Massachusetts Grid Modernization Program Year 2020 Evaluation Report: Monitoring and Control (M&C)

Massachusetts Electric Distribution Companies

Submitted by:

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Introduction

As a part of the Grid Modernization Plan (GMP), the Massachusetts Electric Distribution Companies (EDCs) are investing to enable Monitoring and Control (M&C) on selected circuits across their distribution networks. These investments should enhance grid visibility and control capabilities to increase reliability, facilitate integration of DERs, 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) 2020.

Evaluation Process

The DPU requires a formal evaluation process, including an evaluation plan and evaluation studies, for the EDCs' preauthorized grid modernization plan investments. Guidehouse (formerly Navigant Consulting, Inc.)[1] is completing the evaluation to establish a uniform statewide approach and to facilitate coordination and comparability. The evaluation is to measure and assess progress toward achieving the DPU's grid modernization objectives. The evaluation uses the DPU-established Infrastructure Metrics and Performance Metrics along with a set of Case Studies to understand if the GMP investments are meeting the DPU's objectives.

The original Evaluation Plan developed by Navigant Consulting (now Guidehouse) was submitted to the DPU by the EDCs in a petition for approval on May 1, 2019. Modifications to this original Evaluation Plan were made to 1) request changes to the reporting schedule to accommodate Performance Metrics data availability timing, as discussed in response to DPU EP-1-1 submitted on February 6, 2020[2], and 2) to extend the Grid Modernization term period from the original 3 year term to a 4 year term as ordered by the DPU in its May 12, 2020 Order.[3] Modifications to the original Evaluation Plan were submitted to the DPU by the EDCs in a petition for approval on December 1, 2020. The modified Evaluation Plan has been used to develop the analysis and evaluation provided below in this document.

Table 1 illustrates the key Infrastructure Metrics, Performance Metrics, and Case Studies (shown as Other metrics in the table) relevant for the M&C evaluation by EDC.

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*	✓	✓	✓

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

[2] Submitted to Massachusetts DPU 15-120, 15-121, 15-122

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

Type	M&C Evaluation Metrics	ES	NG	UTL
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	✓	✓	✓
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**		✓	
Other	Case Studies	✓	✓	✓

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

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

** Metrics apply to ADA

Source: Stamp Approved Performance Metrics, July 25, 2019

Data Management

Guidehouse worked with the EDCs to collect data to complete the M&C evaluation for the assessment of Infrastructure Metrics, Performance Metrics and Case Studies. 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 PY2020. Section 3.1.1 details each of the data sources.

Table 2. M&C Data Sources

Data Source	Description
2019 Grid Modernization Plan Annual Report[4,5,6]	Planned device deployment and cost information from each EDC's appendix to the *2019 GMP Annual Report* (filed April 1, 2020). Data was used as the reference to track progress against the GMP targets and are referred to as the GMP Plan in summary tables and figures throughout the report.

[4] Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, Grid Modernization Plan Annual Report 2019. Submitted to Massachusetts DPU on April 1, 2020 as part of DPU 15-120

[5] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2019. Submitted to Massachusetts DPU on April 1, 2020 as part of DPU 15-122

[6] Fitchburg Gas and Electric Light Company d/b/a Unitil, Grid Modernization Plan Annual Report 2019. Submitted to Massachusetts DPU on April 1, 2020 as part of DPU 15-121

2020 Grid Modernization Plan Annual Report[7,8,9]	All PM-related data are from these 2020 GMP Annual Report Appendices. In addition, data collected as part of EDC Data Template (below) was compared to the data submitted by the EDCs to the DPU in the 2020 Grid Modernization Plan Annual Reports and associated Appendix 1 filings. The evaluation team confirmed the consistency of the data from the various sources and reconciled any differences
EDC Device Deployment Data Template	Captures planned and actual device deployment and spend data. Actual device deployment and cumulative spend information were provided by work order ID and specified at the feeder- or substation-level as appropriate. Estimated device deployment information and estimated spend for PY2021 were provided at the most granular level. Data is referred to as EDC Data in summary tables and figures throughout the report.
Eversource's 2021 DPU-Filed Plan[10]	Eversource's GMP extension request was approved by the DPU on February 4, 2021. It includes budgets for PY2021 deployment at the Investment Area level. This data source is included in the EDC Plan for Eversource planned spend at the Investment Area level.

Source: Guidehouse analysis

Guidehouse reviewed all data provided upon receipt, 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. Section 3.1.2 includes additional information about the QA/QC process.

Findings and Recommendations

Table 3 summarizes the Infrastructure Metrics results for each EDC's M&C Investment Area through PY2020.

Table 3. M&C Infrastructure Metrics Summary

Infrastructure Metrics		Eversource	National Grid	Unitil
GMP Plan Total, 2018-2021	Devices	430	160	11
	Spend, $M	$64.79*	$4.77	$1.00
EDC Data Total, 2018-2021	Devices	560	202	14
	Spend, $M	$69.00	$6.21	$1.19
IM-4	# Devices Deployed	435	71	11

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

[8] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2020. Submitted to Massachusetts DPU on April 1, 2021 as part of DPU 21-30. Note: Inconsistencies in calculations and definitions were discovered and Eversource updated the Appendix 1 in May 2021. The updates were provided to Guidehouse.

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

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

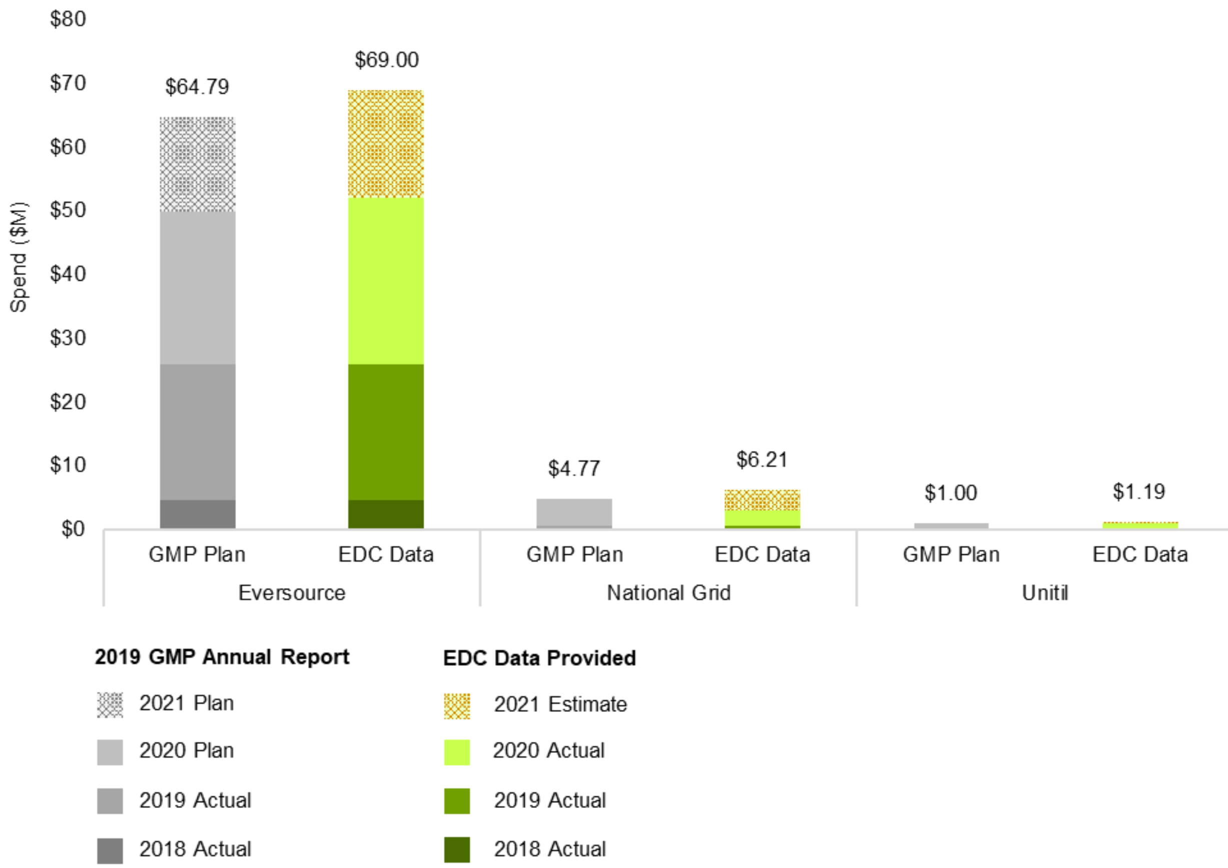
	Number of devices or other technologies deployed through PY2020	% Devices Deployed	101%	44%	100%
IM-5	Cost for Deployment through PY2020	Total Spend, $M	$52.06	$3.03	$0.90
		% Spend	105%	64%	91%
IM-6	Deviation Between Actual and Planned Deployment for PY2020	% On Track (Devices)	102%	43%	100%
		% On Track (Spend)	110%	59%	88%
IM-7	Projected Deployment for the Remainder of the GMP Term	# Devices Remaining	125	131	3
		Spend Remaining, $M	$16.93	$3.18	$0.29

*Includes the Eversource planned spend for PY2021, set forth the in the *GMP Extension and Funding Report*, filed on July 1, 2020 and approved on February 4, 2021.

Source: Guidehouse analysis of 2019 GMP Annual Reports, "GMP Extension and Funding Report," and 2020 EDC Data

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

Figure 1. M&C Spend Comparison (2018-2021, $M)



*Includes the Eversource planned spend for PY2021, set forth the in the *GMP Extension and Funding Report*, filed on July 1, 2020 and approved on February 4, 2021.

