure are discussed in the notes for Table 25.*
Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 25 presents a year-over-year comparison of Eversource's planned, actual, and revised PY 2020 plan SCADA device deployment and spend by technology type from 2018 to 2020 in a tabular format.

Table 25. Eversource Planned vs. Actual SCADA Comparison

SCADA Devices	2018	2019	2020	2018-2020
4-kV Circuit Breaker				
Deployment				
EDC Actual Progress	0	16	-	-
EDC Original Plan[43]	0	21	20	41
% EDC Actual / EDC Plan	-	76%	-	-
EDC Revised Plan[44]	0	16	39	55
% EDC Revised Plan / EDC Plan	-	-	195%	134%
Spend, $M				
EDC Actual Progress	$0.08	$4.09	-	-
EDC Original Plan	$0.08	$2.41	$0.00*	$2.50*
% EDC Actual/EDC Plan	-	169%	-	-
EDC Revised Plan	$0.08	$4.09	$6.98	$11.15
% EDC Revised Plan/EDC Plan	-	-	100%**	446%**

[43] Based on 2018 GMP Annual Report Appendix 1 (filed January 31, 2020).

[44] Based on the EDC's updated projections for PY2020.

SCADA Devices	2018	2019	2020	2018-2020
Network Protector SCADA				
Deployment				
EDC Actual Progress	0	0	-	-
EDC Original Plan	0	50	33	83
% EDC Actual/EDC Plan	-	0%	-	-
EDC Revised Plan	0	0	83	83
% EDC Revised Plan/EDC Plan	-	-	252%	100%
Spend, $M				
EDC Actual Progress	$0.00	$0.87	-	-
EDC Original Plan	$0.00	$2.20	$0.00*	$2.20*
% EDC Actual/EDC Plan	-	40%	-	-
EDC Revised Plan	$0.00	$0.87	$1.13	$2.00
% EDC Revised Plan/EDC Plan	-	-	100%**	91%**
Padmount Switch SCADA				
Deployment				
EDC Actual Progress	3	41	-	-
EDC Original Plan	3	42	17	62
% EDC Actual/EDC Plan	-	100%	-	-
EDC Revised Plan	3	41	18	62[45]
% EDC Revised Plan/EDC Plan	-	-	106%	100%
Spend, $M				
EDC Actual Progress	$0.11	$0.62	-	-
EDC Original Plan	$0.11	$0.30	$0.00*	$0.40*
% EDC Actual/EDC Plan	-	206%	-	-
EDC Revised Plan	$0.11	$0.62	$0.27	$0.99
% EDC Revised Plan/EDC Plan	-	-	100%**	245%**
Recloser SCADA				
Deployment				
EDC Actual Progress	15	19	-	-
EDC Original Plan	15	14	8	37
% EDC Actual/EDC Plan	-	136%	-	-
EDC Revised Plan	15	19	3	37[46]
% EDC Revised Plan/EDC Plan	-	-	163%	127%
Spend, $M				
EDC Actual Progress	$0.96	$0.89	-	-
EDC Original Plan	$0.96	$1.02	$0.00*	$1.99*
% EDC Actual/EDC Plan	-	87%	-	-
EDC Revised Plan	$0.96	$0.89	$0.68	$2.53
% EDC Revised Plan/EDC Plan	-	-	100%**	127%**
Total				
Deployment				
EDC Actual Progress	18	77	-	-
EDC Original Plan	18	127	78	223
% EDC Actual/EDC Plan	-	61%	-	-
EDC Revised Plan	18	76	143	237

[45] There are 4 devices that are currently in the construction phase and 22 devices that are currently in the design phase. Of these 26 devices, Eversource has confirmed that at least 18 are expected to be commissioned in PY 2020.

[46] There are 5 devices that are currently in the construction phase and 8 devices that are currently in the design phase. Of these 13 devices, Eversource has confirmed that at least 3 will be commissioned in PY 2020. 213+223

SCADA Devices	2018	2019	2020	2018-2020
% EDC Revised Plan/EDC Plan	-	-	206%	115%
Spend, $M				
EDC Actual Progress	$1.15	$6.46	-	-
EDC Original Plan	$1.15	$5.94	$0.00*	$7.09*
% EDC Actual/EDC Plan	-	109%	-	-
EDC Revised Plan	$1.15	$6.46	$9.06	$16.67
% EDC Revised Plan/EDC Plan	-	-	100%**	235%**

** Suggested adjustments to these 2018 GMP Annual Report Appendix 1 cost estimate values for 2020 (and total 2018-2020) are as follows: 4 kV circuit breaker SCADA: $2.7M ($5.3M total), network protector SCADA: $2.8M ($5.0M total), padmount switch SCADA: $414,000 ($818,000 total), recloser SCADA: $388,000 ($2.4M total), 2018 total: $6.3M ($13.4M 2018-2020 total).*
*** If these adjustments are used the percentages will vary.*
Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

SCADA device commissioning in PY 2019 was slightly behind the original plans in the 2018 GMP Annual Report. In PY 2020, 76 devices were commissioned compared to the 127 devices that were originally planned. This was caused by delays in the final commissioning of network protector SCADA after construction. Eversource anticipates that these 128 devices will be officially commissioned in early PY 2020 without issues.

Significant progress was made toward PY 2020 device deployment in PY 2019. 12 4 kV circuit breaker SCADA devices are currently in the design phase, and the 2018-2020 estimated deployment is now 34% higher than originally planned. Eversource also pushed additional padmount switch SCADA devices and recloser SCADA devices through the design and construction to account for locations that may not be feasible throughout the program. Eversource has confirmed that at least 18 padmount switch SCADA units and 3 recloser SCADA units will be commissioned to meet the original 2018-2020 totals from the 2018 GMP annual report. Additional units beyond the 2018-2020 totals will be commissioned depending on available resources and funds.

The total estimated spending on SCADA devices for the 2018-2020 period ($16.7 million) is more than double the original estimate in the 2018 GMP Annual Report ($7.1 million).[47] This is primarily caused by a large increase in the unit cost for 4-kV circuit breaker SCADA. The revised estimated unit cost for 4-kV circuit breaker SCADA ($203,000) is three times higher than the original estimate in the 2018 GMP Annual Report ($61,000).[48] Eversource shifted funds from the communications investment area to account for a portion of this increased spending.

5.2.3 Summary of Key Findings

Eversource is on track to meet its original 2018-2020 M&C device deployment targets per the 2018 GMP Annual Report. Progress and spending in PY2019 was slightly

[47] Eversource's suggested adjustment to the 2018 GMP Annual Report Appendix 1 value is $13.4M.

[48] Eversource's suggested adjustment to the 2018 GMP Annual Report Appendix 1 value implies that the unit cost estimate for 4 kV circuit breaker SCADA would have been $128,000/unit.

behind the original projection. This was primarily caused by delayed commissioning for some devices constructed in PY2019 (e.g., 83 4-kV circuit breaker SCADA). However, many devices planned for PY 2020 are already in the construction or design phase. Eversource does not anticipate any issues in PY 2020 and will likely exceed its original 2018-2020 target.

The unit cost for implementing microprocessor relays and 4 kV SCADA is now higher than Eversource originally anticipated in its 2018 GMP Annual Report. As a result, the revised 2018-2020 total estimated spending for M&C investments ($49.8 million) is now 20% higher than the original estimate ($41 million). Eversource is primarily addressing this additional budget by shifting funds away from the originally planned budget for the Communications investment area. Guidehouse project staff interviewed Eversource engineering and analysis staff and reviewed the data and documentation provided and is satisfied that the updated plans are credible and appropriate.

5.3 National Grid

This section discusses National Grid's M&C investment progress through PY 2019 and projected PY 2020 progress as compared to the 2018 GMP Annual Report.

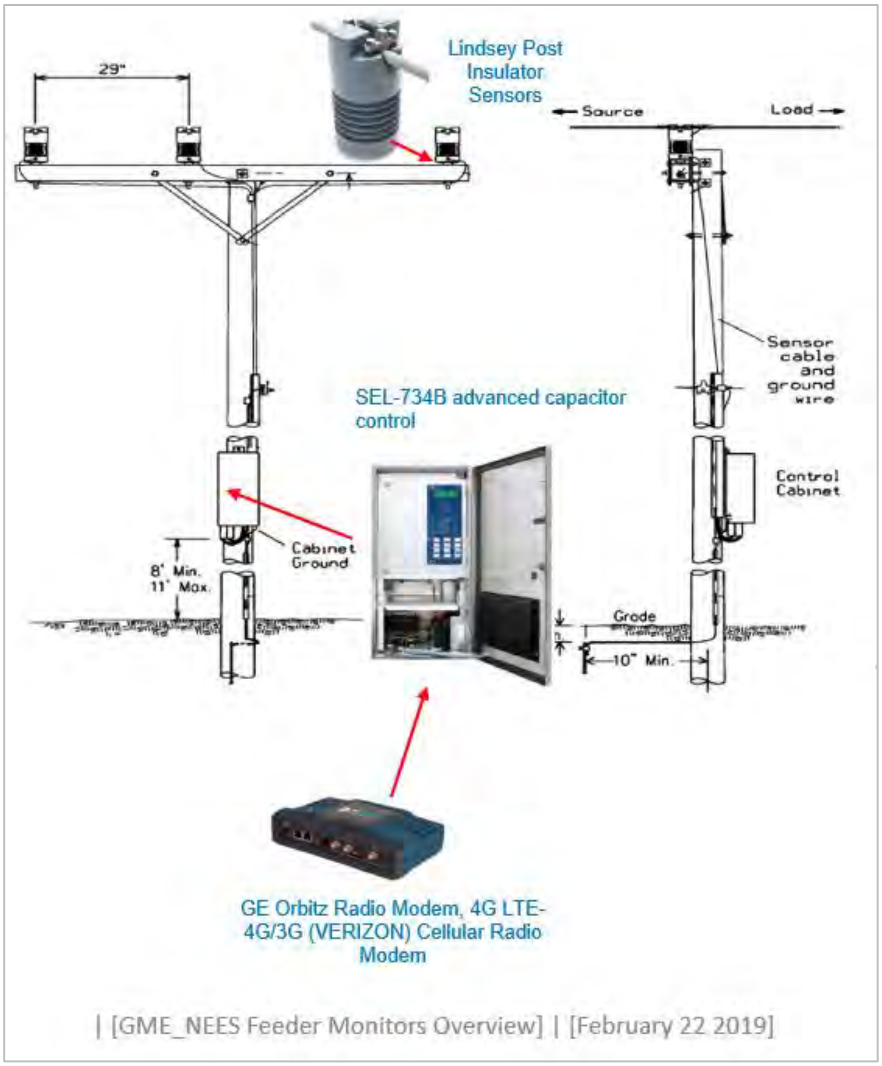
5.3.1 Overview of GMP Deployment Plan

National Grid's M&C investment area goals and objectives include:

- Provide critical data for Operations and Distribution Designer by providing near real-time voltage, current, and power monitoring information to the operations control center
- Focus on overhead feeders within the distribution system and substations with minimal to no existing SCADA

The achieve these goals, National Grid is installing 177 interval power monitoring devices on overhead feeders within its distribution system. National Grid's selected technology will be installed outside of substation fence for increased visibility. Information is transmitted cellularly every 5 minutes. Figure 8 shows a detailed schematic of how the technology will be implemented. Each circuit location includes three sensors (one per phase) and one control box with a communications package. For GMP accounting purposes, National Grid is counting this configuration as a single device deployed on a circuit. Guidehouse adopted this definition in the evaluation for consistency.

Figure 8. Feeder Monitor Schematic



Source: National Grid

5.3.2 M&C Investment Progress through PY 2019

National Grid's M&C investment area was focused on planning in PY 2019 with device deployment primarily targeted for PY 2020. Table 26 presents National Grid's M&C progress through PY 2019 based on the data received in the All Device Deployment data workbook. Five feeder monitors were commissioned in PY 2019. Because devices are installed and commissioned in the same day, no devices are in the construction or design stage.

Table 26. National Grid M&C Deployment Progress

Device	Actual through PY2019		2020 Device Deployment Progress		2018-2020 Revised Plan	
	Commiss-ioned Units	Accrued Cost	Construction	Design	Commiss-ioned Units	Accrued Cost
Feeder Monitors	5	$201K	0	0	177	$3.6M

Source: Guidehouse analysis of EDC Data

Table 27 presents the infrastructure metrics results through PY 2019 for National Grid's feeder monitor deployment.

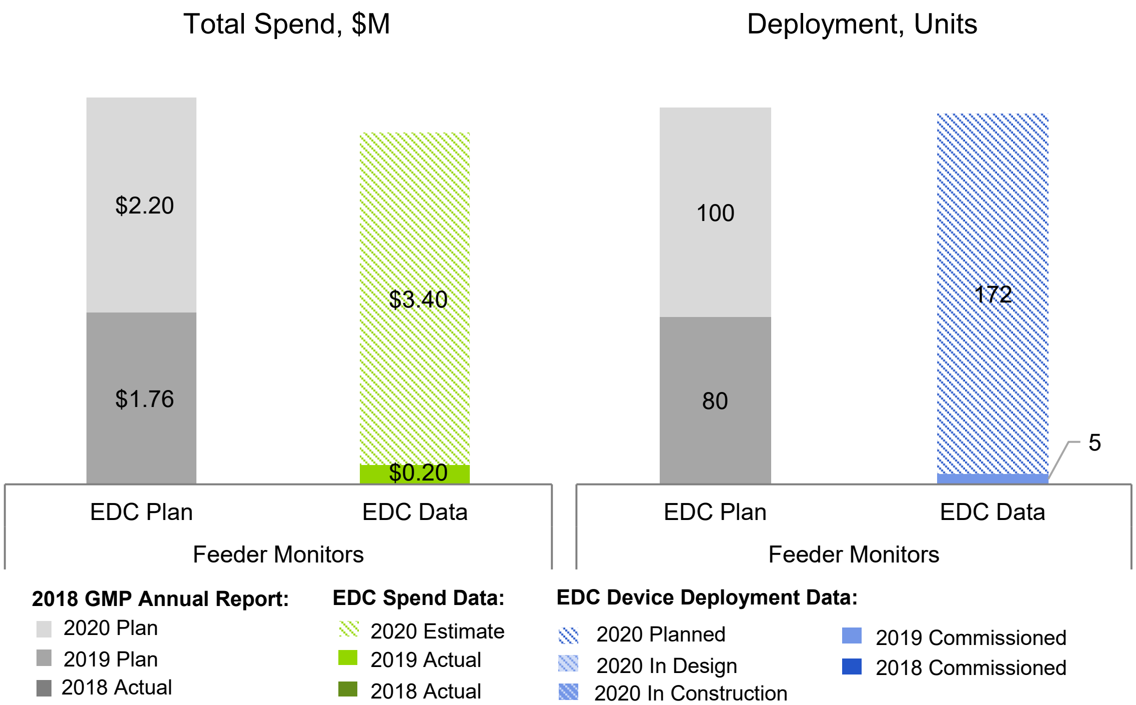
Table 27. National Grid PY2019 Infrastructure Metrics Findings

IM	Metric	Parameter	Feeder Monitors
IM-3	Number of devices/ technologies deployed	# Devices Commissioned	5
		% Devices Commissioned	2.8%
IM-4	Cost for Deployment	Total Spend	$201,000
		% Spend	5.6%
IM-5	Deviation Between Actual and Planned Deployment	% On Track (Devices)	6.3%
		% On Track (Spend)	11.4%
IM-6	Projected Deployment for the Remainder of the 3-Year Term	# Devices Remaining	172
		Spend Remaining	$3.4 million

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Feeder monitor deployment and spend through PY 2019 was lower than planned in the 2018 GMP Annual Report. Five feeder monitors and $201,000 occurred in PY 2019 compared to the 80 feeder monitors and $1.76 million originally planned. Vendor material delivery lead times slowed the deployment, pushing devices and costs to PY 2020. National Grid now anticipants $3.4 million and 172 units in PY 2020, compared to $2.2 million and 100 units originally planned. Figure 9 summarizes these findings.

Figure 9. National Grid Planned vs. Actual Total Comparison (2018-2020)



Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Although progress was slow in PY 2019, National Grid's revised 2018-2020 target of 177 units is only 2% below the original target of 180 units. In addition, the estimated unit cost in PY 2020 ($20,000) is now lower than originally anticipated ($22,000). As a result, the overall estimated spend ($3.6 million) is 11% less than originally planned in the 2018 GMP Annual Report. Table 28 summarizes these findings.

Table 28. National Grid Planned vs. Actual Year-over-Year Comparison

Data	2018	2019	2020	2018-2020
Feeder Monitor Deployment				
EDC Actual Progress	0	5	N/A	N/A
EDC Original Plan[49]	0	80	100	180
% EDC Actual / EDC Plan	N/A	6.25%	N/A	N/A
EDC Revised Plan[50]	0	5	172	177
% EDC Revised Plan / EDC Plan	N/A	N/A	172%	98%

[49] Based on 2018 GMP Annual Report Appendix 1 (filed January 31, 2020).

[50] Based on the EDC's updated projections for PY2020.

Data	2018	2019	2020	2018-2020
Spend, $M				
EDC Actual Progress	$0	0.201	N/A	N/A
EDC Original Plan	$0	$1.76	$2.20	$3.96
% EDC Actual/EDC Plan	N/A	11.4%	N/A	N/A
EDC Revised Plan	$0	$0.20	$3.4	$3.6
% EDC Revised Plan/EDC Plan	N/A	N/A	155%	91%

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Despite the longer than anticipated vendor lead times, National Grid had no issues once it received the sensors from the vendor, and is focused on deploying the 177 units prior to the end of PY 2020. The devices arrive preconfigured and the field crew can install and commission the devices live in under 4 hours. National Grid plans to complete 25 units by March 31, 2020, and average five a week from April 1, 2020 to December 31, 2020.

5.3.3 Summary of Key Findings

National Grid's M&C progress is behind where it had anticipated in its 2018 GMP Annual Report. Vendor material delivery lead times delayed how many devices National Grid was able to deploy in PY 2019. However, the installation process was faster than anticipated and the unit cost was lower than expected. As a result, National Grid anticipates that it will be able to deploy 172 units at $3.4 million in PY 2020 for a 2018-2020 total of 177 units at $3.6 million. Assuming no additional delays, this expectation seems reasonable given the data provided. The total number of feeder units aligns with the 2018 GMP Annual Report while the revised estimated cost is 11% less than originally anticipated. Guidehouse project staff interviewed National Grid engineering and management staff and reviewed the data and documentation provided and is satisfied that the updated plans are credible and appropriate.

5.4 Unitil

This section discusses Unitil's M&C investment progress through PY 2019 and projected PY 2020 progress compared to the 2018 GMP Annual Report.

5.4.1 Overview of GMP Deployment Plan

Unitil's M&C investment area goals and objectives include:

- Provide remote monitoring of conditions on the electric system (e.g., voltage, current)
- Provide remote control of equipment and functions (e.g., circuit breakers/reclosers, transformer load tap changers, capacitor banks)
- Enable technologies required for other GMP projects (e.g., ADMS, VVO)
- Improve integration of outage information from meters into the OMS outage prediction engine to enhance outage prediction process, reduce false positives, and enhance outage location detection

To achieve these goals, Unitil is implementing substation SCADA and integrating the AMI data with their OMS. Table 2929 describes these technologies in greater detail.

Table 29. Unitil M&C Devices and Technologies

Investment Type	Description
Substation SCADA	The installation and interconnection of a SCADA terminal unit at the site, the establishment of communications between the terminal unit and the remotely located SCADA Master system, and the associated programming to implement desired functions.
AMI-OMS Integration	The deployment of software that analyzes AMI status changes and relevant data points, detects suspect outages, and reports them as such to the OMS.

Source: Guidehouse

Unitil's 2018 Annual Report (filed May 1, 2019) is used as the primary data source for the actual and plan information presented below.

5.4.2 M&C Investment Progress through PY 2019

In PY 2019, Unitil began progress toward its substation SCADA retrofitting plan and its OMS/AMI integration plan with significant work anticipated in PY 2020. One substation SCADA project with one circuit terminal was completed in PY 2019 and retrofits at two other substations (three circuit terminal units) is in construction. Unitil's OMS/AMI Intelligent Outage Detection program implementation is in Phase 1 (AMI confidence engine and filter development) and project planning for Phase 2 (advanced detection algorithm) is under development with work ramping up in PY 2020. Table 30 shows this progress and the revised 2018-2020 plan.

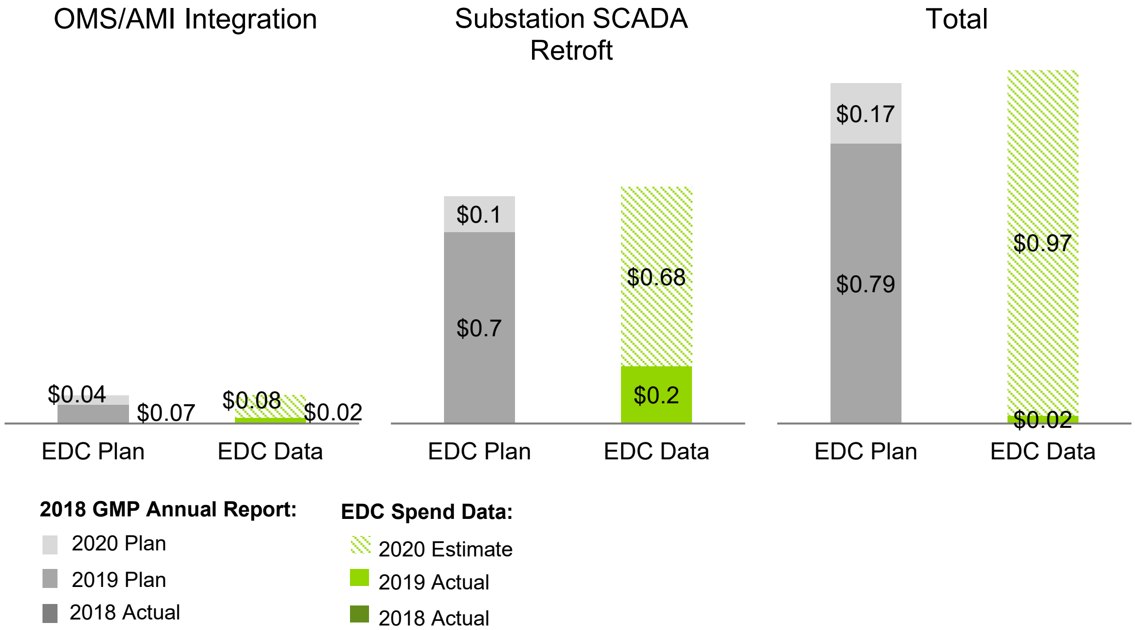
Table 30. Unitil M&C Deployment Progress

Device	Actual PY2019 Progress		PY2020 Device Deployment Progress in PY2019		2018-2020 Revised Plan	
	Circuits Complete	Accrued Cost	Construction	Design	Circuits Complete	Accrued Cost
OMS/AMI Integration	N/A	$23,000	N/A	N/A	N/A	$106,000
Substation SCADA Retrofit	1	$215,000	3	0	10	$891,000
Total	**N/A**	**$238,000**	**N/A**	**N/A**	**N/A**	**$997,000**

Source: Guidehouse analysis of EDC Data

Figure 10 highlights the 2018-2020 planned and actual spend for OMS/AMI integration and substation SCADA retrofit separately and aggregated together. Spending on M&C investments was lower than planned in PY 2019; however, the total estimated spend for 2018-2020 is now marginally higher than originally planned.

Figure 10. Unitil Planned vs. Actual Spend Comparison (2018-2020, $M)



Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 31 presents a year-over-year comparison of Unitil's planned, actual, and revised PY 2020 planned spend for OMS/AMI integration and substation SCADA retrofit from 2018 to 2020.

Table 31. Unitil Planned vs. Actual Year-over-Year Spend (2018-2020, $M)

Spend, $M	2018	2019	2020	2018-2020
OMS/AMI Integration				
EDC Actual Progress	$0	$0.023	-	-
EDC Original Plan[51]	$0	$0.070	$0.035	$0.105
% EDC Actual / EDC Plan	-	33%	-	-
EDC Revised Plan[52]	$0	$0.023	$0.083	$0.106
% EDC Revised Plan / EDC Plan	-	-	239%	101%
Substation SCADA Retrofit				
EDC Actual Progress	$0	$0.215	-	-
EDC Original Plan	$0	$0.720	$0.135	$0.855
% EDC Actual / EDC Plan	-	30%	-	-
EDC Revised Plan	$0	$0.215	$0.676	$0.891
% EDC Revised Plan / EDC Plan	-	-	501%	104%

[51] Based on 2018 GMP Annual Report (filed May 1, 2019).

[52] Based on the EDC's updated projections for PY2020.

Spend, $M	2018	2019	2020	2018-2020
Total				
EDC Actual Progress	$0	$0.238	-	-
EDC Original Plan	$0	$0.790	$0.170	$0.960
% EDC Actual / EDC Plan	-	30%	-	-
EDC Revised Plan	$0	$0.238	$0.759	$0.997
% EDC Revised Plan / EDC Plan	-	-	446%	104%

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Unitil spent $230,000 in PY2019, 70% lower than the $790,000 originally planned in Unitil's 2018 GMP Annual Report. This was caused the Townsend substation retrofit not getting competed as planned in PY 2019. The OMS/AMI integration spending was also delayed because of issues with vendor data accessibility. Projected spending for PY 2020 ($759,000) is now significantly higher than originally projected ($170,000) to account for these spending shifts to PY 2019. The 2018-2020 projected spending is now $997,000, 4% higher than the $960,000 originally planned in the 2018 GMP Annual Report. Table 32 presents the infrastructure metrics results through PY 2019 for the two technologies related to Unitil's M&C investment area.

Table 32. Unitil PY2019 Infrastructure Metrics for M&C Technologies

IM	Metric	Parameter	OMS/AMI Integration	Substation SCADA	Total
IM-3	Number of Devices Deployed[53]	# Circuits Commissioned	N/A	1	N/A
		% Circuits Commissioned	N/A	10%	N/A
IM-4	Cost for Deployment	Total Spend	$23,000	$215,000	$238,000
		% Spend	21%	24%	24%
IM-5	Deviation Between Actual and Planned Deployment	% On Track (Circuits)	N/A	25%	N/A
		% On Track (Spend)	33%	30%	30%
IM-6	Projected Deployment in PY2020	# Circuits	N/A	9	N/A
		Spend	$83,000	$676,000	$759,000

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

The following subsections discuss each technology in greater detail.

5.4.2.1 OMS/AMI Integration

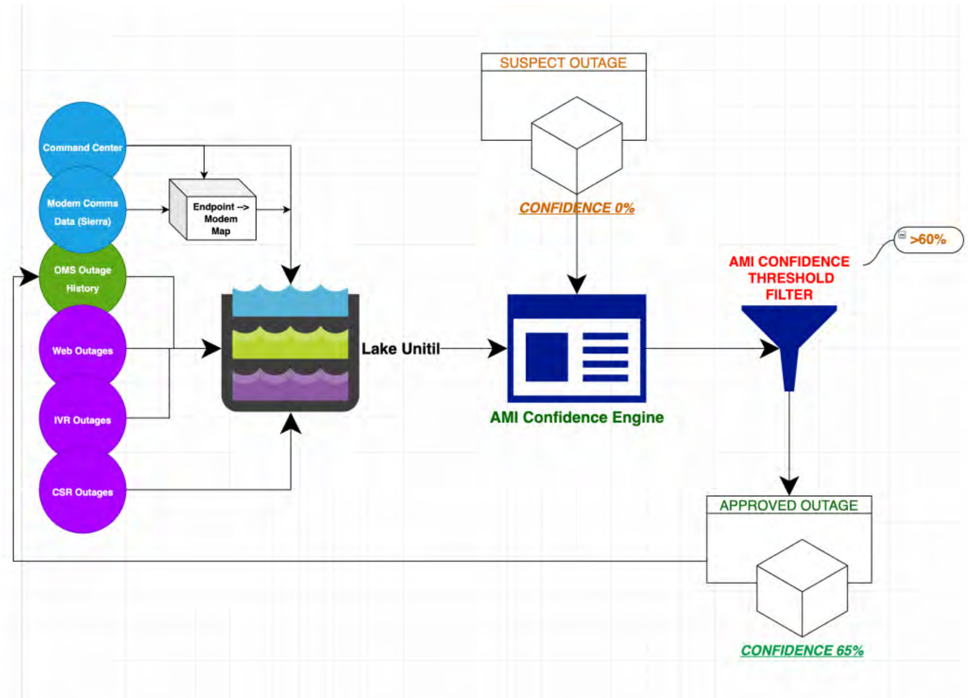
Tracking Unitil's progress toward its original OMS/AMI integration plan is not quantified on a unit basis, but details about the original plan were available in the 2018 GMP Annual Report, which states:

[53] Unitil's substation SCADA progress is tracked by the number of circuits with SCADA enabled.

> "In 2019 and 2020 the plan is to continue to work with the Company's AMI vendor to determine applicable data points to include in outage confidence score calculation and design the statistical model to document and validate the approach. Next, a middleware application will be developed and deployed to calculate outage confidence scores. The system will be tested for accuracy and completeness prior to integrating with the live OMS system."

Guidehouse confirmed that Unitil's overall OMS/AMI plan aligns with the original plan laid out in the 2018 GMP Annual Report. Unitil is in the process of completing Phase 1 (AMI confidence engine and filter) and planning for Phase 2 (advanced detection algorithm). Figure 11 shows a schematic of the phase 1 work.

Figure 11. Phase 1 (Confidence Engine and Filter) Schematic



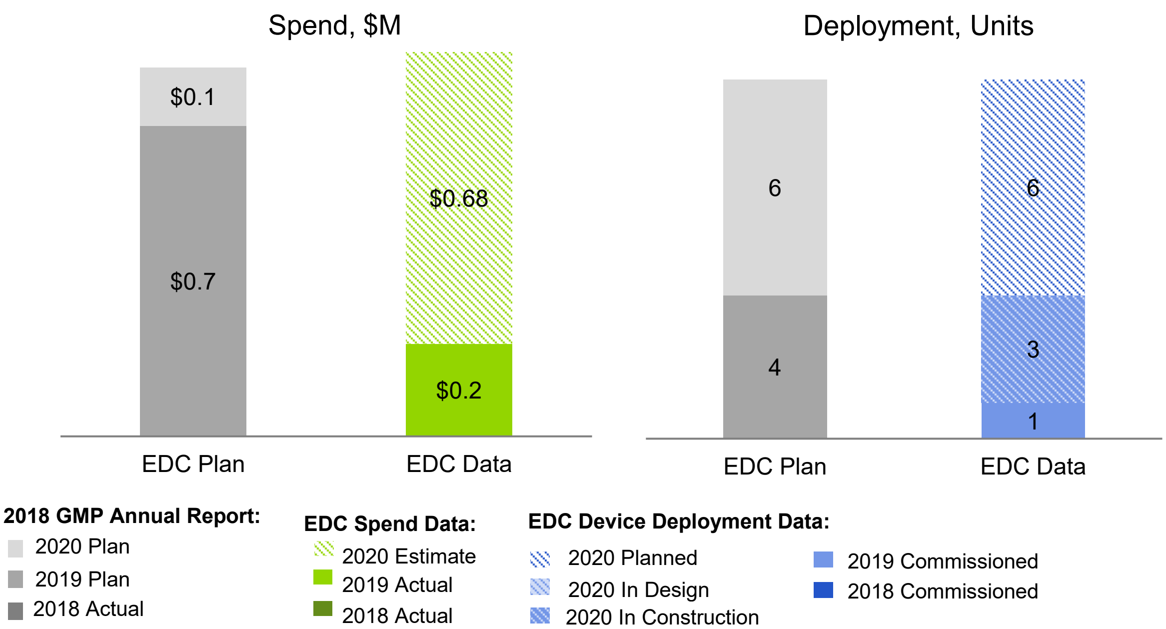
Source: Unitil

Unitil originally anticipated that Phase 1 would be completed at the end of PY 2019; however, vendor data accessibly issues delayed progress. Unitil had to work with the vendor to access data directly from the head-end instead of from a centralized database as originally planned. This change delayed Phase 1 completion and pushed some anticipated spending to PY 2020 (as shown in Table 31). However, Unitil is confident that the project will be completed as originally planned by the end of PY 2020.

5.4.2.2 Substation SCADA Retrofit

Unitil's overall deployment target remains on track with the original plan per the 2018 GMP Annual Report. Figure 12 shows Unitil's planned versus actual SCADA device deployment and spend progress over the 2018-2020 period.

Figure 12. Unitil Substation SCADA Retrofit Comparison (2018-2020)



Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 33 presents a year-over-year comparison of Unitil's planned, actual, and revised PY 2020 planned deployment and spend for substation SCADA retrofit.

Table 33. Unitil Planned vs. Actual Year-over-Year Spend (2018-2020, $M)

Substation SCADA Retrofit	2018	2019	2020	2018-2020
Circuits Commissioned				
EDC Actual Progress	0	1	-	-
EDC Original Plan[54]	0	4	6	10
% EDC Actual / EDC Plan	-	25%	-	-
EDC Revised Plan[55]	0	1	9	10
% EDC Revised Plan / EDC Plan	-	-	150%	100%
Spend, $M				
EDC Actual Progress	$0	$0.215	-	-

[54] Based on 2018 GMP Annual Report (filed May 1, 2019).

[55] Based on the EDC's updated projections for PY2020.

Substation SCADA Retrofit	2018	2019	2020	2018-2020
EDC Original Plan	$0	$0.720	$0.135	$0.855
% EDC Actual / EDC Plan	-	30%	-	-
EDC Revised Plan	$0	$0.215	$0.676	$0.891
% EDC Revised Plan / EDC Plan	-	-	501%	104%

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Unitil's progress in PY 2019 was behind what it had originally anticipated in their 2018 GMP Annual Report. The Townsend substation required more equipment upgrades than originally planned, causing some work and costs to shift to PY 2020. This additional work included:

- Communications additions for an existing recloser control
- Replacement of three hydraulic reclosers with new electronic-controls reclosers and microprocessor-based controls
- Relocation of a fourth recloser
- Addition of ancillary equipment including bus (voltage transformers) VTs, line (current transformers) CTs, trenching, conduit additions, AC panel upgrades, among others

As a result of the additional work Unitil experienced with the Townsend substation, its cost projections for the remaining substations also increased. Table 34 highlights these revised cost projections by substations.

Table 34. Unitil Revised SCADA Retrofit Cost Projections by Substation

Substation	Current Stage	Circuit Count	Original Estimated Cost	Revised Estimated Cost	% Increase in Estimated Cost
Rindge Road	In Service	1	$45,000	$43,138	-4%
Townsend	Construction	3	$675,000	$526,000	-22%
Beech Street	Planned for H2 2020	4	$80,000	$152,939	91%
Lunenburg	Planned for H2 2020	2	$55,000	$168,550	206%
	Total	**10**	**$855,000**	**$890,627**	**4%**

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Despite the additional work, Unitil remains on track to meet the original target in the 2018 GMP Annual Report. Construction has begun at the Townsend substation and work on the Beech Street and Lunenburg substation is anticipated to occur in H2 2020.

5.4.3 Summary of Key Findings

Unitil is behind its anticipated progress for M&C investments in PY 2019. Issues with vendor data accessibility has delayed the completion of Phase 1 for OMS/AMI integration. Additionally, substation SCADA retrofits required more work than anticipated and the Townsend substation work remains under construction. Despite the additional work required, the total estimated 2018-2020 spend for M&C investments is now $997,000, 4% higher than the $960,000 originally estimated. Despite these delays, Unitil believes that they will make up progress in PY 2020 and the 2018-2020 GMP total deployment plans remain unchanged. Guidehouse project staff reviewed Unitil documentation and interviewed engineering and management staff and finds these updated plans to be credible and satisfactory.

6.0 Conclusions & Recommendations

Guidehouse's M&C evaluation has confirmed that all EDCs are progressing towards their M&C plans. Actual progress and spending in PY 2019 was lower than originally anticipated for all EDCs; however, 2018-2020 plans remain largely on target to meet the originally projected GMP investment plans. An update of note to the original plans are that Eversource plans an additional $8M in the M&C investment area. Table 35 summarizes additional key findings from Guidehouse's M&C evaluation for each EDC.

Table 35. EDC-Specific M&C Findings

EDC	Summary of Findings
Eversource	• Majority of progress and spending to date has focused on microprocessor relays. • Progress and spending in PY2019 was slightly behind the original projection because of challenges with the completing the final commissioning for devices. • Many devices planned for PY 2020 are already in the construction or design phase. • The revised 2018-2020 total estimated spending for M&C investments ($49.8 million) is now 20% higher than the original estimate ($41 million) because of higher unit costs for implementing microprocessor relays and 4 kV SCADA and a decision by Eversource to increase funding to this investment area.
National Grid	• PY2019 progress was focused on planning with most deployment now occurring in PY2020. • Vendor lead times delayed feeder monitor deployment progress in PY2019. • A large shipment of sensors was received in late 2019; therefore, National Grid expects to make up the delayed PY2019 progress in PY2020 to meet the original 2018-2020 target. • The revised 2018-2020 total estimated spending ($3.6 million) is now 11% lower than the original estimate ($4.0 million) due to lower unit costs.
Unitil	• Issues with vendor data accessibility has delayed the completion of Phase 1 for OMS/AMI integration; however, Unitil anticipates making up progress in PY2020 to meet the original 2018-2020. • Substation SCADA retrofit required more work than originally planned, delaying the final commissioning planned for PY 2019 to PY 2020. • The revised 2018-2020 total estimated spending ($997,000) is 4% higher than the original estimate ($960,000).

Source: Guidehouse analysis

Guidehouse also submits the following recommendations for EDC consideration in program year 2020:

- Guidehouse should work with the EDCs to implement an updated data collection template and format, using experience gained during the Q2'19 data collection process, to streamline data collection and make the process more efficient.[56]
- EDCs should work with Guidehouse to develop a "case-study approach" to understanding reliability impacts due to M&C investments, and help distinguish between how impacts are attributed to M&C vs ADA where these investments are deployed on same circuit.
- National Grid should consider updating the asset intake process so that equipment ordered for the Grid Modernization Program are clearly identified as assigned/allocated to the GMP program. This may help prevent equipment from being diverted from inventory for other uses within the utility.
- In the future, the EDCs could consider a more sophisticated statistical approach to assessing the reliability impacts of M&C investments. Such techniques require more outage data collection (e.g., outage cause), feeder characteristics (e.g., length, customers, location), equipment installed (e.g., number and type of reclosers), knowledge of other activities (e.g. timing of vegetation trimming), integration with weather data (e.g., hourly wind speed and direction) for feeders that receive the M&C investment and those that do not, but promise more insight on whether the M&C investments are yielding reliability improvements in MED and non-MED situations. This type of approach is more complex and requires additional data collection and more analysis, but it could control for weather and other factors effecting reliability.

[56] Note, the data collection template and format update has already been implemented, as the EDCs and Guidehouse agreed that this was appropriate and would make future data collection and data QA/QC process more efficient.

Massachusetts Electric Distribution Companies

Massachusetts Grid Modernization Evaluation – Program Year 2019

Communications

April 1, 2020

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Disclaimer

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1.0 Executive Summary

1.1 Introduction

As a part of the Grid Modernization Plan, the Massachusetts electric distribution companies (EDCs) are investing in communications infrastructure to enable and support all grid modernization investments. This evaluation focuses on the progress and effectiveness of the Department of Public Utilities (DPU) preauthorized communications investments for each EDC toward meeting the DPU's grid modernization objectives for Program Year (PY) 2019. The focus of this evaluation is on communications infrastructure metrics.

1.2 Data Management

Guidehouse worked with the EDCs to collect data to complete the communications evaluation for the assessment of infrastructure metrics. Guidehouse used a consistent methodology across investment areas and EDCs for evaluating and illustrating EDC progress toward the GMP metrics.

Table 1 summarizes data sources used throughout the evaluation of communications in PY2019. Further detail on each of the data sources is provided in Section 3.1.

Table 1. Communications Data Sources

Data Source	Description
2018 Grid Modernization Plan Annual Report[1,2,3]	Planned device deployment and cost information from each EDC's Supplement to the 2018 GMP Annual Report (filed January 31, 2020). Data were used as the reference to track progress against the GMP targets and are referred to as the "EDC Plan" in summary tables and graphs throughout the report.
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. Planned device deployment information and estimated spend for PY2020 were provided at the most granular level.

Source: Guidehouse

Guidehouse reviewed all data provided upon receipt of requested data. Guidehouse conducted a detailed QA/QC of data inputs used in analysis of infrastructure metrics. These QA/QC steps include checks to confirm each of the required data inputs are accounted for and can be incorporated into analysis. A summary of some of the QA/QC steps conducted for infrastructure metrics and performance metrics is provided in Table 5. A more comprehensive summary is provided in Section 3.2.

[1] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-120

[2] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-122

[3] Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-121

Table 2. Summary of QA/QC Steps Used for Evaluation

Comms Evaluation Area	QA/QC Steps
Infrastructure Metrics	• Check for potential errors in how the forms were filled out (e.g., circuit information provided in the wrong field) • Flag missing or incomplete information • Detect large variation in the unit cost of commissioned devices • Identify variance in the January 1 through June 30, 2019 data provided last year, and the work order-level data provided for PY2019 • Identify variance between the aggregated year-end total information and work order-level data (applicable to Eversource only) • Flag deviation between 2018 GMP Annual Report (filed May 1, 2019) and actual deployment and spend

Source: Guidehouse

After data are received, Guidehouse provides status update memos that summarize the QA/QC to the EDCs, confirming receipt of the datasets and indicating quality. Additional follow-up based on standing questions is required to ensure all EDC-provided data can be used in analysis.

1.3 Evaluation Process

As part of the Grid Modernization Plans (GMPs), the DPU requires a formal evaluation process (including an evaluation plan and evaluation studies) for the EDCs' preauthorized grid modernization plan investments. Guidehouse (formerly Navigant Consulting, Inc.) is completing the evaluation to ensure a uniform statewide approach and to facilitate coordination and comparability. The evaluations' objective is to measure the progress made toward the achievement of DPU's grid modernization objectives. The evaluation uses the DPU-established infrastructure metrics and performance metrics (discussed in Section 2.1.3) to meet the DPU's evaluation objectives.

Table 3 illustrates the key infrastructure metrics relevant for the communications evaluation by EDC. Further detail surrounding infrastructure metrics is provided in Section 4.1.

Table 3. Communications Evaluation Metrics

Metric Type	Communications 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 three-year term	✓	✓	✓

Source: Guidehouse Stage 3 Evaluation Plan

The data supporting the infrastructure metrics have been provided to the evaluation team by the EDCs. Guidehouse presents results from analysis of infrastructure metrics data in Section 5.0.

1.4 Findings

The electric distribution companies (EDCs) spent most of 2019 performing planning and due diligence activities to begin communications deployment. Eversource made a strategic change to its communications strategy, while also beginning deployment. Eversource commissioned three master radio locations (base stations) and completed installation of front-end processors at its north and south dispatch centers located in eastern Massachusetts. Unitil had a third party perform a communications study and subsequently developed an RFP for a turnkey communications solution. National Grid inventoried existing communications assets and assessed routing equipment. At year-end 2019, National Grid had issued an RFP for communications software and evaluated several Field Area Network (FAN) options.

All EDCs are positioned to ramp up construction of communications equipment in 2020. In 2020, National Grid plans to deploy WAN at three substations, and Unitil at one substation. Eversource plans to deploy one mile of fiber optic backhaul in 2020. Further, Eversource and Unitil plan to install FAN devices in 2020. National Grid is currently evaluating its FAN options and will begin FAN deployment in 2022.

When commissioned, these communications investments will enable and support the monitoring and control (M&C), advanced distribution automation (ADA), and Volt/VAR optimization (VVO) equipment being installed at these locations.

Table 4 summarizes key findings related to Guidehouse's Communications evaluation for each EDC.

Table 4. EDC-Specific Communications Findings

EDC	Summary of Findings
Eversource	• Eversource is improving its private radio networks' coverage and performance for the monitoring and operation of grid endpoints. This investment will improve communications latency and enable better performance for ADA, M&C, and VVO deployments in these areas. • Eversource was behind its stated 2019 plan, deploying three instead of six master radios and front-end processor in lieu of one of the masters. • Devices planned for 2020 are well underway, indicating that Eversource will catch up to its stated GMP plan. • Eversource conducted a strategic reevaluation of its fiber optic plan in 2019, shifting most of these funds to other GMP investments with more significant expected benefits. The revised communications deployment plan will be used to benchmark progress in the future.
National Grid	• National Grid is planning and developing construction standards for fiber optic (WAN) deployment at three substations in 2020. National Grid proposes to continue installing fiber optics at additional substations each year thereafter. • National Grid is researching its FAN communication investment options, including public versus private networks. It is designing a strategy that best supports grid modernization investments and other company priorities. A FAN pilot is proposed in 2021 with a deployment expected to begin in 2022. • National Grid is using public cellular for field devices, including new GMP devices that are being installed. National Grid is using fiber optics (WAN) where available for the backhaul. • While ADA, M&C and VVO benefits will begin to accrue immediately upon deployment, they will be maximized when National Grid connects them to a robust, high-performance communication network as proposed in the GMP.
Unitil	• Unitil's communications deployment is expected to begin in 2020, and one substation will be completed each year thereafter. • Unitil plans to deploy communications on the same integrated schedule as other GMP investments. The integrated timeline, if executed, will enhance the benefits of other GMP investments with the integration of a modern communications network. • Unitil is performing due diligence in designing its communications strategy. An initial communications study was completed in 2019 and served to narrow the field of potential technologies to the ones that address Unitil's requirements. • Unitil is also performing due diligence in technology and vendor selection. Unitil issued an RFP where vendors can bid on competitive approaches involving various technologies.

Guidehouse also submits the following recommendations for EDC consideration in program year 2020.

- Guidehouse should work with the EDCs to implement an updated data collection template and format, using experience gained during the Q2’19 data collection process, to streamline data collection and make the process more efficient.
- Guidehouse recommends National Grid develop RFPs for potential solutions to develop FAN infrastructure.
- National Grid should consider accelerating the communications deployment schedule to better align with the deployment schedules of other investment areas to sooner realize full benefits of grid modernization devices.

2.0 Introduction to Massachusetts Grid Modernization

2.1 Massachusetts Grid Modernization Plan Background

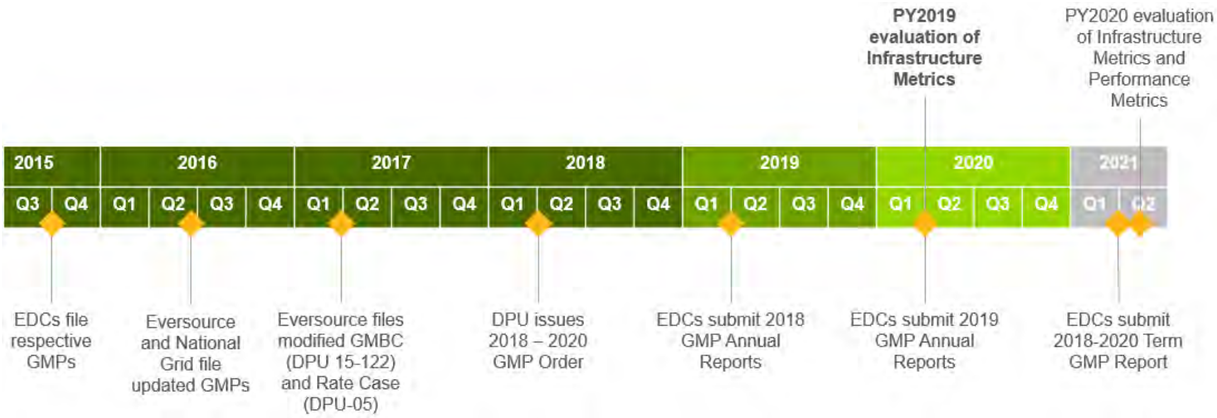
On May 10, 2018, the Massachusetts Department of Public Utilities (DPU) issued its Order[4] regarding the individual Grid Modernization Plans (GMPs) filed by the three Massachusetts electric distribution companies (EDCs): Eversource, National Grid, and Unitil. In the Order, DPU preauthorized grid-facing 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. These preauthorized GMP investments will advance the achievement of DPU’s grid modernization objectives:

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

As part of the GMPs, DPU determined that a formal evaluation process for the preauthorized GMP investments, including an evaluation plan and studies, was necessary to help ensure that the benefits are maximized and achieved with greater certainty. Figure 1 highlights the filing background and timeline of the GMP order and the evaluation process.

[4] Massachusetts D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 (Grid Modernization) Order issued May 10, 2018

Figure 1. MA Grid Modernization Timeline



Source: Guidehouse review of the DPU orders and GMP process

In addition, 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)

This report covers the Program Year (PY) 2019 evaluation of infrastructure metrics and focuses on the Communications investment area. The following subsection discusses these investment areas in greater detail.

2.1.1 Investment Areas

Table 5 summarizes the preauthorized GMP investments.

Table 5. Overview of Investment Areas

Investment Area	Description	Goal/Objective
Monitoring and Control (M&C)	Remote M&C 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)	Isolation of outage events with automated backup for 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/Advanced Load Flow (ADMS and ALF)	New capabilities in real time system control with investments in developing accurate system models and enhancing SCADA and outage management systems to control devices for system optimization and provide support for distribution automation and VVO with high penetration of distributed energy resources (DER)	Enables high penetration of DER by supporting the ability to control devices for system optimization, ADA, and VVO

Investment Area	Description	Goal/Objective
Communications/IoT (Comms)	Fiber middle mile and field area communications systems	Enables the full benefits of grid modernization devices to be realized
Workforce Management (WFM)	Investments 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

Eversource has the largest preauthorized GMP budget at $133 million, with advanced distribution automation (ADA) and monitoring and control (M&C) representing the largest share ($44 million and $41 million, respectively). National Grid's preauthorized budget is $82.2 million, with advanced distribution management systems (ADMS) and advanced load flow (ALF) representing over 50% ($48.4 million). Unitil's preauthorized budget is $5.5 million and VVO makes up nearly 40% ($2.2 million). Table 6 shows the budget for each investment area by EDC.

DPU added flexibility to these budgets based on changing technologies and circumstances. For example, EDCs can shift funds across the different preauthorized investments if a reasonable explanation for these shifts is supplied.

Table 6. 2018-2020 GMP Preauthorized Budget, $M

Investment Areas	Eversource	National Grid	Unitil	Total
ADA	$44.0	$13.4	N/A	**$57.4**
ADMS / ALF	$17.0	$48.4	$0.7	**$66.1**
Comms	$18.0	$1.8	$0.8	**$20.6**
M&C	$41.0	$8.0	$0.75	**$49.8**
VVO	$13.0	$10.6	$2.2	**$25.8**
WFM			$1.0	**$1.0**
3-Year Total	$133	$82.2	$5.5	**$220.7**

Source: DPU Order, May 10, 2018

2.1.2 Evaluation Goal and Objectives

As part of the GMPs, DPU requires a formal evaluation process (including an evaluation plan and evaluation studies) for the EDCs' preauthorized grid modernization plan investments. A third-party company is completing the evaluation to ensure a uniform statewide approach and to facilitate coordination and comparability. The evaluations' objective is to measure the progress made toward the achievement of DPU's grid modernization objectives. The evaluation uses the DPU-established infrastructure metrics and performance metrics (discussed in Section 2.1.3) to meet the DPU's evaluation objectives.

2.1.3 Metrics for Evaluation

The DPU-required evaluation involves both infrastructure metrics and performance metrics for each investment area.

2.1.3.1 Infrastructure Metrics

The infrastructure metrics were designed to help evaluate the deployment of the GMP devices and are summarized in Table 7.

Table 7. Infrastructure Metrics Overview

Metric		Description	Applicable IAs	Metric Responsibility
IM-1	**System Automation Saturation**	Measures the quantity of customers served by fully or partially automated devices.	M&C, ADA	EDC
IM-2	**Number and Percent of Circuits with Installed Sensors**	Measures the total number of circuits with installed sensors which will provide information useful for proactive planning and intervention.	M&C	EDC
IM-3	**Number of Devices Deployed and In Service**	Measures how the EDC is progressing with its GMP from an equipment and/or device standpoint.	All IAs	Evaluator
IM-4	**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-5	**Deviation Between Actual and Planned Deployment for the Plan Year**	Measures how the EDC is progressing under its GMP on a year-by-year basis.	All IAs	Evaluator
IM-6	**Projected Deployment for the Remainder of the Three-Year Term**	Compares the revised projected deployment with the original target deployment as the EDC implements its EDC.	All IAs	Evaluator

Source: Guidehouse review of infrastructure metric filings

2.1.3.2 Performance Metrics

Table 8 summarizes the performance metrics, which are used to evaluate the performance of the GMP investments. The communications investment area does not have any applicable performance metrics.

Table 8. Performance Metrics Overview

Metric	Applicable IAs
VVO Baseline	VVO
VVO Energy Savings	VVO
VVO Peak Load Impact	VVO
VVO Distribution Losses without AMF (Baseline)	VVO
VVO Power Factor	VVO
VVO – GHG Emissions	VVO
Voltage Complaints	VVO
Increase in Substations with DMS Power Flow and Control Capabilities	ADMS/ ALF
Control Functions Implemented by Circuit	ADMS/ ALF
Numbers of Customers that benefit from GMP funded Distribution Automation Devices	ADA
Grid Modernization investments' effect on outage durations	M&C, ADA
Grid Modernization investments' effect on outage frequency	M&C, ADA
Advanced Load Flow – Percent Milestone Completion	ADMS/ ALF
Protective Zone: Average Zone Size per Circuit* (Eversource)	M&C, ADA
Customer Minutes of Outage Saved per Circuit* (Unitil)	M&C, ADA
Main Line Customer Minutes of Interruption Saved* (National Grid)	M&C, ADA

Source: Stamp Approved Performance Metrics, July 25, 2019. [5]
** Note that these metrics primarily apply to ADA but will be completed for M&C as well given interest in understanding how to separately measure the impacts of these two investment areas.*

2.2 Introduction to Communications

The Communications Investment is an enabling technology that will support most (if not all) preauthorized investments, including ADA, VVO, ADMS, and M&C.

Investments in a robust and effective communication network are required for the other preauthorized investments to "(1) optimize system performance (by attaining optimal levels of grid visibility, command and control and self-healing," "(2) optimize system demand," and "(3) interconnect and integrate distributed energy resources." [6]

All EDCs recognize that the successful deployment of communications systems will maximize GMP benefits. If communications network deployment is delayed, it can potentially limit the performance of other grid devices.

Communications Investments proposed by National Grid, Eversource, and Unitil will include a wide area network (WAN) and a field area network (FAN). Table 9 describes the proposed investments. While overall EDC communications goals are similar, each EDC begins with a different set of capabilities and needs, and so is charting its unique course to communications deployment.

Table 9. Communications Device Deployment Under Communications Investment by EDC

Technology	Description	3-Year Deployment Plan		
		Eversource	National Grid	Unitil
Wide area network (WAN)	Usually fiber optic, used as backhaul to bring data from substations to control systems	Existing: Fully redundant WAN. Planned: Only 1 mile of fiber under GMP.	Existing: Limited coverage Planned: 3 substations in 2020 and increasing afterward	No existing WAN. Included in GMP (RFP issued).
Field Area Network (FAN)	Used to monitor and operate field devices	Existing: private network Planned: Expanded coverage	Existing: public network Planned: Exploring tiered FAN options	Existing public network. Included in solutions proposed under the RFP.

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC data

2.2.1 Communications Evaluation Objectives

This evaluation will assess the progress and effectiveness of the DPU preauthorized communications investments for each EDC. Each EDC will be evaluated based on meeting the DPU's grid modernization objectives.[7]

[5] Grid Modernization Plan Performance Metrics (Stamped Approved Performance Metrics) issued July 11, 2019 as part of Massachusetts D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 Order

[6] Massachusetts D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 (Grid Modernization) Order issued May 10, 2018 at p. 106

[7] Massachusetts D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 (Grid Modernization) Order issued May 10, 2018 at p. 106

Table 10 illustrates the key metrics on which the evaluation will report. These include four infrastructure metrics.

Table 10. Communications Evaluation Metrics

Metric Type	Communications 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 three-year term	✓	✓	✓

Source: Guidehouse review of infrastructure metric filings

The data supporting the infrastructure metrics were provided to the evaluation team by the EDCs. Guidehouse presents results from analysis of infrastructure metrics data in Section 5.

Table 11 summarizes the communications M&V objectives and associated research questions that will be addressed in the report.

Table 11. Communications M&V Objectives and Associated Research Questions

Communications M&V Research Questions
Are the EDCs progressing in deployment of their communications networks according to their Grid Modernization Plans?
What factors, if any, are affecting the deployment schedule of communications equipment?
What is the cost of deploying various types of communications equipment, including the FAN devices (radio base stations) and WAN (miles of fiber optics cables)?
Are the communication investments (WAN and FAN) effective at supporting the other DPU approved investments?

Source: Guidehouse Evaluation Plan

3.0 Communications Data Management

Guidehouse worked with the EDCs to collect data to complete the communications evaluation for the assessment of infrastructure and performance metrics. The sections that follow highlight data sources and data QA/QC processes followed by Guidehouse in its evaluation of infrastructure metrics.

3.1 Data Sources

Guidehouse used a consistent methodology (across investment areas and EDCs) to evaluate and illustrate EDC progress toward the GMP metrics. The subsections that follow summarize each of the data sources used in the evaluation of infrastructure metrics.

3.1.1 2018 Grid Modernization Plan Annual Report

Guidehouse used the planned device deployment and cost information from each EDC's Supplement to the 2018 GMP Annual Report 1 (filed January 31, 2020) as the baseline to track progress against the GMP targets.[8] This data source is referred to as the "EDC Plan" in summary tables and graphs throughout the report. Table 12 summarizes the specific data from this source for the planned device deployment.

Table 12. Data Used for the EDC Plan

Representative Color	Data	Description
	2020 Plan	Projected 2020 unit deployment/total spend
	2019 Plan	Estimated 2019 unit deployment/total spend
	2018 Actual	Actual reported unit deployment and spend in 2018

Source: EDCs' 2018 GMP Annual Report Appendix 1

Guidehouse used the Feeder Status tab of the 2018 GMP Annual Report Appendix 1 to obtain feeder characteristics including system voltage, total feeder count, customer count, feeder length, and annual peak load.

3.1.2 EDC Data Sources

Guidehouse collected device deployment data information at the feeder-level using standardized data collection templates for all EDCs. These data sources are referred to as EDC Data in summary tables and figures throughout the report. Table 13 summarizes the file versions used for the evaluation.

Table 13. EDC Data Received for Analysis

Company	All Device Deployment
Eversource	Received 1/22/2020
National Grid	Received 2/11/2020
Unitil	Received 1/20/2020

3.1.3 EDC Device Deployment Data Template

The EDC device deployment data (collected in the All Device Deployment workbook) captured planned and actual device deployment and spend data for all investment areas except ADMS/ALF. Actual device deployment and accumulated spend information were provided by work order ID and specified at the feeder or substation level as appropriate. The current stage of the work order (commissioned, construction, or design), the commissioned date (if applicable), and all accumulated costs associated with the work order were also collected. Planned device deployment information and estimated spend for PY2020 was provided by circuit or substation where available. Table 14 summarizes the device deployment data and the spend data, respectively.

[8] Unitil planned information was obtained directly from their 2018 GMP Annual Report.

Planned device deployment information and estimated spend for PY2020 was provided by circuit or substation where available.[9]

Table 14. EDC Device Deployment Data

Representative Color	Data	Description
Device Deployment Data		
	2020 Plan	remaining units planned for 2020 where work has not yet started
	2020 Design	units in the design phase and will be commissioned in 2020
	2020 Construction	units under construction and will be commissioned in 2020
	2019 Commissioned	units in service and commissioned in 2019
	2018 Commissioned	units in service and commissioned in 2018
Spend Data		
	2020 Estimate	additional cost anticipated in 2020
	2019 Actual	all actual spend that occurred in 2019
	2018 Actual	all actual spend that occurred in 2018

3.2 Data QA/QC Process

Guidehouse reviewed all data provided for infrastructure metrics analysis and performance metrics analysis upon receipt of requested data. The following sections detail the data QA/QC processes adopted for the two analysis areas.

3.2.1 Infrastructure Metrics Data QA/QC

To ensure accuracy, Guidehouse conducted a high-level 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., circuit information provided in the wrong field)
- Missing or incomplete information
- Large variation in the unit cost of commissioned devices
- Variance in the January 1 through June 30, 2019 data provided last year, and the work order-level data provided for PY2019
- Variance between the aggregated year-end total information and work order-level data (applicable to Eversource only)
- Deviation between 2018 GMP Annual Report (filed May 1, 2019) and actual deployment and spend

[9] Eversource provided year-end total actual and planned devices commissioned and spend data. This aggregated data varied slightly from the work order data provided because of nuance's in Eversource's work order accounting methodologies. Guidehouse used the aggregated total data for the 2019 and 2018 commissioned units and spend data. Work order data was used to capture progress towards their updated 2020 plan (per the aggregated year-end total data).

4.0 Communications Evaluation Process

This section presents an overview of Guidehouse's methodologies for the evaluation of infrastructure metrics. Additional details about approaches used in the evaluation are available in the Stage 3 Evaluation Plan.

4.1 Infrastructure Metrics Analysis

Guidehouse annually assesses the progress of each of the EDCs towards communications deployment. Table 15 highlights the infrastructure metrics that were evaluated.

Table 15. Infrastructure Metrics Overview

IM	Metric	Calculation Parameters
IM-4	**Number of devices or other technologies deployed**	# Devices – *total number of devices that have been commissioned, are in the construction phase, and are in the design phase*
		% Devices Deployed – *percent of the total planned devices over the 3-year period that have been commissioned*
IM-5	**Cost for Deployment**	Total Spend – *total spend through PY2019, regardless of whether the device has been commissioned*
		% Spend – *percent of the total estimated spend over the 3-year GMP period*
IM-6	**Deviation Between Actual and Planned Deployment for the Plan Year**	% On Track (Devices) – *devices commissioned through PY2019 divided by the devices planned for commission through PY2019*
		% On Track (Spend) – *actual spend through PY2019 divided by the planned spend through PY2019*
IM-7	**Projected Deployment for the Remainder of the Three-Year Term**	# Devices Remaining – *How many devices remain to be commissioned in PY2020*
		Spend Remaining – *How much spend is estimated for PY2020*

Source: Guidehouse analysis

Section 5.0 provides the results from the evaluation of the infrastructure metrics. To evaluate infrastructure metrics, Guidehouse:

- Ensured alignment of infrastructure metrics with the communications investment
- Obtained an understanding of planned communications investments by EDC
- Interviewed representatives from each EDC to understand the status of the communications investments
- Prepared a summary presentation that describes our understanding of the year's communications investment relative to the baseline and plan

5.0 Communications Deployment Progress and Findings

Guidehouse presents findings from the infrastructure metrics analysis for communications in Section 5.1 through Section 5.4. A set of tables and figures highlighting statewide findings are included, with detailed findings presented thereafter.

5.1 Statewide

The electric distribution companies (EDCs) spent most of 2019 performing planning and due diligence activities to begin communications deployment. Eversource made a strategic change to its communications strategy, while also beginning deployment. Eversource commissioned three master radio locations (base stations) and completed installation of front-end processors at its north and south dispatch centers located in eastern Massachusetts. Unitil had a third party perform a communications study and subsequently developed an RFP for a turnkey communications solution. National Grid inventoried existing communications assets and assessed routing equipment. At year-end 2019, National Grid was developing RFPs for communications software.

All EDCs are positioned to ramp up construction of communications equipment in 2020. In 2020, National Grid plans to deploy WAN at three substations, and Unitil at one substation. Eversource plans to deploy one mile of fiber optic backhaul in 2020. Further, Eversource and Unitil plan to install FAN devices in 2020. National Grid is currently evaluating its FAN options and will begin FAN deployment in 2022.

When commissioned, these communications investments will enable and support the monitoring and control (M&C), advanced distribution automation (ADA), and Volt/VAR optimization (VVO) equipment being installed at these locations.

Table 16 presents an overview of infrastructure metrics analysis for each EDC.

Table 16. 2019 Infrastructure Metrics Findings

Infrastructure Metrics		Parameter	Progress through PY2019		
			Eversource	**National Grid**	**Unitil**
2018-2020 Original Plan[10]		Devices	235	415	-
		Spend (M)	$13.5	$9.20	$0.56
2018-2020 Revised Plan[11]		Devices	11	-	-
		Spend (M)	$3	-	-
IM-4	Number of devices or other technologies deployed	# Devices	3 Master Radios and 1 Front End Processor	-	-
		% Devices Deployed	36%	-	-
IM-5	Cost for deployment	Total Spend (M)	$0.83	-	$0.11
		% Spend	37%	-	100%
IM-6	Deviation between actual and planned deployment for the plan year	% On Track (Devices)	3.1%	-	-
		% On Track (Spend)	5.8%	-	38%

[10] Based on data provided in the 2018 GMP Annual Report.

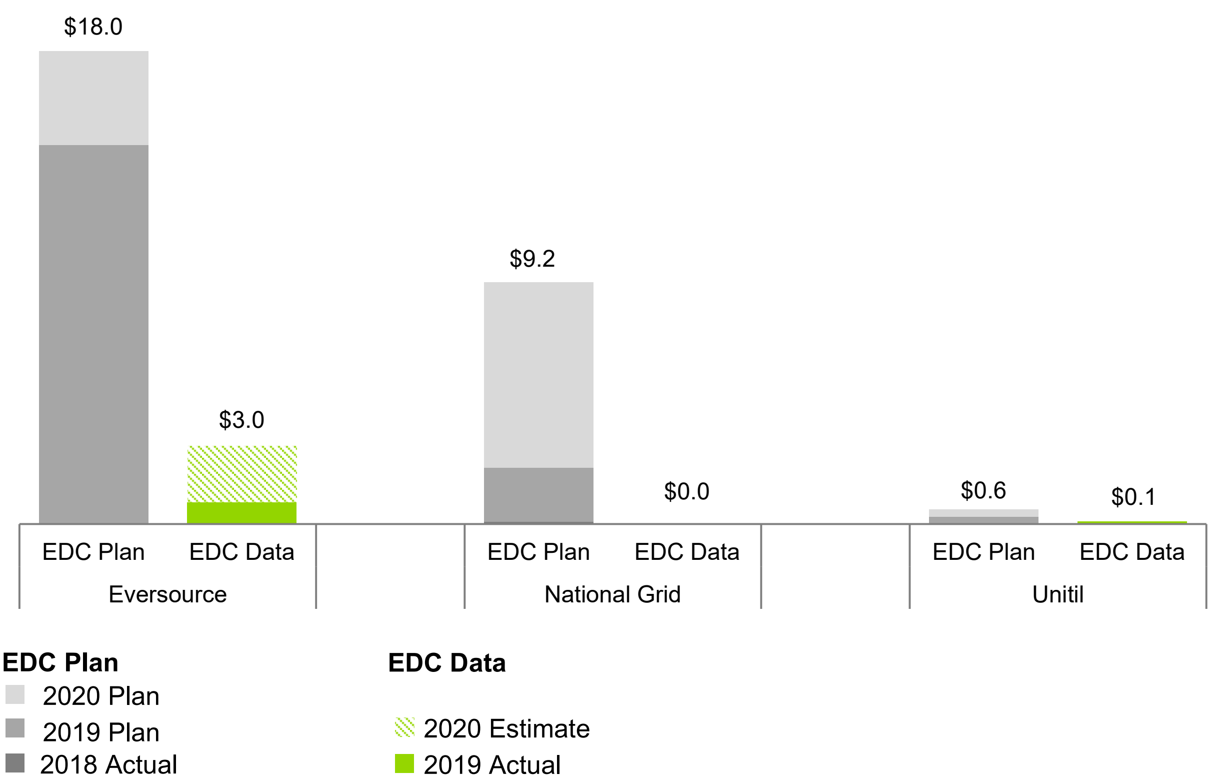
[11] Based on updated PY 2019 data provided by the EDCs.

Infrastructure Metrics		Parameter	Progress through PY2019		
			Eversource	National Grid	Unitil
IM-7	Projected deployment for the remainder of the three-year term	# Devices Remaining	1 Mile of Fiber, 6 Master Radios	-	-
		Spend Remaining (M)	$1.4	-	-

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Figure 2 highlights planned versus actual spend in communications for each of the three EDCs. Detailed differences between planned and actual spend are provided in each specific EDC's results section.

Figure 2. Communications Planned vs. Actual Spend



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.2 Eversource

5.2.1 Overview of GMP Deployment Plan

Eversource's GMP deployment plan, as articulated in its 2018 GMP Annual Report, included an $18 million investment in a high bandwidth communications network to enable near real-time data flows between the field devices and control systems. Eversource proposed enhanced bandwidth and data speeds for both fiber and radio networks across the service territory. These upgraded communications capabilities will support the company's suite of grid modernization investments. This network investment is designed to enable and support SCADA, ADA, M&C, and VVO functionalities.

Based on its analysis in 2019, Eversource determined that its existing WAN network will adequately support its GMP requirements. The communications investment plan was revised to focus on expanding FAN coverage (RF nodes) and perform limited fiber optics expansion. Eversource already owns a fully redundant fiber backhaul to the majority of its major substations. Eversource will reallocate the remaining funds from fiber optics to other investment areas.

Eversource also owns a private radio network that required improvement in specific areas to its coverage, bandwidth, and speed. Eversource is focusing its GMP communications investments on improving its radio network in those areas.

As a result of its analysis of the WAN investment requirement and the actual design and installation costs for the FAN deployment, Eversource revised its investment from $18 million to $3 million over 3 years in GMP communications deployment. Our evaluation did not determine this to be a concern, as Eversource's existing communications system (WAN and FAN) is robust enough in most locations to support GMP deployment and is being upgraded in other locations. Eversource is expected to continue expanding coverage to areas where coverage is poor, in coordination with other GMP investments. Future evaluation reports will treat the revised $3 million communications plan as the benchmark for assessing progress.

Eversource's FAN coverage enhancement coverage strategy is to install additional master radios (mini-base stations) at new and existing locations. Our evaluation has determined that the higher ratio of master to repeater radios will improve the latency and overall performance of the communications system. Eversource found that some of its front-end processors were under stress from increasing number of communicating devices on the distribution grid. So Eversource added installation of new front-end processor devices at its north and south dispatch centers in eastern Massachusetts to its GMP communications investment plan.

5.2.2 Progress to Date

Eversource has commissioned three master radio locations and completed one front-end processor upgrade project. Two additional sites from 2019 are in progress in the first quarter of 2020. By end of PY 2020, Eversource plans to commission a total of nine master radio locations and one front end processor upgrade. Eversource started deploying 1 mile of fiber and will complete it in 2020. Table 17 summarizes infrastructure metrics for Eversource communications investments to date.

Table 17. Eversource Infrastructure Metrics Findings

<table>
<tr><th colspan="2">Infrastructure Metric</th><th colspan="2">Eversource Progress</th><th>Comments</th></tr>
<tr><td colspan="2" rowspan="2">2018-2020 Original Plan</td><td>Devices</td><td>235</td><td rowspan="2">Based on data provided in the 2018 GMP Annual Report</td></tr>
<tr><td>Spend (M)</td><td>$13.5</td></tr>
<tr><td colspan="2" rowspan="2">2018-2020 Revised Plan</td><td>Devices</td><td>11</td><td rowspan="2">Based on updated PY 2019 data provided by the EDCs</td></tr>
<tr><td>Spend (M)</td><td>$3</td></tr>
<tr><td rowspan="2">IM-4</td><td rowspan="2">Number of devices or other technologies deployed</td><td># Devices</td><td>3 Master Radio Locations and 1 Front End Processor</td><td rowspan="2">• One (1) new master radio was installed on the roof of the Prudential Center and one (1) was installed at Shoot Flying Hill tower site.
• At one (1) location (Duxbury), two repeater radios (pole mounted) were converted to master radios
• One (1) Front End Processor upgrade was completed at Plymouth and Mass Ave
• Six (6) master radios and one (1) fiber optic length are planned to be commissioned in 2020.</td></tr>
<tr><td>% Devices Deployed</td><td>36%</td></tr>
<tr><td rowspan="2">IM-5</td><td rowspan="2">Cost for deployment</td><td>Total Spend (M)</td><td>$0.83</td><td rowspan="2">• $0.27 million attributed to radio node deployment in 2019
• $0.25 million attributed to front end processor upgrades
• $0.31 million attributed to fiber construction in 2019.
• $2.2 million is planned to be spent in 2020.</td></tr>
<tr><td>% Spend</td><td>37%</td></tr>
<tr><td rowspan="2">IM-6</td><td rowspan="2">Deviation between actual and planned deployment for the plan year</td><td>% On Track (Devices)</td><td>3.1%</td><td rowspan="2">• 225 miles of fiber were originally planned but Eversource determined this is no longer an optimal investment. Revised plan focuses mostly on radio node deployment.
• $13.5 million and $4.6 million were allocated to fiber and node deployment, respectively. Current plans allocate $3 million to the FAN and limited fiber. The remaining will be shifted to other investment areas.
• Six (6) radio nodes were planned for 2019, but three (3) were commissioned, and a front-end processor project in lieu of a radio node. Planned costs were $1.0 million, but $0.5 million was spent in 2019.
• Future evaluation reports will treat the revised plan as the benchmark for comparison.</td></tr>
<tr><td>% On Track (Spend)</td><td>5.8%</td></tr>
<tr><td>IM-7</td><td>Projected deployment for the remainder of the three-year term</td><td># Devices Remaining</td><td>6 Master Radio Locations and 1 Fiber Project</td><td>• In addition to the two (2) units carried over from 2019 into 2020, four (4) master radios are planned for deployment in 2020.</td></tr>
</table>

Infrastructure Metric		Eversource Progress		Comments
		Spend Remaining (M)	$1.4	• Cost of remaining radio and fiber deployment is $2.2 million.

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Table 18 provides a breakdown of communications investments by deployment stage.

Table 18. Eversource Communications Deployment Progress

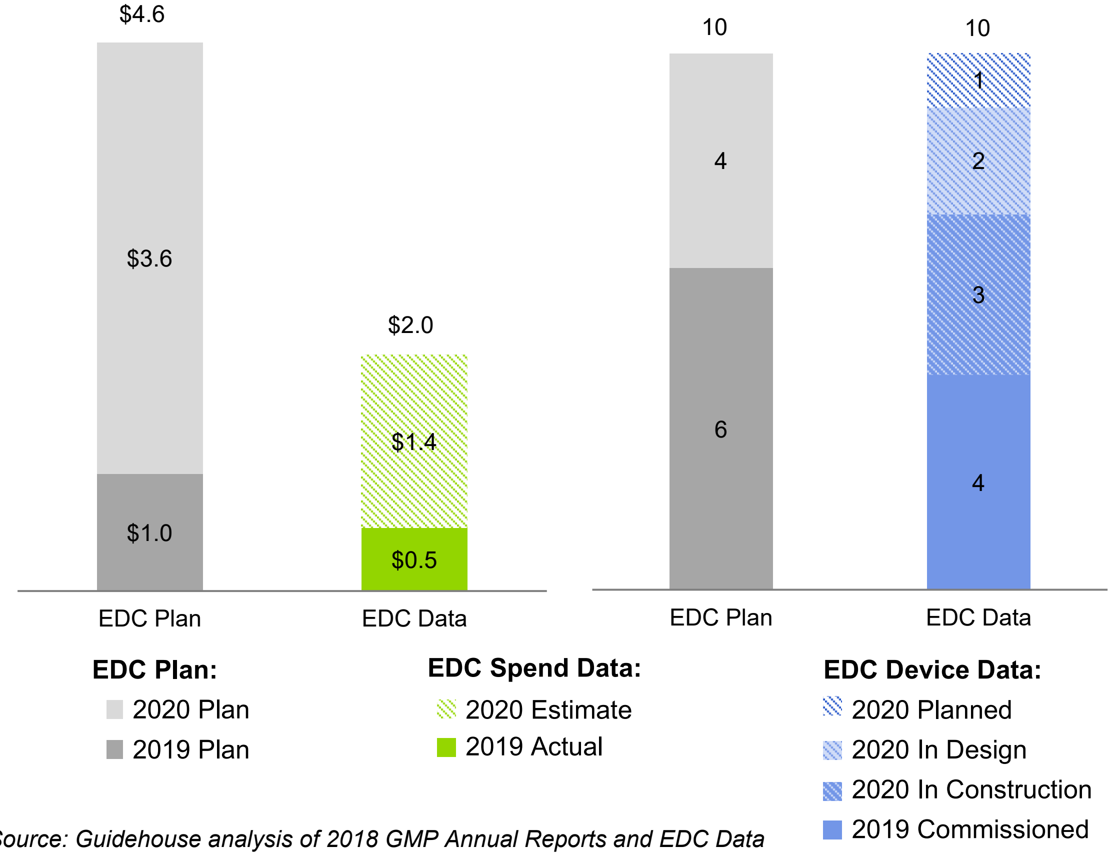
Device	Actual thru. PY2019		2020 Device Deployment Progress			3-Year Plan Total[1]	
	Commissioned	Accrued Cost ($M)	Construction	Design	Planned	Commissioned	Accrued Cost ($M)
Nodes	**4**	**$0.52**	**3**	**2**	**1**	**10**	**$2.0**
Master Radios	3	$0.27	3	2	1	9	$1.75
Front End Processors	1	$0.25	0	0	0	1	$0.25
Miles of Fiber	**0**	**$0.31**	**1**	**0**	**0**	**1**	**$1.0**
Total	**4**	**$0.83**	**4**	**2**	**1**	**11**	**$3.0**

Source: Guidehouse analysis of EDC Data

The radio nodes investment is focused on installing radio masters where there are none and converting repeater radios into masters. Eversource is using licensed private 900 MHz GE Orbit radios along with unlicensed 900MHz GE Transnet (spread spectrum) radios. Data from the radios is collected and concentrated by GE D20MX and is then analyzed, reformatted, and transferred to the Electric Powerlink Control System processor.

As shown in Figure 3 and Figure 4, a total of ten master radios will be deployed with total spending of $2.0 million. The costs are significantly lower than planned, so the remaining $2.6 million will be shifted to other investment areas.

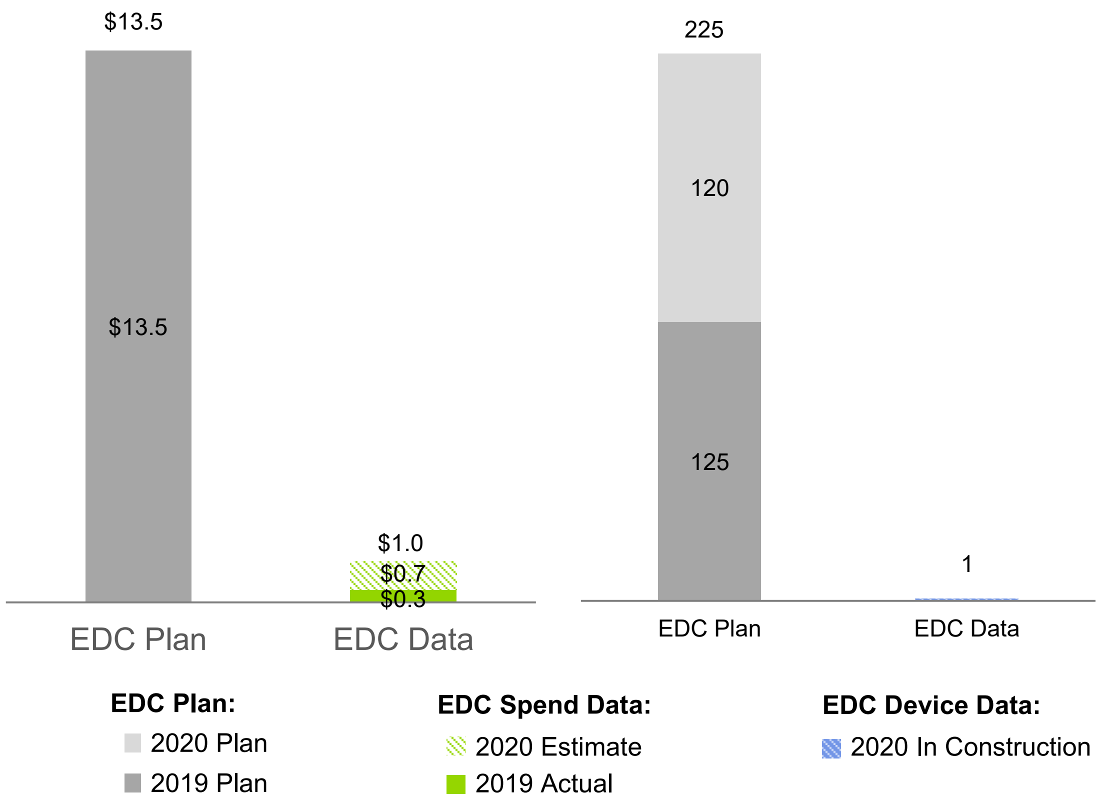
Figure 3. Eversource Planned vs. Actual Deployment and Spend on FAN Investments



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Eversource will deploy 1 mile of fiber under the GMP after reevaluating its fiber needs. In 2019, $0.31 million was spent on design and construction. Commissioning is planned for 2020. The remaining $0.7 million is still under development and therefore has not been developed into a project-level budget. However, these funds will be used in support of other GMP investments, most likely for last-mile ADSS fiber optics to substations. As shown in Figure 4 a total of $13.5 million was originally allocated to fiber deployment, so the remaining $12.5 million will shift to other investment areas.

Figure 4. Eversource Planned vs. Actual Deployment and Spend on Fiber Investment

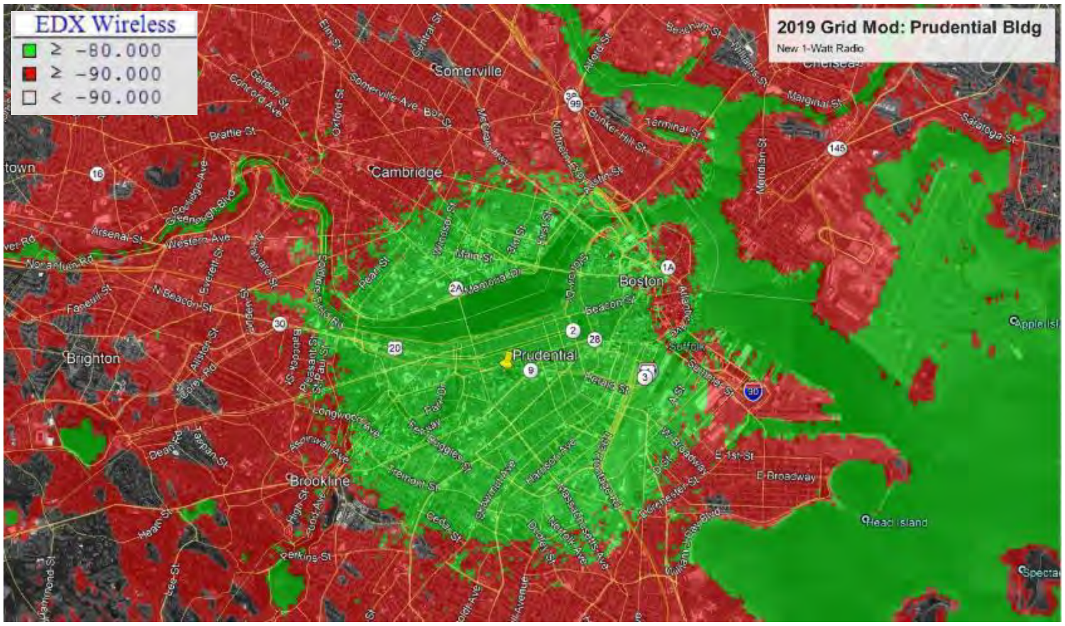


Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.2.3 Progress Highlights

Eversource installed a new master (base-station) radio at the Prudential Center in Boston. It supplemented the existing radio which was getting oversubscribed with the number of remote units programmed to it. The new master radio will allow potential new ADA remotes to be picked up by the radio network. Figure 5 shows a map of radio coverage in the Boston metro area.

Figure 5. Map of Prudential Center Master Radio Coverage



Source: Eversource

Eversource installed a master radio (base station) at the Shoot Flying Hill tower site to improve coverage. The existing unlicensed (spread spectrum) 1 W radio was replaced with a licensed 5 W radio. With a new master radio, Eversource now requires fewer repeaters, which improves latency and overall system performance. Figure 6 shows the increase in radio coverage after the master radio installation at Shoot Flying Hill tower site.

Figure 6. Maps Showing the Increased Coverage with the Addition of a Master Radio at Shoot Flying Hill

Before **After**

Source: Eversource

5.2.4 Key Findings

Eversource is improving its private radio networks' coverage and performance for the monitoring and operation of grid endpoints. This investment will improve communications latency and enable better performance for ADA, M&C, and VVO deployments in these areas.

Eversource was behind its stated 2019 plan, deploying three master radio locations and one front end processor instead of six master radios. Devices planned for 2020 are well underway, indicating that Eversource will catch up to its stated GMP plan.

Eversource conducted a strategic reevaluation of its fiber optic plan in 2019, shifting these funds to other GMP investments with larger expected benefits. This is not a concern, as Eversource has an existing, fully redundant fiber backhaul capable of supporting GMP devices in most locations. The revised communications deployment plan will be used to benchmark progress in the future.

5.3 National Grid

5.3.1 Overview of GMP Deployment Plan

National Grid's legacy communications system consists of a fiber optics network for a limited number of its substations, and a public cellular network to monitor and operate field devices. Recognizing that advanced GMP functions require a modern, reliable communications network, National Grid proposed to modernize its communications network as part of its GMP investments. National Grid's GMP communications proposal included backhaul (WAN) networks substation fiber optics installation, a multi-tiered field-based wireless communication network, and radios for field devices that did not have communications capability.

As stated in National Grid's 2018 GMP Annual Report, the main objectives for the telecommunications (telecom) network plan are to:

- Provide a reliable, cost-effective, two-way communications capability to end devices including grid automation controls, field sensors, and substations.
- Ensure the network meets all technical requirements for the devices and systems deployed. These requirements include availability, latency, bandwidth, security, and other factors.
- Provide to the operations groups the capability to manage, maintain, and troubleshoot the communications network.
- Enable new grid technologies as they become available and future-proof the network as much as possible.

In its GMP, National Grid proposed building both a FAN and WAN. The FAN will provide last mile communications to the end devices. The WAN provides the backbone and ties the end devices to major field communications nodes and ultimately the ADMS and back end data systems. Substations and other facilities make up the major nodes (locations) of their WAN.

In 2017, National Grid hired a third-party communications firm to perform a study to assess its communications requirements. Based on this study and National Grid's internal assessment, National Grid is in the final stage of determining requirements of the FAN and WAN.

5.3.2 Progress to Date

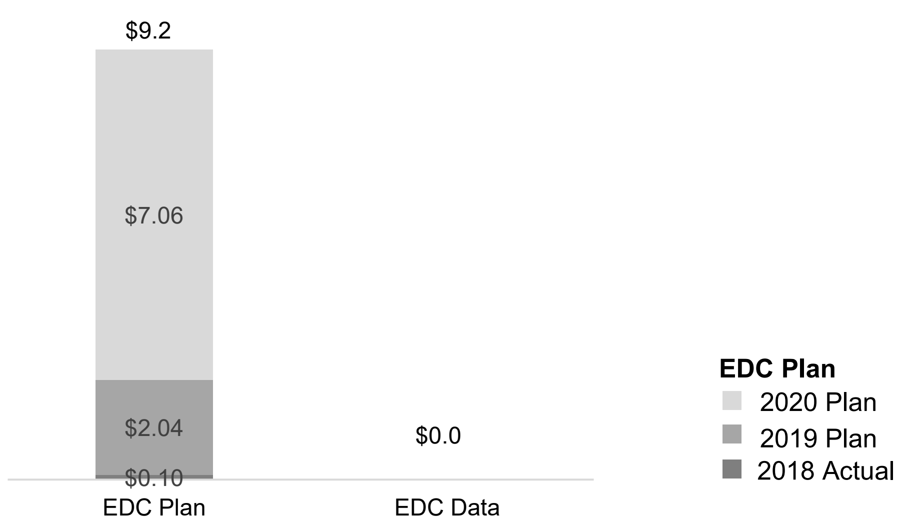
National Grid is currently in the planning stage to determine requirements of its fiber optic (WAN) deployment. It is developing construction standards for fiber optics installation and performing pre-planning and network design. National Grid reports that fiber optic will be deployed to three substations by late 2020, and additional substations each year thereafter.

National Grid is in the research and evaluation stage of its FAN strategy. National Grid reports that it plans a FAN pilot in 2021 and expects to begin deployment in 2022. National Grid recognizes that cellular may not be the preferred technology to operate grid-controlling assets like reclosers, especially during major outage events. Cellular may be hampered by busy signals and relatively slow data transfer speeds and may not have the necessary backup power supply. The company is weighing the options of a public versus private FAN.

While these decisions are pending, progress has been minimal in 2019. National Grid issued an RFP in 2019 for a Telecommunications Operation Management System (TOMS) and is planning an RFP in 2020 for a replacement system for the Nokia DMX SONET system. TOMS is a software tool that will enable the planning, designing, engineering, deploying, commissioning, and maintaining of telecom networks. A replacement system for the Nokia DMX SONET system will be installed to expand the WAN and support the other grid modernization devices.

Until the new FAN network can be built, other GMP devices—ADA, M&C, and VVO—are being connected to the public cellular network to keep projects moving forward.

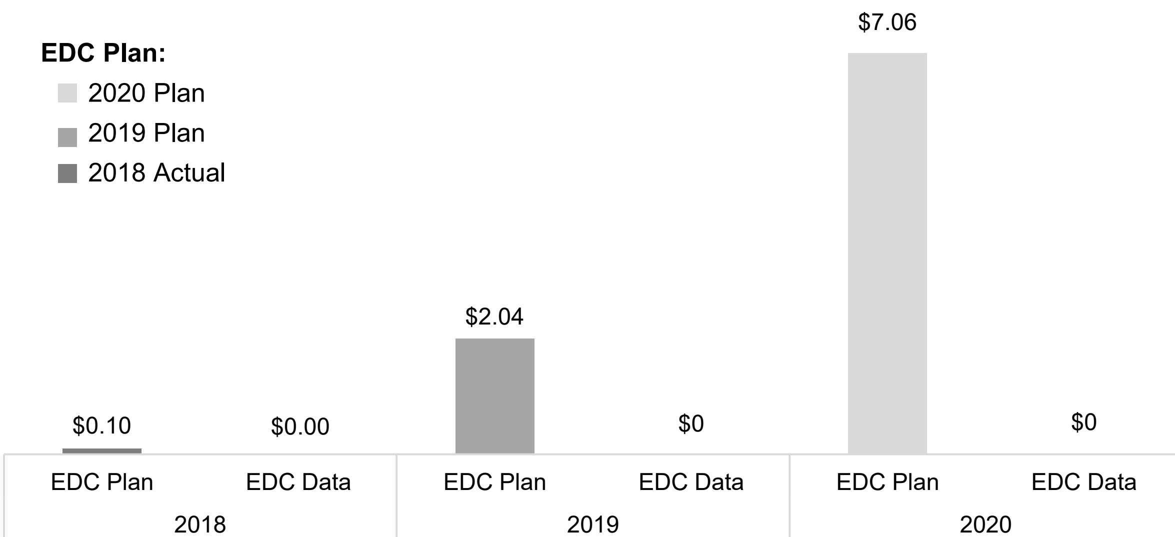
Figure 7. National Grid Total Spend Comparison (2018-2020, $M)



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

National Grid has accrued costs from pre-planning, design, engineering, standards development, and current communications operation. But the costs have not yet been charged to the communications program due to accounting practices, as shown in Figure 7 and Figure 8.

Figure 8. National Grid YoY Spending ($M)



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.3.3 Key Findings:

- National Grid is planning and developing construction standards for fiber optic (WAN) deployment at three substations in 2020. National Grid proposes to install fiber optics at additional substations each year thereafter.
- National Grid is researching its FAN communication investment options, including public versus private networks. It is designing a strategy that best supports grid modernization investments and other company priorities. A FAN pilot is proposed in 2021 with a deployment expected to begin in 2022.
- National Grid is using public cellular for field devices, including new GMP devices that are being installed. National Grid is using fiber optics (WAN) where available for the backhaul.
- While ADA, M&C and VVO benefits will begin to accrue immediately upon deployment, they will be maximized when National Grid connects them to a robust, high-performance communication network as proposed in the GMP.

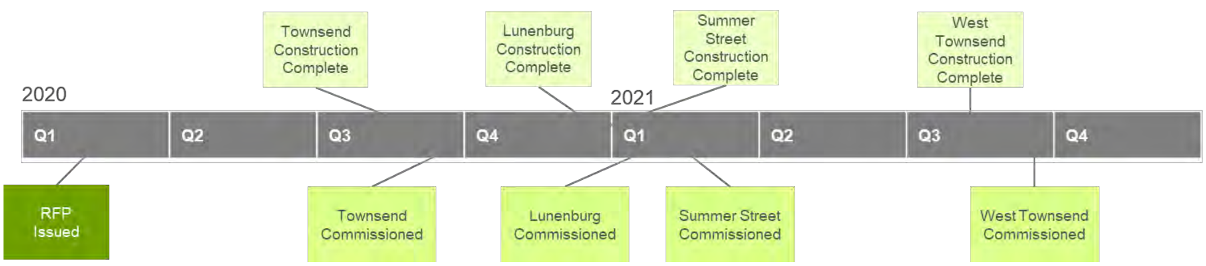
5.4 Unitil

5.4.1 Overview of GMP Deployment Plan

Unitil's legacy communications network consists of a combination of public cellular and land-line telecommunications services, and power-line carrier (PLC) technology for its advanced metering infrastructure (AMI) endpoints. This existing communications network is inadequate to support GMP functions (including M&C and VVO). In its GMP, Unitil proposed to build a FAN for communications between collectors and endpoint devices, and a WAN for the backhaul of communications from substations to the central office.

Unitil recognized that communications necessarily precedes M&C and VVO deployment. In its new integrated GMP deployment schedule, Unitil is prioritizing communications deployment (Figure 9).

Figure 9. Unitil Communications Deployment Timeline



Source: Guidehouse analysis of EDC Data

Unitil plans to deploy communications infrastructure with the same sequence and timing as the other GMP investments. The company plans to commission the Townsend substation in 2020 and the Lunenburg substation in early 2021. This coordinated deployment plan is consistent with the DPU Order stating: "The coordinated deployment of advanced sensing, SCADA, distribution management systems, load flow analytics, advanced communications, and distribution automation will contribute significantly more toward the achievement of grid modernization objectives than a piecemeal deployment of the individual technologies."[12]

5.4.2 Progress in 2019

Unitil hired a third-party communications firm to complete a study in 2019. The DPU recommended the study to help understand and articulate Unitil's communications needs. The study focused on determining the bandwidth, speed, latency, reliability, and availability required by the deployment of grid modernization devices. The study also evaluated types of ownership for the communications network, design considerations, applications, and nonfunctional requirements.

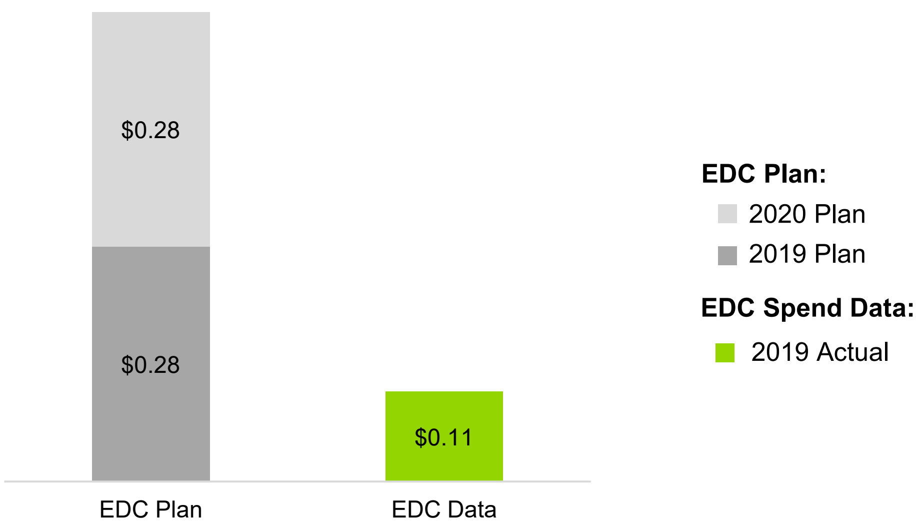
[12] MA DPU GMP Order issued May 10, 2018

The study concluded that the FAN and WAN model is the correct approach for Unitil's GMP. It suggested the following technologies be considered for deployment: WiMAX, 220 MHZ microwave, unlicensed P2MP, fiber, PLC, and WAN carrier circuits.

Following the study, Unitil developed an RFP for a turnkey communication solution to support the GMP investments. This will address the FAN between collectors and endpoints and backhaul (WAN) communications from substations to central command. This RFP was issued in February 2020 and vendor selection is expected to occur in spring 2020.

Unitil spent a total of $107,100 in 2019 on consultant work to complete the study and develop the RFP (Figure 10). A more accurate estimate of communications costs will be determined when construction is under way.

Figure 10. Unitil Communications spend, planned vs actual, 2018-2020



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

The RFP issued in February 2020 will allow Unitil to not only select technologies and vendors but also determine its communications strategy and associated costs. It is typical practice for electric utilities to solicit specialized firms to execute communications projects. The RFP is open for bidders to bid on any combination of a WAN, FAN, and installation service.

Unitil expects to select one or more vendors in Q2 2020. Construction is expected to begin by summer 2020 and the first substation (Townsend) is expected to be commissioned in Q3 2020.

5.4.3 Key Findings

- Unitil plans to deploy communications on the same integrated schedule as other GMP investments, by substation. This approach ensures GMP devices are commissioned with the new communications network, which is vital because Unitil's legacy communications network is inadequate to support new GMP functions.

- The integrated timeline, if executed, will enhance the benefits of other GMP investments with the integration of a modern communications network.
- Unitil is performing due diligence in designing its communications strategy. The initial communications study was completed in 2019. This initial study served to narrow the field of potential technologies to ones that addresses Unitil's requirements.
- Unitil is performing due diligence in technology and vendor selection. Unitil issued an RFP where vendors can bid on competitive approaches involving various technologies.
- Deployment is expected to begin in 2020, and one substation will be completed each year thereafter.

6.0 Conclusions and Recommendations

A robust and high-performance communications network will maximize the benefits of other GMP investments (M&C, VVO, and ADA). The DPU Order emphasized that communications be deployed in tandem with the GMP suite of investments to ensure timely benefit realization. Table 19 summarizes Guidehouse's conclusions from evaluating the progress of the three EDCs toward GMP communications plans.

Table 19. EDC-Specific Communications Findings and Recommendations

EDC	Summary of Findings
Eversource	• Eversource's legacy communications network is capable of supporting present and future GMP deployment in most locations and is being upgraded in other locations. • Eversource has begun to upgrade its FAN in 2019 and will perform further upgrades in 2020 and beyond.
National Grid	• National Grid is planning to begin WAN (fiber optic) deployment in 2020. It is evaluating options for a suitable FAN strategy. • National Grid's FAN timeline is lagging the deployment schedule of other GMP investments (M&C, ADA, and VVO). The benefits of those other investments will be maximized when they are connected to a robust, high performance communications network.
Unitil	• Unitil's third-party communications study is complete, and it has issued an RFP for a turnkey solution to build a FAN and WAN. Construction should begin in 2020.

Guidehouse also submits the following recommendations for EDC consideration in program year 2020.

- Guidehouse should work with the EDCs to implement an updated data collection template and format, using experience gained during the Q2'19 data collection process, to streamline data collection and make the process more efficient.
- Guidehouse recommends National Grid develop RFPs for potential solutions to develop FAN infrastructure.

- National Grid should consider accelerating the communications deployment schedule to better align with the deployment schedules of other investment areas to sooner realize full benefits of grid modernization devices.

Guidehouse

Massachusetts Electric Distribution Companies

Massachusetts Grid Modernization Program Year 2019 Evaluation Report

Advanced Distribution Automation

April 1, 2020

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1.0 Executive Summary

1.1 Introduction

As a part of the Grid Modernization Plan, the Massachusetts electric distribution companies (EDCs) are investing to enable Advanced Distribution Automation (ADA) on selected circuits across their distribution networks. These investments enable greater automation and enhanced reliability.

This evaluation focuses on the progress and effectiveness of the Department of Public Utilities (DPU) preauthorized ADA investments for each EDC toward meeting the DPU's grid modernization objectives for Program Year (PY) 2019.

1.2 Evaluation Process

As part of the Grid Modernization Plans (GMPs), the DPU requires a formal evaluation process (including an evaluation plan and evaluation studies) for the EDCs' preauthorized grid modernization plan investments. Guidehouse (formerly Navigant Consulting, Inc.) is completing the evaluation to ensure a uniform statewide approach and to facilitate coordination and comparability. The evaluations' objective is to measure the progress made toward the achievement of DPU's grid modernization objectives. The evaluation uses the DPU-established infrastructure metrics and performance metrics (discussed in Section 2.1.3) to meet the DPU's evaluation objectives.

Table 1 illustrates the key infrastructure metrics and performance metrics relevant for the ADA evaluation by EDC. Further detail surrounding infrastructure metrics and performance metrics is provided in 4.1 and Section 4.2 respectively.

Table 1. ADA Evaluation Metrics

Metric Type	ADA Evaluation Metrics	ES	NG
IM	System Automation Saturation*	✓	✓
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 three-year term	✓	✓
PM	Numbers of Customers that benefit from GMP-funded Distribution Automation Devices	✓	✓
PM	Grid Modernization investments' effect on outage durations	✓	✓
PM	Grid Modernization investments' effect on outage frequency	✓	✓
PM	Eversource customer outage metric	✓	
PM	National Grid specific metric: Impact of ADA investments on customer minutes of interruption (CMI) for main-line interruptions		✓
PM	Case studies	✓	✓

** Metric calculation is EDC responsibility*
Source: Guidehouse Stage 3 Evaluation Plan

The data supporting the infrastructure metrics and performance metrics have been provided to the evaluation team by the EDCs. Guidehouse presents results from analysis of infrastructure metrics data in Section 5.0. The performance metrics will be evaluated in a subsequent report when sufficient data is available.

1.3 Data Management

Guidehouse worked with the EDCs to collect data to complete the ADA evaluation for the assessment of infrastructure metrics and performance metrics. Guidehouse used a consistent methodology across investment areas and EDCs for evaluating and illustrating EDC progress toward the GMP metrics.

Table 2 summarizes data sources used throughout the evaluation of ADA in PY2019. Further detail on each of the data sources is provided in Section 3.1.

Table 2. ADA Data Sources

Data Source	Description
2018 Grid Modernization Plan Annual Report[1,2,3]	Contains planned device deployment and cost information from each EDC's Supplement to the 2018 GMP Annual Report.[4,5,6] Data were used as the reference to track progress against the GMP targets and are referred to as the "EDC Plan" in summary tables and graphs throughout the report.
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. Planned device deployment information and estimated spend for PY2020 was provided at the most granular level (e.g., circuit-level or substation-level).

Source: Guidehouse

Guidehouse reviewed all data provided upon receipt of requested data and conducted a detailed QA/QC of data inputs used in analysis of infrastructure metrics and performance metrics. These QA/QC steps include checks to confirm each of the required data inputs are accounted for and can be incorporated into analysis. Additional information about the QA/QC process is covered in Section 3.2.

1.4 Findings

Table 3 summarized the infrastructure metrics results for each EDC's ADA investment area through PY 2019.