Source: Guidehouse analysis of 2019 GMP Annual Reports, "GMP Extension and Funding Report," and 2020 EDC Data

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

Table 4. Summary of Infrastructure Metrics Findings for M&C Investment Area

EDC	Summary of Findings
Eversource	• During PY2019, Eversource increased the M&C budget by about 20% from the original DPU-approved budget of $41 million by shifting budget previously allocated to other Investment Areas to the M&C budget. The increased budget helped Eversource accelerate, during PY2020, the investments that enabled SCADA indication on field devices. The M&C program for the deployment of microprocessor relays had some carry over of work from 2020 into 2021. • During PY2020 Eversource further extended the original GMP Plan to include an additional $15 million toward M&C investments, bringing the total M&C planned investment to about $65 million. This expansion was made in response to the DPU decision to extend the original 3-year term to 4 years. • Eversource's M&C actual spend through PY2020 tracks closely to their revised plan issued on July 1, 2020. Eversource used flexibility to shift funds between various investment and device categories, defined and permitted by the DPU, in attempt to meet DPU Grid Modernization Goals but stay within the total prescribed budget.
National Grid	• National Grid's M&C investment consists of a single device type: feeder monitors. Deployment accelerated during PY2020, and National Grid deployed more than tenfold the number of devices deployed during PY2019. However, deployment was still slower than planned for PY2020, and the total number of devices deployed was short of the plan. The delay was primarily due to COVID-19-related impacts.
Unitil	• Unitil's progress toward M&C investments (substation SCADA retrofitting and OMS/AMI integration) tracked closely to the plan. Substation SCADA work was completed at three substations, and significant progress was made toward building out the outage management system/advanced metering infrastructure engine.

Source: Guidehouse analysis of 2019 GMP Annual Reports and EDC Data

Table 5 and Table 6 summarize the Performance Metric Results for each EDC's M&C Investment Area in PY2020. Table 5 shows the results for the Performance Metric that analyzes the Effect on Outage Duration (CKAIDI) and Table 6 shows the results for the Effect on Outage Frequency (CKAIFI). In both tables, the baseline and PY2020 results are summarized for both system-wide circuits and M&C circuits.

Table 5. M&C Performance Metrics Summary: CKAIDI

	2015-2017 Avg. CKAIDI (Baseline)				2020 CKAIDI (Program Year)			
	System-wide		M&C Circuits		System-wide		M&C Circuits	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
Eversource								
Total Circuits	2,083	2,083	197	197	2,083	2,083	197	197
Weighted Average	134	106	90	86	238	238	419	419
Std. Dev.*	136	103	102	87	288	288	441	441
National Grid								
Total Circuits	1,069	1,069	25	25	1,069	1,069	25	25
Weighted Average	219	119	236	111	447	300	1,010	587
Std. Dev.*	258	179	302	62	603	351	821	381
Unitil								
Total Circuits	32	32	3	3	32	32	3	3
Weighted Average	175	66	243	78	254	136	339	165
Std. Dev.*	94	35	71	36	245	218	126	75

*Standard Deviation is based on the simple average

Source: Guidehouse analysis of 2020 GMP Annual Reports

Table 6. M&C Performance Metrics Summary: CKAIFI

	2015-2017 Avg. CKAIFI (Baseline)				2020 CKAIFI (Program Year)			
	System-wide		M&C Circuits		System-wide		M&C Circuits	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
Eversource								
Total Circuits	2,083	2,083	197	197	2,083	2,083	197	197
Weighted Average	1.0	0.9	0.8	0.8	1.2	1.2	1.2	1.2
Std. Dev.*	0.7	0.7	0.6	0.6	1.0	1.0	1.0	1.0
National Grid								
Total Circuits	1,069	1,069	25	25	1,069	1,069	25	25
Weighted Average	1.0	0.9	1.0	0.9	1.5	1.3	2.3	1.9
Std. Dev.*	0.6	0.6	0.5	0.4	1.2	1.1	1.5	1.3
Unitil								
Total Circuits	32	32	3	3	32	32	3	3
Weighted Average	2.0	1.1	2.6	1.1	2.8	1.6	2.2	1.0
Std. Dev.*	0.9	0.5	0.7	0.5	1.7	1.4	0.6	0.5

*Standard Deviation is based on the simple average

Source: Guidehouse analysis of 2020 GMP Annual Reports

Table 7 summarizes key findings related to Guidehouse's M&C Performance Metrics evaluation for each EDC.

Table 7. Summary of Performance Metrics Findings for M&C Investment Area

PM	Eversource	National Grid	Unitil
PM-12: Grid Modernization investments' effect on outage durations	Outage duration for M&C circuits for PY2020 was significantly longer than Baseline. However, this metric is not able to discern whether M&C investments impacted the annual reliability performance.*	Outage duration for M&C circuits for PY2020 was significantly longer than Baseline. However, this metric is not able to discern whether M&C investments impacted the annual reliability performance.*	Outage duration was slightly reduced for M&C circuits compared to the system average, but there is an insufficient number of devices installed to draw general conclusions on the impact of these investments.
PM-13: Grid Modernization investments' effect on outage frequency	Outage frequency for M&C circuits for PY2020 was significantly higher than Baseline. However, this metric is not able to discern whether M&C investments impacted the annual reliability performance.*	Outage frequency for M&C circuits for PY2020 was significantly higher than Baseline. However, this metric is not able to discern whether M&C investments impacted the annual reliability performance.*	Outage frequency was slightly reduced for M&C circuits compared to the system average, but there is an insufficient number of devices installed to draw general conclusions on the impact of these investments.
PM-UTL1: Customer Minutes of Outage Saved per Circuit	N/A – Unitil specific metric	N/A – Unitil specific metric	The OMS/AMI Integration is not complete; this metric cannot yet be evaluated.
Case studies	Case studies showed improvements in reliability from M&C devices evaluated.	Case studies showed improvements in reliability from M&C devices evaluated.	Case studies showed improvements in reliability from M&C devices evaluated.

*Program Year 2020 generally had much worse reliability performance on a system-wide basis across all three EDCs, and evidence suggests that this was due to the size and frequency of storm conditions throughout the year.
Source: Guidehouse Analysis

Guidehouse submits the following recommendations for EDC consideration in PY2021:

1) The CKAIDI and CKAIFI reliability related Performance Metrics as defined have deficiencies in measuring the effectiveness of Grid Modernization Investments. Many factors unrelated to the Grid Modernization investments will affect these metrics in any given year, and it is not possible to distinguish among these factors using the metrics. For example, the variation in storm activity between years can cause significant changes in these metrics, as apparently happened in PY2020. Also, the need for three years of baseline data excludes circuits that have been reconfigured over time, reducing the pool of circuits that can be compared to a baseline value.

    a. Recommendation: Given the difficulty of the Performance Metrics PM-12 and PM-13, as defined, to help determine the efficacy of grid modernization investments in meeting the Departments goals, it would be useful to reassess and perhaps refine the metric definitions to better assess the investments' impact on reliability performance.

   b. Recommendation: Additional Performance Metrics should be explored to determine if it is possible to capture the actual reliability performance attributable to the investments. Exploration could include:
      i. Reviewing the data and techniques necessary to understand the relationship between circuit reliability and weather conditions, vegetation management cycles and other reliability drivers that are independent of the grid modernization investments.
      ii. Expanding the use of case studies to cover a greater proportion of the investments—more outage cases examined on more circuits (see Recommendation 4a below).
      iii. Leveraging new processes and collecting data to more efficiently perform outage case studies, and perhaps extrapolate these results to a broader set of circuits to understand investment performance with more certainty.
      iv. Comparing number of customers out and customer minutes of interruption (CMI) that occurred, with the number of customers out and CMI that would have occurred without Grid Modernization investments.

2) The use of currently defined CKAIDI and CKAIFI reliability related Performance Metrics—which are circuit level metrics—has increasing challenges over time as circuits get re-configured or retired and new circuits are constructed. The comparability of each circuit in the program year to its baseline depends on that circuit not having been reconfigured or significantly changed (e.g., a normally open switch between circuit segments is changed to operate as normally closed, changing the customer counts and outage measurements on that circuit). The number of circuits that are comparable between baseline and program year is reduced year after year as more circuits change due to ongoing operation of the system.

   a. Recommendation: Explore metrics that are robust to these operating changes to help ensure that Grid Mod investment assessment based on these metrics are not misleading, and that they are able to better capture the impact of the investment.

3) Current metrics do not provide an understanding of how M&C and ADA investments facilitate easier interconnection, or more capacity, of DER added to the system

   a. Recommendation: Consider developing additional metrics and/or performing pilot projects that utilize the installation of ADA and M&C investments at DER locations to understand the value or benefits that are provided. This would provide actual data on the effectiveness of these investments to support DER integration.

4) Case studies show detailed functioning and impact of GMP devices, and they are proving to be a useful tool in understanding the effectiveness of the Grid Modernization investments. Based on case studies performed, the M&C investment is yielding reliability and service delivery benefits to customers for each of the EDCs.

   a. Recommendation: Continue to perform case studies in future evaluations, and increase the use of case studies where practicable, to analyze the mitigation of customer outages and help determine the effectiveness of Grid Modernization investments in improving reliability and service delivery.

b. Recommendation: Continue the deployment of M&C technologies as part of the Grid Modernization Program and continue to monitor progress (including through amended or additional metrics to be determined by the Department).

1. Introduction to Massachusetts Grid Modernization

This section provides a brief background to the grid modernization evaluation process along with an overview of the Monitoring and 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.

1.1 Massachusetts Grid Modernization Plan Background

On May 10, 2018, the Massachusetts Department of Public Utilities (DPU) issued its Order[11] regarding the individual Grid Modernization Plans (GMPs) filed by the three Massachusetts Electric Distribution Companies (EDCs): Eversource, National Grid, and Unitil.[12,13] In the Order, the DPU preauthorized grid-facing investments over 3 years (2018-2020) for each EDC and adopted a 3-year (2018-2020) regulatory review construct for preauthorization of grid modernization investments. On May 12, 2020, the DPU issued an Order[14] extending the 3-year grid modernization plan investment term to a 4-year term, which now includes the 2021 program year. The company-specific GMP budget caps did not change with the term extension. On July 1, 2020, Eversource filed a request for an extension of the budget authorization associated with grid modernization investments.[15] The budget extension, approved by the DPU on February 4, 2021, included $14 million for ADA, $16 million for ADMS/ALF, $5 million for Communications, $15 million for M&C, and $5 million for VVO.