Table 3. 2019 Infrastructure Metrics Summary

Infrastructure Metrics	Parameter	Eversource	National Grid
	Devices	417	70

[1] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-120

[2] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-122

[3] Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-121

[4] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Supplement to the 2018 Grid Modernization Plan Annual Report. Submitted to Massachusetts DPU on January 31, 2020 as part of D.P.U. 15-120

[5] NSTAR Electric Company d/b/a Eversource Energy, Supplement to the 2018 Grid Modernization Plan Annual Report. Submitted to Massachusetts DPU on January 31, 2020 as part of D.P.U. 15-120

[6] Fitchburg Gas and Electric Light Company d/b/a Unitil, Supplement to the 2018 Grid Modernization Plan Annual Report. Submitted to Massachusetts DPU on January 31, 2020 as part of D.P.U. 15-120

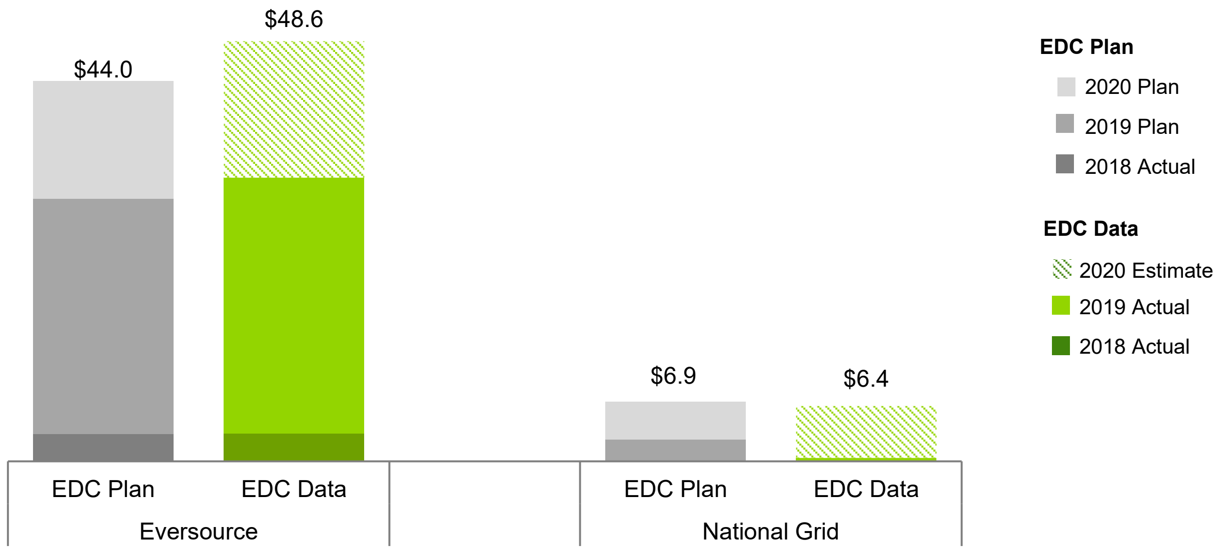
Infrastructure Metrics		Parameter	Eversource	National Grid
2018-2020 Original Plan[7]		Spend, $M	$44.0	$6.89
2018-2020 Revised Plan[8]		Devices	494	82
		Spend, $M	$48.6	$6.43
IM-4	**Number of devices or other technologies deployed**	# Devices	324	0
		% Commissioned	68.2%	0%
IM-5	**Cost for Deployment**	Total Spend, $M	$32.8	$0.41
		% Spend	67.5%	6%
IM-6	**Deviation Between Actual and Planned Deployment for the Plan Year**	% On Track (Devices)	138%	0%
		% On Track (Spend)	108%	16%
IM-7	**Projected Deployment for the Remainder of the Three-Year Term**	# Projected	170	82
		Spend Projected, $M	$15.8	$6.02

Actual spending in PY 2019 was slightly above planned for Eversource and less than planned for National Grid. Eversource deployment is ahead of schedule and National Grid plans to deploy all ADA devices in PY 2020. Figure 1 differentiates between the original planned spend per the 2018 GMP Annual Report and the actual/updated projected spend based on the EDC data provided.

[7] Based on data provided in the 2018 GMP Annual Report.

[8] Based on updated PY 2019 data provided by the EDCs.

Figure 1. ADA Planned vs. Actual Spend



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Table 4 summarizes key findings related to Guidehouse's ADA evaluation for each EDC.

Table 4. EDC-Specific ADA Findings

EDC	Summary of Findings
Eversource	• Eversource exceeded its 2019 deployment targets for all four of its ADA technology groups. • According to reported data, Eversource is on track to achieve GMP 2020 deployment targets. • Eversource selected feeders with high potential customer reliability benefits for ADA investments. It is also targeting lower cost locations first before moving to higher cost locations. • ADA deployment costs are tracking slightly higher than planned because more devices are being deployed than planned. • Ongoing SCADA-system upgrades and migration (non-GMP investment) are moderately impacting the 4 kV auto-reclosing loop investment.
National Grid	• National Grid also selected feeders with poor reliability performance and high potential customer benefits for ADA investments. • 2019 ADA deployment targets were not met due to a combination of factors. • National Grid reevaluated its ADA strategy after recognizing risks in replicating the ADA approach in the Worcester Smart Energy Solutions Pilot. Procurement delays also contributed to the delay. • National Grid reported it overcame initial delays. It has begun engineering and designs to catch up to 2019 targets in the first half of 2020, and to achieve 2020 targets. • National Grid plans to operate GMP ADA devices using a public cellular network until a new GMP-funded communication network is available. National Grid is developing its communications strategy and expects to begin deploying a new FAN in 2022. • ADA benefits will begin to accrue immediately after deployment but will be maximized when the new communications network is established. Some rework may be required to integrate the ADA devices to the new communications system.

Guidehouse also submits the following recommendations for EDC consideration in program year 2020.

- Guidehouse should work with the EDCs to implement an updated data collection template and format, using experience gained during the Q2'19 data collection process, to streamline data collection and make the process more efficient.
- EDCs should work with Guidehouse to develop a case-study approach to understanding reliability impacts due to ADA investments, and helping distinguish between how impacts are attributed to M&C vs ADA where these investments are deployed on same circuit.
- National Grid should consider updating the asset intake process so that equipment ordered for the Grid Modernization Program are marked or designated for that program is clearly identified as assigned/allocated to the GMP program. This may help prevent equipment from being diverted from inventory for other uses within the utility.
- National Grid should consider accelerating the communications deployment schedule to better align with the ADA deployment schedule to sooner realize full benefits of system automation.
- In the future, the EDCs could consider a more sophisticated statistical approach to assessing the reliability impacts of ADA investments. Such techniques require more outage data collection (e.g., outage cause), feeder characteristics (e.g., length, customers, location), equipment installed (e.g., number and type of reclosers), knowledge of other activities (e.g. timing of vegetation trimming), integration with weather data (e.g., hourly wind speed and direction) for feeders that receive the ADA investment and those that do not, but promise more insight on whether the ADA investments are yielding reliability improvements in MED and non-MED situations. This type of approach is more complex and requires additional data collection and more analysis, but it could control for weather and other factors effecting reliability

2.0 Introduction to Massachusetts Grid Modernization

A brief background to the Grid Modernization Evaluation process is provided below in this section along with an overview of the Advanced Distribution Automation (ADA) investment area and specific ADA evaluation objectives. These are provided for context when reviewing the subsequent sections that address the specific evaluation process and findings.

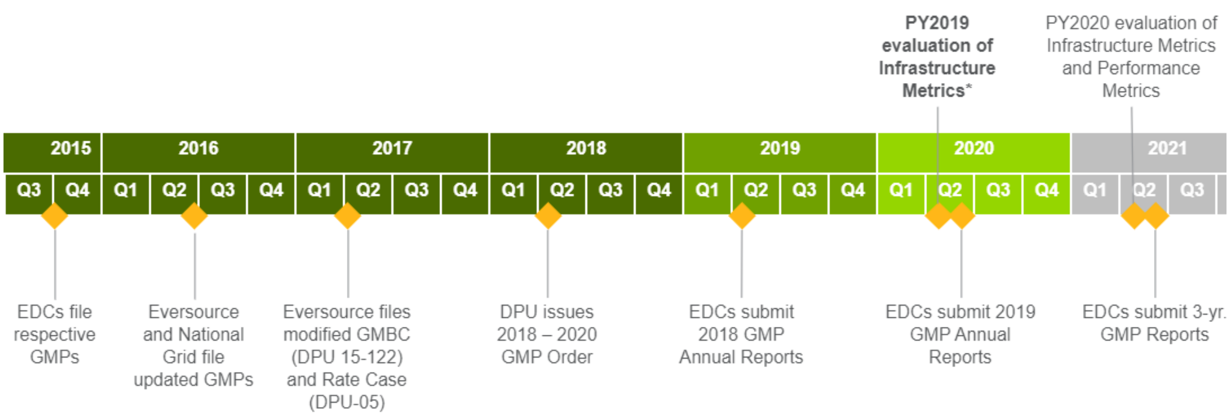
2.1 Background

On May 10, 2018, the Massachusetts Department of Public Utilities (DPU) issued its Order[9] regarding the individual Grid Modernization Plans (GMPs) filed by the three Massachusetts electric distribution companies (EDCs): Eversource, National Grid, and Unitil.[10,11] 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. These preauthorized GMP investments will advance the achievement of DPU's grid modernization objectives:

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

As part of the GMPs, the DPU determined that a formal evaluation process for the preauthorized GMP investments, including an evaluation plan and studies, was necessary to help ensure that the benefits are maximized and achieved with greater certainty. Figure 2 highlights the filing background and timeline of the GMP order and the evaluation process.

Figure 2. MA Grid Modernization Timeline (by Program Year)



** Performance metrics will be included in an addendum report (target date June 2020).*
Source: Guidehouse review of the DPU orders and GMP process

In addition, 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)

[9] Massachusetts D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 (Grid Modernization) Order issued May 10, 2018

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

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

- Advanced Distribution Management Systems/Advanced Load Flow (ADMS and ALF)
- Communications/IoT (Comms)
- Workforce Management (WFM)

The following subsection discusses these investment areas in greater detail in. This report covers the Program Year (PY) 2019 evaluation of infrastructure metrics and focuses on the ADA investment area.

2.1.1 Investment Areas

Table 5 summarizes the preauthorized GMP investments.

Table 5. Overview of Investment Areas

Investment Area	Description	Goal/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)	Isolation of outage events with automated backup for 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/Advanced Load Flow (ADMS and ALF)	New capabilities in real time system control with investments in developing accurate system models and enhancing SCADA and outage management systems to control devices for system optimization and provide support for distribution automation and VVO with high penetration of distributed energy resources (DER)	Enables high penetration of DER by supporting the ability to control devices for system optimization, ADA, and VVO
Communications/IoT (Comms)	Fiber middle mile and field area communications systems	Enables the full benefits of grid modernization devices to be realized
Workforce Management (WFM)	Investments 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

The Massachusetts preauthorized budget for grid modernization varies by investment area and EDC. Eversource has the largest preauthorized budget at $133 million, with ADA and monitoring and control (M&C) representing the largest share ($44 million and $41 million, respectively). National Grid's preauthorized budget is $82.2 million, with advanced distribution management systems (ADMS) and advanced load flow (ALF) representing over 50% ($48.4 million). Unitil's preauthorized budget is $5.5 million and VVO makes up nearly 40% ($2.2 million). Table 6 shows the budget for each investment area by EDC.

DPU added flexibility to these budgets based on changing technologies and circumstances. For example, EDCs can shift funds across the different preauthorized investments if a reasonable explanation for these shifts is supplied.

Table 6. 2018-2020 GMP Preauthorized Budget, $M

Investment Areas	Eversource	National Grid	Unitil	Total
ADA	$44.0	$13.4	N/A	**$57.4**
ADMS/ALF	$17.0	$48.4	$0.7	**$66.1**
Comms	$18.0	$1.8	$0.8	**$20.6**
M&C	$41.0	$8.0	$0.75	**$49.8**
VVO	$13.0	$10.6	$2.2	**$25.8**
WFM			$1.0	**$1.0**
2018-2020 Total	$133	$82.2	$5.5	**$220.7**

Source: DPU Order, May 10, 2018

2.1.2 Evaluation Goal and Objectives

As part of the GMPs, the DPU requires a formal evaluation process (including an evaluation plan and evaluation studies) for the EDCs' preauthorized grid modernization plan investments. Guidehouse (formerly Navigant Consulting, Inc.)[12] is completing the evaluation to ensure a uniform statewide approach and to facilitate coordination and comparability. The evaluations' objective is to measure the progress made toward the achievement of DPU's grid modernization objectives. The evaluation uses the DPU-established infrastructure metrics and performance metrics (discussed in Section 2.1.3) to meet the DPU's evaluation objectives.

2.1.3 Metrics for Evaluation

The DPU-required evaluation involves both infrastructure metrics and performance metrics for each investment area.

2.1.3.1 Infrastructure Metrics

Infrastructure metrics were designed to evaluate the deployment of the GMP investments. The infrastructure metrics are summarized in detail in Table 7.

Table 7. Infrastructure Metrics Overview

Metric		Description	Applicable IAs	Metric Responsibility
IM-1	System Automation Saturation	Measures the quantity of customers served by fully or partially automated devices.	M&C, ADA	EDC
IM-2	Number and Percent of Circuits with Installed Sensors	Measures the total number of circuits with installed sensors which will provide information useful for proactive planning and intervention.	M&C	EDC
IM-4	Number of Devices Deployed and In Service	Measures how the EDC is progressing with its GMP from an equipment and/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

[12] Guidehouse LLP completed its acquisition of Navigant Consulting, Inc, in October of 2019. The two brands are now combined as one Guidehouse.

Metric		Description	Applicable IAs	Metric Responsibility
IM-6	Deviation Between Actual and Planned Deployment for the Plan Year	Measures how the EDC is progressing under its GMP on a year-by-year basis.	All IAs	Evaluator
IM-7	Projected Deployment for the Remainder of the Three-Year Term	Compares the revised projected deployment with the original target deployment as the EDC implements its EDC.	All IAs	Evaluator

Source: Guidehouse review of infrastructure metric filings

2.1.3.2 Performance Metrics

Table 8 summarizes the performance metrics, which are used to evaluate the performance of the GMP investments. Several of the six performance metrics are discussed within this report. They will be quantified in a subsequent addendum to this report and as part of the PY 2020 evaluation reporting process.

Table 8. Performance Metrics Overview

Metric	Applicable IAs
VVO Baseline	VVO
VVO Energy Savings	VVO
VVO Peak Load Impact	VVO
VVO Distribution Losses without AMF (Baseline)	VVO
VVO Power Factor	VVO
VVO – GHG Emissions	VVO
Voltage Complaints	VVO
Increase in Substations with DMS Power Flow and Control Capabilities	ADMS/ ALF
Control Functions Implemented by Circuit	ADMS/ ALF
Numbers of Customers that benefit from GMP funded Distribution Automation Devices	ADA
Grid Modernization investments' effect on outage durations	M&C, ADA
Grid Modernization investments' effect on outage frequency	M&C, ADA
Advanced Load Flow – Percent Milestone Completion	ADMS/ ALF
Protective Zone: Average Zone Size per Circuit* (Eversource)	M&C, ADA
Customer Minutes of Outage Saved per Circuit* (Unitil)	M&C, ADA
Main Line Customer Minutes of Interruption Saved* (National Grid)	M&C, ADA

Source: Stamp Approved Performance Metrics, July 25, 2019 [13]
** Note that these metrics primarily apply to ADA but will be completed for M&C as well given interest in understanding how to separately measure the impacts of these two investment areas.*

2.2 Advanced Distribution Automation (ADA) Investment Area Overview

Eversource Energy and National Grid are making investments in ADA. Unitil does not have preauthorized ADA investments in its GMP. These investments will enable a greater level of distribution grid automation and are expected to result in improved electric system reliability. As identified in the May 1, 2019 Grid Modernization annual reports and shown in Table 6, the ADA investments are planned to total to $50.9 million

[13] Grid Modernization Plan Performance Metrics (Stamped Approved Performance Metrics) issued July 11, 2019 as part of Massachusetts D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 Order

from 2018 to 2020: $44 million by Eversource and $6.9 million by National Grid. EDC-specific approaches to ADA are discussed in the following subsection.

2.2.1 EDC Approach to ADA

National Grid's ADA investments include new installations of overhead reclosers and upgrades to existing reclosers with SCADA. The Eversource investments include new overhead recloser installations, underground oil switch replacements, and the creation of underground auto-reclosing loops. Table 9 summarizes these GMP ADA devices and technologies. These ADA investments all serve to increase visibility of the distribution grid, add more control and restoration options, reduce the customer zone size for fault isolation, and reduce the impact and extent of outages when they occur.

Table 9. Devices and Technologies Deployed Under ADA Investment

EDC	Device/Investment Type	Description
Eversource	New Overhead Recloser Locations	New SCADA-enabled overhead recloser Installations at new locations to increase auto-sectionalizing capability and reduce customer zone size
	New Recloser Locations with Ties	New SCADA-enabled overhead recloser Installations at new locations with ties to adjacent feeders, to add power supply redundancy and increase switching options
	Underground Oil Switch Replacement	New SCADA-enabled switches that replace century-old oil-filled underground switches in Boston and Cambridge, to reduce manual operation and increase auto-sectionalizing capability
	4kV Auto-Reclosing Loops	Previously called 4kV VFI Retrofit Program, Eversource has expanded this investment to loop several circuits together with multiple tie points. This state-of-the-art program is a new proof of concept for Eversource.
National Grid	New Overhead Recloser Locations	SCADA-enabled overhead recloser Installations at new locations to increase auto-sectionalizing capability and reduce customer zone size
	SCADA Upgrades to Existing Overhead Reclosers	Adding automation and control capabilities at existing overhead reclosers which could not previously be remotely controlled, to reduce the duration of outages

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

2.3 ADA Evaluation Objectives

ADA investments are expected to advance the DPU's grid modernization objective "(1) optimize system performance (by attaining optimal levels of grid visibility, command, and control)."[14] The evaluation's goal is to assess the progress and effectiveness of the DPU preauthorized ADA investments for Eversource (ES) and National Grid (NG) toward reducing customer outages and customer minutes of interruption. Table 10 illustrates the key metrics which the multiyear evaluation effort will report. These include four infrastructure metrics (IM) and six performance metrics (PM).

Table 10. ADA Evaluation Metrics

Metric Type	ADA Evaluation Metrics	ES	NG
IM	System Automation Saturation	✓	✓

[14] Massachusetts D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 (Grid Modernization) Order issued May 10, 2018 at p.106.

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 three-year term	✓	✓
PM	Numbers of Customers that benefit from GMP-funded Distribution Automation Devices	✓	✓
PM	Grid Modernization investments' effect on outage durations	✓	✓
PM	Grid Modernization investments' effect on outage frequency	✓	✓
PM	Protective Zone: Average Zone Size per Circuit	✓	
PM	Main Line Customer Minutes of Interruption Saved		✓
PM	Case Study	✓	✓

Source: Guidehouse analysis

This version of the PY 2019 evaluation report focuses only on infrastructure metrics. The performance metrics analyses will be based on reliability and case study data from each EDC and will be provided in a subsequent addendum to this report.[15] This addendum will include case studies to facilitate understanding of the reliability improvements at select Eversource and National Grid feeder locations. These case studies will examine the impact the ADA investments had on reducing the outage frequency or duration and will exemplify system outages with explanation of the mechanisms employed and devices used to achieve the reliability improvement.

The PY 2020 evaluation report will report ADA performance metrics based on statistical and other analyses performed by the evaluation team using data provided by each EDC. The performance metrics involve comparing reliability data before and after ADA device deployment. Eversource began deploying ADA devices in PY 2019; National Grid will start deploying in 2020. Both EDCs release reliability data annually in the February-March timeframe. As such, a full year of post-installation reliability data for circuits where GMP ADA devices were installed in 2019 will be available in 2021. The PY 2020 evaluation report will include further case study descriptions of reliability improvements.

The data supporting the infrastructure metrics have been provided to the evaluation team by the EDCs. Guidehouse presents the results from the analysis of infrastructure metrics data in Section 5.0.

Table 11 summarizes the ADA measurement and verification (M&V) objectives and associated research questions that will be addressed in multiyear evaluation. The ADA evaluation scope includes tracking the ADA infrastructure deployment against the plan and evaluating the impact on system reliability.

[15] The reliability data required for two of the ADA performance metrics will not be available for analysis until March 2020, which was not enough time to include by the April 1st, 2020 filing date for this 2019 Program Year Evaluation Report. An explanation of the need for this timing was provided in response to DPU IR EP-1-1 Attachment A. This timing will lead to the performance metrics being evaluated in an addendum that will be released later in 2020.

Table 11. ADA M&V Research Questions

ADA M&V Research Questions
1) Are the EDCs progressing in deployment of their ADA investments according to their Grid Modernization Plans?
2) What factors, if any, are affecting the deployment schedule of ADA equipment?
3) What is the cost of deploying various types of ADA equipment?
4) What is the effect of ADA investments on key reliability metrics, such as SAIDI and SAIFI?
5) Is the FLISR automation for the overhead and underground equipment operating as designed?

Source: Guidehouse Evaluation Plan

3.0 ADA Data Management

Guidehouse worked with the EDCs to collect data to complete the ADA evaluation and the assessment of infrastructure metrics. The subsections that follow highlight data sources and data QA/QC processes followed by Guidehouse to complete the evaluation and calculate the infrastructure metrics. Information is also included about data for the performance metrics, which will be assessed in an addendum report targeted for June 2020.[16]

3.1 Data Sources

Guidehouse used a consistent methodology (across investment areas and EDCs) for evaluating and illustrating EDC progress toward the GMP metrics. The subsections that follow summarize each of the data sources used to evaluate infrastructure metrics.

3.1.1 2018 Grid Modernization Plan Annual Report

Guidehouse used the planned device deployment and cost information from each EDCs' 2018 GMP Annual Reports, which were filed on May 1, 2019. Additional deployment metrics, progress, cost, and plan details for the 2018 program year were also provided in each EDC's Annual Report Appendix 1, filed on January 31, 2020.[17] These filings served as the sources for planning data in this report[18] and are referred collectively as the EDC "Plan" for each EDC in summary tables and figures throughout this report.

Table 12 provides a legend of the different planned and actual quantities reviewed and specifies the color/shade used to represent each in the remainder of the report.

Table 12. Data Used for the EDC Plan

Representative Color	Data	Description
	2020 Plan	Projected 2020 unit deployment/total spend

[16] The reliability data required for two of the ADA performance metrics will not be available for analysis until late March 2020, which was not enough time to include by the April 1st, 2020 filing date for this 2019 Program Year Evaluation Report. The explanation of the need for this timing was provided in response to DPU IR EP-1-1 Attachment A.

[17] The Appendix 1 filings were submitted after the specific required format was determined by the DPU.

[18] See section 5 for specific details regarding 2018 GMP Annual Report data used for each EDC.

Representative Color	Data	Description
	2019 Plan	Estimated 2019 unit deployment/total spend
	2018 Actual	Actual reported unit deployment and spend in 2018

Source: EDCs' 2018 GMP Annual Report Appendix 1

3.1.2 EDC PY2019 Device Deployment Data Template

Guidehouse collected device deployment data using standardized data collection templates (e.g., the All Device Deployment workbook file) for all EDCs in January – February 2019. The data collected provides an update of planned and actual deployment, in dollars and device units, at the end of PY2019. Data from this source are referred to as "EDC Data" in summary tables and figures throughout the report.

Table 13 summarizes the date of file version receipt used for the evaluation.

Table 13. EDC Data Received for Analysis

EDC	File Version
Eversource	Received 1/22/2020
National Grid	Received 2/11/2020

Source: Guidehouse

Since the receipt of these file versions, several data updates and corrections were discovered through the evaluation process. These revisions were received after the file versions shown in Table 13; however, they were included in Guidehouse's analysis.

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 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 were also collected. Planned device deployment information and estimated spend for PY2020 was provided at the most granular level (circuit or substation, where available). Table 14 summarizes the categories used for the revised planned and actual deployment and spend and specifies the color used to represent each in the remainder of the report.[19]

Table 14. EDC Device Deployment Data

Representative Color	Data	Description
Device Deployment Data		
	2020 Plan	Remaining units planned for 2020 where work has not yet started
	2020 Design	Units in the design phase and will be commissioned in 2020

[19] Eversource provided year-end total actual and planned devices commissioned and spend data. This aggregated data varied slightly from the work order data provided because of nuance's in Eversource's work order accounting methodologies. Guidehouse used the aggregated total data for the 2019 and 2018 commissioned units and spend data. Work order data was used to capture progress towards their updated 2020 plan (per the aggregated year-end total data).

Representative Color	Data	Description
	2020 Construction	Units under construction and will be commissioned in 2020
	2019 Commissioned	Units in service and commissioned in 2019
	2018 Commissioned	Units in service and commissioned in 2019
Spend Data		
	2020 Estimate	Additional cost anticipated in 2020
	2019 Actual	All actual spend that occurred in 2019
	2018 Actual	All actual spend that occurred in 2018

3.1.3 ADA Data for Performance Metrics

Table 15 summarizes the data inputs that are required for performance metrics analysis. Performance metrics will be evaluated in an addendum report. For the ADA investment area, data will be provided by the EDCs or sourced from their annual Service Quality Index (SQI) filings. Information must be provided at the circuit-level for the all circuits receiving ADA investments.

Table 15. Data Required for Performance Metrics Evaluation

PM Evaluation	EDC	Data Required
Effect on outage duration	All	• Baseline circuit average interruptions duration index (CKAIDI)[20] • Evaluation year CKAIDI
Effect on outage frequency	All	• Baseline circuit average interruptions frequency index (CKAIFI)[21] • Evaluation year CKAIFI
Customer Impact	All	• The number of customers for whom the ADA equipment will improve reliability (customers that benefit).
Effect on average protective zone	ES	• Customers per zone per circuit before and after investment.
Effect on main line customer minutes of interruption	NG	• Number of main line CMI reduced per circuit based on OMS and system data
Case Studies	All	• One-line diagrams, available data on specific outage(s), interview with technical and/or operations staff to understand technology use.

Source: Guidehouse Stage 3 ADA Evaluation Plan

3.2 Data QA/QC Process

Guidehouse reviewed all data provided for infrastructure metrics analysis upon receipt of requested data. The following sections detail the data QA/QC process.

3.2.1 Infrastructure Metrics Data QA/QC

To ensure accuracy, Guidehouse conducted a high-level QA/QC of all device deployment data received. This review involved following up with the EDCs for explanations regarding the following:

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[20] For years 2015, 2016, and 2017, on a circuit level for all circuits receiving M&C investments: AVERAGE (‘CKAIDI 2015’+’ CKAIDI Year 2016’+’ CKAIDI Year 2017’) = baseline ‘CKAIDI’

[21] For years 2015, 2016, and 2017, on a circuit level for all circuits receiving M&C investments: AVERAGE (‘CKAIFI 2015’+’ CKAIFI Year 2016’+’ CKAIFI Year 2017’) = baseline ‘CKAIFI’

- Potential errors in how the forms were filled out (e.g., circuit information provided in the wrong field)
- Missing or incomplete information
- Large variation in the unit cost of commissioned devices
- Variance in the January 1 through June 30, 2019 data provided last year, and the work order-level data provided for PY2019
- Variance between the aggregated year-end total information and work order-level data (applicable to Eversource only)
- Deviation between 2018 GMP Annual Report (filed May 1, 2019) and actual deployment and spend from our PY 2019 data collection

During the QAQC process, some inconsistencies were noted between the 2018 GMP Annual Report filing (submitted May 1, 2019) and the Annual Report Appendix 1 filing (submitted January 31, 2020) for one EDC.[22] Also, one EDC identified calculation or conceptual adjustments that would be required in their Appendix 1 filings. [23] These items are described at various points in the report below or otherwise noted in figure or table notes or in footnotes where appropriate. These inconsistencies did not adversely affect the evaluation results.

3.2.2 Performance Metrics Data QA/QC

The QA/QC of performance metrics (provided in the June 2020 Addendum report) will include checks to confirm each of the required data inputs can be incorporated within the performance metrics analysis. This review will include the following criteria:

- Baseline data is calculated correctly
- Reliability data is complete and was provided for the appropriate circuits
- The CKAIDI and CKAIFI metrics are within the expected range, and any outliers have been verified by the EDCs
- Discussion with appropriate personnel to validate the specific operation and corresponding benefits developed in any case studies.

Data irregularities discovered during this process are being discussed with the EDCs and will be explained within the Performance Metrics addendum report.

4.0 ADA Evaluation Process

This section presents a high-level overview of the Guidehouse methodologies for the evaluation of infrastructure and performance metrics.

This ADA evaluation is focused on infrastructure metrics for PY 2019, as data required for the performance metrics is not yet available. The ADA evaluation for PY 2020 will

[22] Eversource excluded the 2018 to 2019 “carry-over” units in their 2019 planned unit totals within the Appendix 1 filing.

[23] Eversource’s planned 2020 cost breakdown by device type in the Annual Report Appendix 1 filing (submitted January 31, 2020) requires adjustment.

include infrastructure metrics, performance metrics, and case studies when all ADA devices and technologies are deployed and commissioned.

4.1 Infrastructure Metrics Analysis

Guidehouse annually assesses the progress of each of the EDCs toward ADA deployment. Table 16 highlights the infrastructure metrics that were evaluated and associated calculation parameters.

Table 16. Infrastructure Metrics Overview

IM	Metric	Calculation Parameters
IM-4	**Number of devices or other technologies deployed**	# Devices – *total number of devices that have been commissioned, are in the construction phase, and are in the design phase*
		% Devices Deployed – *percent of the total planned devices over the 3-year period that have been commissioned*
IM-5	**Cost for Deployment**	Total Spend – *total spend through PY2019, regardless of whether the device has been commissioned*
		% Spend – *percent of the total estimated spend over the 3-year GMP period*
IM-6	**Deviation Between Actual and Planned Deployment for the Plan Year**	% On Track (Devices) – *devices commissioned through PY2019 divided by the devices planned for commission through PY2019*
		% On Track (Spend) – *actual spend through PY2019 divided by the planned spend through PY2019*
IM-7	**Projected Deployment in PY2020[24]**	# Devices Remaining – *How many devices remain to be commissioned in PY2020*
		Spend Remaining – *How much spend is estimated for PY2020*

Source: Guidehouse

Section 5.0 provides the results from the evaluation of infrastructure metrics. To evaluate infrastructure metrics, Guidehouse:

- Reviewed the EDC data provided to ensure the information provided accurately reflected their progress through PY2019 (see Section 3.1.3, “Data QA/QC Process”)
- Interviewed representatives from each EDC to understand the status of the ADA investments, including:
    - Updates to their planned ADA investments
    - Reasons for deviation between actual and planned deployment and spend

4.2 Performance Metrics Analysis

Performance metrics will be evaluated for each of the three EDCs in the upcoming addendum to this report. Table 17 describes the performance metrics that will be evaluated for PY2020.

[24] DPU-approved metric is titled “Project Deployment for Remainder of the 3-Year Term.” Since 2020 is the last year of the 3-year team, Guidehouse abbreviated the metric for simplicity.

Table 17. ADA Performance Metrics Overview

Performance Metrics	EDC	Description
Numbers of Customers that benefit from GMP-funded Distribution Automation Devices	All	Provides insight into how many customers have benefitted from the installation of ADA devices. Compares the automated zone size on GMP ADA-enabled circuits as compared to the previous three-year average for the same circuit.
Grid Modernization investments' effect on outage durations	All	Provides insight into how ADA devices reduce the duration of outages (CKAIDI). Compares the experience of customers on GMP ADA-enabled circuits as compared to the previous three-year average for the same circuit.
Grid Modernization investments' effect on outage frequency	All	Provides insight into how ADA investments can reduce outage durations (CKAIDI). Compares the experience of customers on GMP ADA-enabled circuits as compared to the previous three-year average for the same circuit.
Protective Zone: Average Zone Size per Circuit	ES	Measures Eversource's progress in sectionalizing circuits into protective zones designed to limit outages to customers located within the zone.
Main Line Customer Minutes of Interruption Saved	NG	Measures the impact of ADA investments on the customer minutes of interruption (CMI) for main line interruptions. Compares the CMI of GMP ADA-enabled circuits to the previous three-year average for the same circuit.
Case Studies	All	Examine the impact the ADA investments had on reducing the outage frequency or duration. Exemplify system outages with explanation of the mechanisms employed and devices used to achieve the reliability improvement.

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

The PY 2019 evaluation does not include a performance metrics analysis as there are not sufficient data available for the ADA investments. Data collection and QA/QC processes were ongoing in 2019 to ensure correct inputs were provided and that data are complete, and to facilitate future analysis of performance metrics.

5.0 Deployment Progress and Findings

Guidehouse presents findings from the infrastructure metrics analysis for ADA in Sections 5.1 through 5.3. Tables and figures highlight high level findings, with key findings presented thereafter.

5.1 Statewide Comparison

This section discusses the anticipated impact ADA investments will have on the feeders and customers throughout Massachusetts and summarizes the deployment progress and findings across all three EDCs

5.1.1 Anticipated Impact on Massachusetts

Across the three EDCs in Massachusetts, ADA investments will impact about 15% of total EDC customers and 7% of feeders. Table 18 summarizes the number of feeders and customers covered by GMP ADA investments spanning 2018 through 2020.

Table 18. Number of Massachusetts Feeders and Customers Covered by ADA Investment

ADA Impact	Eversource		National Grid		Total	
	Feeders	Customers[25]	Feeders	Customers	Feeders	Customers
System-wide Total	2,234	1,397,000	1,114	1,320,000	3,348	2,717,000
2018-20 GMP Plan	230	360,200	18	41,200	248	401,400
Percent System Total	10.3%	25.8%	1.6%	3.1%	7.4%	14.8%

Source: Guidehouse analysis of 2018 GMP Annual Reports

5.1.2 Infrastructure Metrics Results

Table 19 summarizes the infrastructure metrics analysis for each EDC. Based on reported data, Eversource made significant progress in ADA device deployment in 2019. It exceeded deployment targets in three out of four ADA technology categories. National Grid redesigned its ADA approach in 2019 and began procurement of ADA devices. It faced procurement delays that pushed 2019 targets to 2020. National Grid plans to achieve 2020 deployment targets on time.

Table 19. 2019 Infrastructure Metrics Findings

Infrastructure Metrics		Parameter	Eversource	National Grid
2018-2020 Original Plan[26]		Devices	417	70
		Spend, $M	$44.0*	$6.89
2018-2020 Revised Plan[27]		Devices	494	82
		Spend, $M	$48.6	$6.43
IM-4	**Number of devices or other technologies deployed**	# Commissioned	324	0
		% Commissioned	68.2%	0%
IM-5	**Cost for Deployment**	Total Spend, $M	$32.8	$0.41
		% Spend	67.5%	6%
IM-6	**Deviation Between Actual and Planned Deployment for the Plan Year**	% On Track (Devices)	138%	0%
		% On Track (Spend)	108%	16%
IM-7	**Projected Deployment in PY 2020**	# Projected	170	82
		Spend Projected, $M	$15.8	$6.02

[25] 2018 Data was used. Customer counts will be updated in 2019 Annual Report

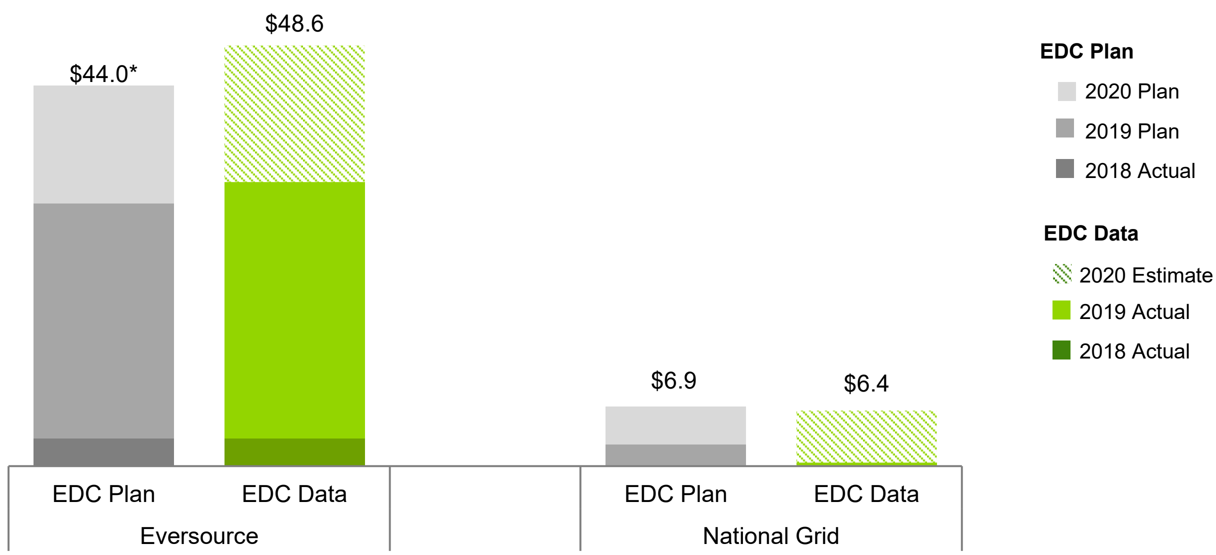
[26] Based on data provided in the 2018 GMP Annual Report.

[27] Based on updated PY 2019 data provided by the EDCs.

**Eversource adjustment to $43.6M. See discussion in Section 5.2 for details.*
Source: Guidehouse analysis

Figure 3 highlights planned versus actual spend in ADA for each of the EDCs. Detailed differences between planned and actual spend are provided in each specific EDC's results section.

Figure 3. ADA Planned vs. Actual Spend (2018 – 2020, $M)



**Eversource adjustment to $43.6M. See discussion in Section 5.2 for details.*
Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.2 Eversource

This section discusses Eversource's ADA investment progress through PY 2019 and its projected PY 2020 progress as compared to the 2018 GMP Annual Report.

5.2.1 Overview of GMP Deployment Plan

Eversource's objective is to increase visibility, control, and more switching options for the distribution grid. Its investments are focused on (a) replacing legacy underground switches with modern, automated switches; and (b) adding automated overhead reclosers at new locations, along a feeder and at tie points that were previously manually operated. These investments will help reduce the impact of outages by decreasing the number of customers in each zone between sectionalizing automated devices.

For its ADA program, Eversource prioritized circuits with customer zone sizes of >500 in Eversource West and >1,000 in Eversource East. It also took reliability scores into account. (A zone is the length of a feeder between two sectionalizing switches.) In the case of outages during major events (e.g., storms), these distribution automation investments will reduce the duration and extent of outage events and will result in meaningful benefits to customers. From a system planning perspective, having real time information increases the flexibility to shift load based on prevailing conditions with the potential to defer capital upgrades. In addition, these new devices will be incorporated into the ADMS platform when it is available.

Table 20. Eversource GMP ADA Technologies

Overhead ADA	**(1) New Recloser Locations** New SCADA-enabled overhead recloser installations at new locations to increase auto-sectionalizing capability and reduce customer zone size	**(2) New Recloser Locations with Ties** New SCADA-enabled overhead recloser Installations at locations with ties to adjacent feeders, to add power supply redundancy and increase switching options
Underground ADA	**(3) Oil Switch Replacement** New SCADA-enabled switches that replace century-old, oil-filled underground switches in Boston and Cambridge, to reduce manual operation and increase auto-sectionalizing capability	**(4) 4 kV Auto-Reclosing Loops** Previously called 4kV VFI Retrofit Program, Eversource has expanded this investment to loop several circuits together with multiple tie points. This state-of-the-art program is a new proof of concept for Eversource

Source: Guidehouse analysis of 2018 GMP Annual Reports and discussions with Eversource

Eversource's 2018 Annual Report Appendix 1 filing was used as the primary data source for the actual and plan information presented below. Guidehouse has determined some inconsistences between the Annual Report information and the data in Appendix 1, and Eversource has suggested additional changes to the some of the Appendix 1 data. While these issues did not adversely affect the evaluation results, we have included notes on the tables and figures below to point them out. These include: the number of planned units for 2019 has been adjusted to accurately reflect Eversource's plan as discussed in the 2018 GMP Annual Report;[28] and, dollar value adjustments for 2020 planned spend period as well as total 2018 through 2020 planned spend are indicated in table notes where applicable.[29]

5.2.2 ADA Investment Progress Through PY2019

The GMP is a continuation of Eversource's grid modernization journey that began several years ago. Eversource used its existing work management systems and processes and created dedicated work orders to track and execute GMP projects, including ADA. We determined that Eversource conducted significant pre-planning to

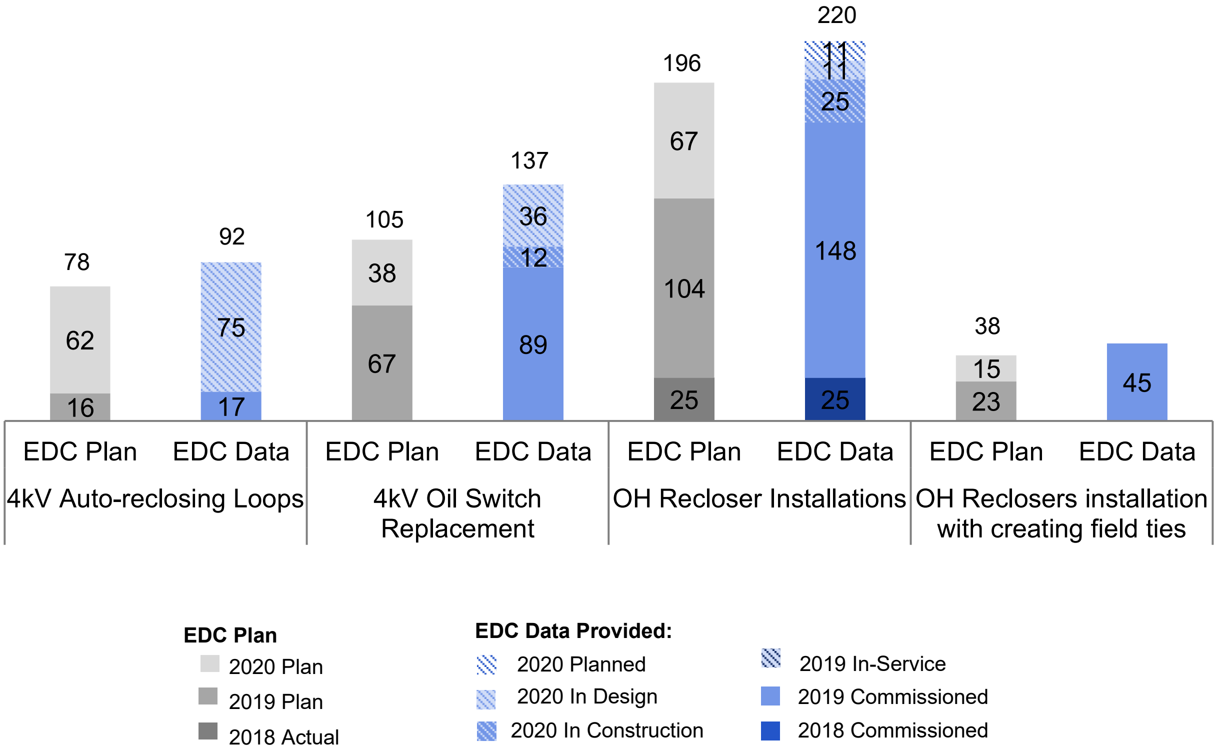
[28] Eversource excluded the 2018 to 2019 "carry-over" units in their 2019 planned unit totals within the 2018 GMP Annual Report Appendix 1 filing (submitted January 31, 2020). Information in their Appendix 1 filing was taken directly from Table S2-4 of their 2018 Annual Report (filed May 1, 2019) and does not include the units shown in Table 5 of the Annual Report. These units must be added to the 2019 planned units shown in Table S2-4 to accurately reflect Eversource's 2019 planned unit deployment.

[29] Additionally, Eversource as suggested that the planned 2020 cost breakdown by device type in the Annual Report Appendix 1 filing requires adjustment, and Eversource supplied updated cost breakdown data for evaluation purposes. Guidehouse has compared this updated data against the original Appendix 1 file and has noted this in places in the evaluation report.

effectively scale up its base operations, build organizational capacity, and deploy incremental GMP devices.

These efforts allowed Eversource to mobilize quickly and exceed deployment targets for all four ADA technologies in 2019. Figure 4 shows that Eversource is ahead of schedule for oil switch replacement and both overhead recloser program installations. For 4kV auto-reclosing loops, the 2019 target devices are installed, in service, and SCADA commissioned. Additionally, all substation and related equipment required to automate the 4kV loops was installed. The final system commissioning for 4kV loop automation was delayed to 2020 due to external vendor resourcing limitations and internal scheduling of major SCADA-system upgrades.

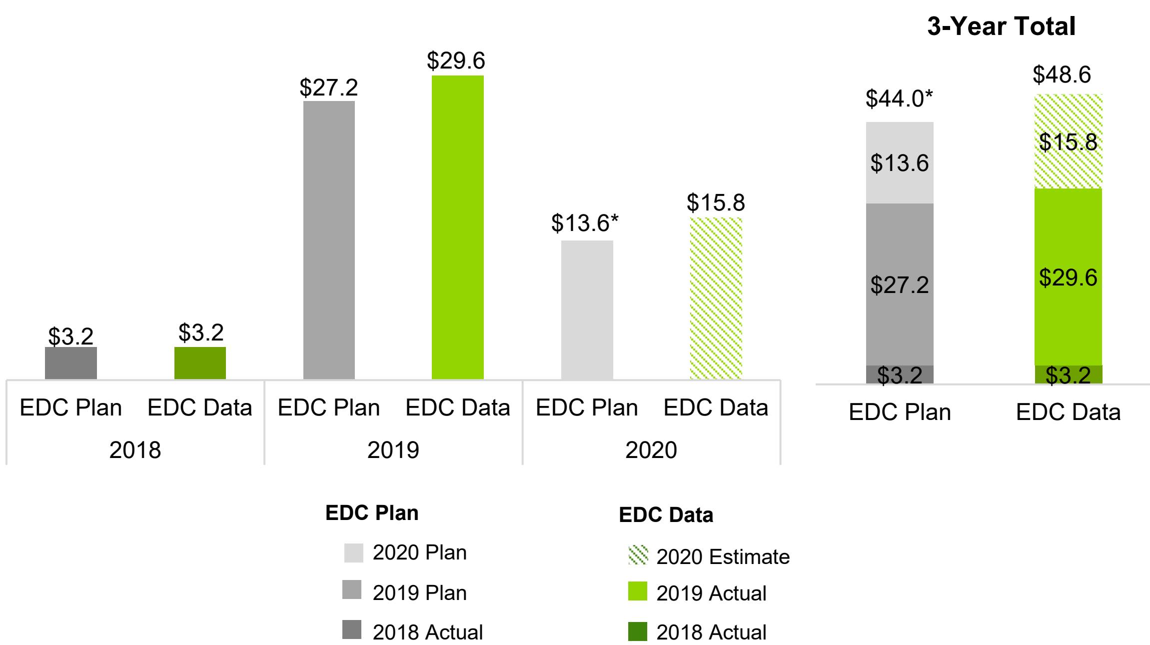
Figure 4. Eversource ADA Device Deployment*



*For 4kV Auto-reclosing loops and OH Recloser Installations, there are more devices that are in the design/ construction phase than Eversource anticipates commissioning in 2020. Eversource's 2018 - 2020 total deployment plan still aligns with the 2018 GMP Annual Report
Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Eversource spending is also tracking closely to planned. Figure 5 shows that total spending is projected to be 10% higher than planned. This projection is in line with expected values since Eversource also exceeded the projected number of device deployment targets in 2019.

Figure 5. Eversource Planned vs. Actual Spend on ADA Investment



**Eversource has suggested that this 2018 GMP Annual Report Appendix 1 value be adjusted to $13.2M. With this adjustment, the corresponding value for 3-Year Total Spending would be $43.6M.*
Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Eversource has tightly integrated incremental GMP deployment with its base capital spending. For example, GMP investments are on an integrated schedule with base capital activities to achieve cost efficiencies. At the same time, certain base activities like SCADA-system upgrades and cutover are moderately impacting the deployment of 4 kV auto-reclosing loops.

Table 21 summarizes infrastructure metrics for Eversource ADA investments.

Table 21. Eversource Infrastructure Metrics Findings

IM	Parameter	4kV AR Loops	4kV Oil Switch Replacement	OH Recloser Installations	OH Recloser Installation with Creating Field Ties	Total
2018-2020 Original Plan[30]	Devices	78	105	196	38	**417**
	Spend, $M[31]	$0.88*	$10.9*	$29.0*	$3.14*	**$44.0***

[30] Based on data provided in the 2018 GMP Annual Report.

[31] Three-year spending was not broken out by device-type in the 2018 GMP Annual Report

IM		Parameter	4kV AR Loops	4kV Oil Switch Replacement	OH Recloser Installations	OH Recloser Installation with Creating Field Ties	Total
2018-2020 Revised Plan[32]		Devices	92	137	220	45	**494**
		Spend, $M	$4.29	$21.3	$16.3	$6.79	**$48.6**
IM-4	Number of devices or other technologies deployed	# Devices	17	89	173	45	**324**
		% Devices Deployed	18.5%	76.1%	78.3%	100%	**68.2%**
IM-5	Cost for Deployment	Total Spend, $M	$0.89	$14.8	$12.1	$5.07	**$32.8**
		% Spend	20.8%	69.5%	74.3%	74.7%	**67.5%**
IM-6	Deviation Between Actual and Planned Deployment for the Plan Year	% On Track (Devices)	106%	133%	134%	196%	**138%**
		% On Track (Spend)	101%	135%	78%	162%	**108%**
IM-7	Projected Deployment for PY 2020	# Devices Remaining	75[33]	48	47	-	**170**
		Spend Remaining, $M	$3.4	$6.5	$4.2	$1.72	**$15.8**

**Eversouce has suggested that these 2018 GMP Annual Report Appendix 1 values be adjusted as follows: 2018-2020 totals for 4kV AR Loops-- $4.3M, 4kV Oil Switch Replacement-- $13.7M, OH Recloser Installations-- $19.4M, OH Recloser Installation with Creating Field Ties-- $6.3M, Total Spending-- $43.6M. Note that under these adjustments, the percentages would vary somewhat as well.*
Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

The following sections provide a detailed evaluation of each ADA technology.

5.2.2.1 Replacement of Underground 4kV Oil Switches

This program is focused on modernizing legacy underground switches in Boston and Cambridge. Installed in 1920-1940, these switches represent some of the oldest assets in Eversource's distribution grid and are not suited to serving the densely populated hubs of Boston and Cambridge. These switches (Figure 6, left panel) cannot be automated or provide remote communication. They require a fault to be traced to one of many manholes, which is often inaccessible and requires lengthy repairs. For these

[32] Based on updated PY 2019 data provided by the EDCs.

[33] Of the 75 devices that are currently in construction or design, Eversource has confirmed that at least 62 will be commissioned in PY 2020.

reasons, Eversource accelerated this program, replacing 89 switches in 2019 ahead of the planned 67.

The new GMP devices, called vacuum fault interrupters (VFI), perform vastly better than legacy devices in terms of improving customer reliability and ease of operation (Figure 6, right panel). The new switches are SCADA-enabled and capable of automatically isolating faults and restoring sections of the grid within seconds. Once the fault zone is isolated, Eversource crews can quickly access the fault location for repairs. The result is an expected reduction in the duration and extent of outages in Boston and Cambridge. Additionally, these devices will integrate with and allow for future automation.

Underground oil switch replacement is complex, in part due to high customer density and inaccessibility of manholes. Outages must be carefully planned to minimize customer impact. Despite these challenges, we have determined that the Eversource deployment is ahead of schedule.

Figure 6. Old Oil-Filled Switches (Left) and New VFI Switches (Right)

Source: Eversource

5.2.2.2 4 kV Underground Auto-Reclosing Loops

In its 2018 GMP annual report, Eversource had proposed retrofitting its underground 4kV VFI switches to enable remote control and automation. Eversource has since expanded this program to also include creating auto-reclosing loops that tie multiple feeders together. This program represents a cutting-edge ADA technology demonstration for Eversource.