The preauthorized GMP investments are expected to advance the achievement of DPU's grid modernization objectives:

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

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 understand progress and help ensure that the objectives were achieved with greater certainty.

The grid modernization investments were organized into six Investment Areas to facilitate understanding, consistency across EDCs, and analysis.

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[11] Massachusetts DPU 15-120; DPU 15-121; DPU 15-122 (Grid Modernization) Order issued May 10, 2018

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

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

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

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

- 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.

1.1.1 Investment Areas

Table 8 summarizes the preauthorized GMP investments.

Table 8. Overview of Investment Areas

Investment Area	Description	Objective
Monitoring and Control (M&C)	Remote monitoring and control of devices in the substation for feeder monitoring or online devices for enhanced visibility outside the substation	Enhancing grid visibility and control capabilities
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 DPU preauthorized budget for grid modernization varies by Investment Area and EDC. Eversource originally had the largest preauthorized budget at $133 million, with ADA and M&C representing the largest share ($44 million and $41 million, respectively). National Grid’s preauthorized budget was $82.2 million, with ADMS and ALF representing over

50% ($48.4 million). Unitil's preauthorized budget was $4.4 million and VVO makes up 50% ($2.2 million).

On July 1, 2020, Eversource filed a request for an extension of the budget authorization associated with grid modernization investments.[16] The budget extension, approved by the DPU on February 4, 2021,[17] includes $14 million for ADA, $16 million for ADMS/ALF, $5 million for Communications, $15 million for M&C, and $5 million for VVO. These values are included in the Eversource total budget by Investment Area in Table 6.

Table 9. 2018-2021 GMP Preauthorized Budget, $M

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

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

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. The following subsections discuss these evaluation goals, objectives, and the metrics to be used.

1.1.2 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 is completing the evaluation to enable a uniform statewide approach and to facilitate coordination and comparability. The evaluation measures the progress made toward the achievement of DPU's grid modernization objectives. The evaluation uses the DPU-established Infrastructure Metrics and Performance Metrics, as well as Case Studies that illustrate the performance of specific technology installations, to help determine if the investments are meeting the DPU's GMP objectives.

1.1.3 Metrics for Evaluation

The DPU-required evaluation involves Infrastructure Metrics and Performance Metrics for each Investment Area. In addition, selected case studies have been added for some Investment

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

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

Areas (e.g., M&C) as part of the evaluation to help facilitate understanding of how the technology performs in specific instances (e.g., in remediating the effects of a line outage).

1.1.3.1 Infrastructure Metrics

The Infrastructure Metrics assess the deployment of the GMP investments. Table 10 summarizes the Infrastructure Metrics.

Table 10. 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 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 Four - Year Term**	Compares the revised projected deployment with the original target deployment as the EDC implements its EDC.	All IAs	Evaluator

IM = Infrastructure Metric, IA = Investment Area

Source: Guidehouse review of Infrastructure Metric filings

1.1.3.2 Performance Metrics

The Performance Metrics assess the performance of all the GMP investments. Table 11 summarizes the Performance Metrics used for the various Investment Areas.

Table 11. Performance Metrics Overview

Metric		Description	Applicable IAs	Metric Responsibility
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 greenhouse gas (GHG) impact measures.	VVO	All
PM-2	**VVO Energy Savings**	Quantifies the energy savings achieved by VVO using the baseline established for the circuit against the annual circuit load with the intent of optimizing system performance.	VVO	All
PM-3	**VVO Peak Load Impact**	Quantifies the peak demand impact VVO/CVR has on the system with the intent of optimizing system demand.	VVO	All
PM-4	**VVO Distribution Losses without Advanced Metering Functionality (AMF) (Baseline)**	Presents the difference between circuit load measured at the substation via the SCADA system and the metered load measured through advanced metering infrastructure.	VVO	All
PM-5	**VVO Power Factor**	Quantifies the improvement that VVO/CVR is providing toward maintaining circuit power factors near unity.	VVO	All
PM-6	**VVO – GHG Emissions**	Quantifies the overall GHG impact VVO/CVR has on the system.	VVO	All
PM-7	**Voltage Complaints**	Quantifies the prevalence of voltage-related complaints before and after deployment of VVO investments to assess customer experience, voltage stability under VVO.	VVO	All
PM-8	**Increase in Substations with DMS Power Flow and Control Capabilities**	Examines the deployment and data cleanup associated with deployment of ADMS, primarily by counting and tracking the number of circuits and substations per year.	ADMS/ ALF	All
PM-9	**Control Functions Implemented by Circuit**	Examines the control functions of DMS power flow and control capabilities, focused on the control capabilities including VVO-CVR and FLISR.	ADMS/ ALF	All

Metric		Description	Applicable IAs	Metric Responsibility
PM-11	**Numbers of Customers that benefit from GMP funded Distribution Automation Devices**	Shows the progress of ADA investments by tracking the number of customers that have benefitted from the installation of ADA devices.	ADA	ES, NG
PM-12	**Grid Modernization investments' effect on outage durations**	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 3-year average for the same circuit.	M&C, ADA	All
PM-13	**Grid Modernization investments' effect on outage frequency**	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 3-year average for the same circuit.	M&C, ADA	All
PM-ES1	**Advanced Load Flow – Percent Milestone Completion**	Examines the fully developed ALF capability across Eversource's circuit population.	ADMS/ ALF	ES
PM-ES2	**Protective Zone: Average Zone Size per Circuit**	Measures Eversource's progress in sectionalizing circuits into protective zones designed to limit outages to customers located within the zone.	ADA	ES
PM-UTL1	**Customer Minutes of Outage Saved per Circuit**	Tracks time savings from faster AMI outage notification than customer outage call, leading to faster outage response and reduced customer minutes of interruption.	M&C	UTL
PM-NG1	**Main Line Customer Minutes of Interruption Saved**	Measures the impact of ADA investments on the customer minutes of interruption (CMI) for main line interruptions. Compares the CMI of GMP ADA-enabled circuits to the previous 3-year average for the same circuit.	ADA	NG

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

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

This report discusses Performance Metrics that pertain specifically to the M&C Investment Area.

1.1.3.3 Case Studies

A case study approach was developed to provide more insight into the actual operation of the GMP devices and to illustrate how these investments provide customer reliability and operational benefits. The impacts of GMP devices on system reliability metrics can be difficult to discern due to the range of factors that affect these metrics. Storm conditions, vehicle accidents and other factors drive reliability from year to year. This is especially likely if the device has less than several full years of operation to affect the metric. The case studies help to illustrate the benefits provided by GMP devices during outage events. This approach investigates outage events on specific circuits where the GMP equipment was used to address the outage. The approach also allows for comparison between what did occur due to the presence of the GMP device and what would have likely happened had the GMP investment not been made.

1.2 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 *2019 Grid Modernization Annual Report*, filed by the EDCs on April 1, 2020, the M&C investments are planned to total to $72 million from 2018 to 2021:

- $65 million by Eversource[18]
- $6.0 million by National Grid
- $1.1 million by Unitil

The following subsection discusses EDC-specific approaches to M&C.

1.2.1 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 12 defines the devices and technologies that each EDC has deployed as part of M&C. Sections 3 (Infrastructure Metrics), 4 (Performance Metrics), and 5 (Case Studies) discuss specifics related to each EDCs' goals and objectives for their M&C Investment Area.

[18] Total planned spend includes $15 million in addition to the *2019 GMP Annual Report* total, as set forth in the "GMP Extension and Budget" filing on July 1, 2020.

Table 12. 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.
	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.
	Recloser SCADA	Addition of communications capability so the device can be centrally monitored and controlled from the dispatch center.
	Padmount Switch SCADA	Addition of a radio package to enable communications and central monitoring.
	Network Protector SCADA	Provide real-time network load data.
	Power Quality Monitors	Provide remote access and storage of power quality meter data for the Eversource system planning, protection, and controls engineering to evaluate disturbance events and share information with customers.
National Grid	Feeder Monitors	Installation of interval power monitoring devices on feeders where National Grid 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

1.3 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 13 illustrates the key Infrastructure Metrics and Performance Metrics relevant for the M&C evaluation.

Table 13. 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	✓	✓	✓
PM	Grid Modernization Investments' Effect on Outage Frequency	✓	✓	✓
Other	Case Studies**	✓	✓	✓

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

* Denotes that generating the metrics is EDC responsibility

** In addition to the IMs and PMs listed, Case Studies were added to the evaluation to help explain the operation and value of the selected M&C investments.

Source: Guidehouse Stage 3 Evaluation Plan filed December 1, 2020

The EDCs provided the data supporting the Infrastructure Metrics and Performance Metrics to the evaluation team. Sections 3.2, 4.2, and 5, present the results from the analysis of Infrastructure Metrics, Performance Metrics, and case study data respectively. The Infrastructure Metrics analysis measures whether the investments are taking place on the projected schedule and budget. The Performance Metrics analysis provides insight into the reliability impacts due to grid modernization investments. The Case Studies facilitate understanding of the reliability improvement mechanisms and performance at select feeder locations.