Auto-reclosing loops will enable field ties with several circuits in an automated switching scheme to add redundancy and backup power supply to customers. They will also enable a large number of switching operations. Eversource is using a Schweitzer (SEL) distribution automation controller (DAC) system to bring in data from field devices and communicate back to the SCADA system. The results of this proof-of-concept project will inform future ADA deployments.

Eversource found underground auto-reclosing loops to be challenging to design and deploy. Eversource installed one scheme in 2019, putting 17 devices in service with SCADA capability. This met the original plan. In 2020, it plans to commission auto-reclosing loop functionality for this scheme and start deploying more schemes like this. The SCADA commissioning of the loop scheme has been impacted by an ongoing system-wide SCADA cutover that is not part of the GMP investments, in which Eversource is migrating three legacy SCADA systems into a single, newer version.

Based on the SCADA cutover schedule, Eversource expects to commission the first scheme in the first half of 2020.

5.2.2.3 New Overhead Reclosers

Eversource is installing pole-top reclosers made by the Cooper manufacturing company at new locations along its overhead distribution lines (Figure 7). Adding new recloser locations reduces zone sizes and increases sectionalizing capability with expected reliability benefits for customers within the new zone created.

Eversource exceeded its 2019 target for overhead recloser installations and deployed 148 instead of 104 devices. It was on track to finish its 2020 planned deployment a year ahead of time in 2019 but faced control and protection coordination issues with a limited number (21 reclosers) in the southeast Massachusetts area. Eversource's implementation schedule indicates it plans to exceed its 2020 planned deployment.

Figure 7. Eversource Overhead Recloser

Source: Eversource

5.2.2.4 New Overhead Reclosers with Feeder Ties

This is the same technology as overhead reclosers in Section 5.2.2.3, except these are installed at strategic locations to tie different feeders together. For the GMP, Eversource has selected locations where feeders are already in close proximity and where ties can be created without adding new line extensions. This approach is a cost-effective way of adding redundancy to Eversource's distribution grid. When Eversource saturates these locations, it will move to other locations where short lengths of overhead lines may need to be installed to create feeder ties.

Eversource exceeded its deployment target for these devices in 2019, deploying 45 overhead reclosers with ties ahead of the planned 23. It had planned 38 devices in the 3-year term, so the term target has been exceeded a year ahead of schedule.

5.2.3 Summary of Key Findings

Guidehouse evaluation findings for Eversource are summarized below:

- Eversource's ADA circuit selection criteria included minimizing customer zone sizes, targeting low reliability areas and minimizing cost.
- Eversource performed significant pre-planning and built organizational capacity to deploy GMP devices on target.
- Eversource exceeded 2019 deployment targets for all four of its ADA technology groups. For one technology (auto-reclosing loops), 2019 target devices were installed on time with SCADA capability, per original plan. The added functionality of automated loop commissioning was postponed to early 2020.
- Eversource ADA deployment costs are projected to be 10% higher than planned, which is in line with Eversource exceeding the projected device deployment targets.
- Eversource's ongoing SCADA- system upgrades and migration (non-GMP investment) are moderately impacting the 4 kV auto-reclosing loop investment.

5.3 National Grid

5.3.1 Overview of GMP Deployment Plan

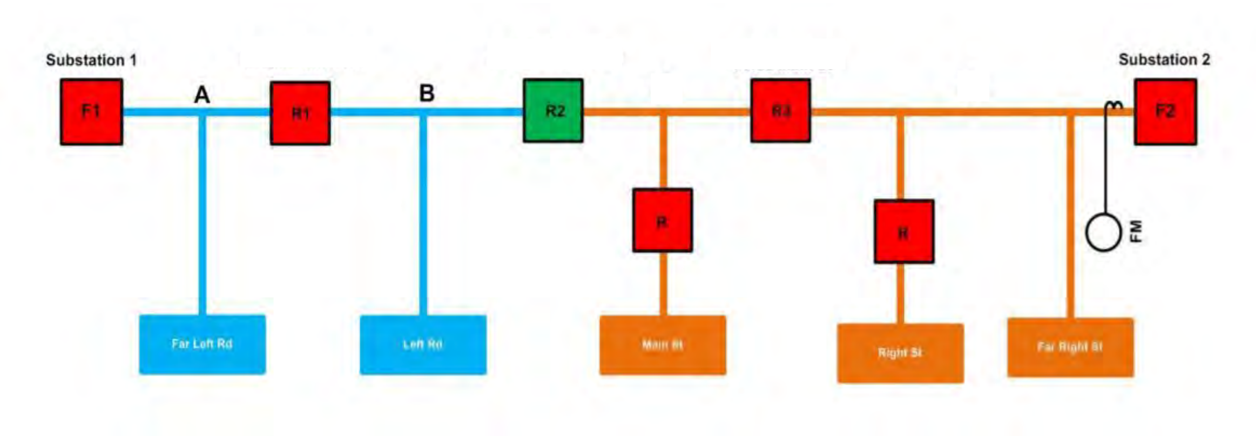
With its ADA investments, National Grid's objective is to improve grid reliability by adding automation and control capabilities at new and existing overhead feeder locations.

National Grid can communicate with some of the existing reclosers on the distribution system but cannot remotely operate these devices to restore power to customers. With the GMP ADA investments, National Grid will add control and automation capability on existing reclosers and add new recloser locations. The ADA program includes replacing manual tie points between adjacent feeders with remote-controlled automated switches.

National Grid's criteria for ADA feeder selection included but was not limited to: feeder metrics, poorly performing or worst-performing feeders, feeder length, and number of customers served. For now, National Grid is not deploying ADA on circuits with moderate to high DER penetration which would require detailed load-flow analysis.

Figure 8 illustrates the benefit of reliable ADA investments on National Grid's distribution grid. It depicts National Grid's distribution feeders, substations, and reclosers. If a fault occurs at point A, F1 (substation breaker) will lock out and R1 (a recloser switch) will automatically open. The entire blue zone will experience loss of power supply from Substation 1. With ADA, R2 (a recloser switch that ties two feeders together) would sense loss of power and close automatically. This would restore power to customers in Zone B, which would then be supplied from Substation 2 instead of Substation 1. This process isolates the effects of a fault to the smallest possible section of the grid, in this case, Far Left Road.

Figure 8. National Grid's illustrative ADA scheme



Source: National Grid

National Grid expects the benefits of ADA to include:

- Optimizing system performance: National Grid anticipates a 25% reduction in main-line customer minutes of interruption ("CMI") on the individual feeders targeted for the ADA deployment.
- Optimizing system demand: The additional operational data collected by the automated switches will support the improved management of the distribution system, assisting in demand optimization.
- Interconnecting and integrating DER: The additional operational data collected by the automated switches will support the improved management of the distribution system, assisting in the interconnection of DG and potential integration of distributed resources as a tool to operate the system.

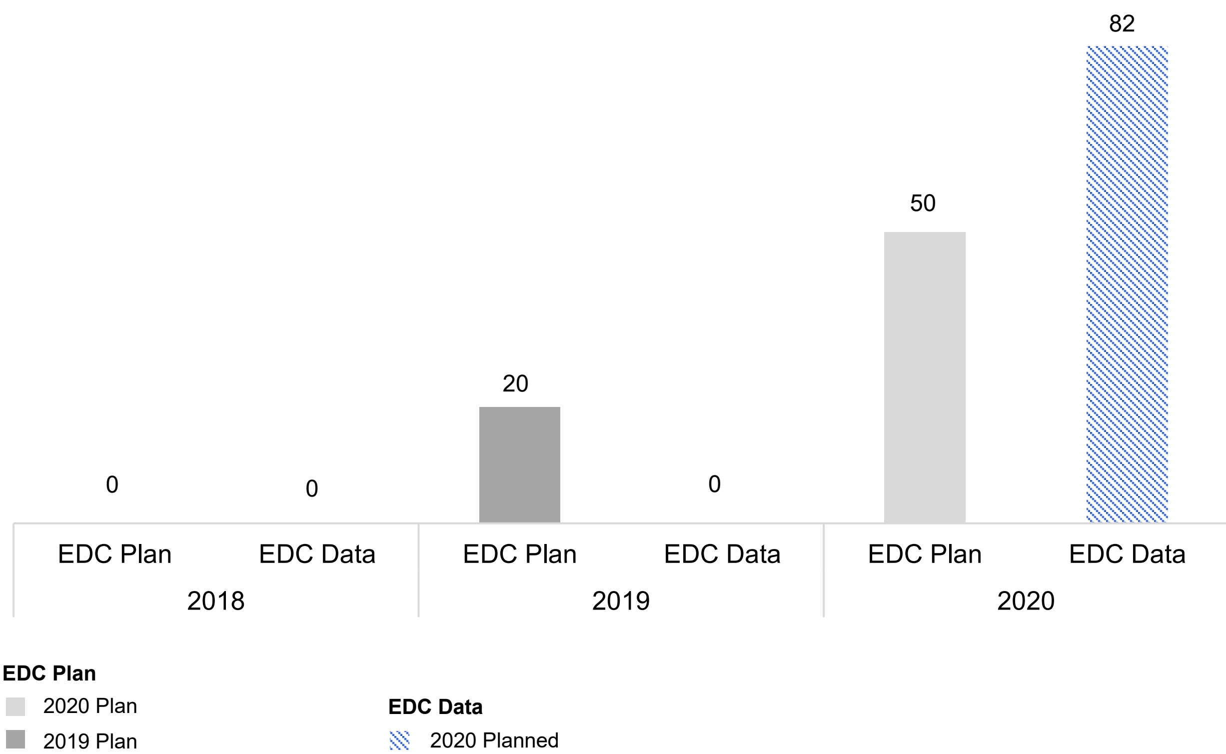
National Grid is integrating lessons learned from the ADA demonstration pilot in its Worcester Smart Energy Solutions (SES) Pilot into the Massachusetts GMP ADA program. National Grid learned that the distributed, localized ADA operating model in Worcester was too difficult to operate and maintain. In the Worcester pilot, when the SCADA System (EMS) lost communications to the field device, devices would continue to check for faults and operate without control room interaction. After a deliberation process with several vendors, National Grid adopted a centralized ADA model instead. A centralized ADA model brings field device data back through the communications network, performs centralized decision-making, provides operator intervention if required, and issues the commands to reclosers.

5.3.2 ADA Investment Progress Through PY2019

National Grid's 2018 GMP Annual Report planned 20 overhead reclosers (new or upgraded) for deployment in 2019. It planned an additional 50 new or upgraded overhead reclosers in 2020. However, its 2019 deployment was delayed and the 2019 targets were pushed to 2020. Figure 9 summarizes progress to date. The delay was due to the following combination of factors:

1. National Grid found risks with replicating its Worcester SES ADA strategy and explored the market for potential alternatives, working with several vendors to redesign its ADA strategy.
2. The new selected vendor made a design/manufacturing upgrade. National Grid standardized equipment to maximize efficiency and protection & control.
3. Materials arrived later than expected, reportedly due to the vendor having a backlog of orders.
4. The GMP program has faced challenges in internally reserving recloser devices due to National Grid requiring the equipment for customer-driven work.

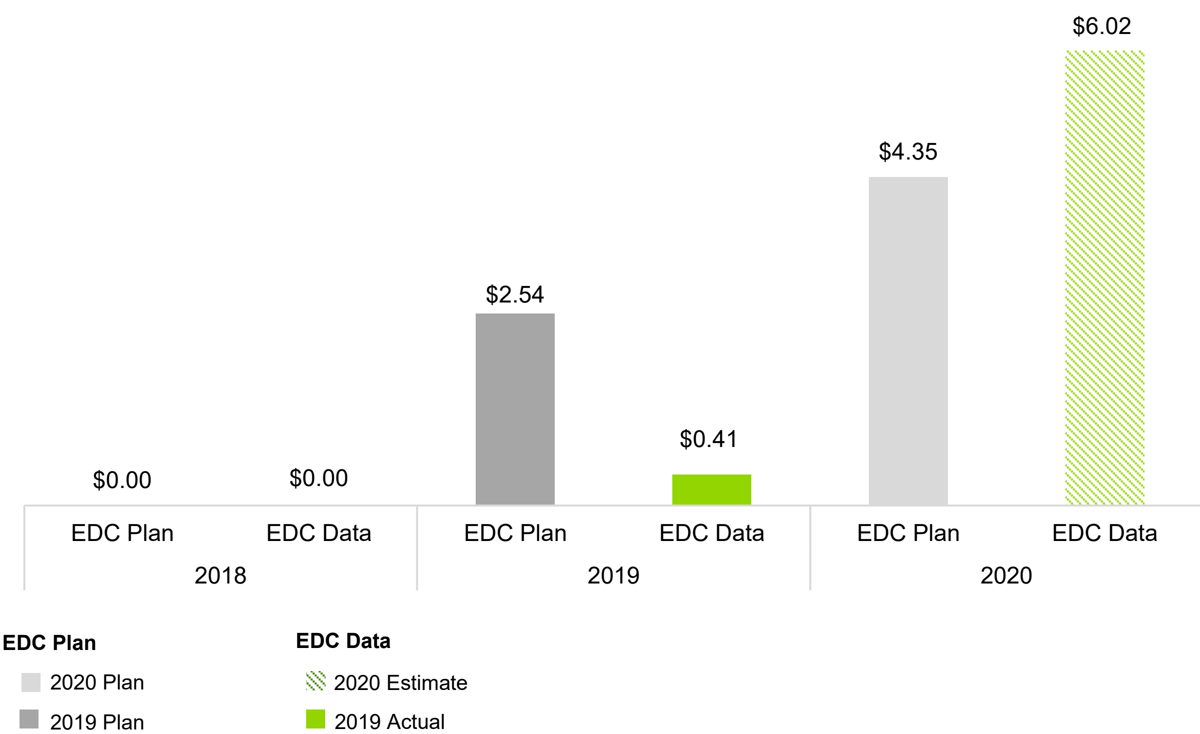
Figure 9. National Grid ADA Device Deployment, Planned vs. Actual



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

While deployment is currently behind schedule, National Grid's implementation schedule indicates it plans to catch up in 2020 and possibly exceed its GMP device target this year (Figure 9). As of February 2020, National Grid has begun engineering and design work for new SCADA-enabled overhead recloser locations and SCADA upgrades for existing locations. National Grid plans to deploy a total of 82 Reclosers in 2020. Reclosers are expected to be both new and retrofitted. Figure 10 shows a small amount of spend in 2019 for planning and engineering work.

Figure 10. National Grid ADA Spending, Planned vs. Actual



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Table 22 summarizes infrastructure metrics for National Grid ADA investments in 2019.

Table 22. PY 2019 Infrastructure Metrics for National Grid ADA

IM	Parameter	OH Recloser Installations
2018-2020 Original Plan[34]	Devices	70
	Spend (M)	$6.89
2018-2020 Revised Plan[35]	Devices	82
	Spend (M)	$6.43

[34] Based on data provided in the 2018 GMP Annual Report.

[35] Based on updated PY 2019 data provided by the EDCs.

IM		Parameter	OH Recloser Installations
IM-4	Number of devices or other technologies deployed	# Devices	0
		% Devices Deployed	0%
IM-5	Cost for Deployment	Total Spend (M)	$0.405
		% Spend	6%
IM-6	Deviation Between Actual and Planned Deployment for the Plan Year	% On Track (Devices)	0%
		% On Track (Spend)	16%
IM-7	Projected Deployment for the Remainder of the Three-Year Term	# Devices Remaining	82
		Spend Remaining (M)	$6.02

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Figure 11 illustrates National Grid's pole-top reclosers and controls, which include G&W Viper Overhead Reclosers and SEL control cabinets. National Grid plans to install three to four reclosers on chosen circuits. It plans to migrate to an ADMS in the coming years, at which point it may use a DMS FLISR application in place of its current NovaTech OrionLX substation automation platform. (See the Guidehouse 2019 ADMS Evaluation Report for more detail.)

Figure 11. National Grid Pole-top Reclosers and Controls

Source: National Grid

National Grid plans to operate the ADA devices it will install in 2020 using its public cellular network. It will use fiber optics (WAN), where available, as the backhaul for data transfer. National Grid recognizes that cellular may not be the preferred technology to operate grid-controlling assets like reclosers, especially in major outage events. Cellular may be hampered by busy signals and relatively slow data transfer speeds and may require backup power. National Grid is developing its communications strategy to modernize its communication network as proposed in the GMP. It expects to begin deploying a new FAN in 2022. When the new communications network is established, some rework may be required to integrate it with the existing ADA devices. (See the Guidehouse 2019 Communications Evaluation Report for more detail.)

5.3.3 Summary of Key Findings

Guidehouse evaluation findings for National Grid are summarized below:

- National Grid incorporated learnings from the Worcester SES in its Massachusetts GMP ADA program.
- National Grid's 2019 ADA deployment targets were not met due to a combination of factors.
- National Grid indicated it overcame initial delays and began engineering and designs to catch up to 2019 targets in the first half of 2020, and to achieve 2020 targets on schedule.
- National Grid plans to operate GMP ADA devices using a public cellular network until a new GMP-funded communication network is available. National Grid is developing its communications strategy and expects to begin deploying a new FAN in 2022.
- ADA benefits will begin to accrue immediately after deployment but will be maximized when the new communications network is established. Some rework may be required to integrate the ADA devices to the new communications system.

6.0 Conclusions and Recommendations

Guidehouse's ADA evaluation has confirmed that the EDCs are progressing towards their ADA plans. Table 23 summarizes key findings from Guidehouse's ADA evaluation.

Table 23. EDC-Specific ADA Findings

EDC	Summary of Findings
Eversource	• Eversource exceeded its 2019 deployment targets for all four ADA technology groups. • According to reported data, Eversource is on track to achieve GMP 2020 deployment targets. • Eversource selected feeders with high potential customer reliability impacts for ADA investments. It is also targeting lower cost locations first before moving to higher cost locations. • ADA deployment costs are tracking slightly higher than planned because more devices are being deployed than planned. • Ongoing SCADA-system upgrades and migration (non-GMP investment) are moderately impacting the 4 kV auto-reclosing loop investment.
National Grid	• National Grid also selected feeders with poor reliability performance and high potential customer benefits for ADA investments. • 2019 ADA deployment targets were not met due to a combination of factors. • National Grid reevaluated its ADA strategy after recognizing risks in replicating the ADA approach in the Worcester Smart Energy Solutions Pilot. Procurement delays also contributed to the delay. • National Grid reported it overcame initial delays. It has begun engineering and designs to catch up to 2019 targets in the first half of 2020, and to achieve 2020 targets. • National Grid plans to operate GMP ADA devices using a public cellular network until a new GMP-funded communication network is available. National Grid is developing its communications strategy and expects to begin deploying a new FAN in 2022. • ADA benefits will begin to accrue immediately after deployment but will be maximized when the new communications network is established. Some rework may be required to integrate the ADA devices to the new communications system.

Guidehouse also submits the following recommendations for EDC consideration in program year 2020.

- Guidehouse should work with the EDCs to implement an updated data collection template and format, using experience gained during the Q2'19 data collection process, to streamline data collection and make the process more efficient.
- EDCs should work with Guidehouse to develop a case-study approach to understanding reliability impacts due to ADA investments, and helping distinguish between how impacts are attributed to M&C vs ADA where these investments are deployed on same circuit.
- National Grid should consider updating the asset intake process so that equipment ordered for the Grid Modernization Program are marked or designated for that program is clearly identified as assigned/allocated to the GMP program. This may help prevent equipment from being diverted from inventory for other uses within the utility.
- National Grid should consider accelerating the communications deployment schedule to better align with the ADA deployment schedule to sooner realize full benefits of system automation.
- In the future, the EDCs could consider a more sophisticated statistical approach to assessing the reliability impacts of ADA investments. Such techniques require more outage data collection (e.g., outage cause), feeder characteristics (e.g., length, customers, location), equipment installed (e.g., number and type of reclosers), knowledge of other activities (e.g. timing of vegetation trimming), integration with weather data (e.g., hourly wind speed and direction) for feeders that receive the ADA investment and those that do not, but promise more insight on whether the ADA investments are yielding reliability improvements in MED and non-MED situations. This type of approach is more complex and requires additional data collection and more analysis, but it could control for weather and other factors effecting reliability.

Massachusetts Electric Distribution Companies

Massachusetts Grid Modernization Program Year 2019 Evaluation Report

Volt-VAR Optimization

April 1, 2020

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Disclaimer

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1.0 Executive Summary

1.1 Introduction

As a part of the Grid Modernization Plan, the Massachusetts electric distribution companies (EDCs) are making investments 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 the Department of Public Utilities (DPU) preauthorized VVO investments for each EDC toward meeting the DPU's grid modernization objectives for Program Year (PY) 2019. The focus of this evaluation is on VVO infrastructure metrics. As VVO investments and VVO commissioning are ongoing and VVO On / Off testing has not yet commenced, a performance metrics analysis is not provided for PY2019. Instead, analysis of performance metrics will be included alongside infrastructure metrics in the PY2020 VVO evaluation after sufficient VVO On / Off testing data have been collected.

1.2 Evaluation Process

As part of the Grid Modernization Plans (GMPs), the DPU requires a formal evaluation process (including an evaluation plan and evaluation studies) for the EDCs' preauthorized grid modernization plan investments. Guidehouse (formerly Navigant Consulting, Inc.) is completing the evaluation to ensure a uniform statewide approach and to facilitate coordination and comparability. The evaluations' objective is to measure the progress made toward the achievement of DPU's grid modernization objectives. The evaluation uses the DPU-established infrastructure metrics and performance metrics (discussed in Section 2.1.3) to meet the DPU's evaluation objectives.

Table 1 illustrates the key infrastructure metrics and performance metrics relevant for the VVO evaluation by EDC.[1] Further detail surrounding infrastructure metrics and performance metrics is provided in Section 4.1 and Section 4.2 respectively.

Table 1. VVO Evaluation Metrics

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 three-year term	✓	✓	✓
PM	VVO Baseline	✓	✓	

[1] Note that Unitil is excluded from the VVO performance metrics analysis. Changes to the original plan for VVO deployment has delayed the deployment of VVO devices. Therefore, no VVO On / Off testing will be occurring during the 2018 through 2020 timeframe. Further, Unitil does not have the necessary pre-period hourly voltage and power data for the feeders spanning the 2018 through 2020 time period. However, Unitil, as part of its grid modernization plan, is installing the necessary SCADA equipment to measure the necessary pre-period hourly voltage and power data for feeders beyond the 2018 through 2020 time period. VVO investment.

Type	VVO Evaluation Metrics	ES	NG	UTL
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	✓	✓	✓

Source: Guidehouse Stage 3 Evaluation Plan

The data supporting the infrastructure metrics and performance metrics have been provided to the evaluation team by the EDCs. Guidehouse presents results from analysis of infrastructure metrics data in Section 5.0. The performance metrics will be based on statistical analyses performed by the evaluation team using data provided by each EDC and are to be evaluated in 2021 to allow adequate data collection to be completed.

1.3 Data Management

Guidehouse worked with the EDCs to collect data to complete the VVO evaluation for the assessment of infrastructure metrics and performance metrics. Guidehouse used a consistent methodology across investment areas and EDCs for evaluating and illustrating EDC progress toward the GMP metrics.

Table 2 summarizes data sources used throughout the evaluation of VVO in PY2019 and to be used in the evaluation of VVO in PY2020. Further detail on each of the data sources is provided in Section 3.1.

Table 2. VVO Data Sources

Data Source	Description
2018 Grid Modernization Plan Annual Report[2,3,4]	Planned device deployment and cost information from each EDC's 2018 GMP Annual Report Appendix 1[5,6,7] as the reference to track progress against the GMP targets. This data source is referred to as the "EDC Plan" in summary tables and graphs throughout the report.
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. Planned device deployment information and estimated spend for PY2020 was provided at the most granular level.
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 cover 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.

[2] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-120

[3] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-122

[4] Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-121

[5] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-120

[6] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-122

[7] Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2018. Submitted to Massachusetts DPU on May 1, 2019 as part of D.P.U. 15-121

Data Source	Description
Additional VVO Data Required for Performance Metrics	Includes data on feeder characteristics, time-series data measuring voltage, real power, etc.), time-series energy data for large distributed-generation facilities, VVO system information including VVO state changes between on and off states and any other VVO modes, and hourly weather data from selected weather stations.

Source: Guidehouse

Guidehouse reviewed all data provided upon receipt of requested data. Guidehouse conducted a detailed QA/QC of data inputs used in analysis of infrastructure metrics and performance metrics. These QA/QC steps include checks to confirm each of the required data inputs are accounted for and can be incorporated into analysis. A summary of some of the QA/QC steps conducted for infrastructure metrics and performance metrics is provided in Table 3. A more comprehensive summary is provided in Section 3.2.

Table 3. Summary of QA/QC Steps Used for Evaluation

VVO Evaluation Area	QA/QC Steps
Infrastructure Metrics	• Check for potential errors in how Guidehouse forms were filled out (e.g., circuit information provided in the wrong field) • Flag missing or incomplete information • Detect large variation in the unit cost of commissioned devices • Identify variance in the January 1 through June 30, 2019 data provided last year, and the work order-level data provided for PY2019 • Identify variance between the aggregated year-end total information and work order-level data (applicable to Eversource only) • Flag deviation between 2018 GMP Annual Report (filed May 1, 2019) and actual deployment and spend
Performance Metrics	• Ensure time series data cover each feeder receiving VVO investments and include variables needed to facilitate analysis of performance metrics, including voltage and real power and reactive or apparent power • Ensure time series data are complete in time and extent of devices and do not include erroneous data (e.g., interpolated values and outliers) • Verify interval data have been provided for large distributed generation facilities • Verify voltage complaints data have been received for each feeder receiving VVO investments and are at an adequate level of detail for analysis

Source: Guidehouse

After data are received, Guidehouse provides status update memos that summarize the QA/QC to the EDCs, confirming receipt of the datasets and indicating quality. Additional follow-up based on standing questions is required to ensure all EDC-provided data can be used in analysis.

1.4 Findings

Table 4 includes the infrastructure metrics results through PY2019 for all EDCs. No feeders have been VVO enabled, as VVO device deployment and VVO commissioning are still in progress for all three EDCs. Further detail surrounding findings for each of the infrastructure metrics are provided in the following subsections.

Table 4. 2019 Infrastructure Metrics for VVO Progress

Infrastructure Metrics		Parameter	Progress thru. PY2019		
			Eversource	National Grid	Unitil
2018 – 2020 Original Plan[8]		# Devices Commissioned	324	160	37
		# Feeders with VVO Enabled	26	16	0
		Total Spend, $M	$13.0M	$11.6M	$1.5M
2018 – 2020 Revised Plan[9]		# Devices Commissioned	367	81	225
		# Feeders with VVO Enabled	26	16	3
		Total Spend, $M	$12.3M	$3.1M	$2.9M
IM-4	Number of Devices/ Technologies Deployed	# Devices Commissioned	337	6	0
		% Devices Commissioned	92%	7.4%	0%
		# Feeders with VVO Enabled	0	0	0
		% Feeders with VVO Enabled	0%	0%	0%
		IT Work Current State	Started	Started	Not Started
IM-5	Cost for Deployment	Total Spend	$8.2M	$310k	$60k
		% Spend	66%	8.4%	2.2%
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Devices)	116%	9%	0%
		% On Track (Spend)	70%	9%	8%
		% On Track (Feeders with VVO Enabled)	N/A	N/A	N/A
IM-7	Projected Deployment in PY2020	# Devices Remaining	30	75	225
		# Feeders Remaining	26	16	3
		Spend Remaining	$4.2M	$2.8M	$2.8M

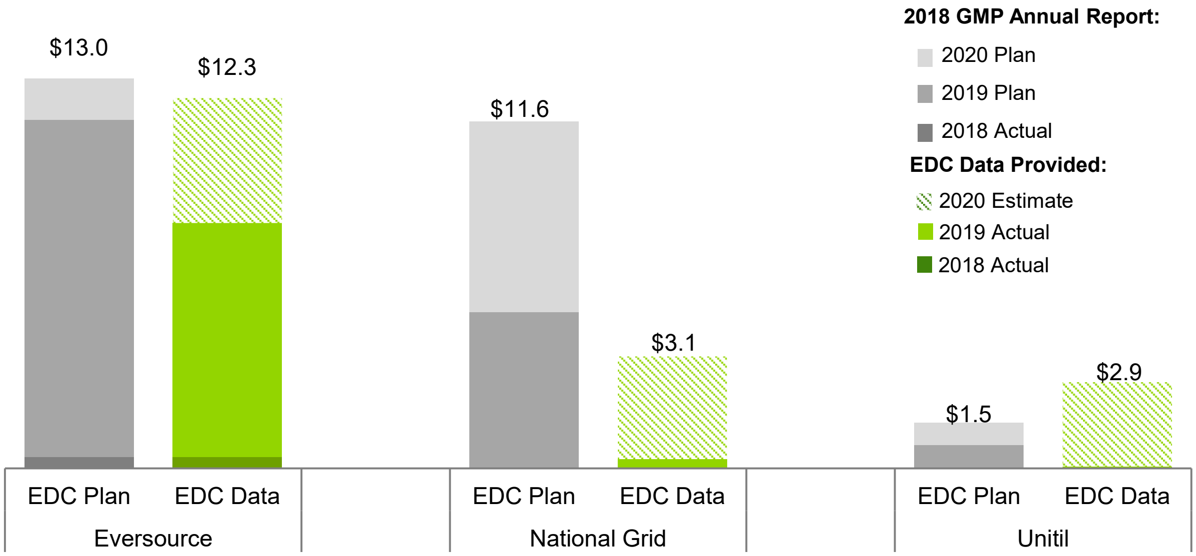
Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Actual spending in PY2019 was less than anticipated for all EDCs. Eversource and National Grid's revised 2018-2020 estimated total spend is lower than originally anticipated while Unitil's revised 2018-2020 estimated spend is higher than originally anticipated. Figure 4 differentiates between the original planned spend per the 2018 GMP Annual Report and the actual/updated projected spend based on the EDC data provided.

[8] Based on data provided in the 2018 GMP Annual Report.

[9] Based on updated PY 2019 data provided by the EDCs.

Figure 1. VVO Planned vs. Actual Spend (2018 – 2020, $M)



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Infrastructure metrics findings for PY2019 show that the EDCs are behind where they had anticipated in their 2018 GMP Annual Reports. Eversource experienced delays in permitting and structural redesigns. National Grid and Unitil faced slow vendor lead times. Unitil experienced higher than expected feeder-level VVO device needs and needed to change its approach to the VVO investment area. Intricacies such as these have slowed the rate of VVO device deployment.

Despite slower than anticipated VVO investment deployment, two of the three EDCs are slated to finish VVO investments at or below planned costs, primarily due to reduced costs of IT work and a lower than expected number of devices needed across VVO feeders.

In addition, the EDCs are slated to make significant headway in 2020. In particular:

- Eversource is finalizing the last of its VVO device deployments. These devices are in the construction and design phases and will be installed and commissioned in time for VVO On / Off testing to begin for all feeders by Summer 2020.
- National Grid is completing VVO device deployment and VVO commissioning during Spring and Summer 2020. VVO enablement is expected by June 2020 for all feeders, with VVO On / Off testing expected to begin by Summer 2020, potentially earlier if VVO server setup is completed early.
- Unitil is working aggressively to deploy devices on feeders substation-by-substation. Deployment of Townsend VVO investments is expected to be completed by early Summer 2020, and VVO is expected to be enabled by the end of 2020. Deployments of Lunenberg and Summer Street VVO investments are expected to be completed in Fall 2020, with VVO expected to be enabled in Spring 2021 and Summer 2021, respectively.

In 2020 and beyond, Guidehouse recommends that:

- To provide results for reporting of performance metrics in 2021, continue with rapid pace of VVO device deployment in early 2020 to ensure adequate data (specifically VVO On / Off data) are collected for the analysis.
- Where possible, conduct VVO device deployment and VVO IT system commissioning in tandem to reduce the amount of time needed for post-deployment VVO commissioning.
- Each EDC should discuss the role of load balancing, phase balancing in the deployment of VVO, and why neither were chosen to be conducted.
- Once VVO is ready for On / Off testing, EDCs follow VVO On / Off cycling for at least 9 months, covering one full summer, one full winter, and one of either the spring or fall shoulder seasons.
- Where possible, National Grid should accelerate the VVO On / Off testing start date to June 1, 2020 from July 1, 2020 to ensure 9 months of VVO On / Off testing can cover one full summer, one full winter, and one of either the spring or fall shoulder seasons.
- EDCs should continue tracking complaints along feeders receiving VVO investment to ensure the analysis of voltage-related complaints is feasible in 2021.
- EDCs should continue discussions with Guidehouse throughout 2020, as analysis of performance metrics will begin to be fine-tuned around nuances surrounding each of the VVO feeders, including:
  - Construction of baselines for analysis of performance metrics
  - Distributed generation penetration, and effects of feeders with high penetration rates on analysis of performance metrics
  - Customer counts per feeder, especially where some feeders have <10 customers

2.0 Introduction to Massachusetts Grid Modernization

A brief background to the Grid Modernization Evaluation process is provided in this section along with 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.

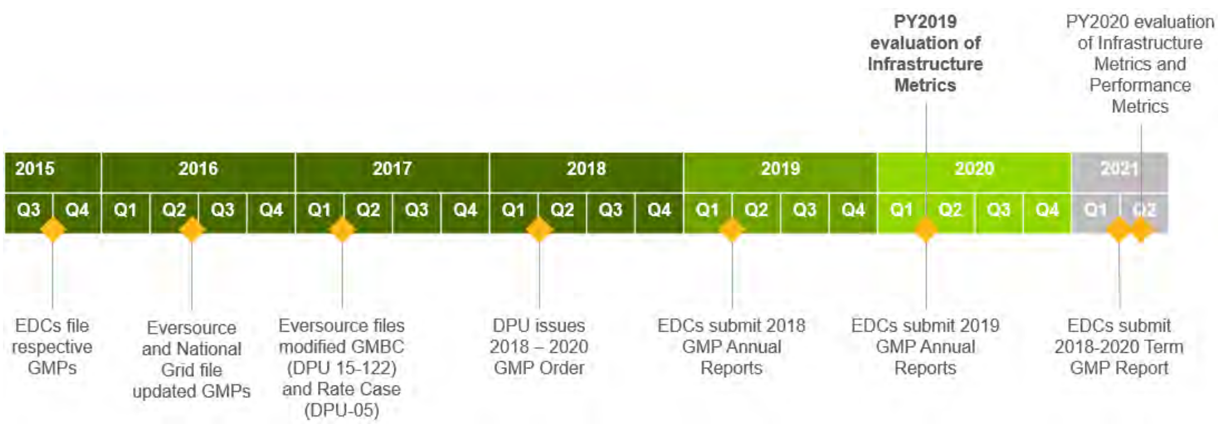
2.1 Massachusetts Grid Modernization Plan Background

On May 10, 2018, the Massachusetts Department of Public Utilities (DPU) issued its Order[10] regarding the individual Grid Modernization Plans (GMPs) filed by the three Massachusetts electric distribution companies (EDCs): Eversource, National Grid, and Unitil.[11,12] 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. These preauthorized GMP investments will advance the achievement of DPU's grid modernization objectives:

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

As part of the GMPs, the DPU determined that a formal evaluation process for the preauthorized GMP investments, including an evaluation plan and studies, was necessary to help ensure that the benefits are maximized and achieved with greater certainty. Figure 2 highlights the filing background and timeline of the GMP order and the evaluation process.

Figure 2. MA Grid Modernization Timeline by Program Year



Source: Guidehouse review of the DPU orders and GMP process

[10] Massachusetts D.P.U. 15-120; D.P.U. 15-121; D.P.U. 15-122 (Grid Modernization) Order issued May 10, 2018

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

[12] On June 16, 2016, Eversource and National Grid each filed updates to their respective grid modernization plans

In addition, 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)

This report covers the Program Year (PY) 2019 evaluation of infrastructure metrics and focuses on the Volt/VAR Optimization (VVO) investment area. The following subsection discusses these investment areas in greater detail.

2.1.1 Investment Areas

Table 5 summarizes the preauthorized GMP investment.

Table 5. Overview of Investment Areas

Investment Area	Description	Goal/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
Advanced Distribution Automation (ADA)	Isolation of outage events with automated backup for 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/Advanced Load Flow (ADMS and ALF)	New capabilities in real-time system control with investments in developing accurate system models and enhancing SCADA and outage management systems to control devices for system optimization and provide support for distribution automation and VVO with high penetration of distributed energy resources (DER)	Enables high penetration of DER by supporting the ability to control devices for system optimization, ADA, and VVO
Communications/IoT (Comms)	Fiber middle mile and field area communications systems	Enables the full benefits of grid modernization devices to be realized
Workforce Management (WFM)	Investments 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

The Massachusetts preauthorized budget for grid modernization varies by investment area and EDC. Eversource has 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 is $82.2 million, with ADMS and ALF representing almost 60% ($48.447 million). Unitil's preauthorized budget is $5.5 million and VVO makes up 40%% ($2.2 million). Table 6 shows the budget for each investment area by EDC.

DPU added flexibility to these budgets based on changing technologies and circumstances. For example, EDCs can shift funds across the different preauthorized investments if a reasonable explanation for these shifts is supplied.

Table 6. 2018-2020 GMP Preauthorized Budget, $M

Investment Areas	Eversource	National Grid	Unitil	Total
ADA	$44.0	$13.4	N/A	**$57.4**
ADMS/ALF	$17.0	$48.4	$0.7	**$66.1**
Comms	$18.0	$1.8	$0.8	**$20.6**
M&C	$41.0	$8.0	$0.75	**$49.8**
VVO	$13.0	$10.6	$2.2	**$25.8**
WFM	N/A	N/A	$1.0	**$1.0**
2018-2020 Total	$133	$82.2	$5.5	**$220.7**

Source: DPU Order, May 10, 2018

2.1.2 Evaluation Goal and Objectives

As part of the GMPs, the DPU requires a formal evaluation process (including an evaluation plan and evaluation studies) for the EDCs' preauthorized grid modernization plan investments. Guidehouse (formerly Navigant Consulting, Inc.) is completing the evaluation to ensure a uniform statewide approach and to facilitate coordination and comparability. The evaluations' objective is to measure the progress made toward the achievement of DPU's grid modernization objectives. The evaluation uses the DPU-established infrastructure metrics and performance metrics (discussed in Section 2.1.3) to meet the DPU's evaluation objectives.

2.1.3 Metrics for Evaluation

The evaluation involves both infrastructure metrics and performance metrics for each investment area.

2.1.3.1 Infrastructure Metrics

Infrastructure metrics were designed to evaluate the deployment of the GMP investments. The infrastructure metrics are summarized in detail in Table 7.

Table 7. Infrastructure Metrics Overview

Metric	Description	Applicable IAs	Metric Responsibility
System Automation Saturation	Measures the quantity of customers served by fully or partially automated devices.	M&C, ADA	EDC
Number and Percent of Circuits with Installed Sensors	Measures the total number of circuits with installed sensors which will provide information useful for proactive planning and intervention.	M&C	EDC
Number of Devices Deployed and In Service	Measures how the EDC is progressing with its GMP from an equipment and/or device standpoint.	All IAs	Evaluator
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
Deviation Between Actual and Planned Deployment for the Plan Year	Measures how the EDC is progressing under its GMP on a year-by-year basis.	All IAs	Evaluator
Projected Deployment for the Remainder of the Three-Year Term	Compares the revised projected deployment with the original target deployment as the EDC implements its EDC.	All IAs	Evaluator

Source: Guidehouse review of infrastructure metric filings

2.1.3.2 Performance Metrics

Table 8 summarizes the performance metrics, which are used to evaluate the performance of the GMP investments. The VVO performance metrics are discussed throughout this report and will be quantified as part of the PY2020 evaluation.

Table 8. Performance Metrics Overview

Metric	Applicable IAs
VVO Baseline	VVO
VVO Energy Savings	VVO
VVO Peak Load Impact	VVO
VVO Distribution Losses without AMF (Baseline)	VVO
VVO Power Factor	VVO
VVO – GHG Emissions	VVO
Voltage Complaints	VVO
Increase in Substations with DMS Power Flow and Control Capabilities	ADMS/ ALF
Control Functions Implemented by Circuit	ADMS/ ALF
Numbers of Customers that benefit from GMP funded Distribution Automation Devices	ADA
Grid Modernization investments' effect on outage durations	M&C, ADA
Grid Modernization investments' effect on outage frequency	M&C, ADA
Advanced Load Flow – Percent Milestone Completion	ADMS/ ALF
Protective Zone: Average Zone Size per Circuit* (Eversource)	M&C, ADA
Customer Minutes of Outage Saved per Circuit* (Unitil)	M&C, ADA
Main Line Customer Minutes of Interruption Saved* (National Grid)	M&C, ADA

Source: Stamp Approved Performance Metrics, July 25, 2019.
** Note that these metrics primarily apply to ADA, but will be completed for M&C as well given interest in understanding how to separately measure the impacts of these two investment areas.*

2.2 Volt/VAR Optimization (VVO) Investment Area Overview

As a part of grid modernization, the Massachusetts EDCs are making investments 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's objective is to reduce circuit demand and energy consumption by flattening and lowering the voltage profile on the circuit 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.

As identified in the May 1, 2019 Grid Modernization annual reports, the VVO investments are planned to total $25.6 million from 2018 to 2020 ($13 million by Eversource, $11.6 million by National Grid, and $1.5 million by Unitil). 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.

2.2.1 VVO Timeline

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 9 provides the four phases and a brief description of each.

Table 9. VVO Deployment Phases

Phase	Description
VVO Investment	Deployment and installation of VVO devices, including but not limited to capacitor banks, 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 pre-determined cycling schedule.

Source: Guidehouse

The four core VVO deployment phases are at varying levels of completion by EDC. The status of each deployment phase is detailed by EDC in the table below. Further detail is provided for all EDCs in Section 5.0.

Table 10. VVO Deployment Timeline by Phase, All EDCs

Phase	3-yr. GMP Estimated Timeframe[1]		
	Eversource	National Grid	Unitil
VVO Investment	Spring 2020 (in progress)	Winter 2019/2020 (in progress)	Calendar Year 2020 (in progress)
VVO Commissioning	Spring 2020 (in progress)	Spring 2020 (plan)	Summer 2020 – Winter 2020/2021 (plan)
VVO Enabled Date	Spring 2020 (plan)	Spring 2020 (plan)	Winter 2020/2021 – Summer 2021 (plan)
VVO On/Off Testing Period	Summer 2020 (plan)	Summer 2020 (plan)	Winter 2020/2021 – Summer 2021 (plan)

Source: Guidehouse review of EDC data

2.2.2 VVO Investment Devices

One of the main focuses of this report are the devices deployed as part of the VVO investment phase. Table 11 defines these assets.

Table 11. Description of Devices Deployed Under VVO Investment

Device	Description
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.
Line Sensors	Voltage sensors, which relay verified field measurements to allow VVO algorithm to regulate voltage and reactive power appropriately.
Load Tap Changer (LTC) Controls	Transformer load tap changers, which automatically adjust feeder voltage based on local measurement. First of the two devices required in order to regulate voltage on a distribution circuit.
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 circuit.

Source: Guidehouse

2.2.3 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.[13] Table 12 illustrates the key infrastructure metrics and performance metrics relevant for the VVO evaluation.

Table 12. 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 three-year 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	✓	✓	✓

Source: Guidehouse Stage 3 Evaluation Plan

The data supporting the infrastructure metrics have been provided to the evaluation team by the EDCs. Guidehouse presents results from analysis of infrastructure metrics data in Section 5.0. The performance metrics will be based on statistical analyses performed by the evaluation team using data provided by each EDC and are to be evaluated in 2021 to allow data collection to be completed

The VVO measurement and verification (M&V) objectives and associated research questions that will be addressed in the report are summarized in Table 13. The scope of the VVO 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 13. 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?
Energy and Peak Savings by Feeder (device deployment)	• How much energy savings has been realized from device deployment 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 much energy savings has been realized from VVO operating on VVO-enabled feeders? • What is the impact on peak load from VVO operating on VVO-enabled feeders? • How much GHG emissions reduction has been 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 Evaluation Plans

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

3.0 VVO Data Management

Guidehouse worked with the EDCs to collect data to complete the VVO evaluation for the assessment of infrastructure metrics and performance metrics. The sections that follow highlight data sources and data QA/QC processes followed by Guidehouse in the evaluation of infrastructure and performance metrics.

3.1 Data Sources

Guidehouse used a consistent methodology (across investment areas and EDCs) for evaluating and illustrating EDC progress toward the GMP metrics. The subsections that follow summarize each of the data sources used to evaluate infrastructure metrics.

3.1.1 2018 Grid Modernization Plan Annual Report

Guidehouse used the planned device deployment and cost information from each EDCs' 2018 GMP Annual Reports, which were filed on May 1, 2019. Additional deployment metrics, progress, cost, and plan details for the 2018 program year were also provided in each EDC's Annual Report Appendix 1, filed on January 31, 2020.[14] These filings served as the sources for planning data in this report[15] and are referred collectively as the EDC "Plan" for each EDC in summary tables and figures throughout this report. Table 14 summarizes the planned and actual deployment and spend data and specifies the color used to represent each in the remainder of the report.

Table 14. Data Used for the EDC Plan

Representative Color	Data	Description
	2020 Plan	Projected 2020 unit deployment/ total spend
	2019 Plan	Estimated 2019 unit deployment/ total spend
	2018 Actual	Actual reported unit deployment and spend in 2018

Source: EDCs' 2018 GMP Annual Report Appendix 1 filed July 31, 2020

Guidehouse used the Feeder Status tab of the 2018 GMP Annual Report Appendix 1 to obtain feeder characteristics including system voltage, total feeder count, customer count, feeder length, and annual peak load.

3.1.2 EDC Data Sources

Guidehouse collected device deployment data and VVO schedule information at the feeder-level using standardized data collection templates, developed by Guidehouse, for all EDCs: the All Device Deployment data and VVO Supplemental workbooks, respectively. These data sources are referred to as EDC Data in summary tables and

[14] The Appendix 1 filings were submitted after the specific required format was determined by the DPU.

[15] See Section 5 for specific details regarding 2018 GMP Annual Report data used for each EDC.

graphs throughout the report. The file versions used for the evaluation are summarized in Table 15.

Table 15. EDC Data Received for Analysis

Company	File Version used for Analysis[16]	
	All Device Deployment	VVO Supplemental
Eversource	Received 1/22/2020	Received 1/21/2020
National Grid	Received 2/11/2020	Received 1/15/2020
Unitil	Received 1/20/2020	Received 1/20/2020

Source: Guidehouse

3.1.3 EDC PY 2019 Device Deployment Data Template

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 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 were also collected. Planned device deployment information and estimated spend for PY2020 was provided at the most granular level (circuit or substation, where available). Table 16 summarizes the categories used for the revised planned and actual deployment and spend and specifies the color used to represent each in the remainder of the report.[17]

Table 16. EDC Device Deployment Data

Representative Color	Data	Description
Device Deployment Data		
	2020 Plan	Remaining units planned for 2020 where work has not yet started
	2020 Design	Units in the design phase and will be commissioned in 2020
	2020 Construction	Units under construction and will be commissioned in 2020
	2019 Commissioned	Units in service and commissioned in 2019
	2018 Commissioned	Units in service and commissioned in 2019
Spend Data		
	2020 Estimate	Additional cost anticipated in 2020
	2019 Actual	All actual spend that occurred in 2019
	2018 Actual	All actual spend that occurred in 2018

Source: Guidehouse analysis

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

[17] Eversource provided year-end total actual and planned devices commissioned and spend data. This aggregated data varied slightly from the work order data provided because of nuances in Eversource's work order accounting methodologies. Guidehouse used the aggregated total data for the 2018 and 2019 commissioned units and spend data. Work order data was used to capture progress towards their updated 2020 plan (per the aggregated year-end total data).

3.1.4 VVO Supplemental Data Template

The VVO supplemental data collection template includes additional information unique to the VVO investment area. Table 17 summarizes the information requested. Data were 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 and covers the baseline period through the VVO On / Off testing period.

Table 17. 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 date, and on/off testing
IT Work	Actual and updated planned IT work progress start / end dates and cost information[18]
Customer Demand Response (DR) Events	DR events (time-stamped log of any system-wide DR (or similar) events, for example: ISO-NE DR, EDC direct load control programs, EDC behavioral DR 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	Distributed generation information (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

3.1.5 Additional VVO Data Required for Performance Metrics

Table 18 summarizes the data inputs required for performance metrics analysis. All fields, except for the weather data, are obtained from the EDCs.

Table 18. Data Required for Performance Metrics Evaluation

Data Type	Description
EDC System information	• Feeder characteristics (e.g., rated primary voltage, rated capacity, feeder length, # customers [res, com, ind, 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) • Distributed generation (gross generation) energy data for large facilities (e.g., >100 kW)
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 from NOAA

Source: Guidehouse Stage 3 Evaluation Plan

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

3.2 Data QA/QC Process

Guidehouse reviewed all data provided for infrastructure metrics analysis and performance metrics analysis upon receipt of requested data. The following sections provide details on the data QA/QC processes adopted for the two analysis areas.

3.2.1 Infrastructure Metrics Data QA/QC

To ensure accuracy, Guidehouse conducted a high-level 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., circuit information provided in the wrong field)
- Missing or incomplete information
- Large variation in the unit cost of commissioned devices
- Variance in the January 1 through June 30, 2019 data provided last year, and the work order-level data provided for PY2019
- Variance between the aggregated year-end total information and work order-level data (applicable to Eversource only)
- Deviation between 2018 GMP Annual Report (filed May 1, 2019) and actual deployment and spend from our PY2019 data collection

During the QAQC process, some inconsistencies were noted between the 2018 GMP Annual Report filing (submitted May 1, 2019) and the Annual Report Appendix 1 filing (submitted January 31, 2020) for two EDCs.[19] Also, one EDC identified calculation or conceptual adjustments that would be required in their Appendix 1 filings.[20] These items are described at various points in the report below or otherwise noted in figure or table notes or in footnotes where appropriate. These inconsistencies did not adversely affect the evaluation results.

3.2.2 Performance Metrics Data QA/QC

The QA/QC of performance metrics data includes checks to confirm each of the required data inputs can 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 and 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)
- Interval data have been provided for large distributed generation facilities

[19] Unitil submitted updated information from their Appendix 1 filing, which was not available in time for the evaluation analysis. Additionally, Eversource excluded the 2018 to 2019 “carry-over” units in their 2019 planned unit totals within the Appendix 1 filing.

[20] Eversource’s planned 2020 cost breakdown by device type in the Annual Report Appendix 1 filing (submitted January 31, 2020) requires adjustment.

- 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. Additional follow-up based on standing questions is required to ensure all EDC-provided data can be applied to performance metrics analysis in 2021.

4.0 VVO Evaluation Process

This section presents a high-level overview of the Guidehouse methodologies for the evaluation of infrastructure metrics and performance metrics. Additional details about approaches used in the evaluation of infrastructure metrics and performance metrics are available in the Stage 3 Evaluation Plan.

This VVO evaluation is focused on infrastructure metrics for PY2019. VVO investments and VVO commissioning are ongoing and VVO On / Off testing has not begun; therefore, the evaluation of performance metrics is not provided for PY2019. Instead, the evaluation for PY2020 for VVO will include both infrastructure metrics and performance metrics, as sufficient VVO On / Off data required for performance metrics analysis will have been collected.

4.1 Infrastructure Metrics Analysis

Guidehouse annually assesses the progress of each of the EDCs toward enabling VVO on their feeders. Table 19 highlights the infrastructure metrics that were evaluated.

Table 19. Infrastructure Metrics Overview

IM	Metric	Calculation Parameters
IM-4	**Number of devices or other technologies deployed**	# Devices – *total number of devices that have been commissioned, are in the construction phase, and are in the design phase*
		% Devices Deployed – *percent of the total planned devices over the 3-yr. period that have been commissioned*
		# Feeders – *total number of feeders with VVO enabled*
		% Feeders – *percent of the total planned VVO feeders over the 3-year period that have VVO enabled*
		IT Work Current State – *how far along the EDC is with their IT work*
IM-5	**Cost for Deployment**	Total Spend – *total spend through PY2019, regardless of whether the device has been commissioned*
		% Spend – *percent of the total estimated spend over the 3-year GMP period*
IM-6	**Deviation Between Actual and Planned Deployment for the Plan Year**	% On Track (Devices) – *devices commissioned through PY2019 divided by the devices planned for commission through PY2019*
		% On Track (Spend) – *actual spend through PY2019 divided by the planned spend through PY2019*
		% On Track (Feeders) – *actual feeders with VVO enabled divided by the planned feeders with VVO enabled through PY2019*
IM-7	**Projected Deployment for the Remainder of the Three-Year Term**	# Devices Remaining – *How many devices remain to be commissioned in PY2020*
		# Feeders Remaining – *Feeders remaining for VVO to be enabled*
		Spend Remaining – *How much spend is estimated for PY2020*
		# Feeders Remaining – *How many VVO feeders remain to be enabled in PY2020*

Source: Guidehouse

Section 5.0 provides the results from the evaluation of infrastructure metrics. To evaluate infrastructure metrics, Guidehouse:

- Reviewed the EDC data provided to ensure the information provided accurately reflected their progress through PY2019 (see Section 3.2, “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

4.2 Performance Metrics Analysis

Performance metrics will be evaluated for each of the three EDCs, focusing on the utility and customer experience with VVO. Table 20 describes the performance metrics that will be evaluated for PY2020.

Table 20. Performance Metrics Overview

PM	Performance Metrics	Description
PM-1	**VVO Baseline**	Establishes a baseline impact factor for each VVO-enabled circuit 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 circuit against the annual circuit 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 circuit 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 circuit 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.

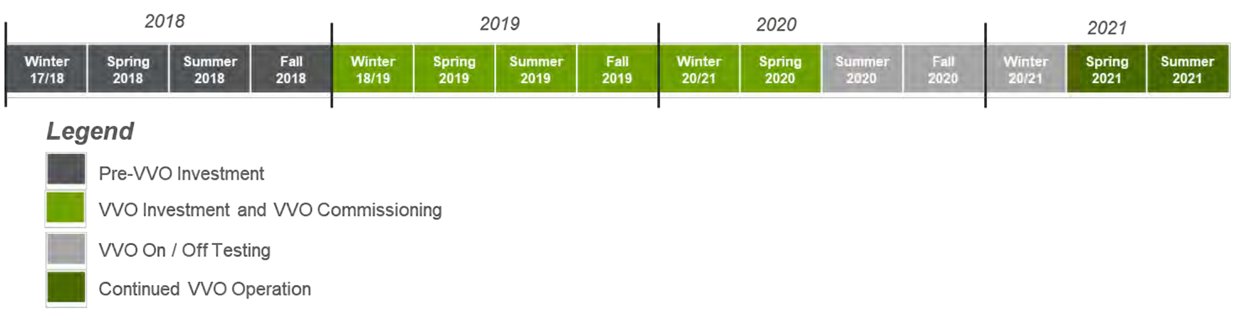
The metrics in Table 20 are all based on a M&V process, which uses statistical analysis to quantify the impacts the VVO system has on the customers it serves. Quantifying VVO performance metrics requires interval measurements of feeder-level voltage and power demand while the voltage and reactive power controls are operated in both baseline (non-VVO) and VVO modes.

For changes associated with VVO being enabled to be quantified, we recommend that that the EDCs continue a VVO On / Off cycling 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. The EDCs plan to follow this recommendation. Performance metrics analysis was not conducted for the PY2019 evaluation, as there are not sufficient data available for the VVO investment as VVO On / Off testing has not started. Data collection and QA/QC processes were ongoing in 2019 to ensure correct inputs were provided and that data are complete and to facilitate future analysis of performance metrics.

4.2.1 Performance Metrics Timeline

Figure 3 highlights the timeline of events that will be covered by performance metrics analysis for Eversource and National Grid.[21] VVO device deployment and VVO commissioning are in process for both EDCs. Eversource and National Grid have planned for VVO On / Off testing to be in effect for all feeders covered by VVO investments by Summer 2020 through Winter 2020/21, leaving 9 months of data covering summer and winter, and the fall shoulder seasons. Sufficient On / Off testing data through Winter 2020/21 will enable Guidehouse to complete evaluation and reporting on performance metrics in 2021.

Figure 3. Performance Metrics Timeline*



**Note: PM analysis timeline for Eversource and National Grid for VVO feeders identified in the May 1, 2019 filing.*
Source: Guidehouse analysis of EDC Data

5.0 Deployment Progress and Findings

Guidehouse presents findings from the infrastructure metrics analysis for the VVO investment area in the following subsections.

5.1 Statewide Comparison

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

5.1.1 Anticipated Impact on Massachusetts

As part of the 2018-2020 GMP, VVO deployment is anticipated to impact 52 feeders serving 78,922 (2.8% of all EDC customers) throughout Massachusetts. Table 21

[21] Unitil is excluded from this performance metrics timeline because, while Unitil investment for VVO has started, VVO will not be enabled until 12/31/2020 at the earliest. Throughout 2019 Unitil changed initial VVO plans in order to facilitate implementation of VVO as a feature of its ADMS. Changes to the original plan for VVO deployment has delayed the deployment of VVO devices considerably. Further, in the Stage 3 Plan, Guidehouse assumed pre-period data would be available. However, upon further investigation, Unitil does not have pre-period hourly voltage and power data for the feeders currently part of its VVO investment. Unitil is installing the ability to capture this data as part of the SCADA investments approved as part of its GMP.

highlights the anticipated impact by EDC. VVO investments are planned to be rolled out in substations located in the following cities and towns[22]:

- Eversource: Agawam, Amherst, and West Springfield
- National Grid: Stoughton, Malden, and Methuen
- Unitil: Fitchburg, Townsend, and Lunenburg

Table 21. Number of Feeders and Customers Covered by VVO Investment

VVO Impact	Eversource		National Grid		Unitil		Total	
	Feeders	Customers[23]	Feeders	Customers	Feeders	Customers	Feeders	Customers
System-Wide Total	2,234	1,427,000	1,114	1,320,100	45	29,900	3,393	2,777,000
2018-20 GMP Plan	26	35,900	16	34,300	10	8,722	52	78,922
% System Total	1.2%	2.6%	1.8%	2.6%	22.2%	29.2%	1.7%	2.8%

Source: Guidehouse analysis of 2018 GMP Annual Report Appendix 1

5.1.2 Approach to VVO

Each EDC has a unique approach to selecting feeders for VVO, deploying VVO devices, and implementing VVO software. Table 22 highlights the substations covered by VVO investment, the planned VVO On / Off testing period start date, and the number of VVO devices required as part of the VVO investment period for each EDC.[24] Specifics related to each EDC's approach to VVO are discussed in the following subsections.

Table 22. VVO Approaches and On / Off Testing by EDC

Company	Substations (Feeder Count)	Plan VVO On/Off Testing Start	VVO Investments Required (3-Yr. Total)			
			Capacitor Banks	Line Sensors[25]	Load Tap Changer (LTC) Controls	Voltage Regulators
Eversource	Agawam (7)	Spring 2020	22	54	2	15
	Piper (6)	Spring 2020	13	36	2	15
	Podick (7)	Summer 2020	19	57	2	44
	Silver (6)	Spring 2020	20	42	2	22
National Grid	E. Methuen (6)	Summer 2020	19	6	2	4
	Maplewood (4)	Summer 2020	17	4	1	1
	Stoughton (6)	Summer 2020	19	6	1	1

[22] Note that cities and towns listed for each EDC cover only the cities and towns in which substations are located. VVO feeders at these substations serve many more cities and towns than covered in this list.

[23] Data used to generate these counts were from 2018. Customer counts will be updated in 2019 Annual Report.

[24] For all the EDCs, VVO devices deployed prior to VVO enablement has been focused on the installation of equipment and commissioning of the VVO software. No load rebalancing has not been conducted during this process.

[25] Count represents 1-phase line sensors for Eversource and 3-phase line sensors for National Grid and Unitil

Company	Substations (Feeder Count)	Plan VVO On/Off Testing Start	VVO Investments Required (3-Yr. Total)			
			Capacitor Banks	Line Sensors[25]	Load Tap Changer (LTC) Controls	Voltage Regulators
Unitil	Townsend (3)	Fall 2020	5	12	1	6
	Lunenburg (2)	Spring 2021	4	23	0	23
	Summer St. (4)	Spring 2021	4	24	1	25

Source: Guidehouse analysis of 2018 GMP Annual Reports

5.1.3 VVO Timeline

VVO investment and VVO commissioning is in progress for all three EDCs. VVO is expected to be ready for On / Off testing for Eversource and National Grid by Summer 2020 and for Unitil in Winter 2020/21. Table 23 summarizes the expected timelines for completion of each of the four VVO investment phases for each EDC. The following subsections include specifics related to each EDC's VVO timeline.

Table 23. VVO Deployment Timeline by Phase and EDC

Phase	3 Year GMP Estimated Timeframe		
	Eversource	National Grid	Unitil
VVO Investment	Spring 2020 (in progress)	Spring 2020 (in progress)	Calendar Year 2020 (in progress)
VVO Commissioning	Spring 2020 (in progress)	Spring 2020 (in progress)	Summer 2020 – Winter 2020/2021 (plan)
VVO Enabled Date	Spring 2020 (plan)	Spring 2020 (plan)	Winter 2020/2021 – Summer 2021 (plan)
VVO On/Off Testing Period	Summer 2020 (plan)	Summer 2020 (plan)	Winter 2020/2021 – Summer 2021 (plan)

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.1.4 Infrastructure Metrics Results

Table 24 includes the infrastructure metrics results through PY2019 for all EDCs. No feeders have been VVO enabled, as VVO device deployment and VVO commissioning are still in progress for all three EDCs. Further detail surrounding findings for each of the infrastructure metrics are provided in the following subsections.

Table 24. 2019 Infrastructure Metrics for VVO Progress

Infrastructure Metrics	Parameter	Progress thru. PY2019		
		Eversource	National Grid	Unitil
2018 – 2020 Original Plan[26]	# Devices Commissioned	324	160	37
	# Feeders with VVO Enabled	26	16	0
	Total Spend, $M	$13.0M	$11.6M	$1.5M
2018 – 2020 Revised Plan[27]	# Devices Commissioned	367	81	225
	# Feeders with VVO Enabled	26	16	3
	Total Spend, $M	$12.3M	$3.1M	$2.9M

[26] Based on data provided in the 2018 GMP Annual Report.

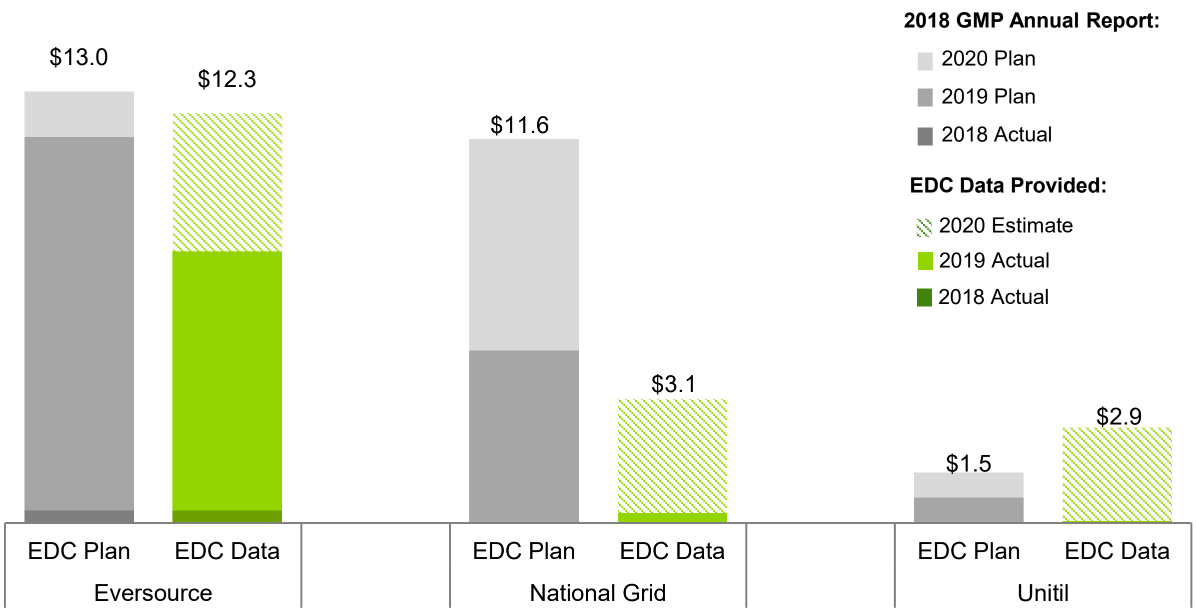
[27] Based on updated PY 2019 data provided by the EDCs.

Infrastructure Metrics		Parameter	Progress thru. PY2019		
			Eversource	National Grid	Unitil
IM-4	Number of Devices/Technologies Deployed	# Devices Commissioned	337	6	0
		% Devices Commissioned	92%	7.4%	0%
		# Feeders with VVO Enabled	0	0	0
		% Feeders with VVO Enabled	0%	0%	0%
		IT Work Current State	Started	Started	Not Started
IM-5	Cost for Deployment	Total Spend	$8.2M	$310k	$60k
		% Spend	66%	8.4%	2.2%
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Devices)	116%	9%	0%
		% On Track (Spend)	70%	9%	8%
		% On Track (Feeders with VVO Enabled)	N/A	N/A	N/A
IM-7	Projected Deployment in PY2020	# Devices Remaining	30	75	225
		# Feeders Remaining	26	16	3
		Spend Remaining	$4.2M	$2.8M	$2.8M

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Figure 4 highlights planned versus actual spend in VVO for each of the three EDCs. Further details on the differences between planned and actual spend are provided in each specific EDC's results sections.

Figure 4. VVO Planned vs. Actual Spend



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

PY2019's infrastructure metrics findings show that the EDCs are behind where they had anticipated in their 2018 GMP Annual Reports. Eversource experienced delays in permitting and structural redesigns. National Grid and Unitil faced slow vendor lead times, and Unitil experienced higher than expected feeder-level VVO device needs and needed to change its approach to the VVO investment area. Intricacies such as these have slowed the rate of VVO device deployment.

Despite slower than anticipated VVO investment deployment, two of the three EDCs are slated to finish VVO investments at or below planned costs, primarily due to the reduced costs of IT work and a lower than expected number of devices needed across VVO feeders.

EDCs are slated to make significant headway in 2020. In particular:

- Eversource is finalizing the last of its VVO device deployment. These devices are in the construction and design phases and will be installed and commissioned in time for VVO On / Off testing to begin for all feeders by Summer 2020.
- National Grid is completing VVO device deployment and VVO commissioning during Spring and Summer 2020. VVO enablement is expected by June 2020 for all feeders, with VVO On / Off testing expected to begin by July 1, 2020, potentially earlier if VVO server setup is completed early.
- Unitil is aggressively deploying devices on feeders substation-by-substation. The deployment of Townsend VVO investments is expected to be completed by early Summer 2020, and VVO is expected to be enabled by the end of 2020. The deployment of Lunenberg and Summer Street VVO investments is expected to be completed in Fall 2020, with VVO expected to be enabled in Spring 2021 and Summer 2021, respectively.

5.2 Eversource

This section discusses Eversource's VVO investment progress through PY2019 and projected PY2020 progress as compared to the 2018 GMP Annual Report.

5.2.1 Overview of GMP Deployment Plan

5.2.1.1 Approach to VVO

Eversource is making VVO investments across four substations, amounting to 26 feeders. In deployment planning, the focus was to ensure substations and feeders could be controlled from a single control room, achieve a mix of residential and commercial and industrial customers, and vary the amount of distributed generation. Substation selections were based on engineering analysis and coordination with grid modernization teams. This resulted in the selection of Agawam, Piper, Podick, and Silver substations.

Table 25 highlights the Eversource VVO feeder characteristics between 2018 and 2020. Feeder lengths and customer counts vary considerably. Consistent with planned rollout of the VVO investment, selected substations present a mix of distributed generation capacity across feeders, with distributed generation capacity ranging from 0 MW to 7.3 MW. Appendix A contains additional information related to the VVO feeders.

Table 25. Eversource VVO Feeder Characteristics

Substation	Feeder	Feeder Length (mi.)	2018 Customer Count	Annual Peak Load (MVA)	Distributed Generation (MW)
Agawam (13.8 kV)	16C11	24	858	4.4	1.6
	16C12	6	70	6.8	2.0
	16C14	15	1,611	6.4	0.1
	16C15	11	1,259	4.9	0.1
	16C16	22	2,547	8.2	2.3
	16C17	29	2,337	7.3	0.9
	16C18	21	2,981	6.3	0.5
Piper (13.8 kV)	21N4	33	2,649	8.8	1.5
	21N5	15	830	8.7	0.2
	21N6	15	760	4.6	0.4
	21N7	5	2	4.3	0.0
	21N8	9	552	8.9	0.1
	21N9	23	2,348	6.7	0.1
Podick (13.8 kV)	18G1	0	N/A	0.0	0.0
	18G2	4	9	0.5	0.0
	18G3	36	1,891	3.5	2.0
	18G4	34	2,292	4.9	5.4
	18G5	39	1,692	5.8	5.4
	18G6	37	1,225	5.1	3.0
	18G7	63	1,974	4.3	6.8
	18G8	45	1,026	7.6	7.3
Silver (13.8 kV)	30A1	36	2,410	8.1	0.8
	30A2	12	974	9.9	0.3
	30A3	11	240	8.8	0.1
	30A4	11	782	7.8	0.2
	30A5	21	1,596	4.9	0.5
	30A6	19	943	4.8	2.4

Source: 2018 GMP Annual Report, Appendix 1 filed January 31, 2020. Distributed Generation data was provided by the EDCs.

5.2.1.2 VVO Timeline

Eversource's VVO On / Off testing is expected to begin during Spring 2020 for all but the Podick substation, which is expected to begin VVO On / Off testing by June 1, 2020. Table 26 summarizes substation-specific progress in each of the four VVO investment phases. Where a phase has not been completed, an expected date of completion is provided.

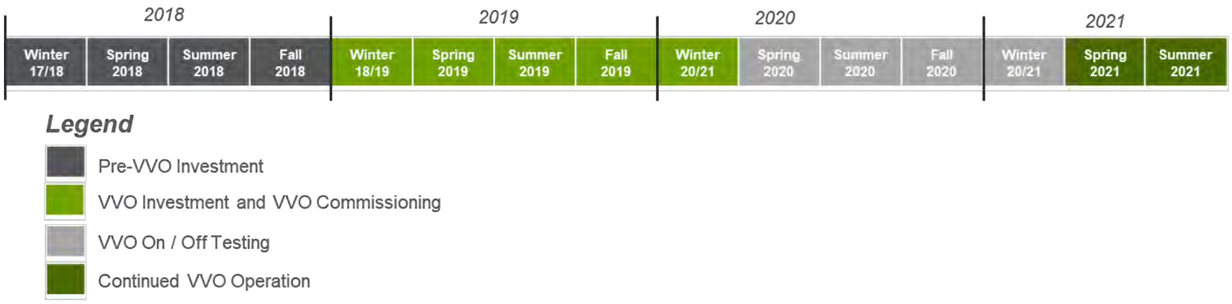
Table 26. Eversource VVO Deployment Progress by Phase and Substation

Phase	Agawam	Piper	Podick	Silver
VVO Investment	In Progress: 1/14/2019-1/31/2020	In Progress: 1/14/2019-2/29/2020	In Progress: 3/29/2019-3/31/2020	In Progress: 1/14/2019-3/31/2020
VVO Commissioning	In Progress: 11/1/2019-1/31/2020	In Progress: 11/1/2019-2/29/2020	In Progress: 11/1/2019-3/31/2020	In Progress: 11/1/2019-3/31/2020
VVO Enabled Date	Plan: 1/31/2020	Plan: 2/29/2020	Plan: 3/31/2020	Plan: 3/31/2020
VVO On/Off Testing Period	Plan: 4/01/2020	Plan: 5/01/2020	Plan: 6/01/2020	Plan: 5/01/2020

Source: Guidehouse analysis of EDC Data

The evaluation of infrastructure metrics currently spans spending and deployment under the VVO investment and VVO commissioning stages. Figure 5 highlights the key performance metric analysis periods for Eversource. Under current progress in VVO device deployment and VVO commissioning, Eversource plans to conduct VVO On / Off testing spanning the spring shoulder, summer, the fall shoulder, and winter. Analysis of performance will be provided in the 2021 report.

Figure 5. Eversource Performance Metrics Analysis Timeline*



**Note: Eversource PM analysis timeline for VVO feeders identified in the May 1, 2019 filing.*
Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.2.2 VVO Investment Progress through PY2019

Table 27 presents the infrastructure metrics results through PY2019 for each investment type related to Eversource's VVO investment area. The following subsections include details surrounding the findings for each infrastructure metric.

Table 27. 2019 Eversource Infrastructure Metrics for VVO Devices

IM	Metric	Parameter	Cap. Banks	Line Sensors	LTC Controls	Regulat-ors	IT Work	Total
IM-4	Number of Devices Deployed	# Devices Commissioned	71	189	8	69	N/A	337
		% Devices Deployed	96%	100%	100%	72%	N/A	92%
IM-5	Cost for Deployment	Total Spend, $M	$2.6	$0.7	$1.4	$2.4	$1.2	$8.2
		% Spend	100%	100%	100%	79%	25%	66%
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Devices)	93%	151%	80%	86%	N/A	116%
		% On Track (Spend)	None Planned	None Planned	113%	46%	23%	70%
IM-7	Projected Deployment in PY2020	# Devices Remaining	3	0	0	27	N/A	30
		Spend Remaining, $M	$0.0	$0.0	$0.0	$0.7	$3.5	$4.2

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 28 presents VVO enablement progress. VVO is expected to be enabled over all substations by the end of March 2020, and most feeders will be ready to begin On / Off testing by May 2020.

Table 28. 2019 Eversource Infrastructure Metrics for VVO Feeders

IM	Metric	Parameter	Number of Feeders
IM-4	Number of Devices/ Technologies Deployed	# Feeder with VVO Enabled	0
		% Feeders with VVO Enabled	N/A
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Feeders with VVO Enabled)	N/A
IM-7	Projected Deployment for the Remainder of the 3 Year Term	# Feeders Remaining for VVO Enablement	26

Source: Guidehouse analysis of EDC Data

Table 29 highlights the status of VVO investments through PY2019 for each device/investment type per the EDC data provided. Eversource has made significant progress toward its 3-year plan total, with 27 voltage regulators and three capacitor banks remaining to be installed. These remaining devices are expected to be installed by early Spring 2020. IT work has also been less costly than anticipated.

Table 29. Eversource VVO Deployment Progress

Device	Actual through PY2019		2020 Device Deployment Progress		3-Year Plan Total[11]	
	In-Service Units	Accrued Cost ($)	Construct-ion	Design	In-Service Units	Accrued Cost ($)
Capacitor Banks	71	$2.6M	3	0	74	$2.6M
Line Sensors	189	$0.7M	0	0	189	$0.7M
LTC Controls	8	$1.4M	0	0	8	$1.4M
Regulators	69	$2.4M	18	9	96	$3.0M
VVO IT Work	N/A	$1.2M	N/A	N/A	N/A	$4.7M
Total	**337**	**$8.2M**	**21**	**9**	**367**	**$12.4M**

Source: Guidehouse analysis of EDC Data

Table 30 presents VVO enablement progress by substation. To date, no VVO enablement has occurred as device deployment and VVO commissioning are still in progress. VVO is expected to be enabled over all substations by the end of March 2020. Thereafter, final adjustments to servers and IT systems will be made to ensure the systems are ready for VVO On / Off testing. This process is expected to be complete across most feeders by May 2020, at which point VVO On / Off testing will begin.

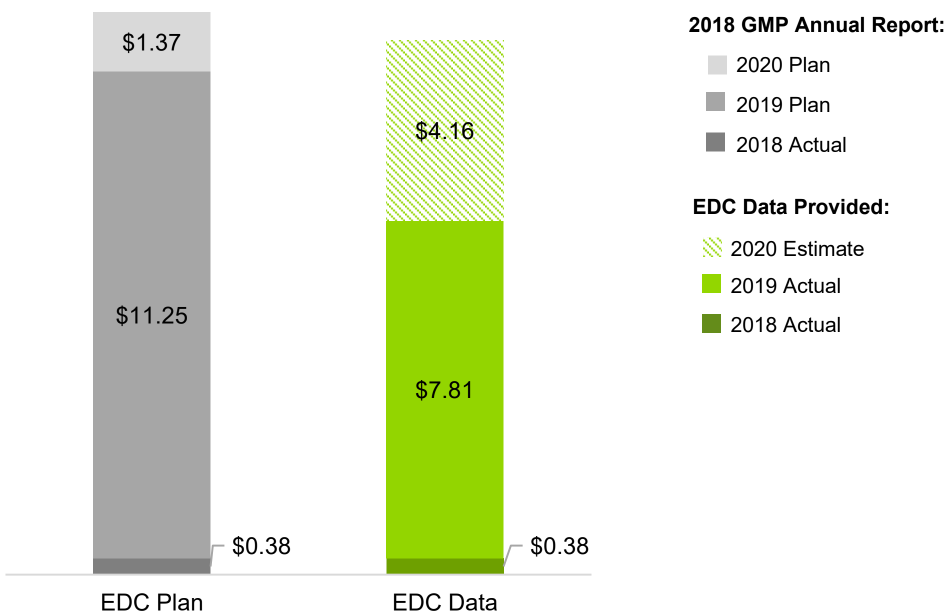
Table 30. Eversource VVO Enabled Progress by Substation

Substation	Anticipated VVO Enabled Date	Actual VVO Enabled Date	Current Status
Agawam	1/31/2020	N/A	Device deployment and VVO commissioning in progress
Piper	2/29/2020	N/A	Device deployment and VVO commissioning in progress
Podick	3/31/2020	N/A	Device deployment and VVO commissioning in progress
Silver	3/31/2020	N/A	Device deployment and VVO commissioning in progress

Source: Guidehouse analysis of EDC Data

Spending on VVO investments was lower than planned in 2019. This is due to 27 voltage regulators and three capacitor banks remaining to be deployed in 2020. In addition, spending on VVO IT work was lower than initially planned. As a result, both the cost through PY2019 and the overall 3-year estimated cost are lower than were anticipated in the 2018 GMP Annual Report. Figure 6 summarizes this finding.

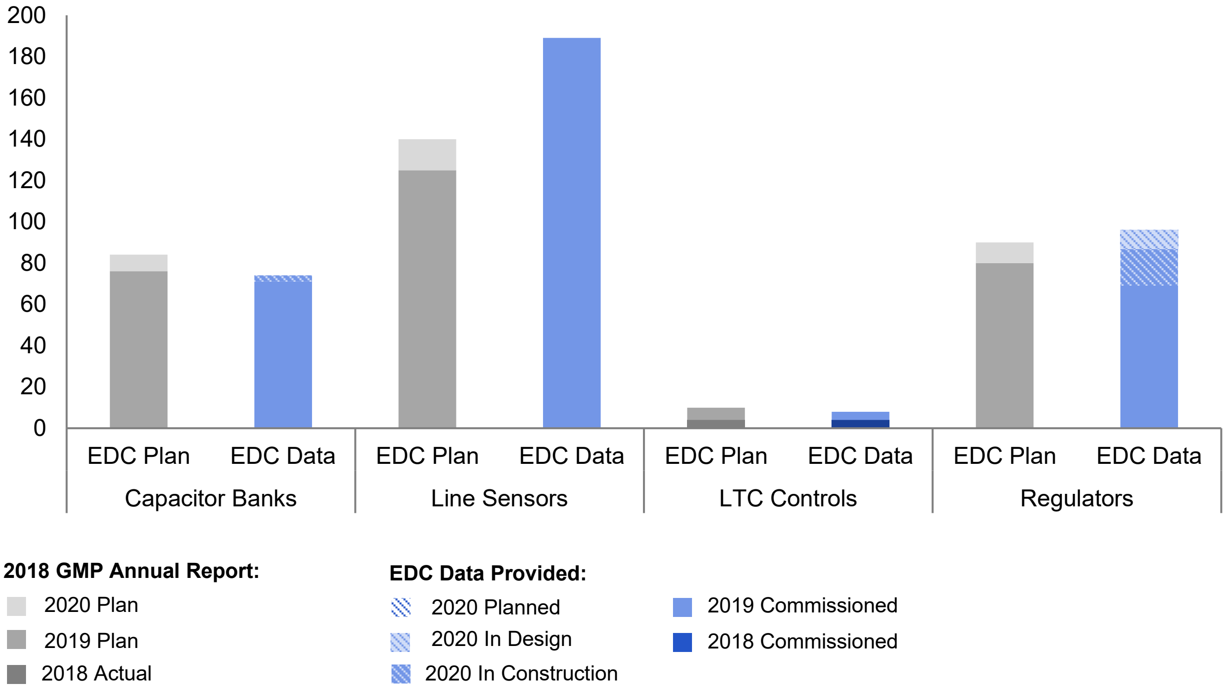
Figure 6. Eversource Total Spend Comparison (2018-2020, $M)



Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Figure 7 shows the actual device deployment for all device types compared to the projected deployment in the 2018 GMP Annual Report. Eversource saw lower deployment of capacitor banks and LTC controls, and increased deployment in line sensors and voltage regulators.[28]

Figure 7. Eversource Planned vs Actual Deployment (2018 – 2020, Unit Count)



Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 35 summarizes Eversource's planned versus actual VVO enablement and spend in 2018 through 2020. Actual VVO enablement is behind schedule, as five feeders were initially planned to be VVO enabled by the end of 2019. All VVO feeders are now expected to be enabled during the Spring 2020, with VVO On / Off testing slated to begin across all feeders by Summer 2020. Actual spend is consistently on track or lower than planned throughout the 2018-2019 timeframe. The revised plan spend is expected to be 95% of what was originally planned.

Table 31. Eversource Planned vs. Actual Year-over-Year Comparison

Data	2018	2019	2020	2018-2020
Cumulative Feeders with VVO Enabled				
EDC Actual Progress	0	0	N/A	N/A
EDC Original Plan[29]	0	5	26	26
% EDC Actual / EDC Plan	N/A	0%	N/A	N/A
EDC Revised Plan[30]	N/A	N/A	26	26
% EDC Revised Plan / EDC Plan	N/A	N/A	100%	100%
Spend				
EDC Actual Progress	$0.4	$7.8	N/A	N/A
EDC Original Plan	$0.4	$11.3	$1.4	$13.0
% EDC Actual / EDC Plan	100%	69%	N/A	N/A
EDC Revised Plan	N/A	N/A	$4.2	$12.4
% EDC Revised Plan / EDC Plan	N/A	N/A	304%	95%

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

5.2.3 Summary of Key Findings

Guidehouse's review of Eversource's VVO progress confirmed that Eversource is behind where they had anticipated in their 2018 GMP Annual Report. Key findings related to Eversource's progress includes:

- Eversource faced delays in permitting and structural redesign. Three capacitor banks and 27 voltage regulators remain for Eversource to complete its VVO investments. These devices are in the construction and design phases and will be installed and commissioned in time for VVO On / Off testing in Spring 2020.
- Both the cost through PY2019 and the overall 2018-2020 GMP estimated cost were lower than anticipated because of shifting remaining voltage regulator deployment to Q1 2020 and lower than anticipated IT cost.
- VVO On / Off testing is expected to begin for three of the four substations during Spring 2020. On / Off testing for the fourth substation is expected to begin at the start of Summer 2020.

5.3 National Grid

This section discusses National Grid's VVO investment progress through PY2019 and projected PY2020 progress as compared to the 2018 GMP Annual Report.

5.3.1 Overview of GMP Deployment Plan

5.3.1.1 Approach to VVO

National Grid plans to deploy VVO across three substations, amounting to 16 feeders, from 2018 through 2020. Selection of the substations and feeders was guided by a data modeling approach to identify potential feeders. The modeling was informed by physical characteristics, number of customers and benefit potential, historic and projected

[29] Based on 2018 GMP Annual Report Appendix 1 (filed January 31, 2020).

[30] Based on the EDC's updated projections for PY2020.

loading and capacity, and substation automation levels. This resulted in the selection of the East Methuen, Stoughton, and Maplewood substations.

Table 32 highlights National Grid VVO feeder characteristics between 2018 and 2020. Similar to Eversource, feeder lengths and customer counts vary considerably. Selected substations also present a mix of distributed generation capacity across feeders, with distributed generation capacity ranging from 0.3 MW to 2.9 MW. Appendix B contains additional information related to the VVO feeders.

Table 32. National Grid VVO Feeder Characteristics

Substation	Feeder	Feeder Length (mi.)	2018 Customer Count	Annual Peak Load (MVA)	Distributed Generation (MW)
E. Methuen (13.2 kV)	74L1	38	3,016	10.6	2.9
	74L2	17	1,586	7.4	0.7
	74L3	20	3,236	7.8	1.0
	74L4	9	1,559	6.9	0.9
	74L5	55	2,797	9.0	0.8
	74L6	8	1,697	5.6	0.3
Stoughton (13.8 kV)	913W17	14	1,351	4.9	1.4
	913W18	12	1,493	4.5	0.3
	913W43	32	2,143	6.9	0.8
	913W47	16	1,697	6.6	0.3
	913W67	13	746	2.3	0.5
	913W69	31	3,485	9.6	1.1
Maplewood (13.8 kV)	16W1	17	3,488	10.2	0.6
	16W2*	10	3,274	9.5	0.5
	16W3	13	2,864	7.2	0.4
	16W4	8	1,109	7.0	0.7
	16W5	8	2,043	5.8	0.7
	16W6*	21	4,537	10.5	1.0
	16W7*	14	3,788	11.1	0.9
	16W8*	16	3,256	9.7	0.9

** Additional feeders that were not included in the original set of 16 reported for 2018 – 2020 VVO investment.*
Source: 2018 GMP Annual Report, Appendix 1 filed January 31, 2020. Distributed Generation data was provided by the EDCs.

National Grid's VVO deployment involved continency planning. In addition to the four circuits that were originally planned for Maplewood for 2018–2020, National Grid targeted four other Maplewood feeders in the event that some select feeders were not able to receive VVO investments. Due to contingency planning, a total of 20 feeders are receiving VVO investments. These additional four feeders will not be evaluated.

National Grid's approach to VVO investment prior to VVO enablement focused on deploying capacitors, regulators, LTC devices, and line sensors. LTC devices and regulators were deployed first. No load balancing is occurring during this time, with plans for some feeders to be phase balanced in early 2020. After these deployments, VVO commissioning is to occur and includes device-level, feeder-level, and aggregate (whole system) vendor commissioning. As discussed under the VVO timeline, VVO device deployment and VVO commissioning is occurring rapidly and VVO will be enabled by June 2020 for all feeders.

5.3.1.2 VVO Timeline

For National Grid, VVO On / Off testing is expected to begin during Summer 2020. Table 33 summarizes substation-specific progress in each of the four VVO investment phases. Where a phase has not been completed, an expected date of completion is provided.

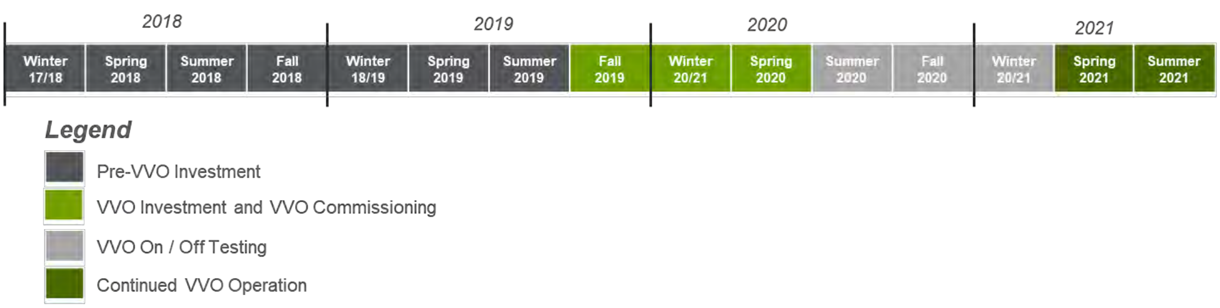
Table 33. National Grid VVO Deployment Progress by Phase and Substation

Phase	E. Methuen	Maplewood	Stoughton
VVO Investment	In Progress: 1/12/2020 – 2/28/2020	In Progress: 1/12/2020 – 4/15/2020	In Progress: 11/15/2019 – 2/28/2020
VVO Commissioning	Plan: 4/1/2020 – 5/15/2020	In Progress: 3/1/2020 – 5/15/2020	In Progress: 2/15/2020 – 3/31/2020
VVO Enabled Date	Plan: 5/30/2020	Plan: 5/30/2020	Plan: 5/1/2020
VVO On/Off Testing Period	Plan: 7/1/2020	Plan: 7/1/2020	Plan: 7/1/2020

Source: Guidehouse analysis of EDC Data

The evaluation of infrastructure metrics spans spending and deployment under the VVO investment and VVO commissioning stages. Figure 8 highlights National Grid's key performance metric analysis periods. Under current progress in VVO device deployment and VVO commissioning, National Grid plans to conduct approximately 9 months of VVO On / Off testing spanning summer, the fall shoulder, and winter. Performance analysis will be provided in the 2021 report.

Figure 8. National Grid Performance Metrics Analysis Timeline*



**Note: National Grid PM analysis timeline for VVO feeders identified in the May 1, 2019 filing.*
Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.3.2 VVO Investment Progress Through PY2019

Table 34 presents the infrastructure metrics results through PY2019 for each investment type related to National Grid's VVO investment area. The following sections provide further detail surrounding the findings for each of the infrastructure metrics.

Table 34. National Grid Infrastructure Metrics Findings

IM	Metric	Parameter	Cap. Banks	Line Sensors	LTC Controls	Regulat-ors	IT Work	Total
IM-4	Number of Devices Deployed	# Devices Commissioned	4	2	0	0	0	6
		% Devices Deployed	7.3%	12.5%	0%	0%	N/A	7.4%
IM-5	Cost for Deployment	Total Spend, $M	$0.12	$0.04	$0.0	$0.0	$0.15	$0.31
		% Spend	7.3%	12.5%	0%	0%	100%	8.4%
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Devices)	10%	16.7%	0%	0%	N/A	9.1%
		% On Track (Spend)	10%	16.7%	0%	0%	None Planned	5.0%
IM-7	Projected Deployment in PY2020	# Devices Remaining	51	14	4	6	0	75
		Spend Remaining, $M	$1.6	$0.3	$0.6	$0.3	$0.0	$2.8

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 35 presents VVO enablement progress. VVO is expected to be enabled over all substations by June 2020, as device deployment and VVO commissioning are still in progress. VVO On / Off testing is expected to begin on all 16 feeders by July 2020.

Table 35. 2019 National Grid Infrastructure Metrics for VVO Feeders

IM	Metric	Parameter	Number of Feeders
IM-4	Number of Devices/Technologies Deployed	# Feeder with VVO Enabled	0
		% Feeders with VVO Enabled	N/A
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Feeders with VVO Enabled)	N/A
IM-7	Projected Deployment for the Remainder of the 3-Year Term	# Feeders Remaining for VVO Enablement	16

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

VVO device deployment and spending in 2019 were limited to four capacitor banks and two line sensors due to vendor lead times. VVO device deployment is expected to occur rapidly in 2020, with deployment and VVO commissioning to be complete by Summer 2020. Table 36 highlights the status of VVO investments through PY2019 for each device/investment type per the EDC data provided.

Table 36. National Grid VVO Deployment Progress

Device	Actual through PY2019		2020 Device Deployment Progress		3-Year Plan Total[14]	
	In-Service Units	Accrued Cost ($)	Construct-ion	Design	In-Service Units	Accrued Cost ($)
Capacitor Banks	4	$120k	1	0	55	$1.7M
Line Sensors[31]	2	$40k	1	0	16	$330k
LTC Controls	0	$0	0	0	4	$600k
Regulators	0	$0	0	0	6	$300k
VVO IT Work	N/A	$150k	0	0	0	$150k
Total	**6**	**$310k**	**2**	**0**	**81**	**$3.1M**

Source: Guidehouse analysis of EDC Data

Table 37 presents VVO enablement progress by substation. No VVO enablement has occurred as device deployment and VVO commissioning are still in progress. VVO should be enabled over all substations by June 2020, and most feeders will be ready to begin On / Off testing by July 2020.

Table 37. National Grid VVO Enabled Progress by Substation

Substation	Anticipated VVO Enabled Date	Actual VVO Enabled Date	Current Status[32]
E. Methuen	5/30/2020	N/A	Device deployment in progress
Maplewood	5/30/2020	N/A	Device deployment in progress
Stoughton	5/1/2020	N/A	Device deployment in progress

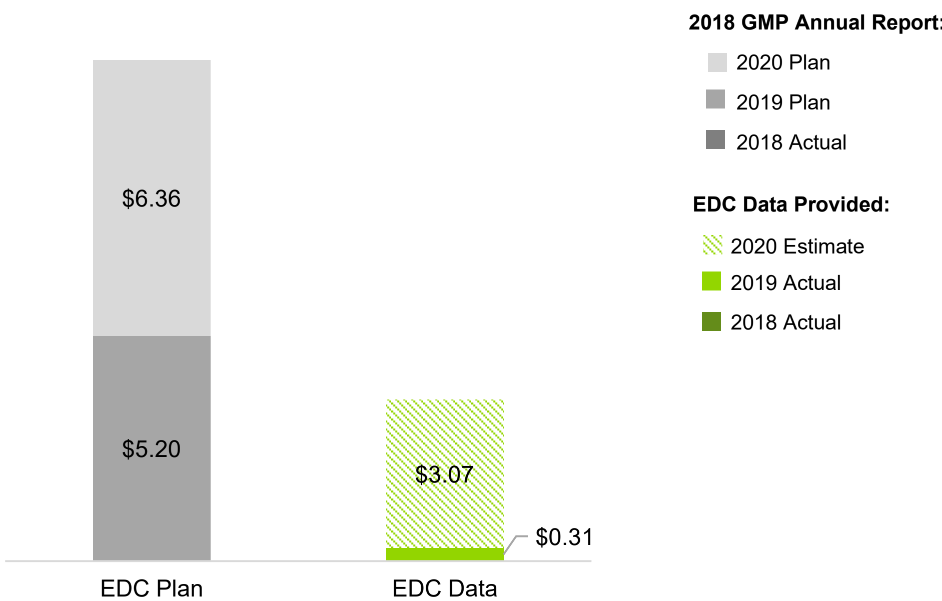
Source: Guidehouse analysis of EDC Data

Spending on VVO investments was lower than planned in 2019. Vendor lead times slowed the deployment of VVO devices, which has limited spending to IT work and the limited number of devices that were able to be deployed in 2019. Spending is expected to ramp up in Spring and Summer 2020. In addition, the overall estimated spend is much lower than originally planned. This is summarized in Figure 9 and Table 38

[31] Unitil counts line sensors per three-phase

[32] Status can be: planning, design, construction, device deployment complete, VVO commissioning in process, or VVO enabled.

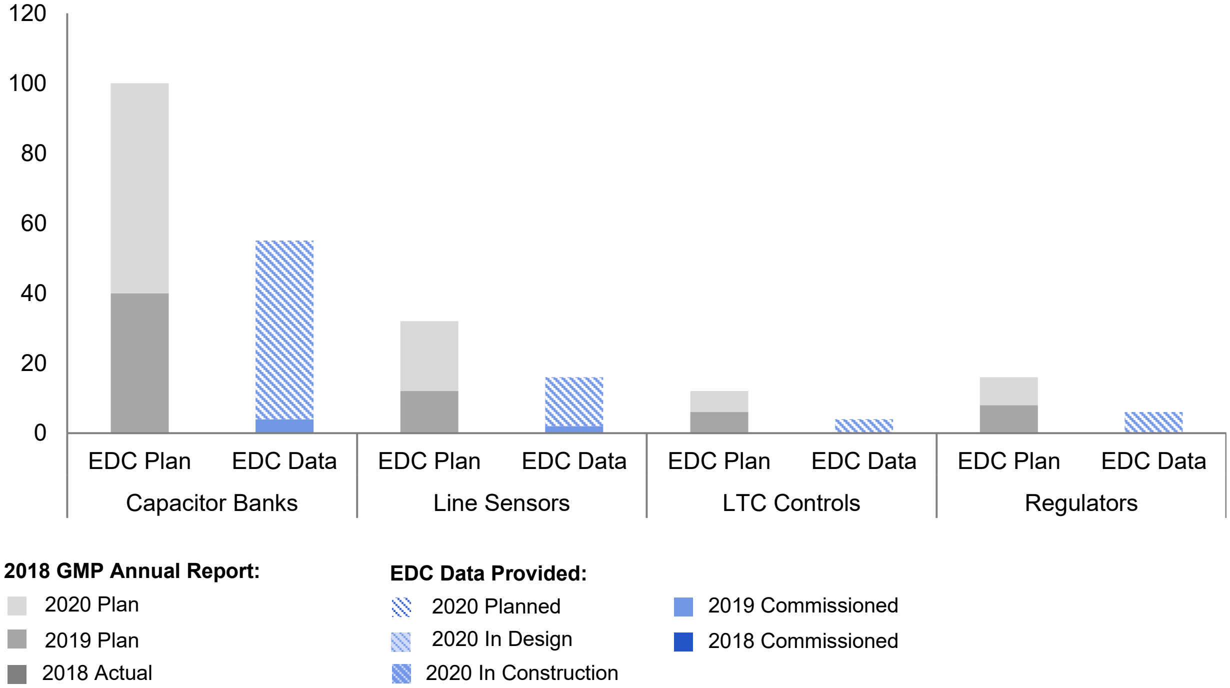
Figure 9. Total Spend Comparison (2018 – 2020, $M)



Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Figure 10 shows the actual device deployment for all device types compared to the projected deployment in the 2018 GMP Annual Report. National Grid VVO device deployment in 2019 was limited to four capacitor banks and two line sensors due to vendor lead times. In addition, 2020 EDC-planned VVO device deployment is lower than was initially planned.

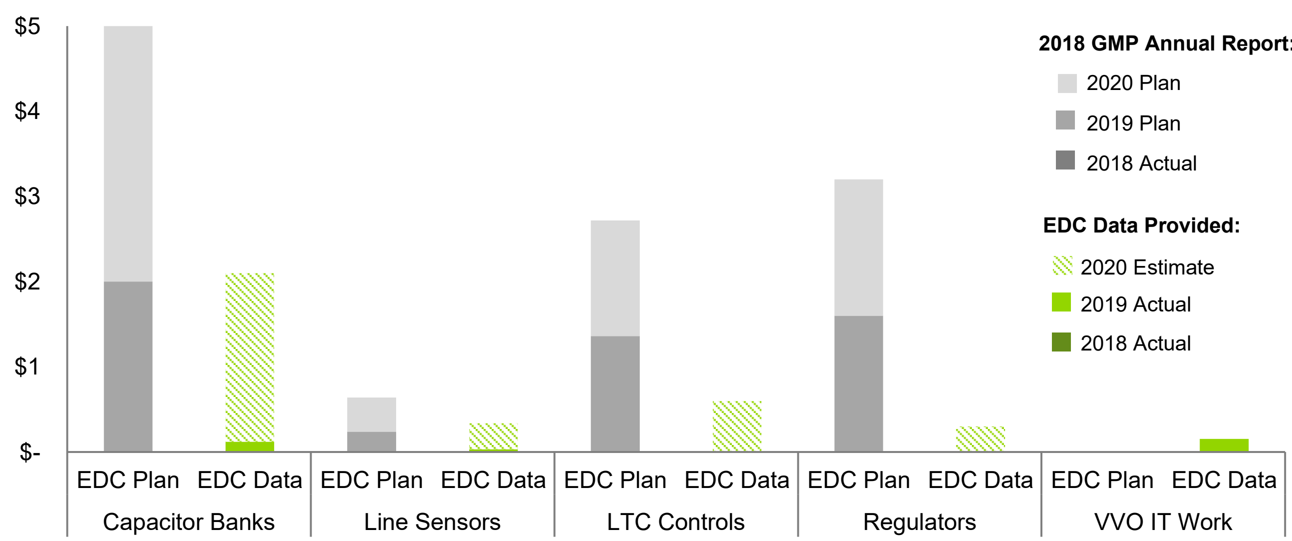
Figure 10. National Grid Planned vs. Actual Deployment (2018 – 2020, Unit Count)



Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Figure 11 shows the actual device spend for all device types compared to the projected spend in the 2018 GMP Annual Report. National Grid VVO device deployment in 2019 was limited to four capacitor banks and two line sensors due to vendor lead times. In addition, 2020 EDC-planned VVO device deployment is lower than was initially planned.

Figure 11. National Grid Planned vs. Actual Device Spend (2018 – 2020, $M)



Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 38 compares National Grid's planned versus actual VVO enablement and spend in 2018 through 2020. All VVO feeders are expected to be enabled by Summer 2020, with VVO On / Off testing slated to begin across all feeders by July 1, 2020. Actual spend is consistently lower than planned throughout the 2018-2019 timeframe, largely because of vendor lead times delaying VVO device deployment. The revised plan cumulative spend is expected to be 32% of what was originally planned. This is primarily due to a reduction in the number of VVO devices in the EDC Revised Plan, which dropped significantly compared to what was in the original EDC Plan.

Table 38. National Grid Planned vs. Actual Year-over-Year Comparison

Data	2018	2019	2020	2018-2020
Cumulative Feeders with VVO Enabled				
EDC Actual Progress	0	0	N/A	N/A
EDC Original Plan[33]	0	0	16	16
% EDC Actual / EDC Plan	N/A	0%	N/A	N/A
EDC Revised Plan[34]	N/A	0	16	16
% EDC Revised Plan / EDC Plan	N/A	N/A	100%	100%
Spend				
EDC Actual Progress	$0	$310k	N/A	N/A
EDC Original Plan	$0	$5.2M	$6.4M	$11.6M
% EDC Actual / EDC Plan	N/A	9%	N/A	N/A
EDC Revised Plan	N/A	N/A	$2.8M	$3.1M
% EDC Revised Plan / EDC Plan	N/A	N/A	54%	32%

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

5.3.3 Summary of Key Findings

National Grid's VVO progress is behind where it had anticipated in its 2018 GMP Annual Report. Vendor lead times have slowed the rate at which National Grid could deploy devices across VVO substations. Despite this, significant progress is slated to occur by Summer 2020, including:

- Completion of VVO device deployment and VVO commissioning during Spring and Summer 2020. VVO enablement is expected by June 2020 for all feeders.
- VVO On / Off testing is expected to begin by Summer 2020, potentially earlier if VVO server setup is completed early.

[33] Based on 2018 GMP Annual Report Appendix 1 (filed January 31, 2020).

[34] Based on the EDC's updated projections for PY2020.

5.4 Unitil

This section discusses Unitil's VVO investment progress through PY2019 and projected PY2020 progress as compared to the 2018 GMP Annual Report.

5.4.1 Overview of GMP Deployment Plan

5.4.1.1 Approach to VVO

Unitil plans to deploy VVO across all substations within its jurisdiction over a 10-year period. As part of the 2018-2020 GMP, VVO investments will be deployed across three substations, amounting to 10 feeders.

Table 39 highlights Unitil VVO feeder characteristics between 2018 and 2020. Similar to Eversource and National Grid, feeder lengths and customer counts vary considerably. Selected substations also present a mix of distributed generation capacity, with distributed generation capacity ranging from 0 MW to 4.7 MW. Appendix C contains additional information related to the VVO feeders.