Table 14 summarizes the M&C evaluation 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 14. M&C Evaluation Objectives and Associated Research Questions

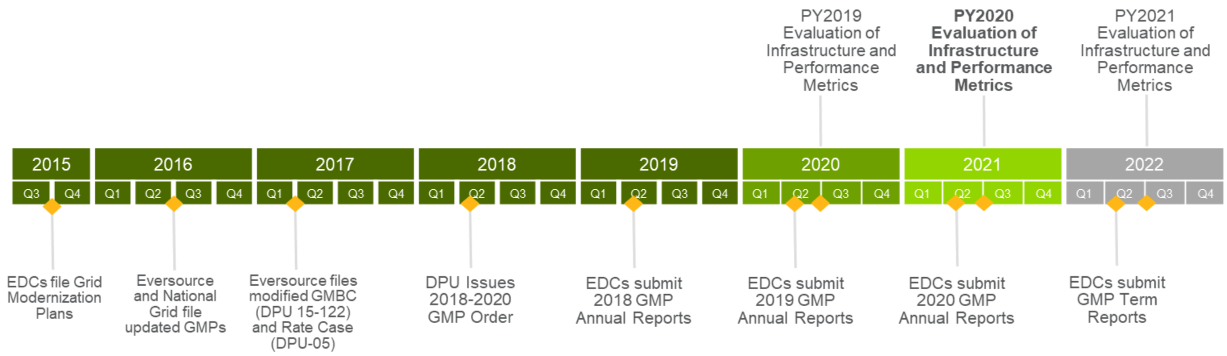
Associated Research Questions	IM	PM
1) Are the EDCs progressing in deployment of their M&C investments according to their GMPs?	✓	
2) What factors, if any, are affecting the deployment schedule of M&C equipment?	✓	
3) What is the cost of deploying various types of M&C equipment, including SCADA retrofits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

Source: Guidehouse Stage 3 Evaluation Plan filed December 1, 2020

2. M&C Evaluation Process

This section presents a high level overview of the Guidehouse methodologies for the evaluation of Infrastructure and Performance Metrics as well as Case Studies. Figure 2 highlights the filing background and timeline of the GMP Order and the evaluation process.

Figure 2. M&C Evaluation Timeline



Source: Guidehouse review of the DPU orders and GMP process

2.1 Infrastructure Metrics Analysis

Guidehouse annually assesses the progress of each EDC toward enabling M&C devices and technologies on their feeders. Table 15 highlights the evaluated Infrastructure Metrics and their associated calculation parameters.

Table 15. Infrastructure Metrics Overview

Infrastructure Metrics			Calculation
IM-4	Number of devices or other technologies deployed thru. PY2020	# Devices Deployed	$\sum_{PY=2018}^{2020}(Devices\ Commissioned)_{PY}$
		% Devices Deployed	$\frac{\sum_{PY=2018}^{2020}(Devices\ Commissioned)_{PY}}{\sum_{PY=2018}^{2019}(Devices\ Commissioned)_{PY} + (Planned\ Devices)_{PY2020}}$
IM-5	Cost through PY2020	Total Spend, $M	$\sum_{PY=2018}^{2020}(Actual\ Spend)_{PY}$
		% Spend	$\frac{\sum_{PY=2018}^{2020}(Actual\ Spend)_{PY}}{\sum_{PY=2018}^{2019}(Actual\ Spend)_{PY} + (Planned\ Spend)_{PY2020}}$
IM-6	Deviation Between Actual and Planned Deployment for PY2020	% On Track (Devices)	$\frac{(Devices\ Commissioned)_{PY2020}}{(Planned\ Devices)_{PY2020}}$
		% On Track (Spend)	$\frac{(Actual\ Spend)_{PY2020}}{(Planned\ Spend)_{PY2020}}$

IM-7	Projected Deployment for 2021	# Devices Remaining	$(Devices\ Planned)_{PY2021}$
		Spend Remaining, $M	$(Planned\ Spend)_{PY2021}$

Source: Guidehouse

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

- Reviewed the EDC data provided from the EDCs to confirm the information accurately reflected their progress through PY2020 (see Section 3.1.2, “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

2.2 Performance Metrics Analysis

Performance Metrics were evaluated for each EDC, focusing on the reliability metrics (CKAIDI and CKAIFI) at the circuit level. Table 16 describes the Performance Metrics included in the PY2020 evaluation.

Table 16. M&C Performance Metrics Overview

Performance Metric		EDC	Description
PM-12	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.
PM-13	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 with the prior three-year average for the same circuit.
PM-UTL1	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.

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

2.3 Case Study Analysis

The evaluation team developed a case study approach to provide more insight into the actual operation of the GMP devices and to illustrate how these investments provide customer reliability and operational benefits. The impacts of GMP devices on system reliability metrics can be difficult to discern due to the range of factors that affect these metrics. Storm conditions, vehicle accidents and other factors drive reliability from year to year. This is especially likely if the device has less than several full years of operation to affect the metric. The case studies help to illustrate the benefits provided by GMP devices during outage events. This approach investigates outage events on specific circuits where the GMP equipment operated to address the outage. The approach also allows for comparison between what did occur due to the presence of the GMP device and what would have likely happened had the GMP investment not been made.

The team performed six case studies for the M&C evaluation: three for Eversource, two for National Grid and one for Unitil. Section 5 examines the details of the analysis and the results.

3. M&C Infrastructure Metrics

Assessment of the Infrastructure Metrics included Infrastructure Metric data collection and QA/QC, assessment of M&C deployment progress for each EDC, and determination of conclusions from the analysis.

3.1 Data Management

Guidehouse worked with the EDCs to collect data to complete the M&C evaluation and the assessment of Infrastructure Metrics. The following subsections highlight data sources and the data QA/QC processes followed to complete the evaluation and calculate the Infrastructure Metrics.

3.1.1 Data Sources

Guidehouse used a consistent methodology (across Investment Areas and EDCs) for evaluating the data and illustrating EDC progress toward the GMP metrics. The following subsections summarize data sources.

3.1.1.1 2019 Grid Modernization Plan Annual Report

Guidehouse used the planned device deployment and cost information from each EDCs' *2019 GMP Annual Reports*, which were filed on April 1, 2020. Additionally, Guidehouse included Eversource's planned spending for PY2021 by Investment Area as filed in the *2021 Grid Modernization Program Extension and Funding Report*, which was approved by the DPU on February 4, 2021.[19] These filings served as the sources for planning data in this report and are referred collectively as the GMP Plan for each EDC in summary tables and figures throughout this report.

Table 17 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 17. Deployment Categories Used for the EDC Plan

Representative Color	Data	Description
(light dotted grey)	2021 Plan	Projected 2021 unit deployment and spend
(light grey)	2020 Plan	Projected 2020 unit deployment and spend
(medium grey)	2019 Actual	Actual reported unit deployment and spend in 2018
(dark grey)	2018 Actual	Actual reported unit deployment and spend in 2018

Source: 2021 Plan (Applicable to Eversource only) is sourced from the "2021 Grid Modernization Program Extension and Funding Report," filed July 1, 2020; Other plan and actual data is sourced from the EDCs' 2019 GMP Annual Report Appendix 1 filed April 1, 2020.

[19] Note the plan filed did not provide data at the device type level, only at the aggregate Investment Area level. This data is only included in the GMP Plan when the totals by Investment Area are presented.

3.1.1.2 EDC PY2020 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 2021. The data collected provides an update of planned and actual deployment, in dollars and device units, through the end of PY2020. Data from this source are referred to as EDC Data in summary tables and figures throughout the report. Table 18 summarizes the date of file version receipt used for the evaluation. The collected data was compared to the data submitted by the EDCs to the DPU in the 2020 Grid Modernization Plan Annual Reports and associated Appendix 1 filings.[20,21,22] The evaluation team confirmed the consistency of the data from the various sources and reconciled any differences.

Table 18. All Device Deployment Data File Versions for Analysis

EDC	File Version
Eversource	Received 2/18/2021
National Grid	Received 2/24/2021
Unitil	Received 1/21/2021

Source: Guidehouse

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 implementation stage of the work order (commissioned, in service, construction, or design/engineering), 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 PY2021 was provided by the EDCs at the most granular level (circuit or substation) where available. Table 19 summarizes the categories used for the planned and actual deployment and spend from the EDC Data and specifies the color and pattern used in bar graphs to represent each in the remainder of the report.

Table 19. EDC Device Deployment Data

Representative Color	Data	Description
Device Deployment Data		
	2021 Estimate	Remaining units planned for 2021 where work will begin in 2021
	2020 Design/ Engineering	Detailed design and engineering is in progress but the device is not yet in construction

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

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

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

Representative Color	Data	Description
	2020 Construction	Field construction is in progress but the device is not yet in service
	2020 In Service	Device is installed and is used and useful but not yet commissioned to enable all grid modernization functionalities
	2020 Commissioned	Device is fully operational with all grid modernization functionalities, and so is considered deployed in PY2020
	2019 Actual	Actual devices commissioned in 2019
	2018 Actual	Actual devices commissioned in 2018
Spend Data		
	2021 Estimate	Projected 2021 spend
	2020 Actual	Actual 2020 spend[23]
	2019 Actual	Actual 2019 spend[24]
	2018 Actual	Actual 2018 spend

Source: Guidehouse analysis

3.1.2 Data QA/QC Process

To enable 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 between the aggregated year-end total information and work order-level data
- Variance between the actual unit costs and planned unit costs

3.2 Deployment Progress and Findings

Guidehouse presents findings from the Infrastructure Metrics analysis for the M&C Investment Area in the following subsections.

[23] The 2020 actual costs shown in the tables and figures include only capital spending and do not include operations and maintenance (O&M) spending. This has been done to maintain consistency and comparability with the EDC's 2020 Annual GMP Filings (Appendix 1 required format). O&M spending information is included separately in Section **Error! Reference source not found.**.

[24] The 2019 and 2018 spending reported by the EDCs in the Annual Reports (and in the Appendix 1) included the associated O&M costs as well as Capital costs. The O&M costs are small relative to the capital costs for M&C so were not removed from the analysis.

3.2.1 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.

3.2.1.1 Impact on Massachusetts

Across the three EDCs in Massachusetts, M&C investments have impacted about 9% of total EDC customers and 9% of feeders. Table 20 summarizes the number of feeders and customers covered by GMP M&C investments spanning 2018 through 2020.