Table 39. Unitil VVO Feeder Characteristics

Substation	Feeder	Feeder Length (mi.)	2018 Customer Count	Annual Peak Load (MVA)	Distributed Generation (MW)
Townsend (13.8 kV)	15W14	N/A	N/A	0.0	0.0
	15W15	0.1	1	3.7	0.0
	15W16	41.1	1,500	5.4	1.6
	15W17	11.4	557	1.4	0.4
Lunenburg (13.8 kV)	30W30	45.8	1,328	4.7	1.5
	30W31	45.4	1,637	4.0	4.7
Summer Street (13.8 kV)	40W38	0.6	4	2.2	1.8
	40W39	7.9	420	3.2	1.3
	40W40	18.5	1,571	7.6	1.7
	40W42	12.4	1,704	3.5	0.3

Source: 2018 GMP Annual Report, Appendix 1 filed January 31, 2020. Distributed Generation data was provided by the EDCs.

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 pushed out due to complexities associated with tying VVO to the ADMS, M&C, and Communications investment areas. This necessitated an extensive review of vendors during the VVO investment process to ensure regulators and capacitors could accommodate both investment areas. Deployment of VVO also relies on SCADA system being in place, tying the VVO deployment to the M&C investment area. As such, SCADA deployment has been accelerated beyond installing at one substation per year. The VVO project is also tied with the Field Area Network deployment plan which will allow communication from the ADMS to the field devices. Further, regulators used for VVO have both source-side and load-side voltage sensors for use by ADMS, tripling the amount of data being processed by SCADA system.

5.4.1.2 VVO Timeline

For Unitil, the Townsend substation is expected to be ready for On / Off testing during Winter 2020/21. Table 40 summarizes substation-specific progress in each of the four VVO investment phases. Where a phase has not been completed, an expected date of completion is provided.

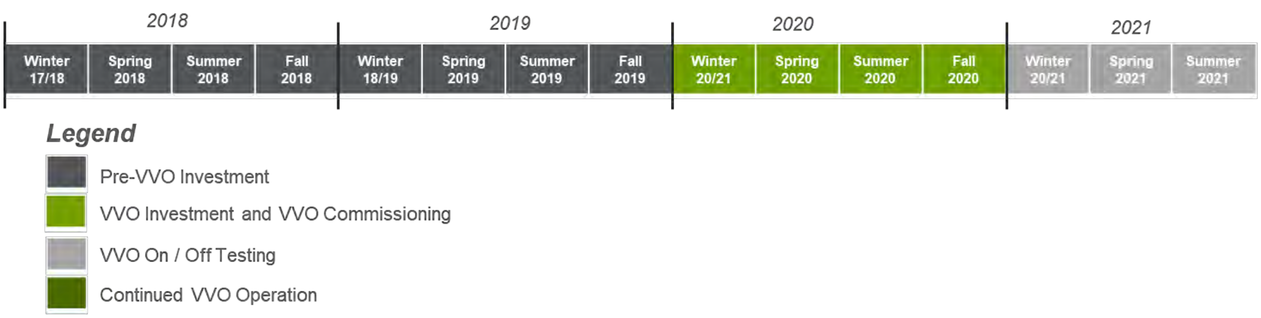
Table 40. Unitil VVO Deployment Progress by Phase and Substation

Phase	Townsend	Lunenburg	Summer St.
VVO Investment	In Progress: 1/1/2020 – 6/30/2020	In Progress: 1/1/2020 – 10/31/2020	In Progress: 1/1/2020 – 11/30/2020
VVO Commissioning	Plan: 7/1/2020 – 9/30/2020	Plan: 11/1/2020 – 1/31/2021	Plan: 12/1/2020 – 2/28/2021
VVO Enabled Date	Plan: 12/31/2020	Plan: 3/31/2021	Plan: 6/30/2021
VVO On/Off Testing Period	TBD	TBD	TBD

Source: Guidehouse analysis of EDC Data

The evaluation of infrastructure metrics spans spending and deployment under the VVO Investment stage across the Townsend, Lunenburg, and Summer Street substations. Figure 12 highlights the key time periods for Unitil for the Townsend substation during the evaluation period. Lunenburg and Summer Street substations have VVO investment, commissioning, and On / Off testing occurring following the Townsend substation. The 9 months of VVO On / Off testing data will not be available for evaluation and nuances to SCADA data collection during the baseline period for Unitil, as a result there will be no analysis of performance metrics beyond an analysis of voltage complaints (PM-7).

Figure 12. Unitil Performance Metrics Analysis Timeline*



**Note: Unitil PM analysis timeline only applicable for Townsend substation, whose VVO Investment, Commissioning, and On / Off testing fall within the Guidehouse reporting period.*
Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.4.2 VVO Investment Progress Through PY2019

Table 41 presents the infrastructure metrics results through PY2019 for each investment type related to Unitil's VVO investment area. The following subsections include further detail surrounding findings for each of the infrastructure metrics.

Table 41. 2019 Unitil Infrastructure Metrics Findings

IM	Metric	Parameter	Cap. Banks	Line Sensors	LTC Controls	Regulat-ors	IT Work[35]	Total
IM-4	Number of Devices Deployed	# Devices Commissioned	0	0	0	0	N/A	0
		% Devices Deployed	0%	0%	0%	0%	N/A	0%
IM-5	Cost for Deployment	Total Spend, $M	$0.1	$0.00	$0.1	$0.00	N/A	$0.1
		% Spend	6.5%	0%	12.1%	0.2%	N/A	2.2%
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Devices)	0%	0%	0%	0%	N/A	0%
		% On Track (Spend)[36]	N/A	N/A	N/A	N/A	N/A	8.6%
IM-7	Projected Deployment in PY2020	# Devices Remaining	26	118	3	108	N/A	255
		Spend Remaining, $M	$0.7	$0.7	$0.1	$1.3	N/A	$2.8

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 42 presents VVO enablement progress. As device deployment and VVO commissioning are still in progress, VVO is not expected to be enabled for any Unitil feeders until December 2020, at which point the Townsend substation will have VVO enabled. VVO On / Off testing is not expected to begin until early 2021.

Table 42. 2019 Unitil Infrastructure Metrics for VVO Feeders

IM	Metric	Parameter	Number of Feeders
IM-4	Number of Devices/Technologies Deployed	# Feeder with VVO Enabled	0
		% Feeders with VVO Enabled	N/A
IM-6	Deviation Between Actual and Planned Deployment	% On Track (Feeders with VVO Enabled)	N/A
IM-7	Projected Deployment for the Remainder of the 3-Year Term	# Feeders Remaining for VVO Enablement	3

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 43 highlights the status of VVO investments through PY2019 for each device/investment type per the data provided by Unitil.

[35] Unitil's VVO IT Work is included with ADMS.

[36] Guidehouse is unable to calculate % On Track (Spend) by device type because Unitil's 2018 GMP Annual Report did not included device-level estimated spending.

Table 43. Unitil VVO Deployment Progress

Device	Actual through PY2019		2020 Device Deployment Progress		3-Year Plan Total	
	In-Service Units	Accrued Cost ($)	Construct-ion	Design	In-Service Units	Accrued Cost ($)
Capacitor Banks	0	$50k	9	4	26	$780k
Line Sensors[37]	0	$0	0	59	118	$690k
LTC Controls	0	$10k	1	0	3	$90k
Regulators	0	$0	29	25	108	$1.3M
VVO IT Work[38]	N/A	N/A	N/A	N/A	N/A	N/A
Total	**0**	**$60k**	**39**	**88**	**255**	**$2.9M**

Source: Guidehouse analysis of EDC Data

Table 44 shows Unitil's planned VVO enablement for substations included as part of the GMP. Unitil's VVO enablement will occur in phases with one to two substations per year for the next 10 years. Combined with delays in VVO device deployment, the Townsend substation will be VVO enabled after December 31, 2020.

Table 44. Unitil VVO Enabled Progress by Substation

Substation	Anticipated VVO Enabled Date	Actual VVO Enabled Date	Current Status[39]
Townsend	12/31/2020	N/A	Device deployment in progress
Lunenburg	3/31/2021	N/A	Device deployment in progress
Summer St.	6/30/2021	N/A	Device deployment in progress

Source: Guidehouse analysis of EDC Data

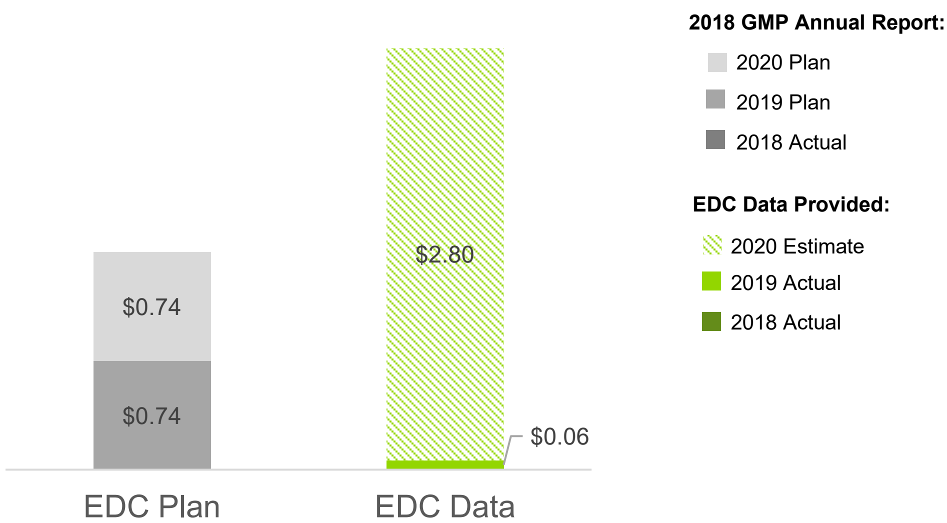
Spending on VVO investments in 2019 was lower than anticipated because of changes to the VVO rollout, as ADMS is now integrated with VVO. Unitil increased its 2018-2020 total spend because of device deployment requirements were higher than originally expected. Figure 13 summarizes this.

[37] Unitil counts line sensors per three-phase

[38] VVO IT work cost is included in ADMS

[39] Status can be: planning, design, construction, device deployment complete, VVO commissioning in process, or VVO enabled.

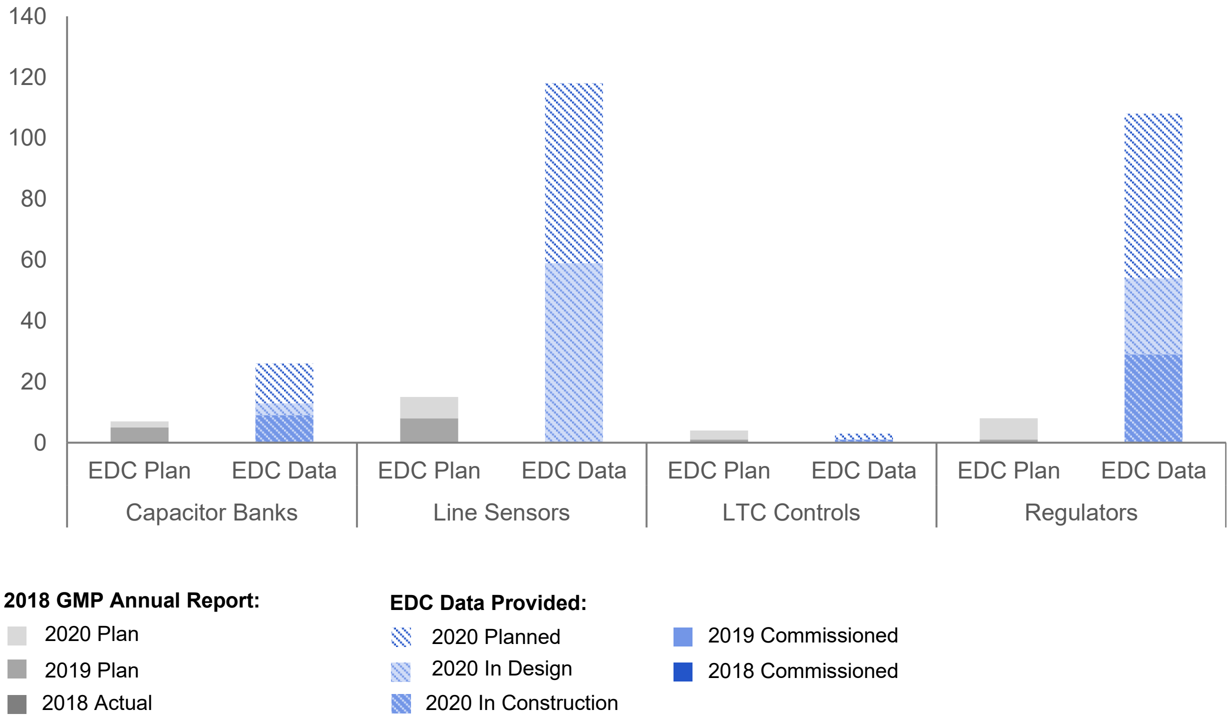
Figure 13. Unitil Total Spend Comparison (2018 – 2020, $M)



Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Figure 14 compares the actual device deployment for all device types to the projected deployment in the 2018 GMP Annual Report. No deployment occurred by the end of 2019. More extensive feeder conditioning will occur in 2020 than was originally planned due to Townsend, Lunenburg, and Summer Street requiring higher levels of device deployment than other substations to be covered by VVO over the remainder of Unitil's 10-year planned term.

Figure 14. Unitil Planned vs Actual Deployment (2018 – 2020, Unit Count)



Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

Table 45 compares Unitil's planned versus actual VVO enablement and spend between 2018 and 2020. Three feeders at the Townsend substation are expected to be enabled during Winter 2020/21, with VVO On / Off testing slated to begin across these feeders later in 2021. Actual spend is consistently lower than planned throughout the 2018-2019 timeframe due to delays in VVO device deployment, as VVO is now integrated with ADMS. For 2020, expected costs highlighted in Unitil's Revised Plan exceed those highlighted in the 2018 GMP Annual Report. Unitil expects that Townsend, Lunenburg, and Summer Street are among the most expensive substations to roll VVO out along due to equipment needs, and expects costs will begin to fall for the remainder of their 10-year planned term.

Table 45. Unitil Planned vs. Actual Year-over-Year Comparison

Data	2018	2019	2020	2018-2020
Cumulative Feeders with VVO Enabled				
EDC Actual Progress	0	0	N/A	N/A
EDC Original Plan[40]	0	0	0	0
% EDC Actual / EDC Plan	N/A	0%	N/A	N/A
EDC Revised Plan[41]	N/A	N/A	3	3
% EDC Revised Plan / EDC Plan	N/A	N/A	100%	100%
Spend				
EDC Actual Progress	$0	$60k	N/A	N/A
EDC Original Plan	$0	$740k	$740k	$2.9M
% EDC Actual / EDC Plan	100%	9%	N/A	N/A
EDC Revised Plan	N/A	N/A	$2.8M	$1.5M
% EDC Revised Plan / EDC Plan	N/A	N/A	379%	194%

Source: Guidehouse analysis of 2018 GMP Annual Report and EDC Data

5.4.3 Summary of Key Findings

Unitil's VVO progress is behind where it had anticipated in its 2018 GMP Annual Report for their PY2019 progress. Unitil faced a confluence of factors during PY2019 that ultimately delayed VVO progress, including:

- Recalibration of VVO deployment being required, as selected feeders had more VVO devices needed than was previously anticipated.
- Interplay between VVO and ADMS necessitating shifts in how the VVO investment area was approached during 2019 delayed VVO device deployment. An assessment of vendor equipment, such as capacitor banks and voltage regulators, was required to ensure equipment was capable of accommodating both VVO and ADMS. SCADA infrastructure needed to be fine-tuned[42] to ensure that it could handle additional data burdens associated with collecting both VVO- and ADMS-related interval data. The VVO project is also tied with the Field Area Network deployment plan which will allow communication from the ADMS to the field devices. All of these shifts culminated in shifting costs to PY2020.
- Competitive bidding process with equipment to ensure least cost, high performance outcomes for VVO.
- Backlogs of orders from vendors, as they are working to accommodate growing demand from other utilities.

Despite low device deployment for 2019, Unitil is aggressively deploying devices substation-by-substation. The deployment of Townsend VVO investments is expected to be completed by early Summer 2020, and VVO is expected to be enabled by the end of 2020. Deployments of Lunenberg and Summer Street VVO investments are expected to be completed in Fall 2020, with VVO expected to be enabled in Spring 2021 and Summer 2021, respectively.

[40] Based on 2018 GMP Annual Report Appendix 1 (filed January 31, 2020).
[41] Based on the EDC's updated projections for PY2020.
[42] Fine-tuning processes include back-end processes to ensure precision of SCADA data inputs – such as voltage bands, power flows, and real power measurements – under both ADMS and VVO.

6.0 Conclusions and Recommendations

Infrastructure metrics findings for PY2019 show that the EDCs are behind where they had anticipated in their 2018 GMP Annual Reports. Eversource experienced delays in permitting and structural redesigns. National Grid and Unitil faced slow vendor lead times. Unitil experienced higher than expected feeder-level VVO device needs and needed to change its approach to the VVO investment area. Intricacies such as these have slowed the rate of VVO device deployment.

Despite slower than anticipated VVO investment deployment, two of the three EDCs are slated to finish VVO investments at or below planned costs, primarily due to reduced costs of IT work and a lower than expected number of devices needed across VVO feeders.

In addition, the EDCs are slated to make significant headway in 2020. In particular:

- Eversource is finalizing the last of its VVO device deployments. These devices are in the construction and design phases and will be installed and commissioned in time for VVO On / Off testing to begin for all feeders by Summer 2020.
- National Grid is completing VVO device deployment and VVO commissioning during Spring and Summer 2020. VVO enablement is expected by June 2020 for all feeders, with VVO On / Off testing expected to begin by Summer 2020, potentially earlier if VVO server setup is completed early.
- Unitil is working aggressively to deploy devices on feeders substation-by-substation. Deployment of Townsend VVO investments is expected to be completed by early Summer 2020, and VVO is expected to be enabled by the end of 2020. Deployments of Lunenberg and Summer Street VVO investments are expected to be completed in Fall 2020, with VVO expected to be enabled in Spring 2021 and Summer 2021, respectively.

In 2020 and beyond, Guidehouse recommends that:

- To provide results for reporting of performance metrics in 2021, continue with rapid pace of VVO device deployment in early 2020 to ensure adequate data (specifically VVO On / Off data) are collected for the analysis.
- Where possible, conduct VVO device deployment and VVO IT system commissioning in tandem to reduce the amount of time needed for post-deployment VVO commissioning.
- Each EDC should discuss the role of load balancing, phase balancing in the deployment of VVO, and why neither were chosen to be conducted.
- Once VVO is ready for On / Off testing, EDCs follow VVO On / Off cycling for at least 9 months, covering one full summer, one full winter, and one of either the spring or fall shoulder seasons.
- Where possible, National Grid should accelerate the VVO On / Off testing start date to June 1, 2020 from July 1, 2020 to ensure 9 months of VVO On / Off testing can cover one full summer, one full winter, and one of either the spring or fall shoulder seasons.
- EDCs should continue tracking complaints along feeders receiving VVO investment to ensure the analysis of voltage-related complaints is feasible in 2021.

- EDCs should continue discussions with Guidehouse throughout 2020, as analysis of performance metrics will begin to be fine-tuned around nuances surrounding each of the VVO feeders, including:
    - Construction of baselines for analysis of performance metrics
    - Distributed generation penetration, and effects of feeders with high penetration rates on analysis of performance metrics
    - Customer counts per feeder, especially where some feeders have <10 customers

Appendix A. Eversource

Table 46. Additional Eversource Feeder Characteristics

Substation	Feeder	Avg Customer Loading (kVA/customer)	Customer Density (customer/mi.)	Load Density (MVA/mi.)	DG Penetration (DG MW/MVA)
Agawam (13.8 kV)	16C11	5.1	36	0.18	0.36
	16C12	97	12	1.1	0.29
	16C14	4.0	107	0.43	0.02
	16C15	3.9	114	0.45	0.02
	16C16	3.2	116	0.37	0.28
	16C17	3.1	81	0.25	0.12
	16C18	2.1	142	0.30	0.08
Piper (13.8 kV)	21N4	3.3	80	0.27	0.17
	21N5	10	55	0.58	0.02
	21N6	6.1	51	0.31	0.09
	21N7	2,150	0.4	0.86	0.0
	21N8	16	61	0.99	0.01
	21N9	2.9	102	0.29	0.01
Podick (13.8 kV)	18G1	N/A	N/A	N/A	N/A
	18G2	56	2.3	0.13	0.00
	18G3	1.9	53	0.10	0.57
	18G4	2.1	67	0.14	1.1
	18G5	3.4	43	0.15	0.93
	18G6	4.2	33	0.14	0.59
	18G7	2.2	31	0.07	1.6
	18G8	7.4	23	0.17	0.96
Silver (13.8 kV)	30A1	3.4	67	0.23	0.10
	30A2	10	81	0.83	0.03
	30A3	37	22	0.80	0.01
	30A4	10	71	0.71	0.03
	30A5	3.1	76	0.23	0.10
	30A6	5.1	50	0.25	0.50

Source: Guidehouse analysis of 2018 GMP Annual Report

Appendix B. National Grid

Table 47. 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)
E. Methuen (13.2 kV)	74L1	3.5	79	0.28	0.27
	74L2	4.7	93	0.44	0.09
	74L3	2.4	162	0.39	0.13
	74L4	4.4	173	0.77	0.13
	74L5	3.2	51	0.16	0.09
	74L6	3.3	212	0.70	0.05
Stoughton (13.8 kV)	913W17	3.6	97	0.35	0.29
	913W18	3.0	124	0.38	0.07
	913W43	3.2	67	0.22	0.12
	913W47	3.9	106	0.41	0.05
	913W67	3.1	57	0.18	0.22
	913W69	2.8	112	0.31	0.11
Maplewood (13.8 kV)	16W1	2.9	205	0.60	0.06
	16W2*	2.9	327	0.95	0.05
	16W3	2.5	220	0.55	0.06
	16W4	6.3	139	0.88	0.10
	16W5	2.8	255	0.73	0.12
	16W6*	2.3	216	0.50	0.10
	16W7*	2.9	271	0.79	0.08
	16W8*	3.0	204	0.61	0.09

Source: Guidehouse analysis of 2018 GMP Annual Report

Appendix C. Unitil

Table 48. Additional Unitil Feeder Characteristics

Substation	Feeder	Avg Customer Loading (kVA/customer)	Customer Density (customer/mi.)	Load Density (MVA/mi.)	DG Penetration (DG MW/MVA)
Townsend (13.8 kV)	**15W14**	N/A	N/A	N/A	N/A
	15W15	3,700	10	37	0.0
	15W16	3.6	36	0.13	0.30
	15W17	2.5	49	0.12	0.29
Lunenburg (13.8 kV)	**30W30**	3.5	29	0.10	0.32
	30W31	2.4	36	0.09	1.2
Summer Street (13.8 kV)	**40W38**	550	7	3.7	0.82
	40W39	7.6	53	0.41	0.41
	40W40	4.8	85	0.41	0.22
	40W42	2.1	137	0.28	0.09

Source: Guidehouse analysis of 2018 GMP Annual Report

Massachusetts Electric Distribution Companies

Massachusetts Grid Modernization Program Year 2019 Evaluation Report

Advanced Distribution Management System/ Advanced Load Flow (ADMS/ALF)

April 1, 2020

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1.0 Executive Summary

1.1 Introduction

Advanced distribution management system/advanced load flow (ADMS/ALF) is a software platform investment and is fundamental to a modernized grid. ADMS consists of a combination of SCADA, outage management systems (OMSs), distribution management systems (DMSs), and advanced applications including operational power flow, Volt-VAR optimization (VVO), fault location isolation and service restoration (FLISR), and distributed energy resource management systems (DERMSs). ADMS's capabilities are key to delivering on all three of the Department of Public Utilities' (DPU's) grid modernization objectives. These objectives include the ability to control devices for system optimization, providing support for advanced distribution automation (ADA) and VVO, and serving as an enabling platform to support a high penetration of distributed energy resources (DER). ALF investments are tightly coupled with ADMS investments at Eversource, the only electric distribution company (EDC) with a separate investment plan for ALF.

The preauthorized ADMS/ALF investments for the EDCs in the Program Year (PY) PY2018 to PY2020 timeframe are summarized below.

Table 1. ADMS/ALF Investments

EDCs	Description
Eversource	Planning for ADMS supported by implementation of ALF
National Grid	Implementation of DMS and integration with SCADA
Unitil	Planning for ADMS

Source: Guidehouse review of 2018 GMP Annual Reports and EDC Data

1.2 Evaluation Process

The evaluation process assesses the progress and effectiveness of the DPU preauthorized ADMS and ALF investments for each EDC to help meet the DPU's grid modernization objectives.[1] The evaluation process guides the investments' contribution to meeting all three DPU objectives: "(1) optimize system performance (by attaining optimal levels of grid visibility, command and control and self-healing)," "(2) optimize system demand," and "(3) interconnect and integrate distributed energy resources."

ADMS is a fundamental enabling technology that has the potential to significantly enhance the utility's ability to meet the DPU objectives. ALF enables ADMS and supports all three of the DPU's objectives, including improved modeling of the distribution system's current and future states. ALF is tightly coupled with the ADMS investment for Eversource in that the GIS and other system data cleanup components of ALF enable the ability to perform engineering load flow in Synergi, but also are necessary for operational load flow, and other ADMS functions in their future ADMS

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

investment. GIS Data Cleanup is a component of each of the ADMS / ALF investments and is addressed differently at each EDC.

Evaluation of the ADMS/ALF investments consist of four tasks:

- Task 1. Evaluation Plan
- Task 2. Data Assimilation and Collection
- Task 3. Complete Analysis and Presentation
- Task 4. Reporting

The first task in the evaluation of ADMS/ALF is to develop the evaluation plan consisting of defining overall study goals and metric identification. This task includes a round of plan refinement and coordination with the EDCs prior to finalization. Data assimilation and collection (Task 2) occurs semiannually and includes written data requests to each EDC, followed by each EDC providing the data specified and Guidehouse conducting follow-up data review meetings. At the end of the year and following the data collection tasks, Guidehouse analyzed the data (Task 3), producing a year-end draft presentation for each EDC to review. Outputs from task 3 feed directly into preparation for the reporting task (Task 4). Following the yearly analysis review meetings with the EDCs, Guidehouse provided an interim draft report that incorporated feedback into this final evaluation report. The evaluation reports are provided to the EDCs to incorporate into filings and reports to the DPU.

1.3 Data Management

The objective of data management is to collect planning and cost information. Data management tracks enabled power flow and control capabilities at regular intervals with each EDC based on the approved evaluation plan. It includes defining details on the data to be collected, identifying the timing of data collection, and designating owners at each EDC for the ADMS data with designating owners at Eversource for ALF data.

The evaluation strategy for the implementation of ADMS components is followed by the progression of functional realization of each EDCs' ADMS. This progression means that the data helps identify the progress each EDC has made to establish the functionality of their ADMS. This starts with evaluating the foundational prerequisites, moves to basic ADMS software, and finishes with advanced application functionality. These steps include integrating OMS and DSCADA components if needed, data cleanup, enablement of functionality (including load flow on circuits and substations), and advanced functionality potentially including VVO, FLISR, and DERMS.

For Eversource's ALF investment, the data helps identify Eversource's progress toward establishing the functionality of the ALF starting with foundational prerequisites, basic Synergi software, integration of Synergi to GIS and other systems, and data cleanup in both GIS and other systems.

Table 2 summarizes data sources used throughout the evaluation of ADMS/ALF in PY 2019 and to be used in the evaluation of ADMS/ALF in PY 2020. Section 3.1 details each of the data sources.

Table 2. ADMS/ALF Data Sources

Data Source	Description
2018 Grid Modernization Plan Annual Report	Planned device deployment and cost information from each EDC's Supplement to the 2018 Grid Modernization Annual Report (filed January 31, 2020) as the baseline to track progress against the GMP targets. This data source is referred to as the "EDC Plan" in summary tables and graphs throughout the report.
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. Planned device deployment information and estimated spend for PY2020 was provided at the most granular level.
ADMS/ALF Supplemental Data Template	Includes additional information unique to the ADMS/ALF investment area spanning inputs required for the infrastructure metrics and the performance metrics. Data cover actual versus planned ADMS/ALF implementation, data cleanup, schedule, and cost. Information was requested at the feeder and substation-level where possible.

Source: Guidehouse

Guidehouse reviewed all data provided upon receipt of requested data and conducted a detailed QA/QC of data inputs used in the analysis of infrastructure and performance metrics. These QA/QC steps include checks to confirm each of the required data inputs are accounted for and can be incorporated into analysis.

After data are received, Guidehouse provides status update memos that summarize the QA/QC to the EDCs, confirming receipt of the datasets and indicating quality. Additional follow-up based on standing questions is required to ensure all EDC-provided data can be used in analysis.

1.4 Findings

The EDCs realize that IT/OT applications, including ADMS/ALF, are different from device-centric investments and require a different approach to planning, budgeting, and monitoring. Guidehouse found that estimates for the ADMS/ALF investments were initially high-level and the EDCs refined them as they progressed through the evaluation period. The EDCs have, through the first two years of their GMPs, refined the capital and operational components of the ADMS/ALF investment plans as those plans have progressed.

Eversource closely followed the defined deployment plan with deployment in PY 2019 slightly exceeding the plan and the same forecasted for PY 2020. National Grid experienced a slower than expected project startup of ADMS/ALF in PY 2019 and was reviewing opportunities to catch up to the three-year plan in PY2020. Unitil is just beginning its ADMS investment, with an accelerated schedule to be able to use ADMS as the platform for the Volt-VAR optimization (VVO) investment.

Table 3 presents the infrastructure metrics results through PY 2019 for all EDCs. Additional detail surrounding findings for each of the infrastructure metrics are provided in subsections. Although infrastructure metrics are the same across all investment areas, ADMS/ALF investments are not tracked by device. Instead, ADMS/ALF investments are tracked by technology or software implementation. Throughout the ADMS/ALF portion of this report, the term "technology or software implementation" is used instead of "device deployment."

Table 3. 2019 Infrastructure Metrics for ADMS/ALF

Infrastructure Metrics		Parameter	Progress through PY2019		
			Eversource	National Grid	Unitil
IM-4	Number of devices or other technologies deployed	# Devices (Technology[2]) Deployed	2,242[3] circuits with static ALF	0	0
		% Devices (Technology) Deployed	50%	N/A	N/A
IM-5	Cost for Deployment	Total Spend, $M	$2.78	$1.05	$0
		% Spend	28%	3%	N/A
IM-6	Deviation Between Actual and Planned Deployment for the Plan Year	% On Track (Devices/ Technology)	89%	N/A	N/A
		% On Track (Spend)	41%	6%	N/A
IM-7	Projected Deployment for the Remainder of the Three-Year Term	# Devices (Technology) Remaining	2,234[4] circuits with enhanced semi-auto ALF	196 circuits	N/A
		Spend Remaining, $M	$10.1	$31.4	$0.4

Source: Guidehouse analysis of 2018 GMP Annual Reports

1.4.1 Eversource

Eversource's ADMS/ALF progress is in line with what was anticipated in its 2018 GMP Annual Report. GIS Survey is complete for the Eastern MA region supporting both ADMS and ALF. The implementation plan for ALF is on track with a target to implement enhanced semi-automatic ALF by the end of PY2020. ADMS was still in its planning stages for PY2019 with limited deployment for PY2020. The total spend to date and overall are less than originally planned for ALF.

1.4.2 National Grid

National Grid began project planning and mobilization of the ADMS investment in PY 2018. Guidehouse found that in PY2019 the initiative experienced a slower than expected startup. National Grid was reviewing opportunities to catch up on the intended 3-year ADMS spend with potential deployment of ADMS Phase 1 by end of PY 2020.

[2] ADMS/ALF is not tracked by "device"; it is tracked by "technology" implementation. Circuits that have implemented static ALF are at 50% functionality and semi-automatic ALF are at 100% functionality.

[3] Total number of Eversource circuits at time of evaluation. All circuits are at 50% functionality (static ALF) as of end of PY2019. The remaining 50% functionality (semi-automated ALF) will be implemented on all circuits in PY2020.

[4] Number of circuits excluding those going through reconfiguration / retirement

1.4.3 Unitil

Unitil's ADMS progress is in line with what was anticipated in its 2018 GMP Annual Report. There are concerns about the amount of data ADMS will need, but Unitil is working on gathering the data to feed into ADMS and making sure it is of adequate quality and format for ADMS. Deployment of ADMS is on track in PY 2020 with the schedule realigned to use ADMS as a platform for VVO. Total spend was less than originally planned for ADMS.

2.0 Introduction to Massachusetts Grid Modernization

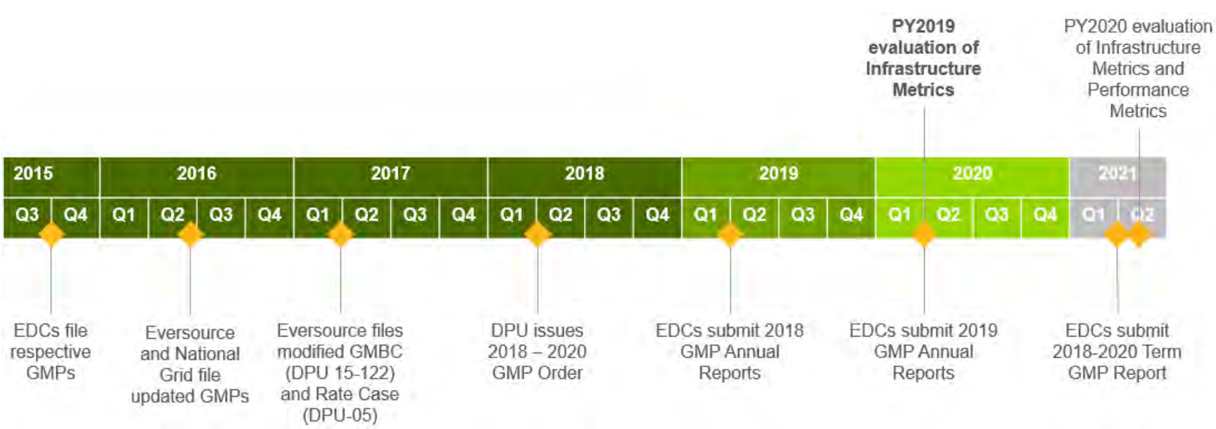
2.1 Massachusetts Grid Modernization Plan Background

On May 10, 2018, the Massachusetts Department of Public Utilities (DPU) issued its Order regarding the individual Grid Modernization Plans (GMPs) filed by the three Massachusetts electric distribution companies (EDCs): Eversource, National Grid, and Unitil. 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. These preauthorized GMP investments will advance the achievement of DPU's grid modernization objectives:

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

As part of the GMPs, the DPU determined that a formal evaluation process for the preauthorized GMP investments, including an evaluation plan and studies, was necessary to help ensure that the benefits are maximized and achieved with greater certainty. Figure 1 highlights the filing background and timeline of the GMP order and the evaluation process.

Figure 1. MA Grid Modernization Timeline



Source: Guidehouse review of the DPU orders and GMP process

In addition, 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)

The following subsection discusses these investment areas in greater detail in. This report covers the Program Year (PY) 2019 evaluation of infrastructure metrics and focuses on the advanced distribution management system (ADMS) investment area.

2.1.1 Investment Areas

Table 4 summarizes the preauthorized GMP investment.

Table 4. Overview of Investment Areas

Investment Area	Description	Goal/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)	Isolation of outage events with automated backup for 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/Advanced Load Flow (ADMS and ALF)	New capabilities in real time system control with investments in developing accurate system models and enhancing SCADA and outage management systems to control devices for system optimization and provide support for distribution automation and VVO with high penetration of distributed energy resources (DER)	Enables high penetration of DER by supporting the ability to control devices for system optimization, ADA, and VVO
Communications/IoT (Comms)	Fiber middle mile and field area communications systems	Enables the full benefits of grid modernization devices to be realized
Workforce Management (WFM)	Investments 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

The Massachusetts preauthorized budget for grid modernization varies by investment area and EDC. Eversource has the largest preauthorized budget at $133 million, with advanced distribution automation (ADA) and monitoring and control (M&C) representing the largest share ($44 million and $41 million, respectively). National Grid's preauthorized budget is $82.2 million, with ADMS and ALF representing almost 60% ($48.44 million). Unitil's preauthorized budget is $5.5 million and VVO makes up 40% ($2.2 million). Table 5 shows the budget for each investment area by EDC.

DPU added flexibility to these budgets based on changing technologies and circumstances. For example, EDCs can shift funds across the different preauthorized investments if a reasonable explanation for these shifts is supplied.

Table 5. 2018-2020 GMP Preauthorized Budget, $M

Investment Areas	Eversource	National Grid	Unitil	Total
ADA	$44.0	$13.4	N/A	**$57.4**
ADMS/ALF	$17.0	$8.4	$0.7	**$66.1**
Comms	$18.0	$1.8	$0.8	**$20.6**
M&C	$41.0	$8.0	$0.75	**$49.8**
VVO	$13.0	$10.6	$12.2	**$25.8**
WFM			$1.0	**$1.0**

Investment Areas	Eversource	National Grid	Unitil	Total
3 Year Total	$133	$82.2	$5.5	**$220.7**

Source: DPU Order, May 10, 2018

This report covers the Program Year (PY) 2019 evaluation of infrastructure metrics and focuses on the ADMS/ALF investment area.

2.1.2 Evaluation Goal and Objectives

As part of the GMPs, the DPU requires a formal evaluation process (including an evaluation plan and evaluation studies) for the EDCs' preauthorized grid modernization plan investments. Guidehouse (formerly Navigant Consulting, Inc.) is completing the evaluation to ensure a uniform statewide approach and to facilitate coordination and comparability. The evaluation uses the DPU-established infrastructure metrics and performance metrics (discussed in Section 2.1.3) to meet the DPU's grid modernization evaluation objectives.

2.1.3 Metrics for Evaluation

The DPU-required evaluation involves both infrastructure metrics and performance metrics for each investment area.

2.1.3.1 Infrastructure Metrics

Infrastructure metrics were designed to evaluate the deployment of the GMP investments. The infrastructure metrics are summarized in detail in Table 6.

Table 6. Infrastructure Metrics Overview

Metric		Description	Applicable IAs	Metric Responsibility
IM-1	**System Automation Saturation**	Measures the quantity of customers served by fully or partially automated devices.	M&C, ADA	EDC
IM-2	**Number and Percent of Circuits with Installed Sensors**	Measures the total number of circuits with installed sensors which will provide information useful for proactive planning and intervention.	M&C	EDC
IM-3	**Number of Devices Deployed and In Service**	Measures how the EDC is progressing with its GMP from an equipment and/or device standpoint.	All IAs	Evaluator
IM-4	**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-5	**Deviation Between Actual and Planned Deployment for the Plan Year**	Measures how the EDC is progressing under its GMP on a year-by-year basis.	All IAs	Evaluator
IM-6	**Projected Deployment for the Remainder of the Three-Year Term**	Compares the revised projected deployment with the original target deployment as the EDC implements its EDC.	All IAs	Evaluator

Source: Guidehouse review of infrastructure metric filings

2.1.3.2 Performance Metrics

Table 7 summarizes the performance metrics, which are used to evaluate the performance of the GMP investments. These metrics are discussed throughout this report but will be quantified as part of the PY2020 evaluation.

Table 7. Performance Metrics Overview

Metric		Applicable IAs
PM-1	VVO Baseline	VVO
PM-2	VVO Energy Savings	VVO
PM-3	VVO Peak Load Impact	VVO
PM-4	VVO Distribution Losses without AMF (Baseline)	VVO
PM-5	VVO Power Factor	VVO
PM-6	VVO – GHG Emissions	VVO
PM-7	Voltage Complaints	VVO
PM-8	Increase in Substations with DMS Power Flow and Control Capabilities	ADMS/ ALF
PM-9	Control Functions Implemented by Circuit	ADMS/ ALF
PM-10	Numbers of Customers that benefit from GMP funded Distribution Automation Devices	ADA
PM-11	Grid Modernization investments' effect on outage durations	M&C, ADA
PM-12	Grid Modernization investments' effect on outage frequency	M&C, ADA
PM-13	Advanced Load Flow – Percent Milestone Completion	ADMS/ ALF

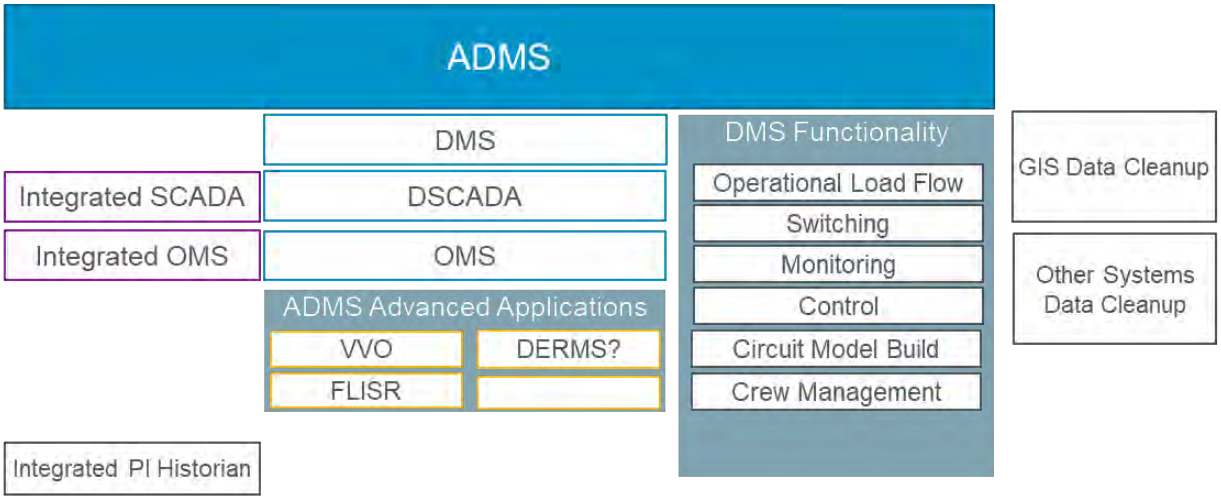
Source: Stamp Approved Performance Metrics, July 25, 2019.

2.2 Introduction to ADMS/ALF

ADMS/ALF is a software platform investment and is fundamental to a modernized grid. ADMS consists of a combination of SCADA, OMS, DMS, and advanced applications including operational power flow, VVO, FLISR, and DERMS. The capabilities of ADMS are key to delivering on all three of the DPU's Grid Modernization objectives including the ability to control devices for system optimization, providing support for ADA and VVO, and serving as an enabling platform to support a high penetration of DER.

Figure 2 shows the typical components of ADMS. This diagram shows the normal native and integrated components of ADMS and a functionality stack related to the DMS component of ADMS. The components and functionality are foundational to the industry status of ADMS and serve as the consistent picture for evaluation of ADMS at the EDC. Each of the EDC are implementing solution components, integration, and functionality and supporting data cleanup with different plans and timeframes in response to the IA and their needs.

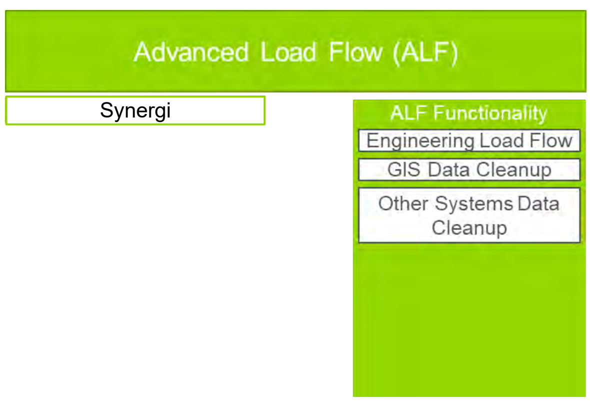
Figure 2. ADMS Evaluation Components and Functionality



Source: Guidehouse

A picture of the ALF context is shown in Figure 3. This diagram shows Synergi and a functionality stack related to the data cleanup component of ALF. The components and functionality shown in the figure are foundational to the industry status of ALF and serve as the consistent picture for evaluation of ALF at Eversource.

Figure 3. ALF Evaluation Components and Functionality



Source: Guidehouse

2.3 ADMS/ALF Evaluation Objectives

This evaluation will focus on the progress and effectiveness of the DPU preauthorized ADMS and ALF investments for each EDC toward meeting the DPU's grid modernization objectives.[5] Table 8 illustrates the key metrics on which the evaluation will report. These include two infrastructure metrics and two performance metrics.

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

Table 8. ADMS Evaluation Metrics

Metric Type	ADMS Evaluation Metrics	ES	NG	UTL
IM	Deviation between actual and planned deployment for the plan year	✓	✓	
IM	Projected deployment for the remainder of the three-year term	✓	✓	
PM	Increase in circuits and substations with DMS power flow and control capabilities	✓	✓	
PM	Control functions implemented by circuit and substation	✓	✓	
N/A[6]	DMS implementation (planning, procurement, development, deployment, go-live)	✓	✓	✓
N/A	DSCADA implementation or integration (planning, procurement, development, deployment, go-live)	✓	✓	✓
N/A	OMS implementation or integration (planning, procurement, development, deployment, go-live)	✓	✓	✓
N/A	Cleanup of GIS data by circuit, substation, and region		✓	
N/A	Cleanup of Other Data by circuit, substation, and region		✓	

Source: Stage 3 Plan, Stamp Approved Performance Metrics, July 25, 2019

Table 9. ALF Evaluation Metrics

Metric Type	ALF Evaluation Metrics	ES	NG	UTL
IM	Deviation between actual and planned deployment for the plan year	✓		
IM	Projected deployment for the remainder of the three-year term	✓		
PM	Advanced Load Flow – Percent Milestone Completion	✓		
N/A[7]	Data cleanup of GIS and Other Systems by circuit, substation, sub-region, and region	✓		
N/A	Use of load flow tools for engineering (e.g., CYME, Synergi) by % of service territory	✓		
N/A	% of region and sub-region using automated scripting on a monthly basis	✓		
N/A	Use of near-real time system telemetry in load flow analysis	✓		
N/A	% of DG interconnection requests that use Advanced Load Flow investment	✓		
N/A	Comparison of reduction in average DG interconnection request between ALF-enabled vs. non-ALF-enabled feeders	✓		

Source: Stage 3 Plan, Stamp Approved Performance Metrics, July 25, 2019

The data supporting the infrastructure metrics were provided to the evaluation team by the EDCs. Guidehouse presents results from analysis of infrastructure metrics data in Section 5.0. The performance metrics will be based on statistical analyses performed by the evaluation team using data provided by each EDC and are to be evaluated in 2021 to allow data collection to be completed

The scope of the ADMS/ALF measurement and verification (M&V) includes tracking the ADMS/ALF software implementation against plan, data cleanup progress, and cost.

[6] Metric type "N/A" is for metrics not specifically outlined by the DPU but will be measured to understand all aspects of ADMS/ALF for a comprehensive holistic evaluation. See Stage 3 Plan.

[7] Metric type "N/A" is for metrics not specifically outlined by the DPU but will be measured to understand all aspects of ADMS/ALF for a comprehensive holistic evaluation. See Stage 3 Plan.

Table 10. ADMS/ALF M&V Objectives and Associated Research Questions

ADMS/ALF M&V Objective	Associated Research Questions
Software Implementation	• How do the ADMS and ALF investments align with optimizing system performance, optimizing system demand, and enabling interconnection and integration of DER? • What is each EDC's specific investment plan strategy for ADMS and ALF implementation (components and timeframes) during the preauthorized investment period, 2018-2020? • What does each EDC plan to leverage as a baseline ADMS and ALF application/ component stack (GIS, PI Historian, DSCADA, OMS, Synergi, Other Systems, and/or other)? • What does each EDC plan to do related to ADMS functionality, including operational load flow, VVO, FLISR, and DERMS? • What does each EDC plan to do related to ALF functionality, including static analysis, semi-automated analysis, and fully automatic analysis? • What is the specific timing of ADMS implementation, integration with supporting systems, and data cleanup in GIS and Other Systems?
Data Cleanup	• What is the specific timing of ALF investment components including GIS data cleanup, Other System data cleanup, and Synergi implementation?

Source: Guidehouse

3.0 ADMS/ALF Data Management

Guidehouse worked with the EDCs to collect data to complete the ADMS/ALF evaluation for the assessment of infrastructure and performance metrics. The following sections highlight Guidehouse's data sources and data QA/QC processes used in the evaluation of infrastructure and performance metrics.

3.1 Data Sources

Guidehouse used a consistent methodology (across investment areas and EDCs) for evaluating and illustrating EDC progress toward the GMP metrics. The subsections that follow summarize each of the data sources used to evaluate infrastructure metrics.

3.1.1 2018 Grid Modernization Plan Annual Report

Guidehouse used the planned device deployment and cost information from each EDC's 2018 GMP Annual Report Appendix 1 (filed January 31, 2020) as the baseline to track progress against the GMP targets.[8] This data source is referred to as the "EDC Plan" in summary tables and graphs throughout the report. Table 11 summarizes the specific data from this source for the planned device deployment.

Table 11. Data Used for the EDC Plan

Representative Color	Data	Description
	2020 Plan	Projected 2020 unit deployment/ total spend

[8] Unitil planned information was obtained directly from their 2018 GMP Annual Report.

Representative Color	Data	Description
	2019 Plan	Estimated 2019 unit deployment/ total spend
	2018 Actual	Actual reported unit deployment and spend in 2018

Source: EDCs' 2018 GMP Annual Report Appendix 1 filed July 31, 2020

Guidehouse used the Feeder Status tab of the 2018 GMP Annual Report Appendix 1 to obtain feeder characteristics including system voltage, total feeder count, customer count, feeder length, and annual peak load.

3.1.2 EDC Data Sources

Guidehouse collected device deployment data at the feeder-level using standardized data collection templates for all EDCs (the all device deployment data and ADMS/ALF supplemental workbooks). These data sources are referred to as EDC Data in summary tables and figures throughout the report. Table 12 summarizes the file versions used for the evaluation.

Table 12. EDC Data Received for Analysis

Company	ADMS/ALF Supplemental Data Template
Eversource	Received 1/22/2020
National Grid	Received 1/10/2020
Unitil	Received 1/20/2020

Source: Guidehouse

3.2 Data QA/QC Process

Guidehouse reviewed all data provided for infrastructure metrics analysis and performance metrics analysis upon receipt of requested data. The following sections provide details on the data QA/QC processes adopted for the two analysis areas.

3.2.1 Infrastructure Metrics Data QA/QC

To ensure accuracy, Guidehouse conducted a high level QA/QC of all 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., circuit information provided in the wrong field)
- Missing or incomplete information
- Differences between the number of circuits ALF supported on in PY2019 and projected to be addressed in PY2020
- Deviation between 2018 GMP Annual Report (filed May 1, 2019) and actual deployment and spend

3.2.2 Performance Metrics Data QA/QC

During PY 2019, no performance metric information was provided for ADMS/ALF. If performance metrics were provided, 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.

4.0 ADMS/ALF Evaluation Process

This section presents a high-level overview of the Guidehouse methodologies for the evaluation of infrastructure metrics and performance metrics. Additional details on the evaluation approaches for infrastructure metrics and performance metrics are available in the Stage 3 Evaluation Plan.

This ADMS/ALF evaluation is focused on infrastructure metrics for PY2019. ADMS/ALF data cleanup and planning are ongoing, and the use of ADMS/ALF functionality has not begun; therefore, the evaluation of performance metrics is not provided for PY2019. Instead, the evaluation for PY2020 for ADMS/ALF will include both infrastructure metrics and performance metrics, as sufficient ADMS/ALF data required for performance metrics analysis will have been collected.

4.1 Infrastructure Metrics Analysis

Guidehouse annually assesses the progress of each of the EDCs toward enabling ADMS/ALF on their feeders and substations. Table 13 highlights the infrastructure metrics that were evaluated. Although infrastructure metrics are the same across all investment areas, ADMS/ALF investments are not tracked by device. Instead, ADMS/ALF investments are tracked by technology or software implementation. Throughout the ADMS/ALF portion of this report, the term “technology or software implementation” is used instead of “device deployment.”