Table 20. Number of Feeders and Customers Impacted by M&C Investments

M&C Impact	Eversource		National Grid		Unitil		Total	
	Feeders	Customers	Feeders	Customers	Feeders	Customers	Feeders	Customers
Systemwide Total	2,350	1,399,076	1,112	1,342,182	38	29,990	3,500	2,771,248
2018-2020 Installed	306	232,280	57	87,807	10	9,178	373	329,265
% System Total	13%	17%	5%	7%	26%	31%	11%	12%

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

3.2.1.2 Infrastructure Metrics Results

Table 21 summarizes the Infrastructure Metrics results for each EDC's M&C Investment Area through PY2020. Sections 3.2.2 through 3.2.4 explain each EDC's progress and plans in greater detail.

Table 21. M&C Infrastructure Metrics Summary

Infrastructure Metrics			Eversource	National Grid	Unitil
GMP Plan Total, 2018-2021		Devices	430	160	11
		Spend, $M	$64.79*	$4.77	$1.00
EDC Data Total, 2018-2021		Devices	560	202	14
		Spend, $M	$69.00	$6.21	$1.19
IM-4	Number of devices or other technologies deployed through PY2020	# Devices Deployed	435	71	11
		% Devices Deployed	101%	44%	100%
IM-5	Cost for Deployment through PY2020	Total Spend, $M	$52.06	$3.03	$0.90
		% Spend	105%	64%	91%
IM-6	Deviation Between Actual and Planned Deployment for PY2020	% On Track (Devices)	102%	43%	100%
		% On Track (Spend)	110%	59%	88%
IM-7		# Devices Remaining	125	131	3

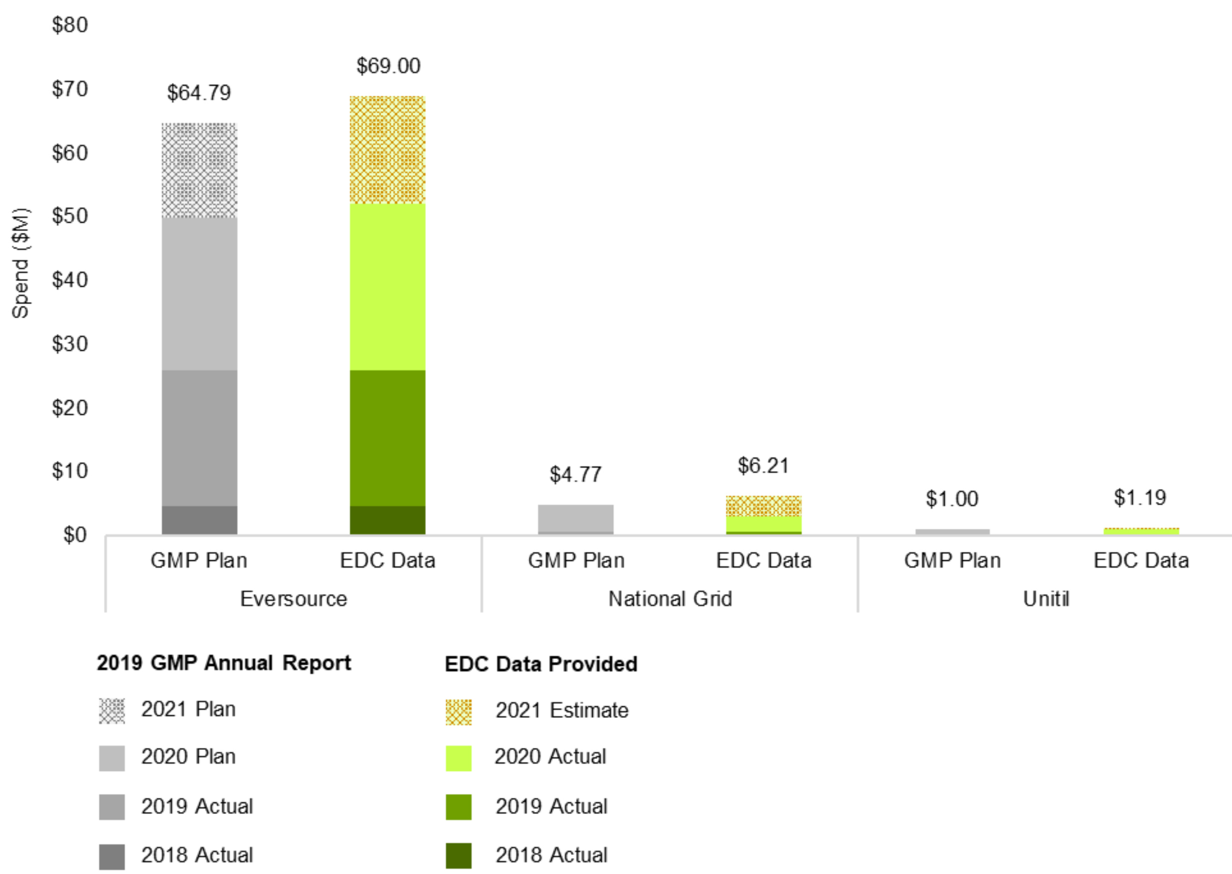
Projected Deployment for the Remainder of the GMP Term	Spend Remaining, $M	$16.93	$3.18	$0.29

*Includes the Eversource planned spend for PY2021, set *forth the in the GMP Extension and Funding Report, filed on July 1, 2020 and approved on February 4, 2021.*

Source: Guidehouse analysis of 2019 GMP Annual Reports, "GMP Extension and Funding Report," and 2020 EDC Data

Despite COVID-19-related delays, all EDCs made progress in the M&C Investment Area in PY2020. Actual deployment and spending in PY2020 were slightly higher than planned for Eversource and lower than planned for National Grid and Unitil (see IM-6 in Table 21). The total estimated deployment, including the 2021 estimates, exceeds the GMP plan for all EDCs. Much of the work completed through PY2020 has positioned all EDCs to steadily continue or ramp up deployment in PY2021. Figure 3 compares the GMP plans and EDC data totals and year-over-year spending for each EDC.

Figure 3. M&C Spend Comparison (2018-2021, $M)



Note: Includes the Eversource planned spend for PY2021, set forth the in the GMP Extension and Funding Report, filed on July 1, 2020 and approved on February 4, 2021.

Source: Guidehouse analysis of 2019 GMP Annual Reports, GMP Extension and Funding Report, and 2020 EDC Data

In addition to the capital costs shown in Figure 3, Eversource incurred approximately $0.54 million toward Administration and Regulatory costs across the GMP investments in PY2020. National Grid incurred approximately $0.19 million in O&M costs toward the M&C Investment Area in PY2020. National Grid also incurred approximately $1.79 million Administration and Regulatory costs across the GMP investments in PY2020. Unitil incurred approximately $12,000 toward Administration and Regulatory costs across the GMP investments in PY2020.

3.2.2 Eversource

This section discusses Eversource's M&C investment progress through PY2020 and estimated PY2021 progress.

3.2.2.1 Overview of GMP Deployment Plan

Eversource's M&C Investment Area goals and objectives include:

- Increasing the amount of data that is 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 deploying a range of M&C devices on its distribution network. Table 22 details the technologies and devices that are being implemented as part of Eversource's M&C Investment Area.

Table 22. 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.
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.
Recloser SCADA	Addition of communications capability so the device can be centrally monitored and controlled from the dispatch center.
Padmount Switch SCADA	Addition of a radio package to enable communications and central monitoring.
Network Protector SCADA	Provides real-time network load data and remote control capability to underground network.
Power Quality Monitors[25]	Provide remote access and storage of power quality meter data for the Eversource system planning, protection, and controls engineering to evaluate disturbance events and share information with customers.

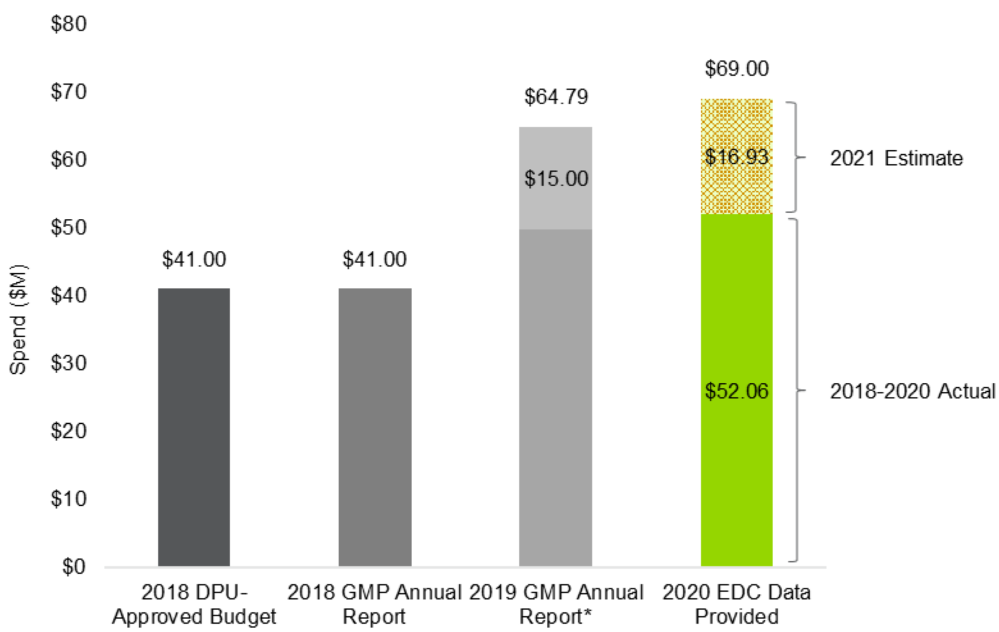
Source: Guidehouse analysis of GMP Annual Reports and EDC Data

[25] *Power Quality Monitors* was added as a new GMP device type during PY2020.

3.2.2.2 M&C Deployment Plan Progression

Figure 4 shows the progression of Eversource's M&C deployment plans from DPU-approval in 2018 through PY2020, as well as progress estimates for PY2021.

Figure 4. Eversource M&C Planned and Actual Spend Progression, $M



* Includes the Eversource plan for 2021, set forth the in the *GMP Extension and Budget Funding Report* filed on July 1, 2020

Source: Guidehouse analysis of DPU Order (May 10, 2018), 2019 GMP Annual Reports, "GMP Extension and Funding Report" (filed July 1, 2020), and EDC Data

During PY2019, Eversource shifted budget previously allocated to other Investment Areas to the M&C budget, which was increased by about 20% from the original DPU-approved budget of $41 million. The increased budget accelerated M&C deployment and helped surpass the original deployment plans. The PY2020 deployment and spend slightly surpassed the original plan, which explains the difference between the 2020 EDC Data Provided and 2019 GMP Annual Report columns in Figure 4.

During PY2020, Eversource extended the original GMP plan to include an additional $15 million toward M&C investments, bringing the total M&C planned investment to about $65 million. The estimated 2021 deployment and spend track slightly above this planned total at $69M.

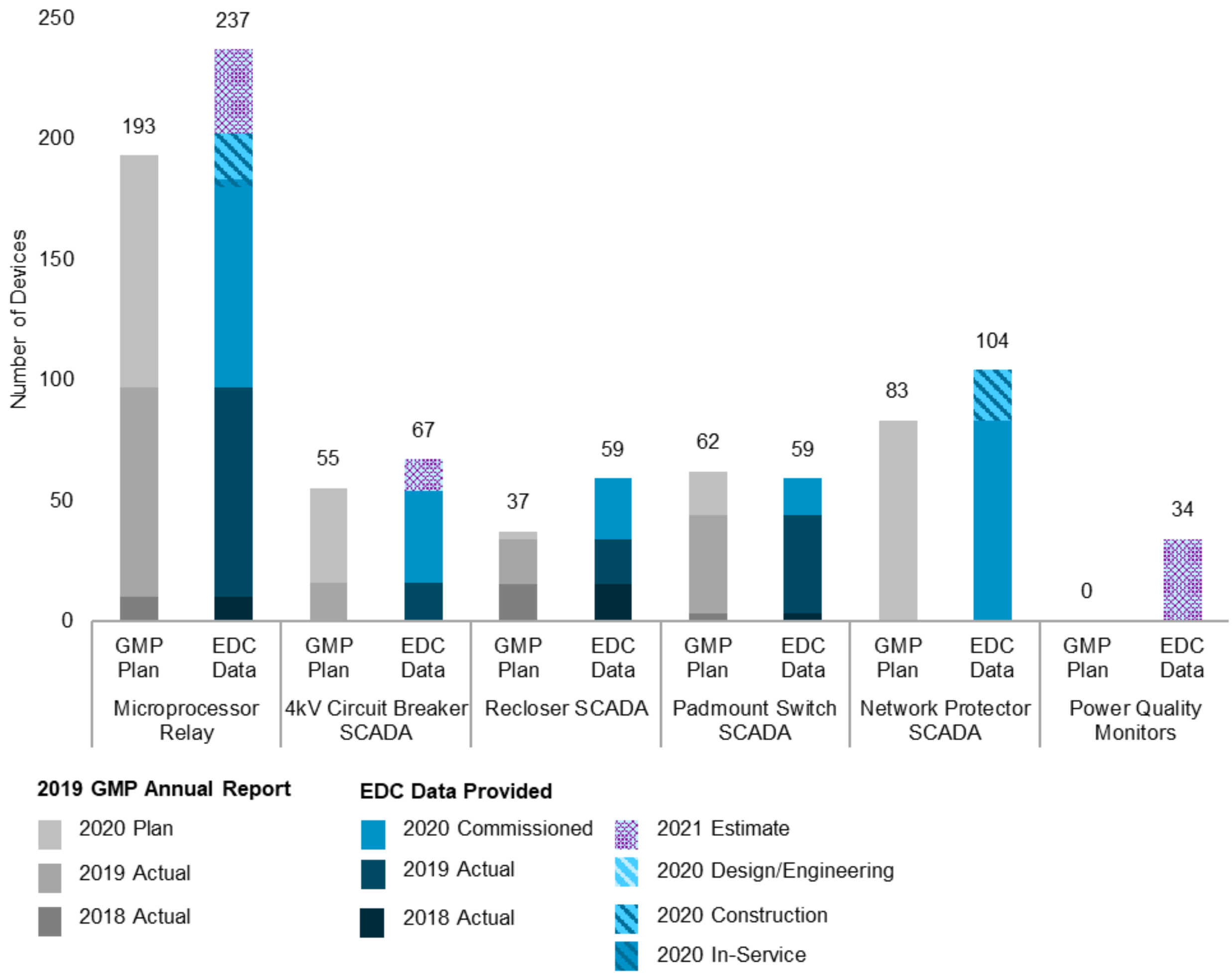
3.2.2.3 M&C Investment Progress through PY2020

Overall, the number of Eversource's M&C devices deployed exceeded plans for PY2020. Figure 5 shows the progress and details of each device type for the 2018-2021 period.

For PY2020 the 4kV circuit breaker SCADA deployment was one unit less than planned due to a circuit reconfiguration. Overall, from PY2018 through PY2020 the number of 4kV circuit breaker SCADA completed was 3 greater than plan (as filed in Eversource 2019 Annual Report).

Recloser SCADA deployment significantly exceeded plan as Eversource intentionally expanded this program to take advantage of lower unit costs and locations that had already been identified. The number of locations requiring SCADA to be installed on padmounts was less than originally forecasted. Microprocessor relays installation was less than forecasted; although it was noted that these relay installations were completed in March of 2021.

Figure 5. Eversource M&C Device Deployment Comparison (2018-2021)



* Note: the Eversource plan for 2021, set forth in the *GMP Extension and Budget* filing on July 1, 2020 did not provide device or spend data at the device type level, only at the aggregate Investment Area level. The numbers shown here reflect the 3-year plan.

Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

Along with increased deployment of microprocessor relays, initial investment in power quality monitors is planned for PY2021, and continued deployment of 4 kV circuit breaker SCADA and network protector SCADA. Deployment of recloser SCADA and padmount switch SCADA was completed during PY2020. Eversource considers these deployments to have met their objectives, and there are no plans for continued deployment of these device types in PY2021.

The EDC Data presented in Figure 5 is also shown in tabular form in Table 23 to provide the specific deployment units in each category.

Table 23. Eversource M&C Plan & Actual Device Deployment (2018 - 2021)

	Microprocessor Relay	4kV Circuit Breaker SCADA	Recloser SCADA	Padmount Switch SCADA	Network Protector SCADA	Power Quality Monitors
2018-2021 Total	**237**	**67**	**59**	**59**	**104**	**34**
PY2021 Estimate[26]	35	13	-	-	-	34
Engineering/Design during PY2020	-	-	-	-	-	-
Construction during PY2020	19	-	-	-	21	-
In Service during PY2020	3	-	-	-	-	-
Commissioned in PY2020	83	38	25	15	83	-
Commissioned in PY2019	87	16	19	41	-	-
Commissioned in PY2018	10	-	15	3	-	-

* Note: the Eversource plan for 2021, set forth in the *GMP Extension and Budget* filing on July 1, 2020 did not provide device or spend data at the device type level, only at the aggregate Investment Area level. The numbers shown here reflect the original 3-year plan and PY 2021 estimates are from the evaluation data request.

Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

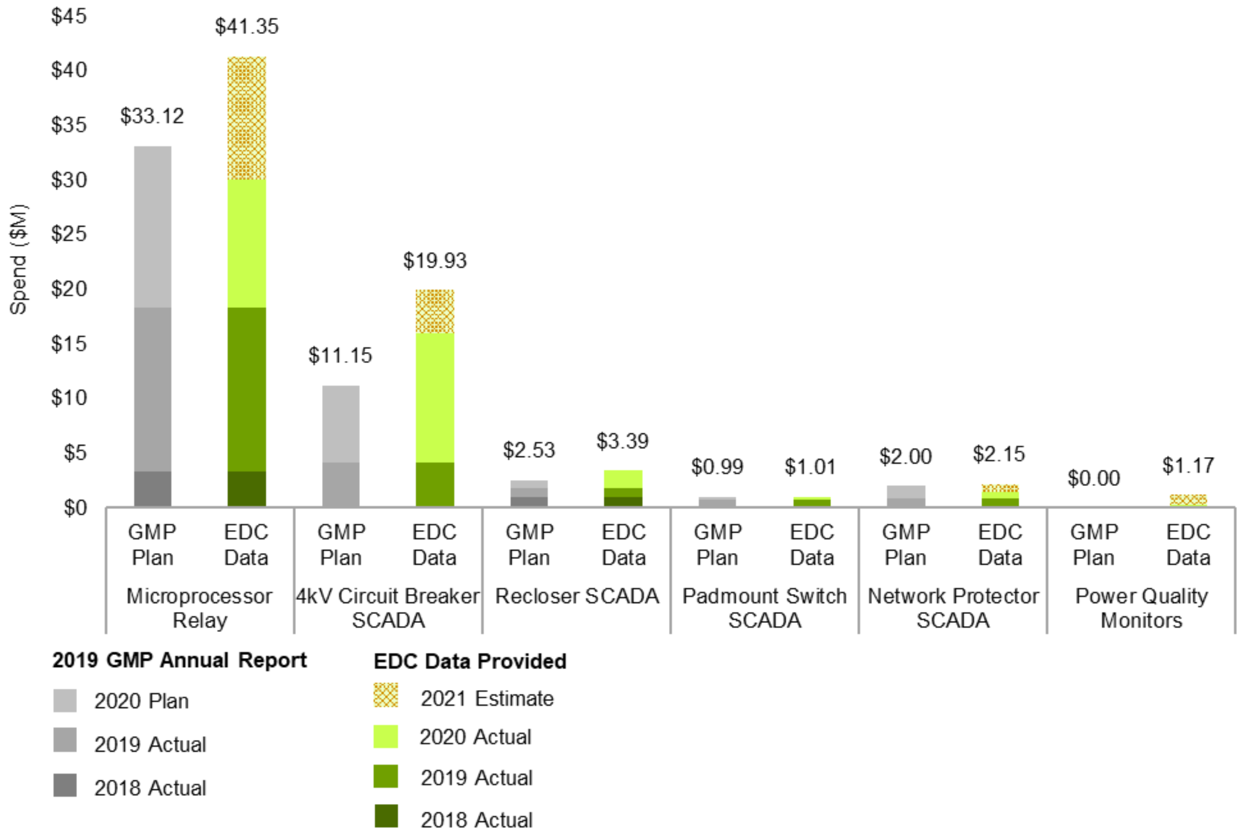
Figure 6 shows Eversource's corresponding planned versus actual spend over the 2018-2021 period, broken out by device type.