Table 13. Infrastructure Metrics Overview

IM	Metric	Calculation Parameters
IM-4	**Number of devices or other technologies deployed**	# Devices – *total number of devices that have been commissioned, are in the construction phase, and are in the design phase*
		% Devices Deployed – *percent of the total planned devices over the 3-yr. period that have been commissioned*
IM-5	**Cost for Deployment**	Total Spend – *total spend through PY2019, regardless of whether the device has been commissioned*
		% Spend – *percent of the total estimated spend over the 3-year GMP period*
IM-6	**Deviation Between Actual and Planned Deployment for the Plan Year**	% On Track (Devices) – *devices commissioned through PY2019 divided by the devices planned for commission through PY2019*
		% On Track (Spend) – *actual spend through PY2019 divided by the planned spend through PY2019*
IM-7	**Projected Deployment for the Remainder of the Three-Year Term**	# Devices Remaining – *How many devices remain to be commissioned in PY2020*
		Spend Remaining – *How much spend is estimated for PY2020*

Source: Guidehouse

Section 5.0 provides the results from the evaluation of infrastructure metrics. To evaluate infrastructure metrics, Guidehouse:

- Reviewed the EDC data provided to ensure the information provided accurately reflected their progress through PY2019 (see Section 3.2 , "Data QA/QC Process")
- Interviewed representatives from each EDC to understand the status of the ADMS/ALF investments, including:
    - Updates to their planned ADMA/ALF investments
    - Reasons for deviation between actual and planned deployment and spend

4.2 Performance Metrics Analysis

Performance metrics will be evaluated for each of the three EDCs. The EDCs have proposed to score and then count the number of substations with fully implemented and successful ADMS power flow analysis and the number of circuits with the specified control functions implemented. For ALF, Eversource proposed a metric designed to demonstrate progress toward the final completion of a fully automated modeling tool. Table 14 describes the performance metrics that will be evaluated for PY2020.

Table 14. Performance Metrics Overview[9]

PM	Performance Metrics	Description
PM-1	**ADMS Capabilities**	Increase in circuits and substations with DMS power flow and control capabilities
PM-2	**ADMS Control Functions**	Control functions implemented by circuit and substation
PM-3	**ALF Completion**	Percent milestone completion of circuits with ALF capabilities

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

5.0 Infrastructure Metrics Findings

Guidehouse presents findings from the infrastructure metrics analysis for ADMS in Sections 5.1 through 5.4. Tables and figures highlight high level findings, with key findings presented thereafter.

5.1 Statewide

This section discusses statewide ADMS/ALF investment progress through PY2019 and projected PY2020 progress.

Table 15 presents the infrastructure metrics results through PY 2019 for all EDCs. Additional detail surrounding findings for each of the infrastructure metrics are provided in subsections. Although infrastructure metrics are the same across all investment areas, ADMS/ALF investments are not tracked by device. Instead, ADMS/ALF investments are tracked by technology or software implementation. Throughout the ADMS/ALF portion of this report, the term "technology or software implementation" is used instead of "device deployment."

[9] Note: Potential metrics in the future would be to assess the implementation and functionality of ADMS advanced applications such as VVO and FLISR.

Table 15. 2019 Infrastructure Metrics for ADMS/ALF

Infrastructure Metrics		Parameter	Progress through PY2019		
			Eversource	National Grid	Unitil
IM-4	Number of devices or other technologies deployed	# Devices (Technology[10]) Deployed	2,242[11] circuits with static ALF	0	0
		% Devices (Technology) Deployed	50%	N/A	N/A
IM-5	Cost for Deployment	Total Spend, $M	$2.78	$1.05	$0
		% Spend	28%	3%	N/A
IM-6	Deviation Between Actual and Planned Deployment for the Plan Year	% On Track (Devices/ Technology)	89%	N/A	N/A
		% On Track (Spend)	41%	6%	N/A
IM-7	Projected Deployment for the Remainder of the Three-Year Term	# Devices (Technology) Remaining	2,234[12] circuits with enhanced semi-auto ALF	196 circuits	N/A
		Spend Remaining, $M	$10.1	$31.4	$0.4

Source: Guidehouse analysis of 2018 GMP Annual Reports

The following table presents technology implementation progress in 2019 for all EDCs.

Table 16. Device Deployment Status

Device	Actual through PY2019		2020 Device Deployment Progress		3-Year Planned Total[13]	
	In-Service (% Units)	Accrued Cost ($M)	Planned (% Units)	Planned Cost ($M)	% Units	Cost ($M)
Eversource						
ADMS[14]	0%	$0	0%	$2.0	0%	$2.0
ALF	50%	$2.78	50%	$10.1	100%	$12.9
National Grid						

[10] ADMS/ALF is not tracked by "device"; it is tracked by "technology" implementation. Circuits that have implemented static ALF are at 50% functionality and semi-automatic ALF are at 100% functionality.

[11] Total number of Eversource circuits at time of evaluation. All circuits are at 50% functionality (static ALF) as of end of PY2019. The remaining 50% functionality (semi-automated ALF) will be implemented on all circuits in PY2020.

[12] Number of circuits excluding those going through reconfiguration / retirement

[13] Based on EDC data provided.

[14] Eversource planned limited ADMS implementation for the evaluation period.

Device	Actual through PY2019		2020 Device Deployment Progress		3-Year Planned Total[13]	
	In-Service (% Units)	Accrued Cost ($M)	Planned (% Units)	Planned Cost ($M)	% Units	Cost ($M)
ADMS	0%	$1.05	100%	$31.4	100%	$32.4
Unitil						
ADMS	0%	$0	100%	$0.4	100%	$0.4

Source: Guidehouse analysis of 2018 GMP Annual Reports

As part of the 2018-2020 GMP, ADMS/ALF investments are anticipated to affect 73% of total EDC circuits in Massachusetts across the three EDCs. Table 17 highlights the anticipated impact by EDC. All three EDCs have operating territories that include Massachusetts and surrounding states. The ADMS/ALF programs include investments in Massachusetts as addressed and evaluated in this report.

Regions that contain feeders with planned ADMS/ALF investments include:

- Eversource: All Massachusetts operating territory
- National Grid: All Massachusetts operating territory
- Unitil: Cities/towns of Fitchburg, Townsend, and Lunenburg

Table 17. ADMS/ALF Investments Planned

Investment Area	Eversource ALF[15]		National Grid ADMS		Unitil ADMS[16]		ADMS/ALF Total	
	Circuit	Substation	Circuits	Substations	Circuits	Substations	Circuits	Substations
PY2018 – 19 Implementation	2,242[17]	246	0	0	N/A	N/A	**2,242**	**246**
PY2020 Planned Implementation	2,234[18]	246	196	46	N/A	N/A	**2,473**	**293**
3-Year. GMP Total	2,234	246	196	46	N/A	N/A	**2,473**	**293**
System-Wide Total	2,234[19]	-	1,104[20]	-	-	-	**3,393**	**-**
Percent System Total	**100%**	**-**	**12%**	**-**	**-**	**-**	**73%**	**-**

[15] Eversource planned limited ADMS implementation for the evaluation period.

[16] Unitil ADMS functionality is not planned for the 3-year evaluation period. See Section 5.4 for more details on Unitil ADMS implementation.

[17] Number of circuits/substations with static ALF

[18] Number of circuits/substations with enhanced semi-automatic ALF

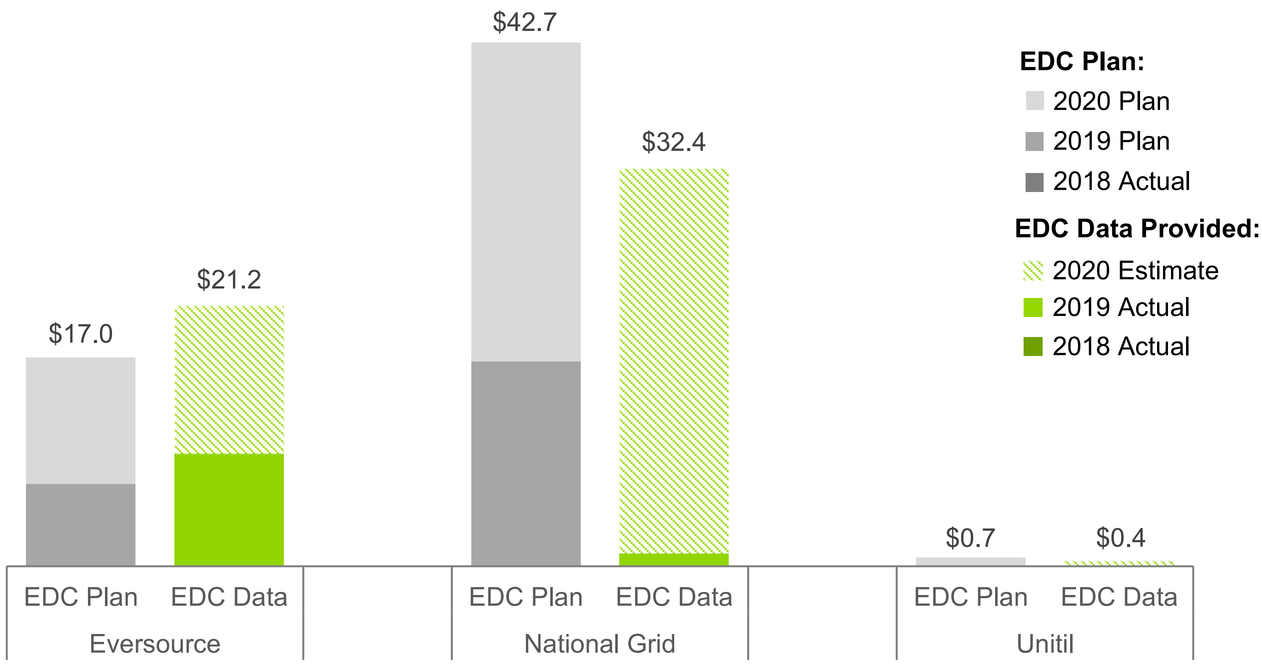
[19] Number of circuits excluding those going through reconfiguration/retirement

[20] Not all National Grid feeders can be included in ADMS process. The feeders that are not candidates are fully underground feeders, including (but not limited to) feeders sourcing networked secondary.

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Figure 4 highlights planned versus actual spend in ADMS/ALF for each of the three EDCs. The specific EDC's results sections detail the differences between planned and actual spend.

Figure 4. ADMS/ALF Planned vs. Actual Spend, 2018-2020[21]



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

For Eversource, GIS Survey is no longer reported in the same IA as ADMS/ALF as GIS Survey spending has been operations and maintenance spending, not capital. While the planned spend includes GIS Survey, the actual spend does not.

For National Grid, GIS Data investments are identified as a separate IA from the base ADMS allowance. The planned spend above is inclusive of GIS data, while the actual spend does not.

5.1.1 Key Findings

Infrastructure metrics findings for PY2019 show that the EDCs are, for the most part, where they had anticipated in their 2018 GMP Annual Reports.

- Eversource is closely following the deployment plan. Deployment in PY 2019 slightly exceeded the plan and the same is expected for PY 2020.

[21] The $21.2M of Eversource data provided includes $6.4 million expenses for GIS Survey.

- National Grid experienced a slower mobilization which will impact the initial plans to deploy ADMS/ALF by the end of PY 2020.
- Unitil is just beginning with its ADMS investment, with an accelerated schedule to use ADMS as the platform for the VVO investment.

5.2 Eversource

This section discusses Eversource's ALF investment progress through PY 2019 and projected PY 2020 progress as compared to the 2018 GMP Annual Report.

5.2.1 GMP Objectives

Table 18 presents the GMP objectives that Eversource aims to achieve with their ADMS and ALF implementation. Static ALF is implemented on 2,242[22] circuits and ADMS implementation has not started.

Table 18. Eversource ADMS/ALF GMP Objective Summary

Company	GMP Objective	Software Implementation
Eversource	Implement ALF and ADMS throughout the region to: • Increase visibility • Enhance the grid for DER customers • Increase DER hosting capacity	ADMS • Limited ADMS implementation planned for given evaluation period (2018-2020)
		ALF • Enhanced semi-automatic ALF planned (instead of fully automatic) by the end of 2020 • 2,242[23] circuits across 246 substations • Static ALF is complete on all circuits • Software chosen is Synergi

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

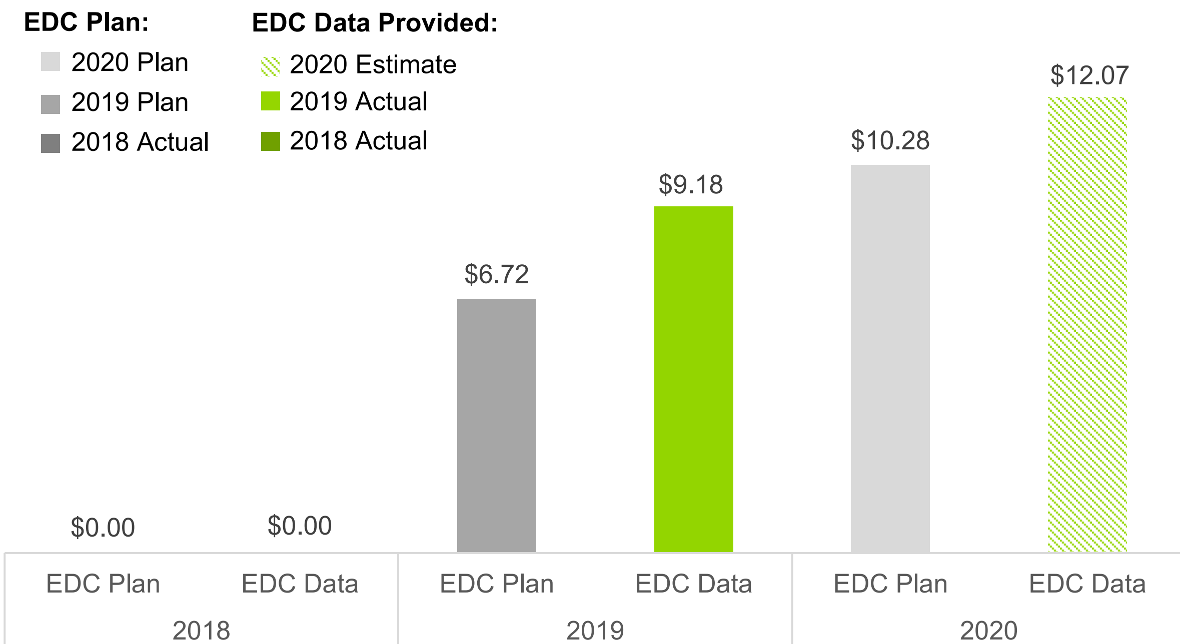
5.2.2 Progress to Date

Eversource's ADMS/ALF investment is on track with its revised plan. Figure 5 summarizes the planned and actual spend for Eversource's ADMS/ALF investment.

[22] Eversource is in the process of circuit reconfiguration, the original 2,242 circuits will become a total of 2,234 circuits.

[23] Ibid. See footnote 12 above.

Figure 5. Eversource ADMS/ALF Planned vs. Actual Spend[24]

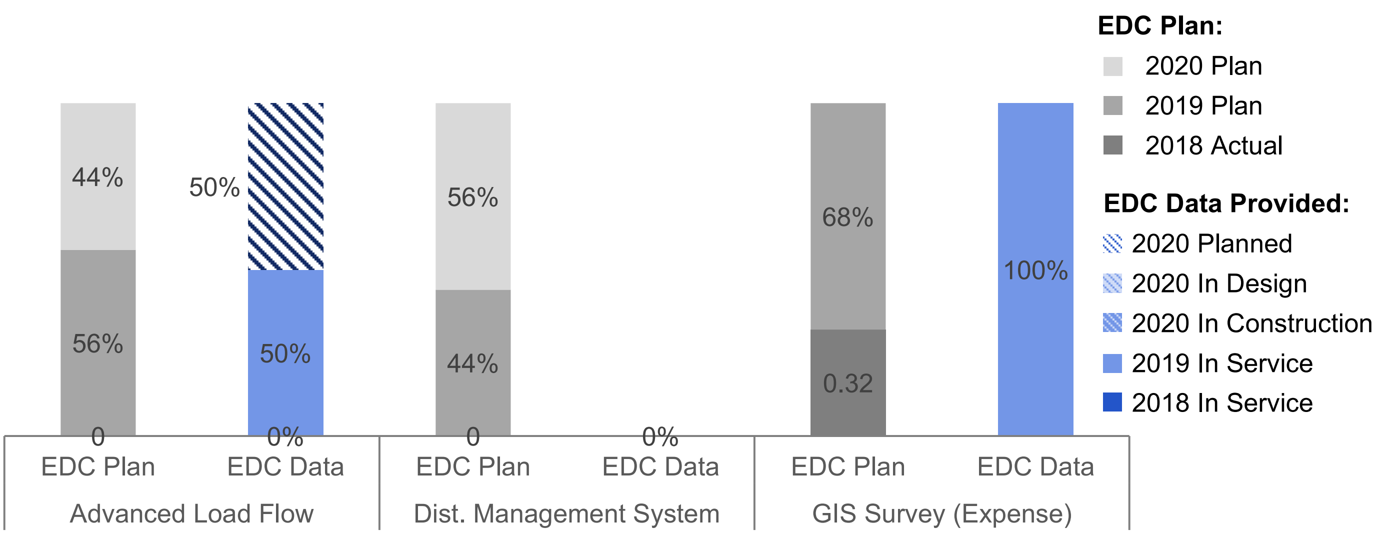


Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Overall ALF implementation is on schedule and limited ADMS is planned for the evaluation period. GIS Survey is included as part of the ADMS/ALF IA for Eversource. Figure 6 summarizes the planned and actual technology implementation progress for Eversource's ADMS/ALF investment.

[24] $6.4M GIS Survey expense spend from Eversource is included in the "2019 Actual" amount

Figure 6. Eversource ADMS/ALF Planned vs. Actual Implementation



Note: Eversource no longer reports GIS Survey in the same IA as ADMS and ALF.
Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.2.3 Key Findings

Guidehouse's review of Eversource's ADMS/ALF progress confirmed that Eversource is in line with where it had anticipated to be in its 2018 GMP Annual Report. Key findings related to Eversource's progress include:

- Implementation plan for ALF is on track with a target of enhanced semi-automatic ALF by the end of PY 2020.
- Internal tracking of ALF progress broken out by western and eastern Massachusetts as ALF models are built by region, not broken out by circuit or substation.
- Limited ADMS implementation is planned for 2018-2020.
- Total spend to date is less than planned for ALF.
- Total spend overall is less than planned for ALF.

5.3 National Grid

This section discusses National Grid's ADMS investment progress through PY 2019 and projected PY 2020 progress as compared to the 2018 GMP Annual Report.

5.3.1 GMP Objectives

Table 19 presents the GMP objectives that National Grid aims to achieve with their ADMS implementation. ADMS investment is moving forward in 2020 with a three-phase approach.

Table 19. National Grid Summary

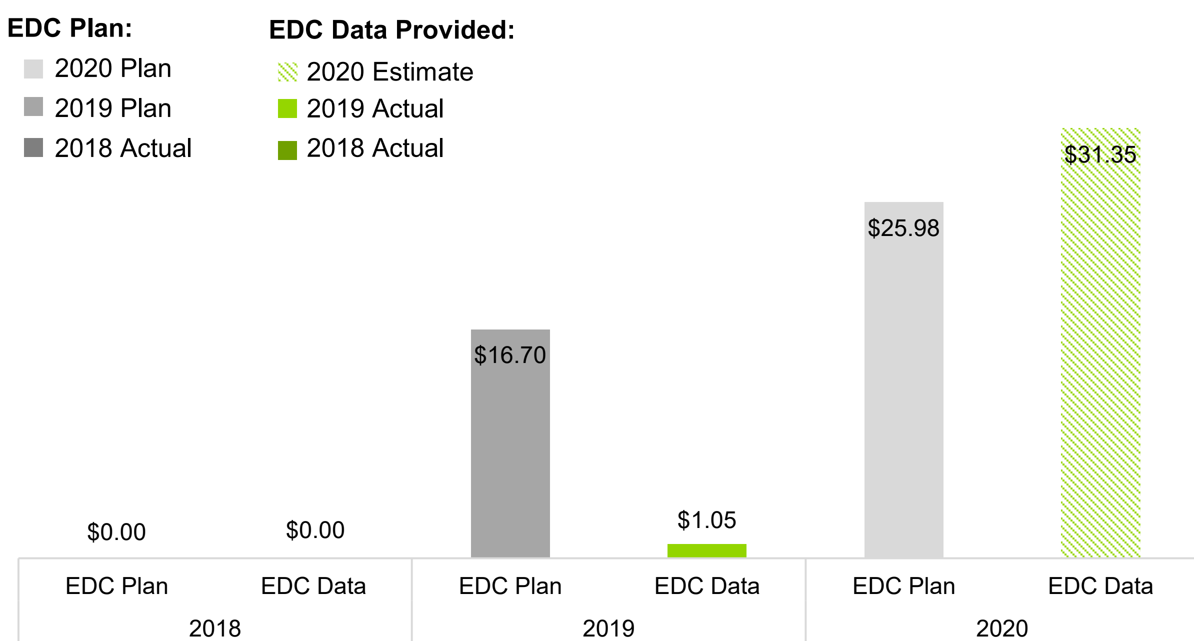
Company	GMP Objective	Software Implementation
National Grid	Utilizing ADMS to optimize: • Performance • Demand • DER integration ADMS also helps reach the overall reliability and customer experience objectives.	ADMS • 196 circuits planned for end of 2020 across 46 substations • Three-phase implementation approach: 1. Monitor and inform 2. Manage and control 3. Implement DERMS

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.3.2 Progress to Date

National Grid plans to catch up on intended 3-year ADMS spend in 2020. Figure 7 summarizes the planned and actual spend for National Grid's ADMS investment.

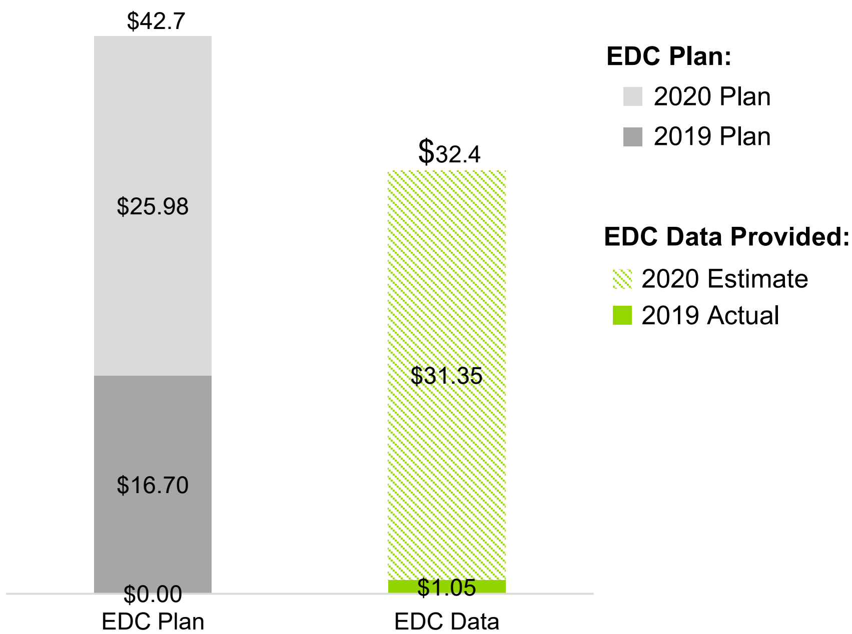
Figure 7. National Grid ADMS Planned vs. Actual Spend



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Figure 8 summarizes the total spend for National Grid's ADMS investment over the 3-year evaluation period. ADMS spending is estimated to be less than planned.

Figure 8. National Grid ADMS Planned vs. Actual Total Spend, 2018-2020



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Table 20 presents the circuits planned for ADMS implementation by region in National Grid operating territory. In 2020, there are plans to implement ADMS on 196 circuits across the Massachusetts operating territory.

Table 20. Circuits Planned for ADMS – National Grid

Region	Circuits		
	Actual through PY19	*Planned through PY19*	*Total Planned 2018-2020*
Central	0	0	26
Southeast	0	0	37
South Shore	0	0	35
Western	0	0	36
Merrimack Valley	0	0	28
North Shore	0	0	27
Nantucket	0	0	7
System	0	0	196

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.3.3 Key Findings

Guidehouse's review of National Grid's ADMS progress confirmed that National Grid has been moving forward with the ADMS investment in PY 2018 and PY 2019 but lagging their original plan. National Grid plans increased spending in PY2020 and may come in below the intended 3-year ADMS spend in PY 2020. Key findings related to its progress include:

- Deployment of the solution may fall into the next 3-year plan period
- Internal tracking of ADMS progress is comprehensive and it is treated as a large software project
- National Grid has initiated GIS data clean-up activities for the connected mode
- National Grid has 196 circuits identified for initial deployment

5.4 Unitil

This section discusses Unitil's ADMS investment progress through PY 2019 and projected PY 2020 progress compared to the 2018 GMP Annual Report.

5.4.1 GMP Objectives

Table 21 presents the GMP objectives that Unitil aims to achieve with their ADMS implementation. ADMS implementation in 2020 is planned with reduced spending.

Table 21. Unitil Summary

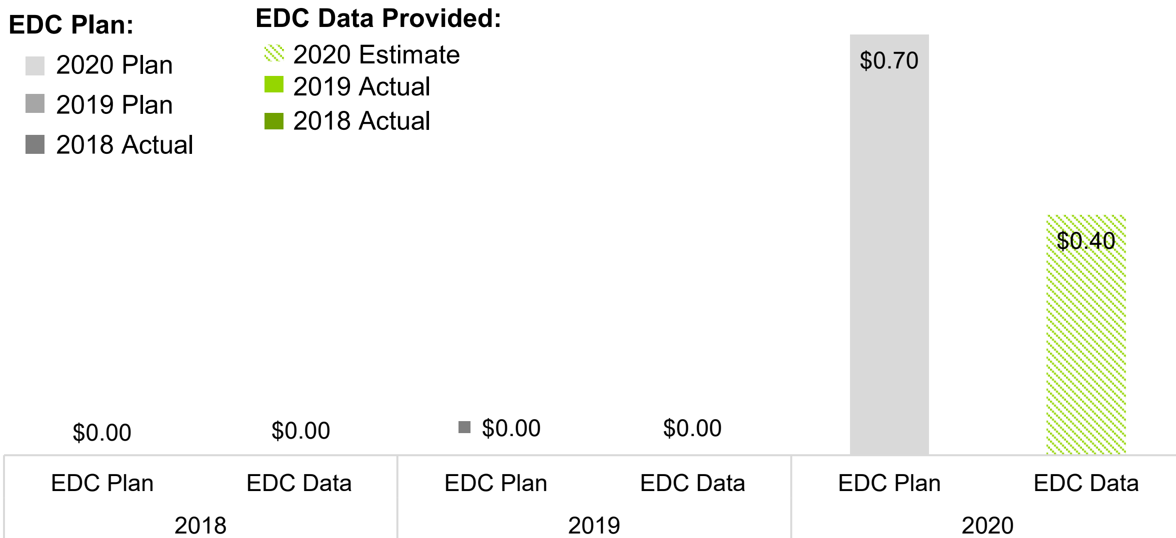
Company	GMP Objective	Software Implementation
Unitil	• Improve reliability • Use current SCADA system more effectively • Use ADMS as the platform for VVO, providing the most customer savings • *Future application*: DERMS, increasing M&C of distributed energy resources on the system	ADMS • Accelerating the ADMS project to go hand in hand with other investments – Original plan was to have no ADMS spending in first 3 years – As VVO investment developed, ADMS was chosen as platform for VVO – Went through competitive bidding process to decide on an ADMS vendor • Actual spending on ADMS will not happen until 2020 – $700,000 planned spending from May 2019 filing has changed to $400,000

Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

5.4.2 Progress to Date

Figure 9 summarizes the planned and actual spend for Unitil's ADMS investment.

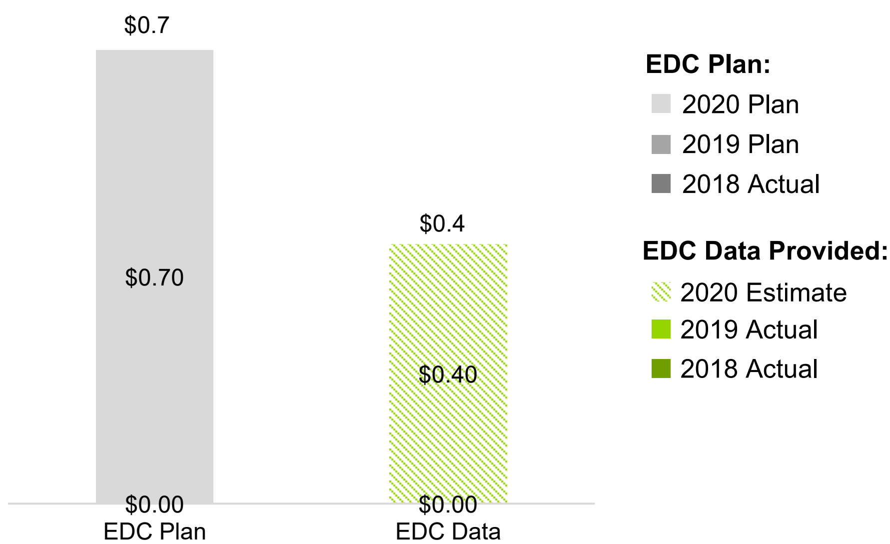
Figure 9. Unitil ADMS Planned vs. Actual Spend



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Figure 10 summarizes the total spend for Unitil's ADMS investment over the 3-year evaluation period.

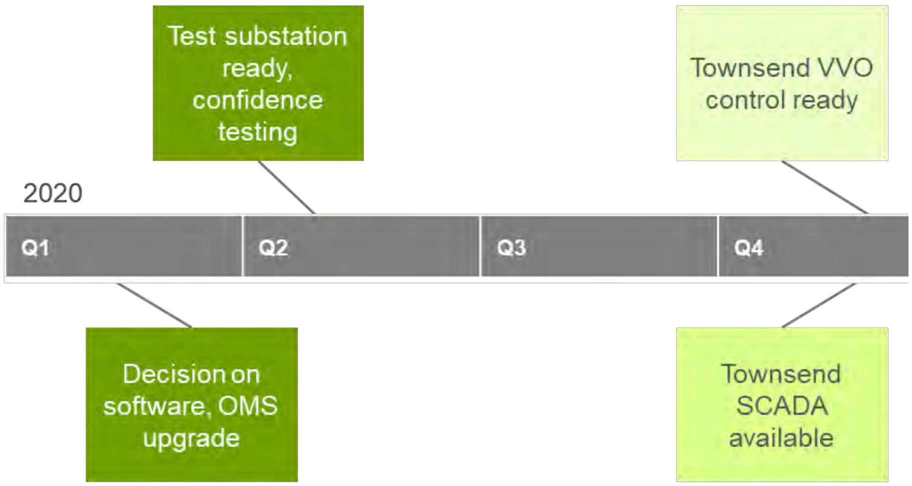
Figure 10. Unitil ADMS Total Spend 2018-2020



Source: Guidehouse analysis of 2018 GMP Annual Reports and EDC Data

Figure 11 presents the revised schedule and milestones to accommodate ADMS as the platform for VVO in PY 2020.

Figure 11. 2020 Unitil ADMS Schedule and Major Milestones



Source: EDC Data

5.4.3 Key Findings

Guidehouse's review of Unitil's ADMS progress confirmed that Unitil is in line with what was anticipated in its 2018 GMP Annual Report. Key findings related to Unitil's progress include:

- Unitil has concerns about the amount of data needed to deploy ADMS, but is working on gathering the data to feed into ADMS and making sure it is in the right quality and format for ADMS
- Internal tracking of ADMS progress is comprehensive
- Deployment is on track, with the schedule realigned to allow using ADMS as a platform for VVO, another investment area
- Total spend is less than planned on ADMS

6.0 Conclusions and Recommendations

Throughout the PY 2018 and PY 2019 period, Guidehouse worked with the EDCs on the evaluation process. Guidehouse' conclusions and recommendations are listed below.

Conclusions:

- The EDCs are learning that IT/OT applications, specifically ADMS/ALF, are different from device-centric investments and require a different approach to planning, budgeting, and monitoring.
- The EDCs are developing experience planning and implementing these new IT/OT applications and are finding that application implementation, integration, data cleanup, and change management, which are interrelated, add complexity to the projects.

- Estimates for ADMS/ALF applications were initially high level, and the EDCs refined estimates as they progressed through the PY 2019 evaluation period.
- The EDCs have, through the first two years of capital and operating their GMPs, refined their detailed plans.

Recommendations:

- The EDCs should plan out each investment moving forward to explicitly include capital and operational components of ADMS/ALF to insure complete visibility both internally and externally.
- The EDCs should continue to keep investments in cleaning data to support ADMS/ALF separate from investments in the actual ADMS software, implementation, and operationalization in order to avoid common problems experienced in the industry.

Massachusetts
Electric Vehicle Infrastructure Program

Charging Station Analysis Report
2019

Prepared by:

A Division of Akimeka, LLC

3/8/2020

Electric Vehicle Infrastructure Program

On November 30, 2017, the Department of Public Utilities issued Order 17-05, approving NSTAR ELECTRIC COMPANY AND WESTERN MASSACHUSETTS ELECTRIC COMPANY d.b.a. Eversource Energy (Eversource) to spend up to $45 million over five years on an electric vehicle (EV) infrastructure program (Program).

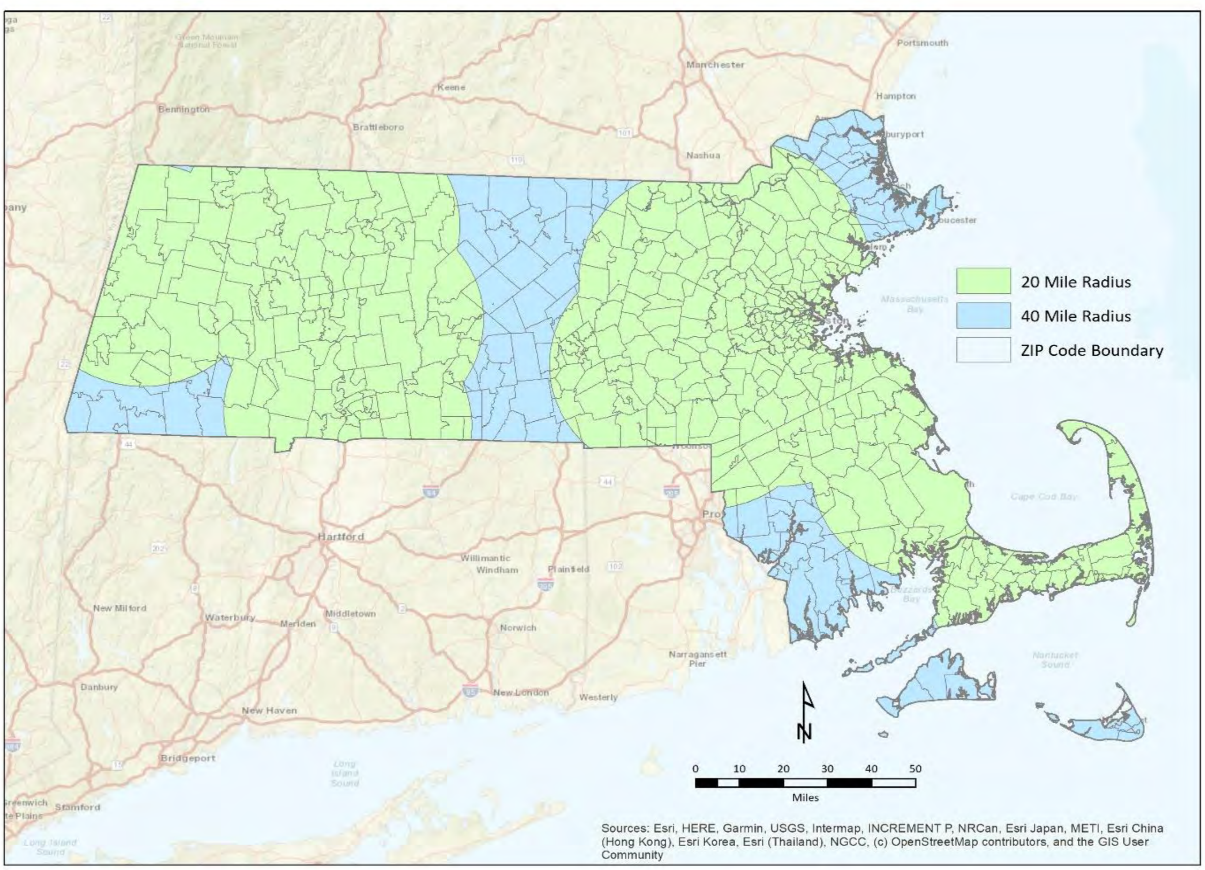
Eversource is supporting the deployment of EV charging ports by installing electrical equipment and components necessary to connect EV chargers to its distribution system. Eversource is installing the “Eversource-side Infrastructure,” and contracting with third-party electrical contractors to install behind the meter “Participant-side Infrastructure.” Specifically, the EV infrastructure that Eversource installs and owns includes: (1) distribution primary lateral service feed; (2) necessary transformer and transformer pad; (3) new service meter; (4) new service panel; and (5) associated conduit and conductor necessary to connect each piece of equipment.

Between 2018 and 2022, Eversource plans to support the deployment of up to 72 direct current fast charging (DCFC) ports at 36 sites, and up to 3,500 Level 2 charging ports at 450 sites, throughout its service territories in Massachusetts. Eversource hopes to accelerate implementation of the Make-Ready Program based on customer demand.

Eversource Customers Served by Program Installations

Approximately **87%** of Eversource customers are within 20 miles of a Program charging station

100% of Eversource customers are within 40 miles of a Program charging station



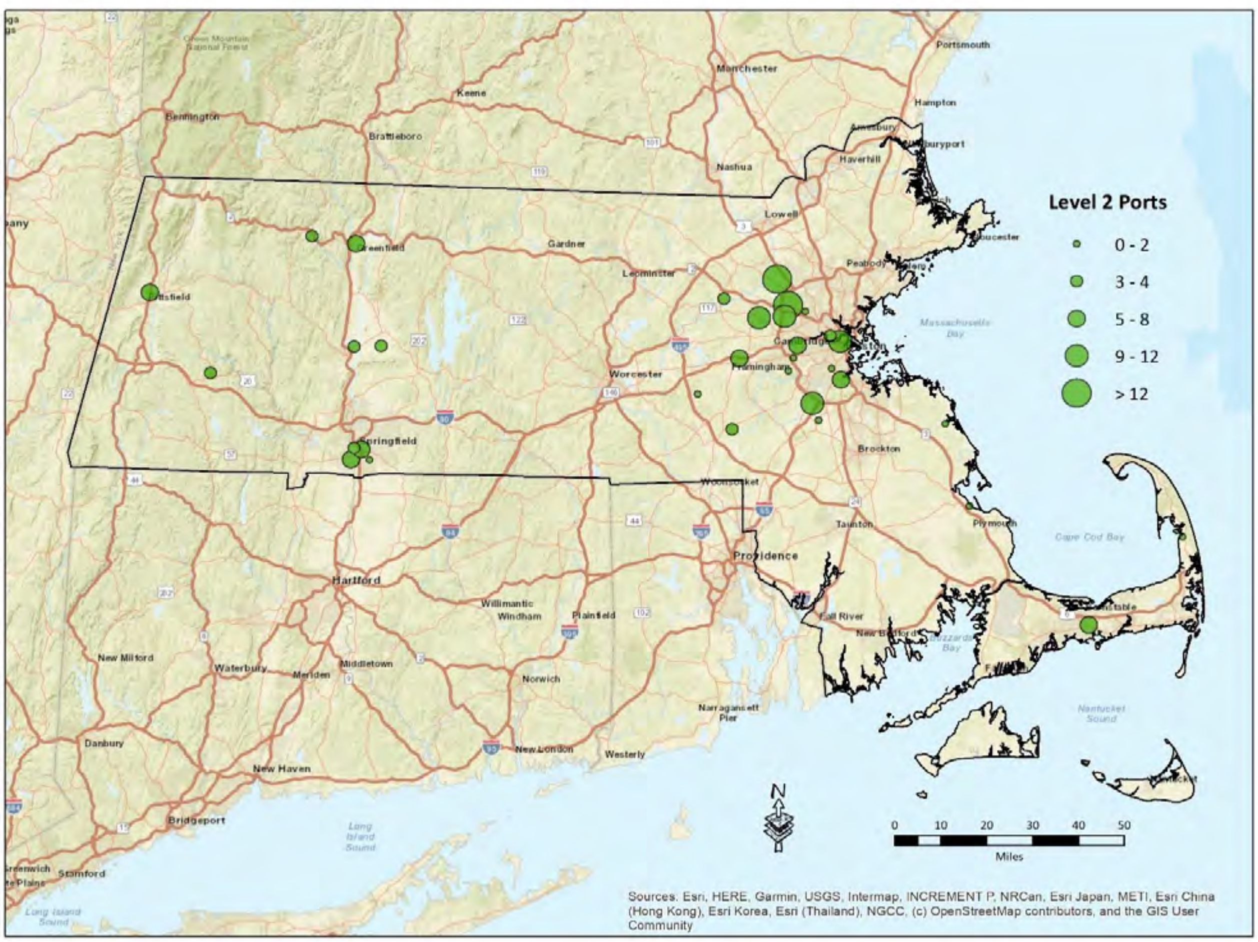
Program Station Installations

Level 2 ports provide drivers approximately 20 miles of electric driving range for each hour of charging.

198 Level 2 Ports Installed by the Program to Date

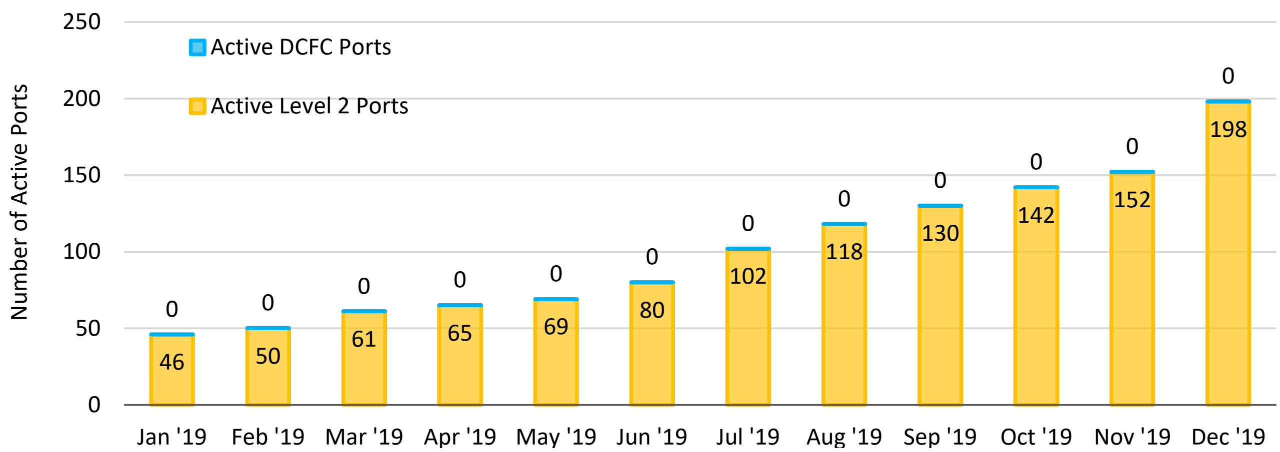
DCFC ports provide drivers 50-150 miles of electric range in 20 minutes of charging.

0 DCFC Ports Installed by the Program to Date

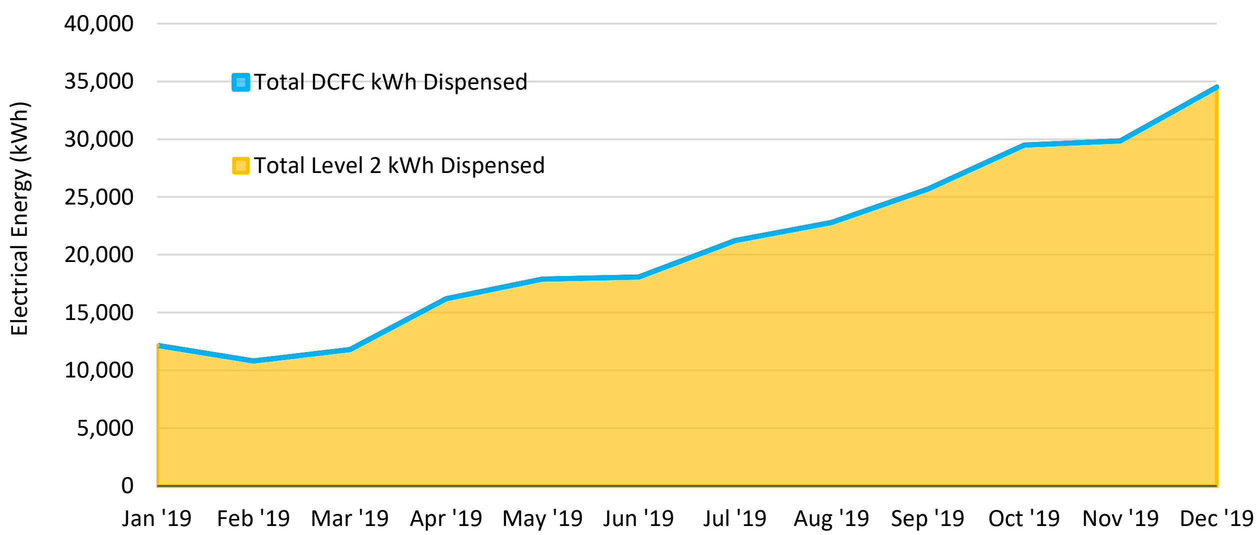


Program Station Installations

Ports are "Active" based on activation date provided by service provider, excluding known periods when repairs were needed.



Energy Dispensed



Environmental Impacts

		2019 Q1	2019 Q2	2019 Q3	2019 Q4	2019 Total
Total Charging Events[1]	Level 2	2,881	4,274	5,597	7,236	**19,988**
	DCFC	0	0	0	0	**0**
	Total	**2,881**	**4,274**	**5,597**	**7,236**	**19,988**
Total Energy Dispensed (kWh)	Level 2	34,803	52,189	69,730	93,866	**250,588**
	DCFC	0	0	0	0	**0**
	Total	**34,803**	**52,189**	**69,730**	**93,866**	**250,588**
Gallons of Gasoline Displaced[2]		**5,202**	**7,801**	**10,423**	**14,031**	**37,457**
Tons of Carbon Dioxide Saved[3]		**36.7**	**55.0**	**73.5**	**99.0**	**264.2**

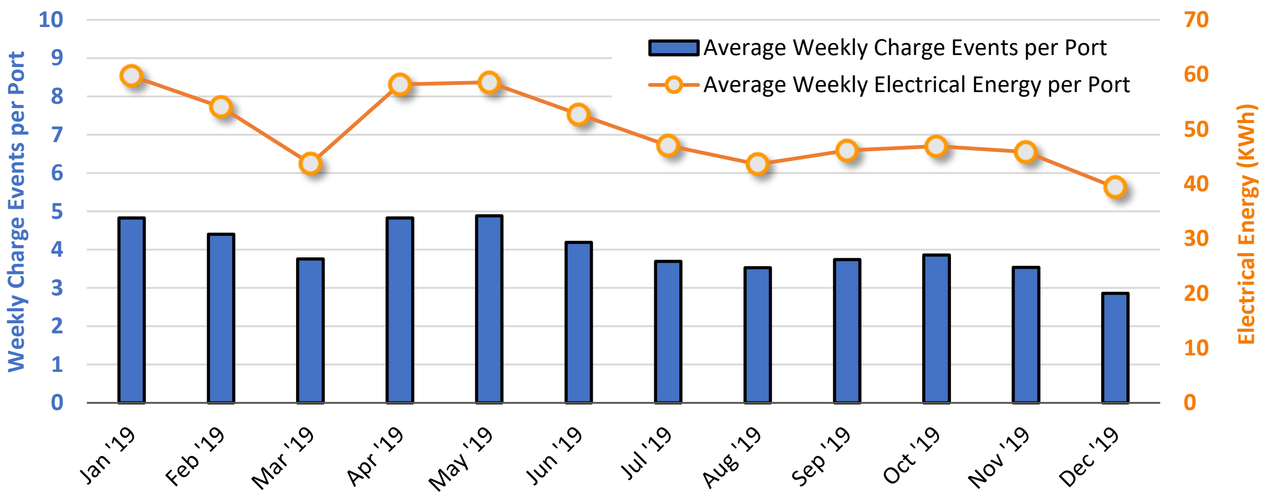
1 A recorded event is classified as a charging event if at least 0.2 kilowatt-hours (kWh) is dispensed.

2 Average EV efficiency = 0.3 kWh/mile (Plug In America). Average U.S. light duty vehicle fuel efficiency (2017) = 22.3 mpg (USDOT)

3 CO_2 emmissions/gallon = 19.6 pounds. MA output emmission rate = 821 lb/MWh (USEPA)

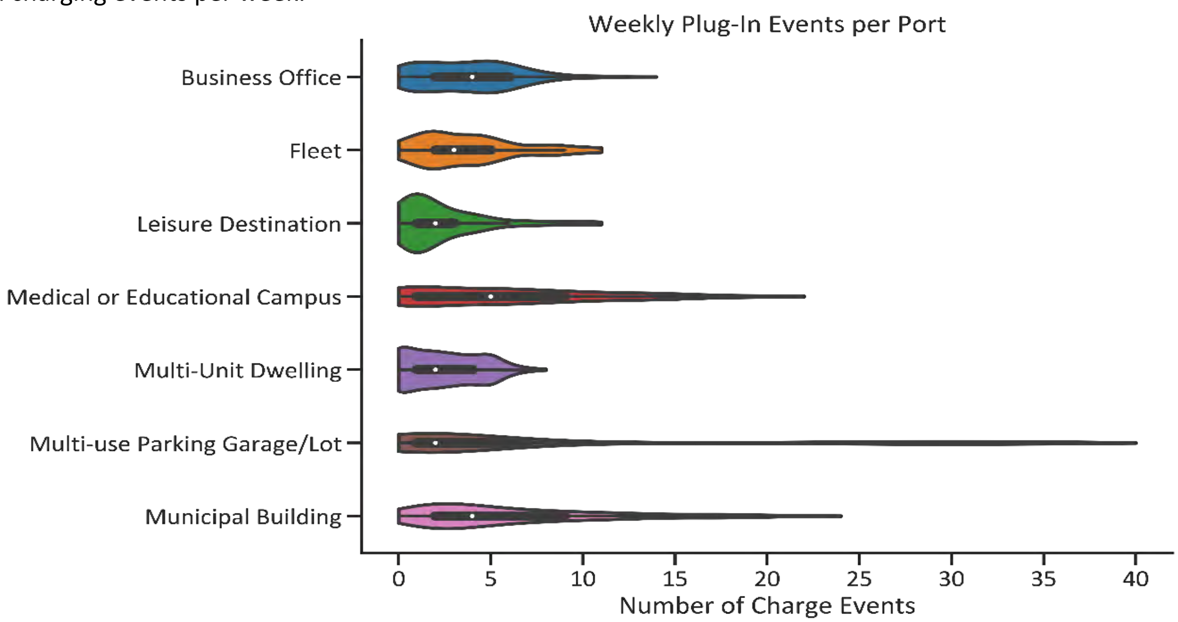
Level 2 Port Utilization

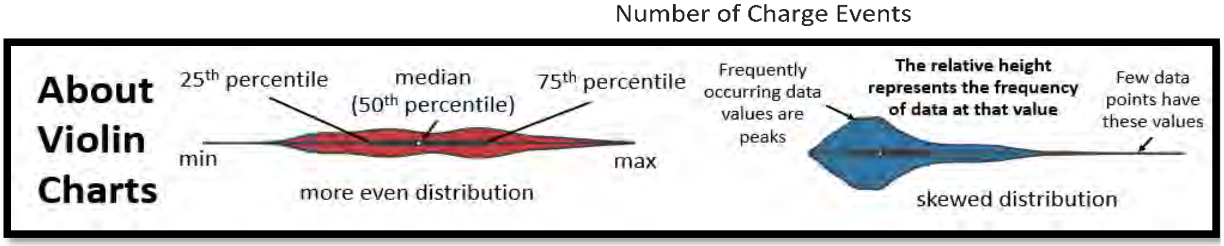
Average station utilization has slightly decreased throughout the year as more program stations were installed (utilization at newly installed stations is typically a little lower initially before EV drivers become familiar with the station location).