Spending in PY2020 followed similar trends to device deployment, as expected. Spending on microprocessor relays and padmount switch SCADA was less than planned, but remained nearly proportionate to the device counts. Similarly, the increase in recloser SCADA spend is due to the increased deployment. Network protector SCADA unit costs were lower, but 4 kV circuit breaker SCADA costs were higher than anticipated on a per unit basis, which represents the largest deviation from the PY2020 plan.

Spending estimated for PY2021 is largely allocated toward 4kV circuit breaker SCADA, microprocessor relays, with additional spending also on the new power quality monitors device type.

[26] This includes the devices planned for 2021 that are not yet in engineering/design, construction, or in-service phases as of the end of PY2020.

Figure 6. Eversource M&C Spend Comparison (2018-2021, $M)



Note: the Eversource plan for 2021, set forth the in the *GMP Extension and Budget* filing on July 1, 2020 did not provide device or spend data at the device type level, only at the aggregate Investment Area level. The numbers shown here reflect the 3-year plan.

Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

The EDC Data presented in Figure 6 is also shown in Table 24 to provide the specific dollar spend in each category.

Table 24. Eversource M&C Plan and Actual Spend (2018-2021, $M)

	Micro-processor Relay	4 kV Circuit Breaker SCADA	Recloser SCADA	Padmount Switch SCADA	Network Protector SCADA	Power Quality Monitors
2018-2021 Total	**$41.35**	**$19.93**	**$3.39**	**$1.01**	**$2.15**	**$1.17**
PY2021 Estimate	$11.26	$4.00	$0.00	$0.00	$0.72	$0.96
PY2020 Actual	$11.74	$11.76	$1.53	$0.29	$0.56	$0.21
PY2019 Actual	$14.99	$4.09	$0.89	$0.62	$0.87	$0.00

	Micro-processor Relay	4 kV Circuit Breaker SCADA	Recloser SCADA	Padmount Switch SCADA	Network Protector SCADA	Power Quality Monitors
PY2018 Actual	$3.36	$0.08	$0.96	$0.11	$0.00	$0.00

Note: the Eversource plan for 2021, set forth the in the *GMP Extension and Budget* filing on July 1, 2020 did not provide device or spend data at the device type level, only at the aggregate Investment Area level. The numbers shown here reflect the 3-year plan.

Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

The following sections discuss the progress through PY2020 and estimates for PY2021 for each device type.

Microprocessor Relays

Microprocessor relay deployment in PY2020 was slightly lower than projected. Overall resource constraints and various disruptions, including storm emergency restoration events and COVID-19 restrictions impacted deployment timing and increased costs.

During PY2020 work was completed on 83 microprocessor relays with commissioning being completed. Also during PY2020, three additional microprocessor relays were constructed and placed into service but not commissioned.

4 kV Circuit Breaker SCADA

The deployment of 4 kV circuit breaker SCADA units was almost exactly on target with the plans. However, the program ran significantly over budget in PY2020. The higher than anticipated costs were largely due to the complex nature of the workplan and unanticipated additional work required. Furthermore, the program experienced COVID-19-related delays which triggered missed outage windows, both of which pushed work to later in the year. The complexity and program delays required expanded scope and overtime work, which increased labor costs and contributed to the overall increased spending during PY2020.

Despite the challenges, the deployment progress is staying on track and is expected to exceed the original 3-year planned deployment. Eversource plans on continuing the 4 kV circuit breaker SCADA program to meet the PY2021 plan.

Recloser SCADA

Deployment of recloser SCADA was intentionally accelerated and far exceeded the planned deployment for PY2020. Spending during PY2020 exceeded the plan, but at a much lower rate than device deployment, as unit costs were lower than anticipated.

Padmount Switch SCADA

Padmount switch SCADA deployment fell slightly short of the plan for PY2020. However, this was due to exhausting all potential locations that would accept communications-only upgrades, as per the plan. Spending was slightly higher than projected.

Network Protector SCADA

The original GMP 2018-2020 network protector SCADA units were commissioned in March 2020. The original set of work was done on the West Springfield substation, but with the successful completion ahead of schedule, Eversource decided to include several additional locations. This additional work will be completed in PY2021 and the budget is not expected to exceed the original plan, which indicates the unit costs should be lower than planned.

Power Quality Monitors

During PY2020, the power quality monitoring initiative was identified as a potential addition to the grid modernization portfolio of projects. This project includes both installing monitoring and event-recording devices and providing remote access capabilities. Eversource initiated preparatory exploratory work in PY2020, which included a relatively small amount of spending. This work was commissioned in March of 2021, with system testing planned for six months.

The need for this program is due to several substations feeding large commercial customers in Eastern Massachusetts where there is insufficient access to information about sub-cycle disturbance events because they are equipped with analog metering and electromechanical relays that lack data storage and remote access capability.

Eversource selected an initial substation to be included in the program. This project added monitoring capabilities to all 34 feeders and bus sections within the substation, which enabled power quality data collection. Eversource's engineering team will use this data during disturbances to perform rapid post-event analyses and evaluations to confirm correct protection system operations and to develop solutions to issues that affect customers and are outside of IEEE tolerances. Additionally, this data can be shared with the large commercial customers to evaluate the responses of their systems.

3.2.2.4 Infrastructure Metrics Results and Key Findings

Table 25 presents the Infrastructure Metrics results through PY2020 for each device type related to Eversource's M&C Investment Area.

Table 25. Eversource M&C: Infrastructure Metrics Summary

Infrastructure Metrics			Micro-processor Relay	4kV Circuit Breaker SCADA	Recloser SCADA	Padmount Switch SCADA	Network Protector SCADA	Power Quality Monitors
GMP Plan Total, 2018-2020*		Devices	193	55	37	62	83	-
		Spend, $M	$33.12	$11.15	$2.53	$0.99	$2.00	-
EDC Data Total, 2018-2021		Devices	237	67	59	59	104	34
		Spend, $M	$41.35	$19.93	$3.39	$1.01	$2.15	$1.17
IM-4	Number of Devices or other Technologies Deployed through PY2020	# Devices Deployed	180	54	59	59	83	-
		% Devices Deployed	93%	98%	159%	95%	100%	N/A

Infrastructure Metrics			Micro-processor Relay	4kV Circuit Breaker SCADA	Recloser SCADA	Padmount Switch SCADA	Network Protector SCADA	Power Quality Monitors
IM-5	Cost for Deployment through PY2020	Total Spend, $M	$30.09	$15.93	$3.39	$1.01	$1.43	$0.21
		% Spend	91%	143%	134%	102%	71%	N/A
IM-6	Deviation Between Actual and Planned Deployment for PY2020	% On Track (Devices)	86%	97%	833%	83%	100%	N/A
		% On Track (Spend)	80%	168%	227%	106%	49%	N/A
IM-7	Projected Deployment for the Remainder of the GMP Term	# Devices Remaining	57	13	-	-	21	34
		Spend Remaining, $M	$11.26	$4.00	-	-	$0.72	$0.96

Note: the Eversource plan for 2021, set forth the in the *GMP Extension and Budget* filing on July 1, 2020 did not provide device or spend data at the device type level, only at the aggregate Investment Area level. The numbers shown here reflect the 3-year plan.

Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

Eversource has extended deployment objectives—both device number targets and commensurate costs—into the fourth year of the expanded 4-year term to continue momentum in its GMP.

Eversource's device deployment through PY2020 tracked closely to original 2018-2020 GMP plan (the original 3-year term) in most device categories and spend per device category also tracked to original plan but with more variance. Recloser SCADA exceeded original plan for devices and spend, as Eversource decided to accelerate deployment.

The 4 kV circuit breaker SCADA deployment met the original plan and the revised plan to complete additional units. Eversource decided to not complete installation of one unit since the circuit is planned to be converted to 13 kV. The deployment of this unit was no longer required.

Eversource PY2020 actual device deployment varied slightly from plan, with microprocessor relays and padmount switch SCADA coming in slightly below (within 20%) of plan and 4 kV circuit breaker SCADA and network protector SCADA coming in almost exactly at plan. Recloser SCADA deployment intentionally far exceeded plan (see above).

In PY2020, actual spend varied with microprocessor relays spend commensurate with slightly reduced unit volume and padmount switch SCADA slightly (within 10%) exceeding plan although at lower unit volume, indicating higher unit costs. 4 kV circuit breaker SCADA costs were over 50% higher than plan due to increased costs and units, and network protector SCADA costs were low relative to plan. Recloser SCADA costs far exceeded plan, but the much higher unit deployment indicates that unit costs were much lower than anticipated.

The padmount switch SCADA program was successfully completed in PY2020. There were additional padmount units that were forecasted to be performed, but a review of the "specific equipment type" determined these additional units could not have SCADA capability installed. Microprocessor relay work not completed in PY2020 rolled over to PY2021 and was completed in March of 2021. The total number of 4 kV circuit breaker SCADA to be installed was reduced by one unit based on the conversion of the circuit from 4 kV to 13 kV.