Level 2 Weekly Charging Events by Venue Type

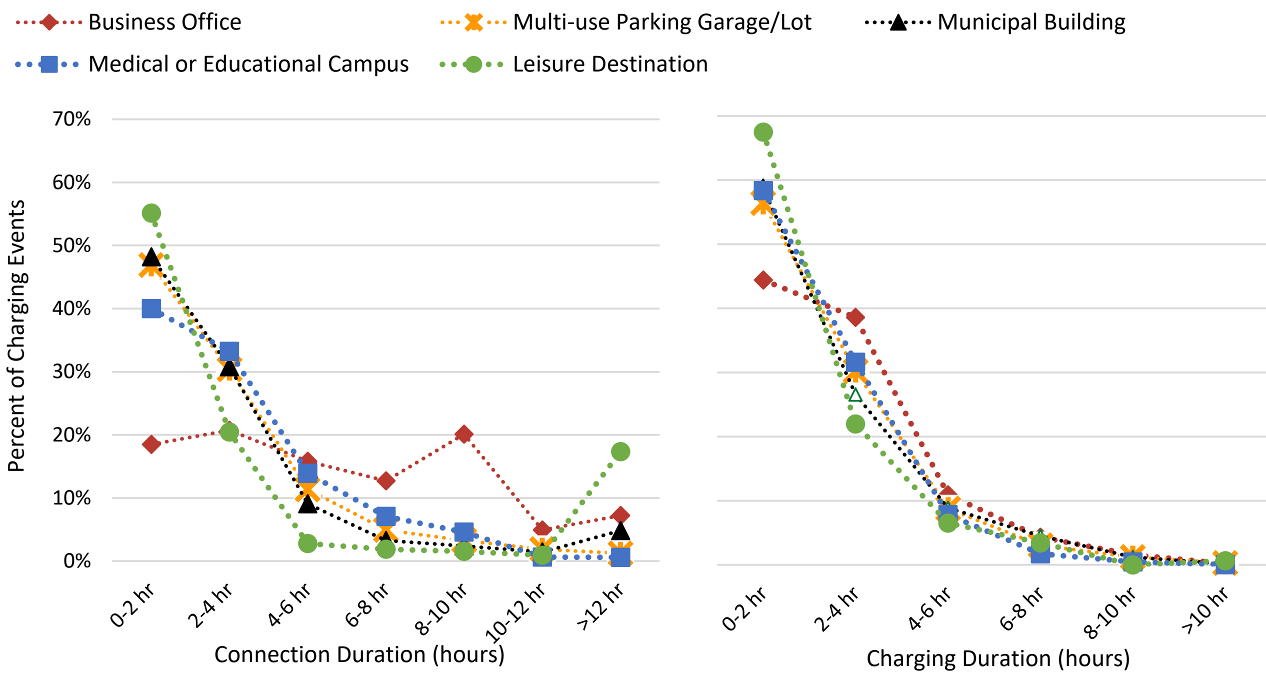
Stations at Medical/Educational campuses, Multi-use Parking Garages/Lots and Municipal Buildings experience the broadest range of utilization, with Medical/Educational campuses and Municipal Buildings having the highest median charging events per week.





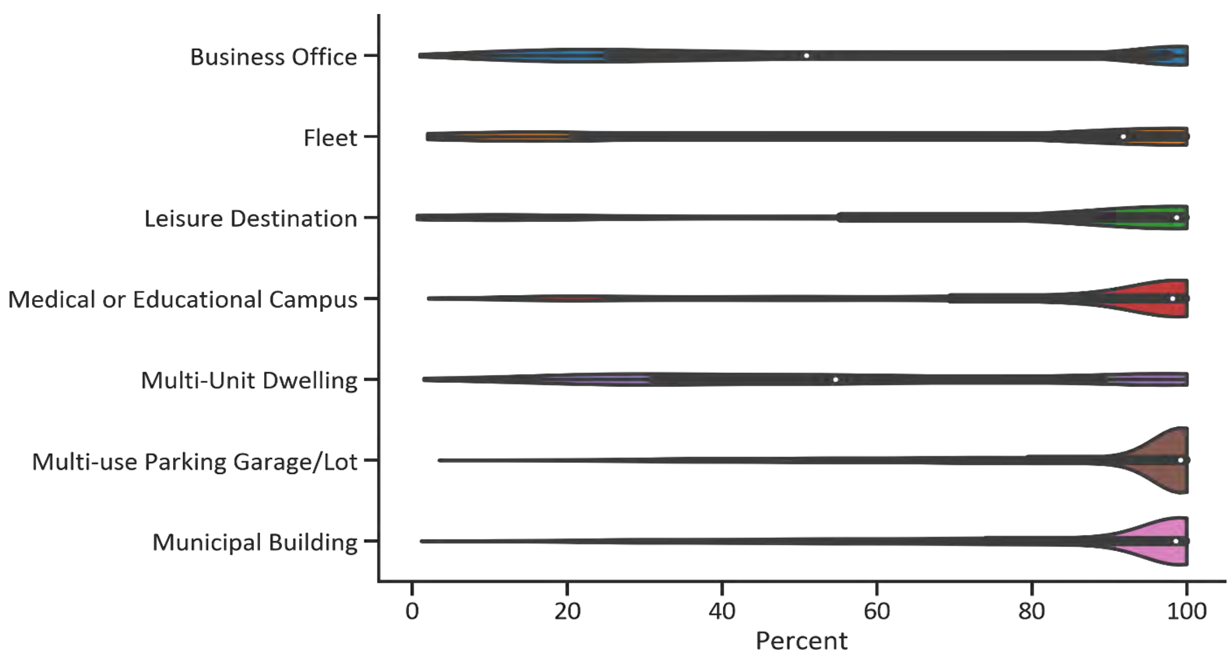
Durations for Level 2 Charging Events

Stations at Business Offices experience some longer plug-in times (workday durations of 8-10 hours) than other venues, although stations a Leisure Destinations had some long durations. At all venues, most charging is completed after 4 hours.



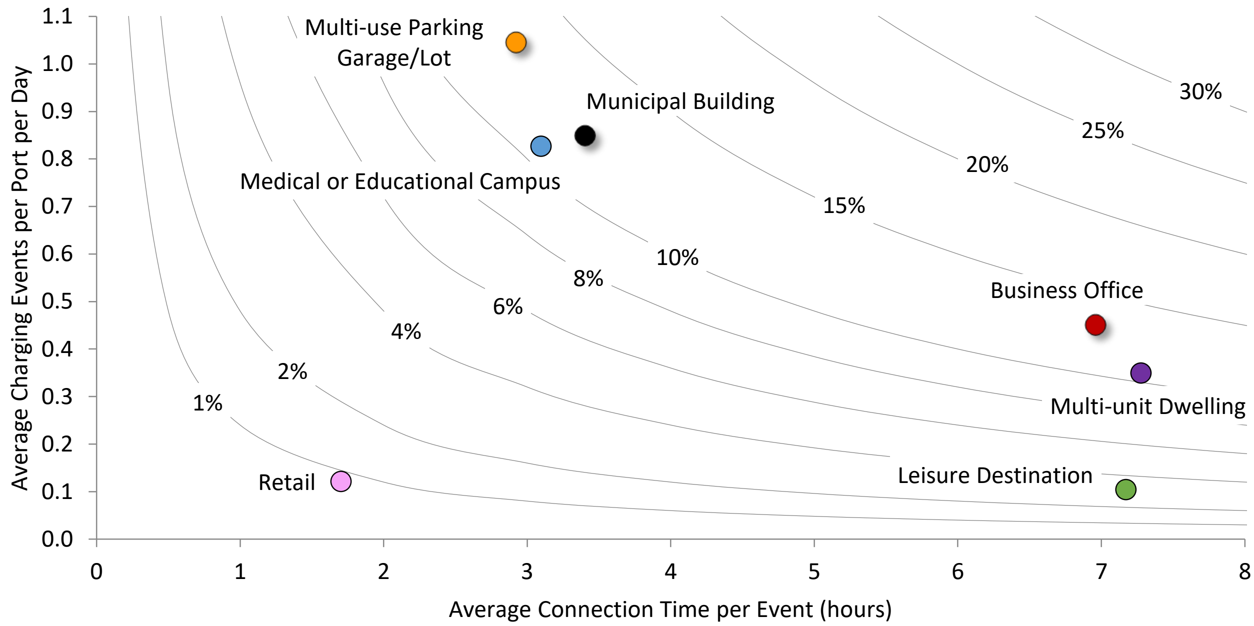
Connection Time Spent Charging for Level 2 Charging Ports

EVs often remain plugged in at Business Office and Multi-unit Dwelling stations longer than needed (charging only about half of the time is the median), whereas at other venues the connection and charge times are often similar.



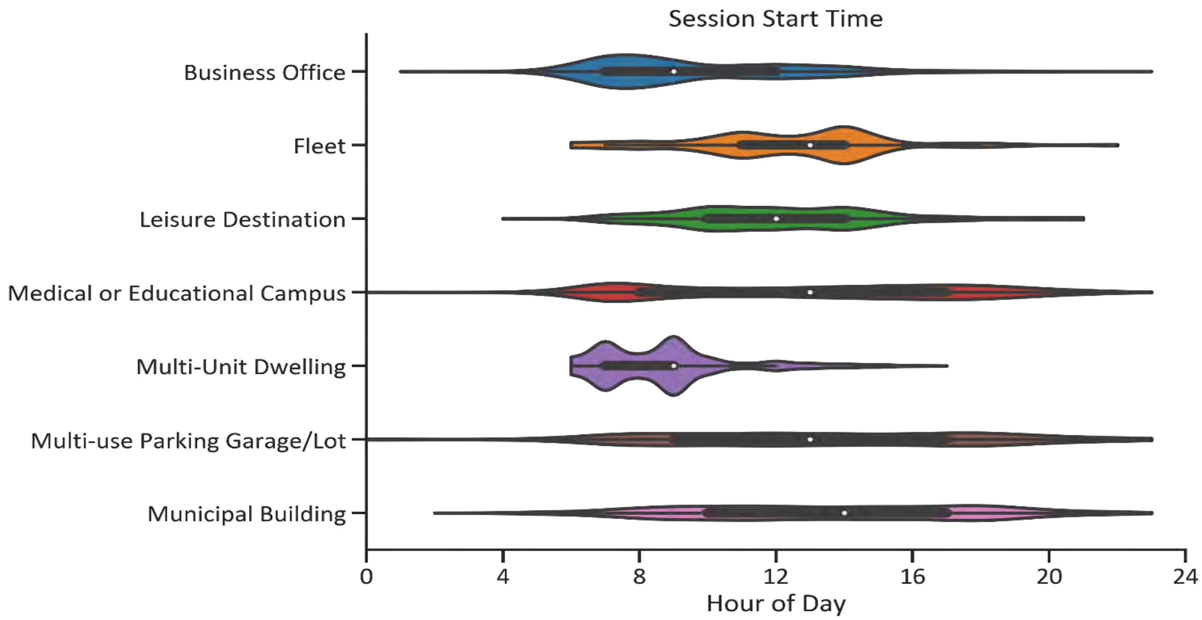
Level 2 Charging Characteristics by Venue Type

The average connection time per charge session plotted against the average number of charging events per port per day show charging session characteristic differences by venue. Profile curves represent the connection utilization percentage. Stations at Business Offices and Multi-use Parking Garages/Lots have high utilization around 13% of the time, but at Business Offices these charge events are less frequent but longer, whereas charge events at Multi-use Parking Garages/Lots are more frequent, but shorter in duration.



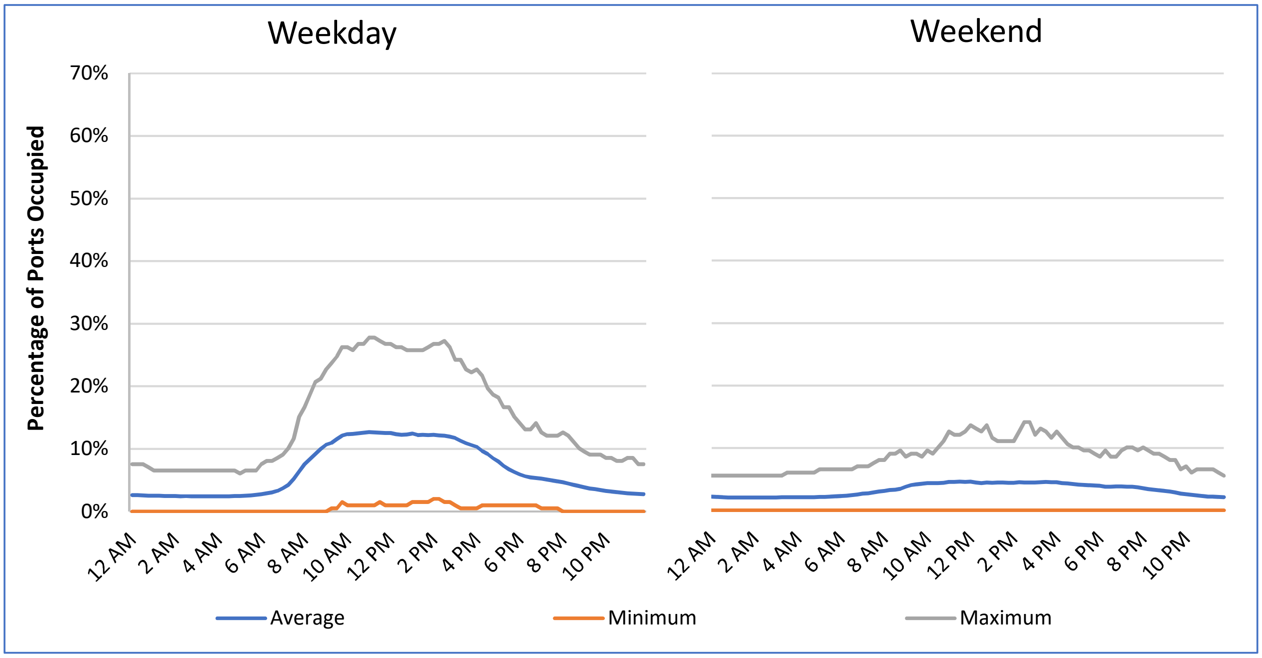
Level 2 Charging Event Start Times

A large portion of charging events at Business Offices start earlier in the day, around 7-9 am, most likely when employees arrive for work. Stations at other locations also have many charging events starting during the morning hours, but show flatter distributions, indicating charging events starting throughout the day. Charging events at Multi-unit Dwellings also apear to mostly start at the beginning of the day, but a limited number of installations currently might be skewing these results.

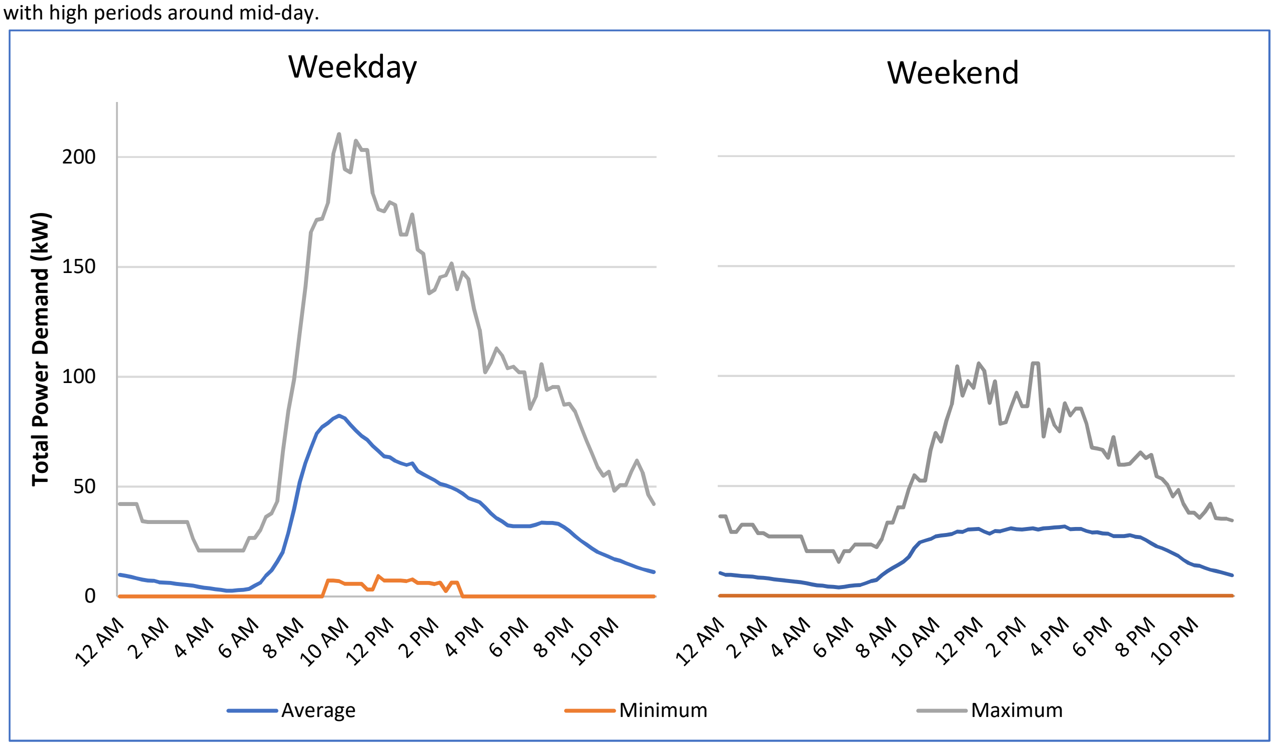


Level 2 Charging Impact on Power Grid - All Venues

Port Availability: Percentage of active charging ports in use across the time of day for weekdays and weekends. Utilization is considerably higher during weekdays.

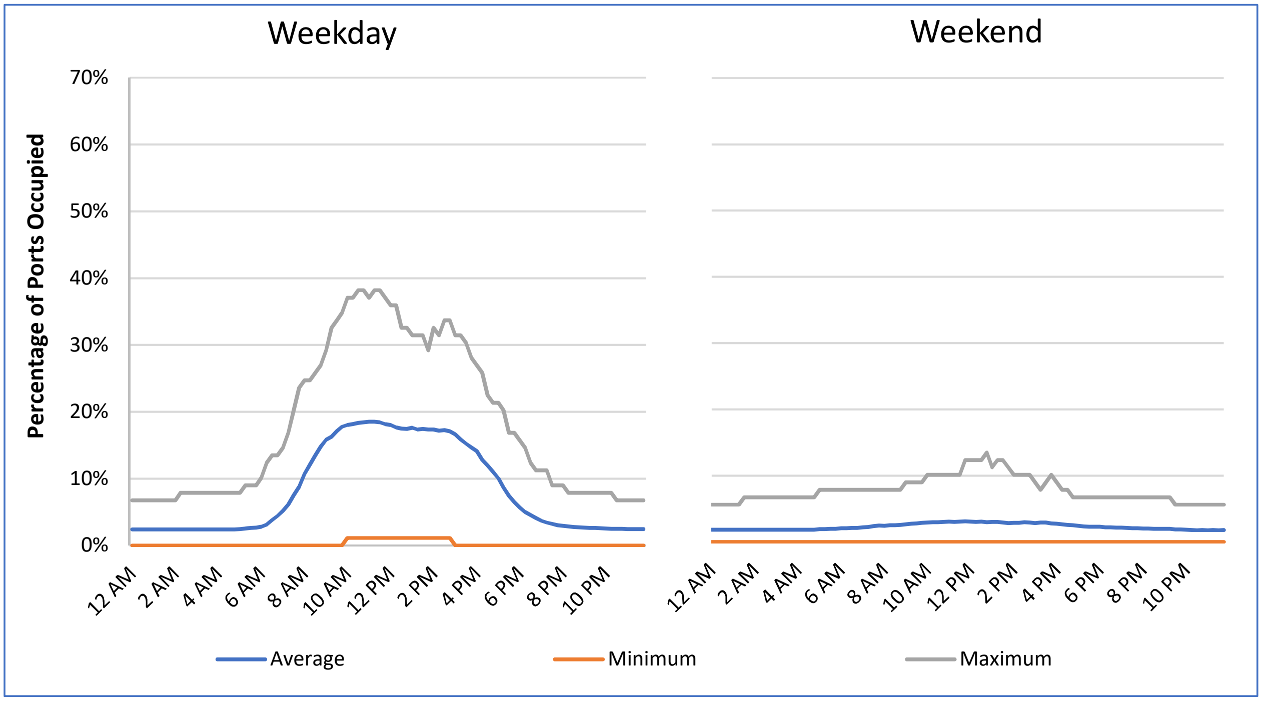


Estimated Total Charging Demand: Total power draw (calculated using average power per charging event for the charging duration) from all stations for weekdays and weekends. Weekday peak is during the late morning hours, whereas the weekend has a less defined peak with high periods around mid-day.

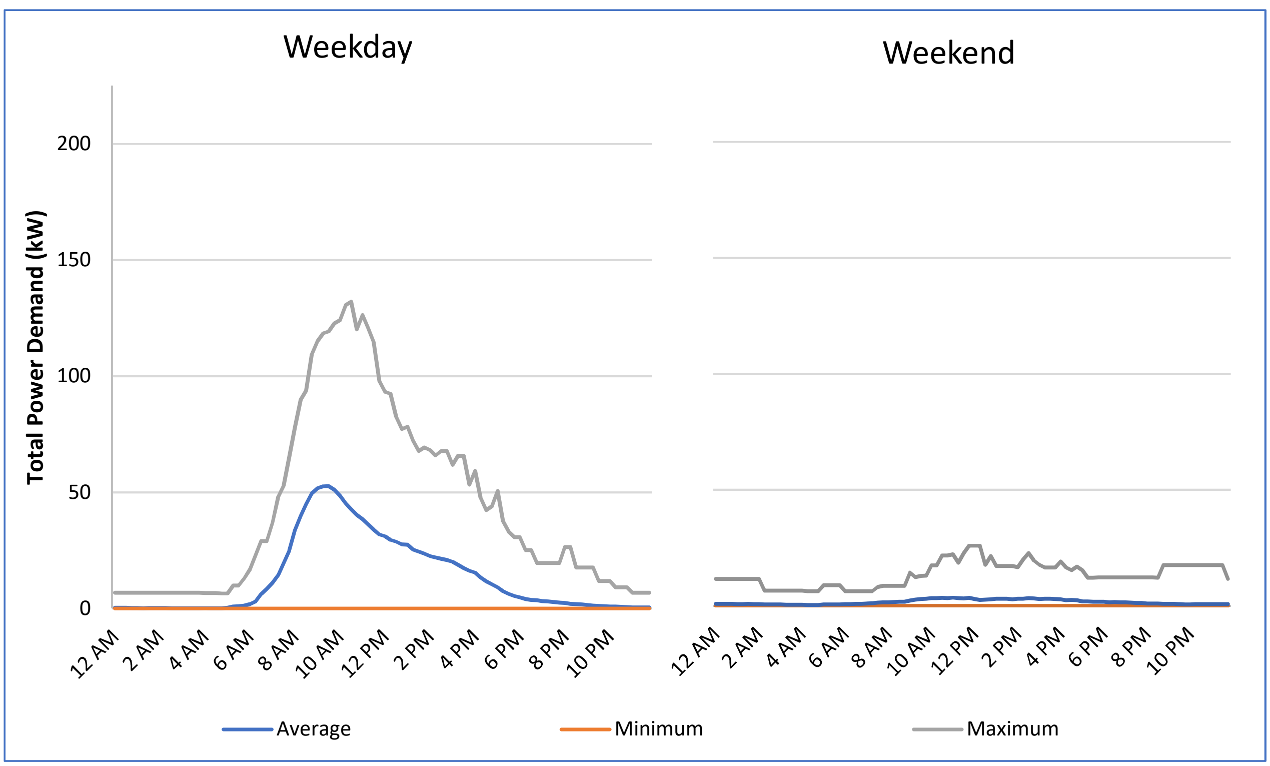


Level 2 Charging Impact on Power Grid - Business Offices

Port Availability: Percentage of active charging ports in use across the time of day for weekdays and weekends. Utilization is considerably higher during weekdays.

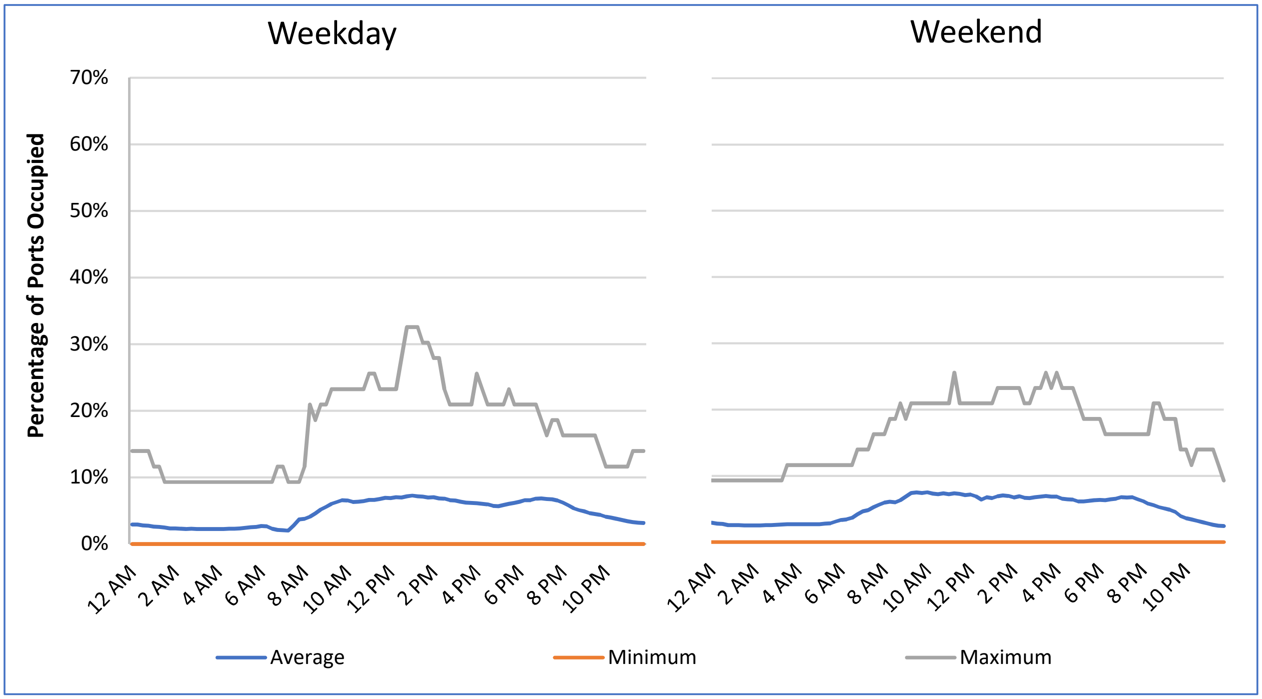


Estimated Total Charging Demand: Total power draw (calculated using average power per charging event for the charging duration) from all stations for weekdays and weekends.

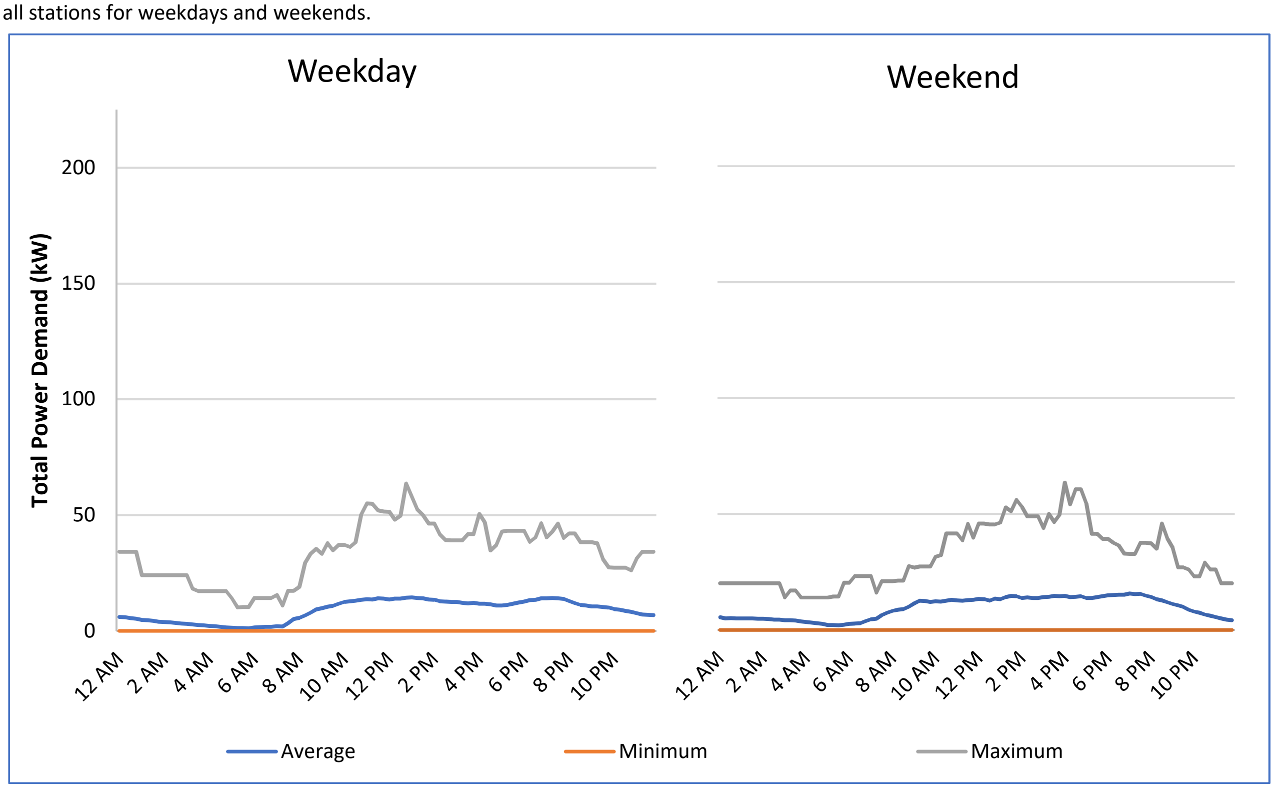


Level 2 Charging Impact on Power Grid - Multi-use Parking

Port Availability: Percentage of active charging ports in use across the time of day for weekdays and weekends. Utilization is similar during weekdays and weekends.

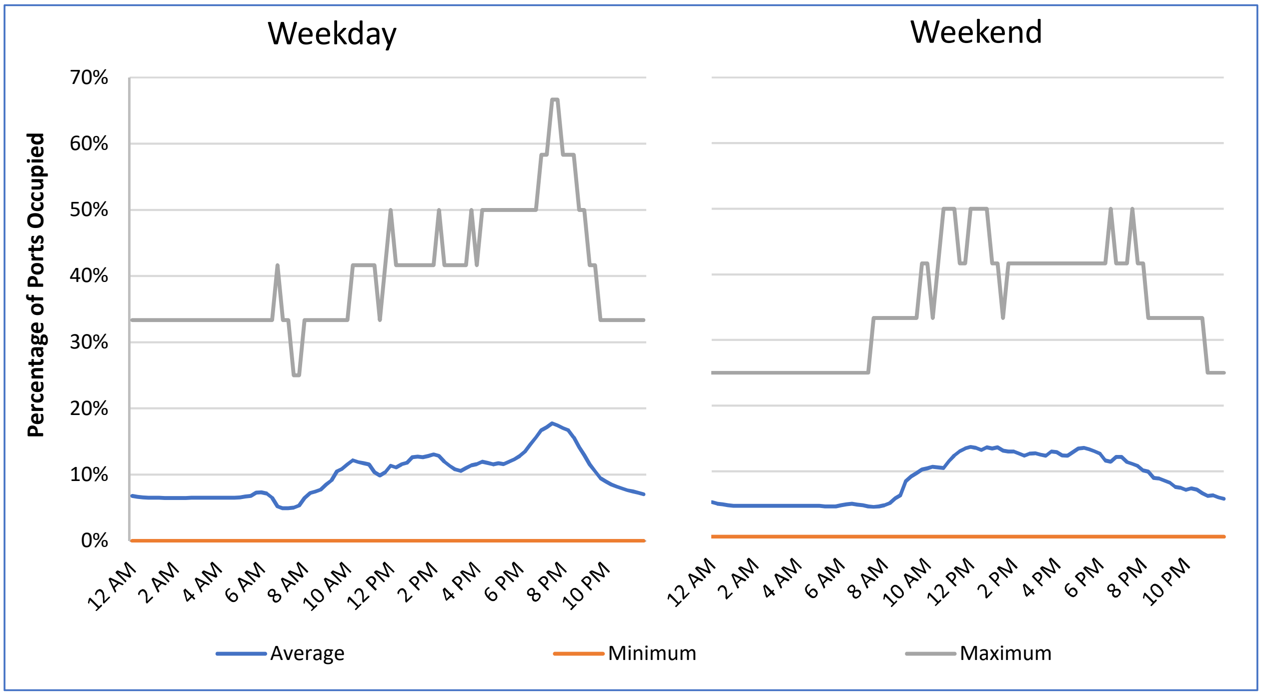


Estimated Total Charging Demand: Total power draw (calculated using average power per charging event for the charging duration) from all stations for weekdays and weekends.

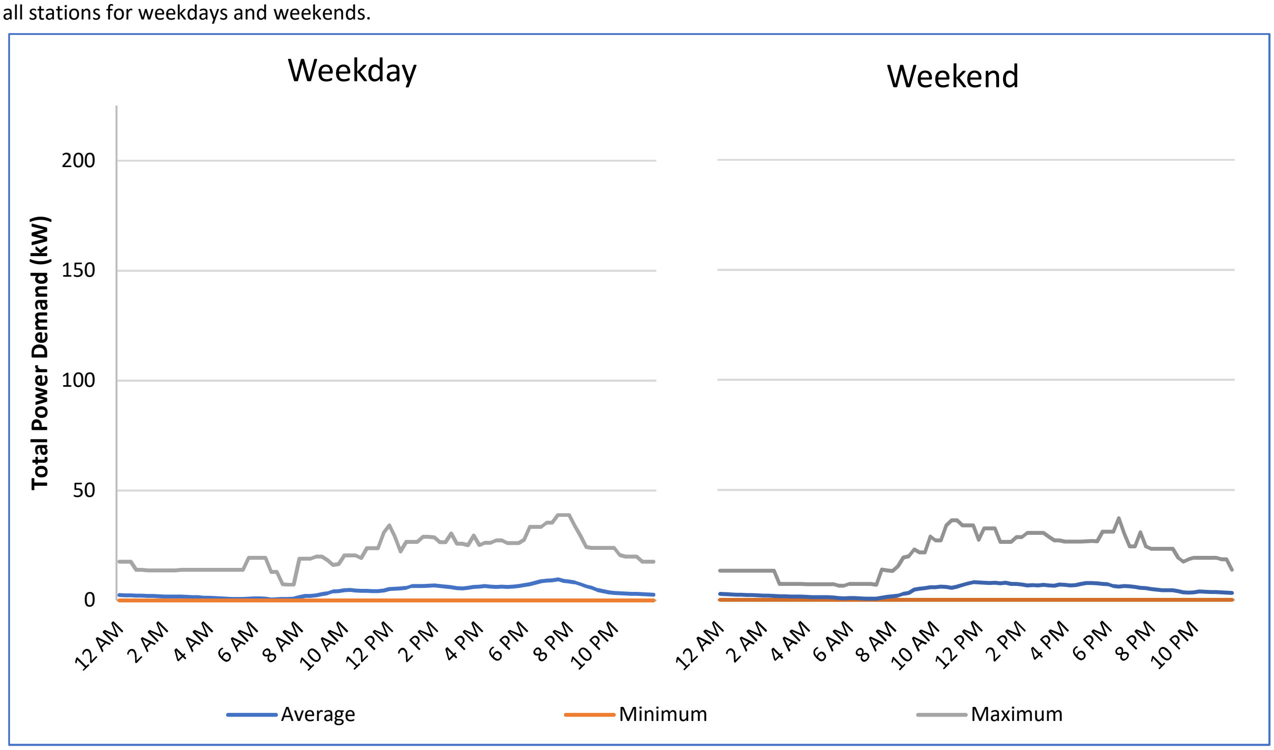


Level 2 Charging Impact on Power Grid - Municipal Buildings

Port Availability: Percentage of active charging ports in use across the time of day for weekdays and weekends. Utilization is slightly higher during weekday evenings, but overall stations at Municipal Buildings have higher utlitization than most other venues.

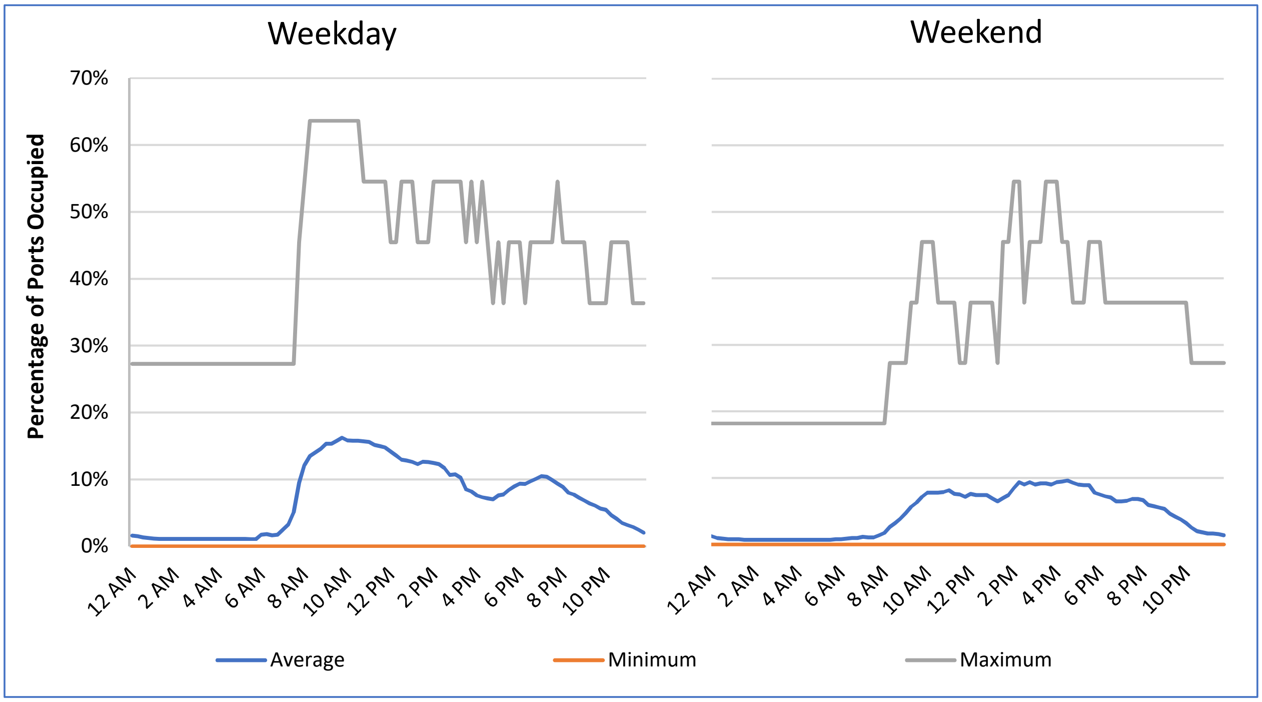


Estimated Total Charging Demand: Total power draw (calculated using average power per charging event for the charging duration) from all stations for weekdays and weekends.

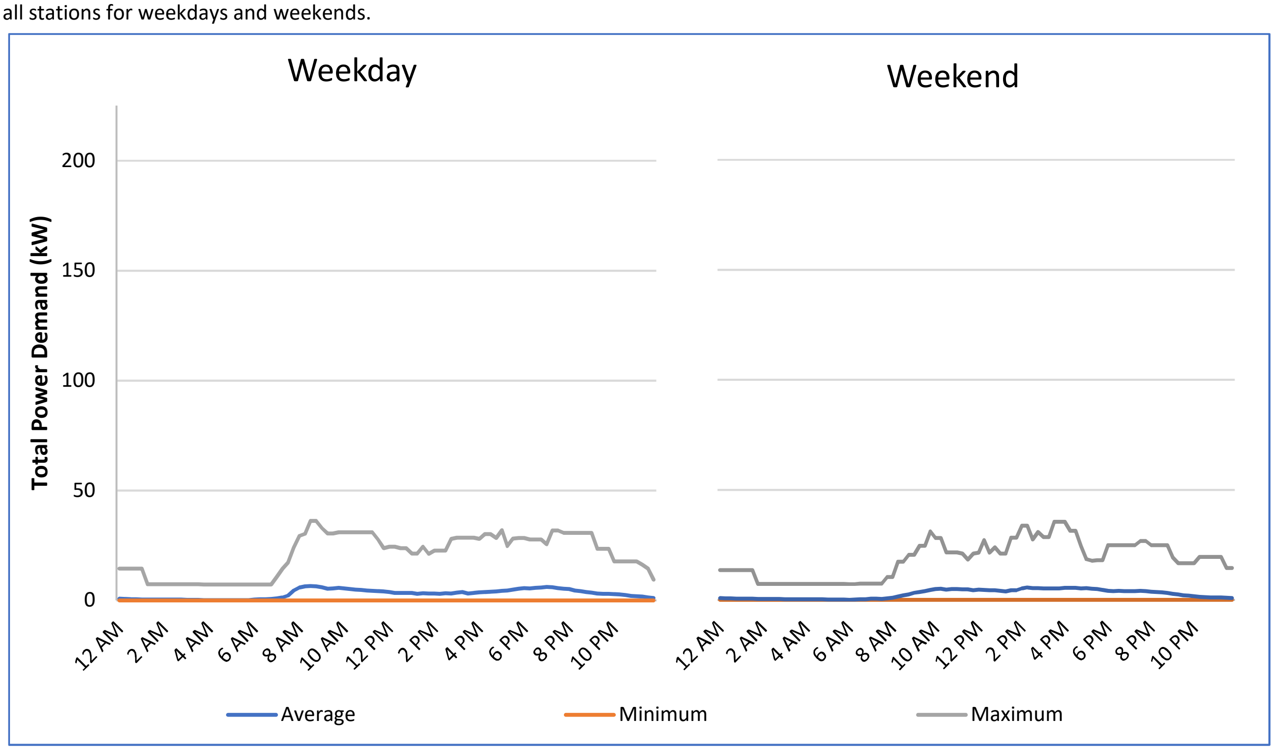


Level 2 Charging Impact on Power Grid - Medical/Educational

Port Availability: Percentage of active charging ports in use across the time of day for weekdays and weekends. Utilization is slightly higher during weekdays, but overall stations at Medical and Educational Campuses have higher utlitization than most other venues.

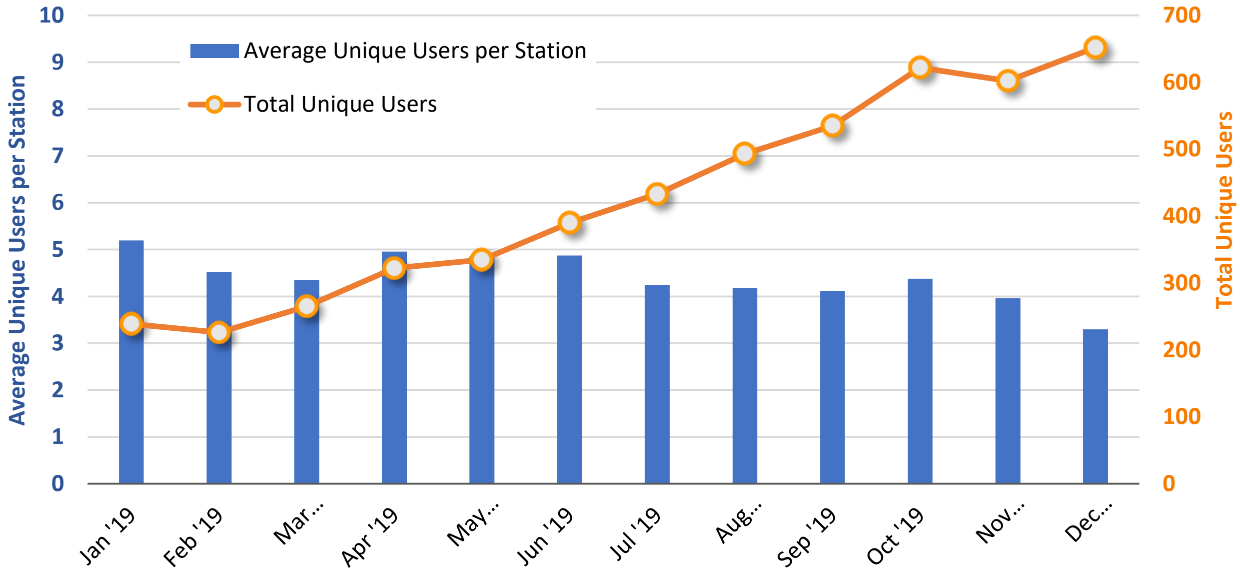


Estimated Total Charging Demand: Total power draw (calculated using average power per charging event for the charging duration) from all stations for weekdays and weekends.

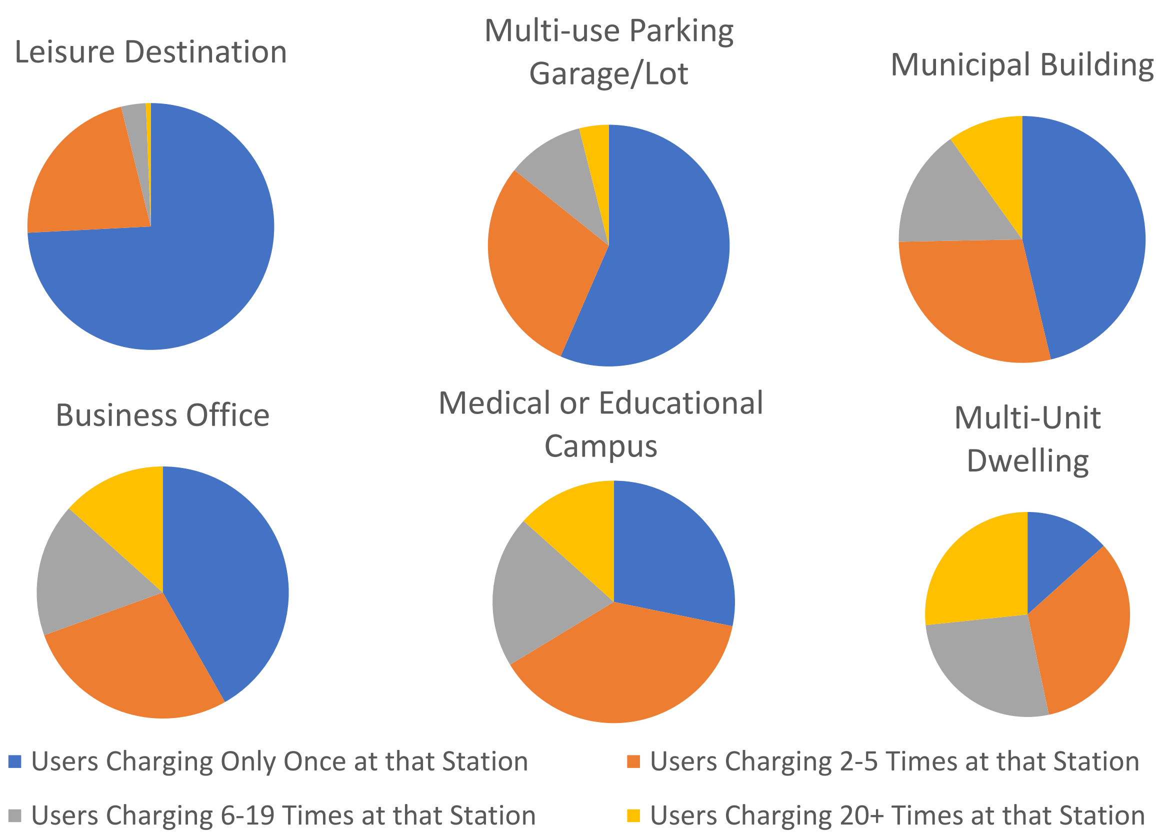


Unique EV Drivers Using the Program Charging Stations

Unique Users: The total number of unique users at Program charging stations consistently increased, but the rate of station installations was slightly higher so the average number of unique users per station decreased slightly throughout the year.



Average Portion of Frequent Users: Different charging station venues will be used by a variety of different users, many of which might only charged there once (i.e., Leisure Destination, Multi-use Parking), while other venues are used by the same EV drivers many times throughout the year (i.e., Multi-Unit Dwelling, Medical/Educational).



Detailed Level 2 Charging Station Usage Statistics

Venue Type	Ports	Total Days of Port Availability	Charging Events (CE)	Charging Events per day	Plug-in Time		Charging Time		% of Plug-in time charging	Total Energy (kWh)	Energy per CE (kWh)
					Hours	Hours per CE	Hours	Hours per CE			
Business Office	89	16,369	7,377	0.5	51,345	7.0	18,915	2.6	37%	88,188	12.0
Multi-use Parking Garage/Lot	43	5,955	6,225	1.0	18,193	2.9	13,873	2.2	76%	78,912	12.7
Municipal Building	12	3,456	2,935	0.8	9,989	3.4	6,485	2.2	65%	36,040	12.3
Medical or Educational Campus	11	2,475	2,047	0.8	6,333	3.1	4,269	2.1	67%	25,104	12.3
Multi-Unit Dwelling	9	1,893	662	0.3	4,816	7.3	2,618	4.0	54%	13,838	20.9
Fleet	2	730	395	0.5	4,600	11.6	1,031	2.6	22%	5,050	12.8
Leisure Destination	18	3,094	323	0.1	2,316	7.2	606	1.9	26%	3,214	10.0
Retail	10	132	16	0.1	27	1.7	25	1.6	92%	148	9.2
Transit Facility	4	526	8	0.0	84	10.5	29	3.6	34%	93	11.6
Hotel	0	0	0	0.0	0	0.0	0	0.0	0%	0	0.0

Region	Ports	Total Days of Port Availability	Charging Events (CE)	Charging Events per day	Plug-in Time		Charging Time		% of Plug-in time charging	Total Energy (kWh)	Energy per CE (kWh)
					Hours	Hours per CE	Hours	Hours per CE			
Boston Metro	128	22,966	16,378	0.7	81,277	5.0	40,364	2.5	50%	214,853	13.1
Western	54	8,586	2,116	0.2	10,146	4.8	4,884	2.3	48%	22,198	10.5
Southeast	16	3,078	1,494	0.5	6,280	4.2	2,604	1.7	41%	13,537	9.1

Land Use Type[4]	Ports	Total Days of Port Availability	Charging Events (CE)	Charging Events per day	Plug-in Time		Charging Time		% of Plug-in time charging	Total Energy (kWh)	Energy per CE (kWh)
					Hours	Hours per CE	Hours	Hours per CE			
Urban	168	27,517	18,137	0.7	92,224	5.1	44,406	2.4	48%	235,454	13.0
Rural	30	7,113	1,851	0.3	5,479	3.0	3,446	1.9	63%	15,133	8.2
Highly Rural	0	0	0	0.0	0	0.0	0	0.0	0%	0	0.0

[4] *Utilizes the US Census Bureau's definition for "Urban", "Rural" and "Highly Rural" (www.ruralhealth.va.gov/about/rural-veterans.asp)*
- Urban Area: population density of at least 1,000 people per square mile.
- Rural Area: Any non-urban or non-highly rural area.
- Highly Rural Area: An area having less than 7 people per square mile.