The continued deployment of rolled-over and new microprocessor relays makes up the most significant portion of work estimated for PY2021. Furthermore, during PY2020 Eversource expanded plans for M&C investments to include a new program, power quality monitors, which will be deployed in PY2021. Total spending over the 4-year term is estimated to track closely to the planned spend.

3.2.3 National Grid

This section discusses National Grid's M&C investment progress through PY2020 and projected PY2021 estimates.

3.2.3.1 Overview of GMP Deployment Plan

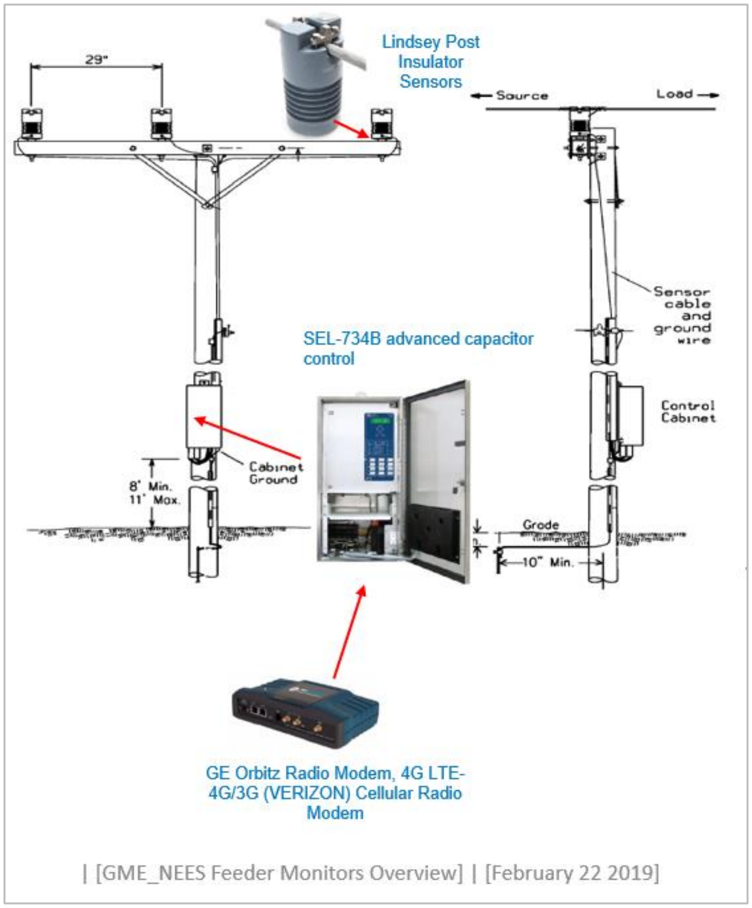
National Grid's M&C Investment Area goals and objectives include:

- 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 interval power monitoring devices on overhead feeders within its distribution system. National Grid's selected technology will be installed outside of the substation fence for increased visibility. Information is transmitted cellularly every 5 minutes. Figure 7 shows a detailed schematic of how the EDC will implement the technology. Each circuit location includes three sensors (one per phase) and one control box with a communications package.[27]

[27] 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 7. Feeder Monitor Schematic

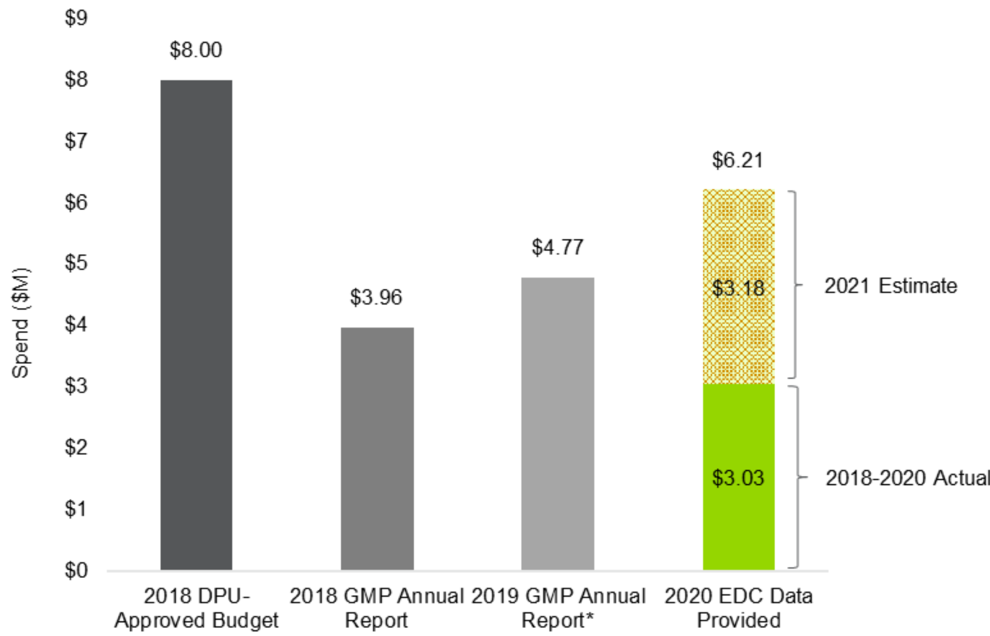


Source: National Grid

3.2.3.2 M&C Deployment Plan Progression

Figure 8 shows the progression of National Grid's M&C deployment plans from DPU-approval in 2018 through PY2020.

Figure 8. National Grid M&C Planned and Actual Spend Progression, $M



Source: Guidehouse analysis of DPU Order (May 10, 2018), 2018 and 2019 GMP Annual Reports, GMP Extension and Budget Report, and EDC Data

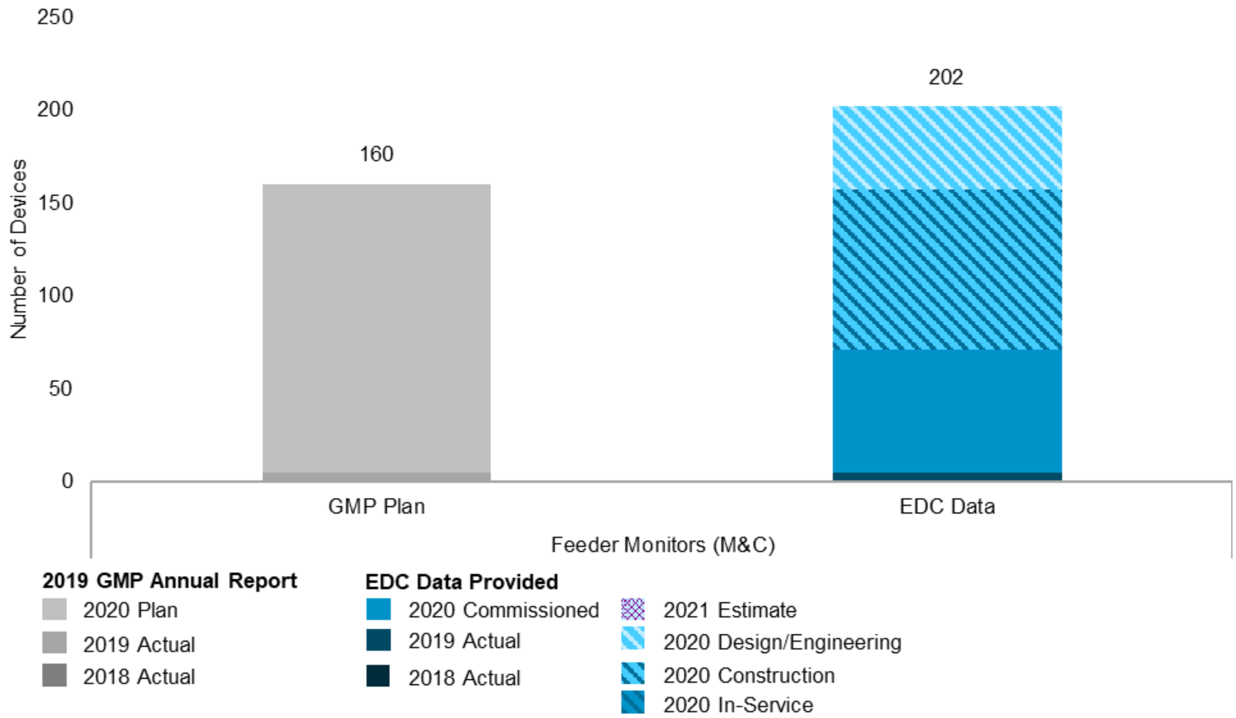
At the start of the GMP term the M&C budget was adjusted downward from the original DPU-approved plan. The budget was slightly increased during PY2019 as deployment plans were revised, and then increased again during PY2020 due the inclusion of additional feeder monitors estimated for deployment in PY2021. The changes in budgets and forecast were due to lead times for materials between PY2019 and PY2020, then followed by the COVID-19 pandemic, which again affected the schedule. Actual spending in PY2020 was lower than expected due to delays that are discussed in the following sections. However, the total deployment and spending at the end of PY2021 is expected to surpass the plan set forth in the *2019 GMP Annual Report*.

3.2.3.3 M&C Investment Progress through PY2020

National Grid's M&C investment consists of a single device type, feeder monitors. Deployment of feeder monitors accelerated during PY2020, and National Grid deployed more than tenfold the number of devices deployed during PY2019. However, deployment was still slower than planned for PY2020, and the total number of devices deployed was short of the plan. The delay was primarily due to COVID-19-related impacts.

Figure 9 shows National Grid's planned versus actual device deployment progress over the 2018-2021 period. The EDC Data presented in Figure 9 is also shown in Table 26.

Figure 9. National Grid M&C Device Deployment Comparison (2018-2021)



Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

Table 26. National Grid M&C Plan and Actual Device Deployment (2018-2021)

	Feeder Monitors (M&C)
2018-2021 Total	**202**
PY2021 Estimate[28]	-
Engineering/Design during PY2020	45
Construction during PY2020	86
In Service during PY2020	-
Commissioned in PY2020	66
Commissioned in PY2019	5
Commissioned in PY2018	-

Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

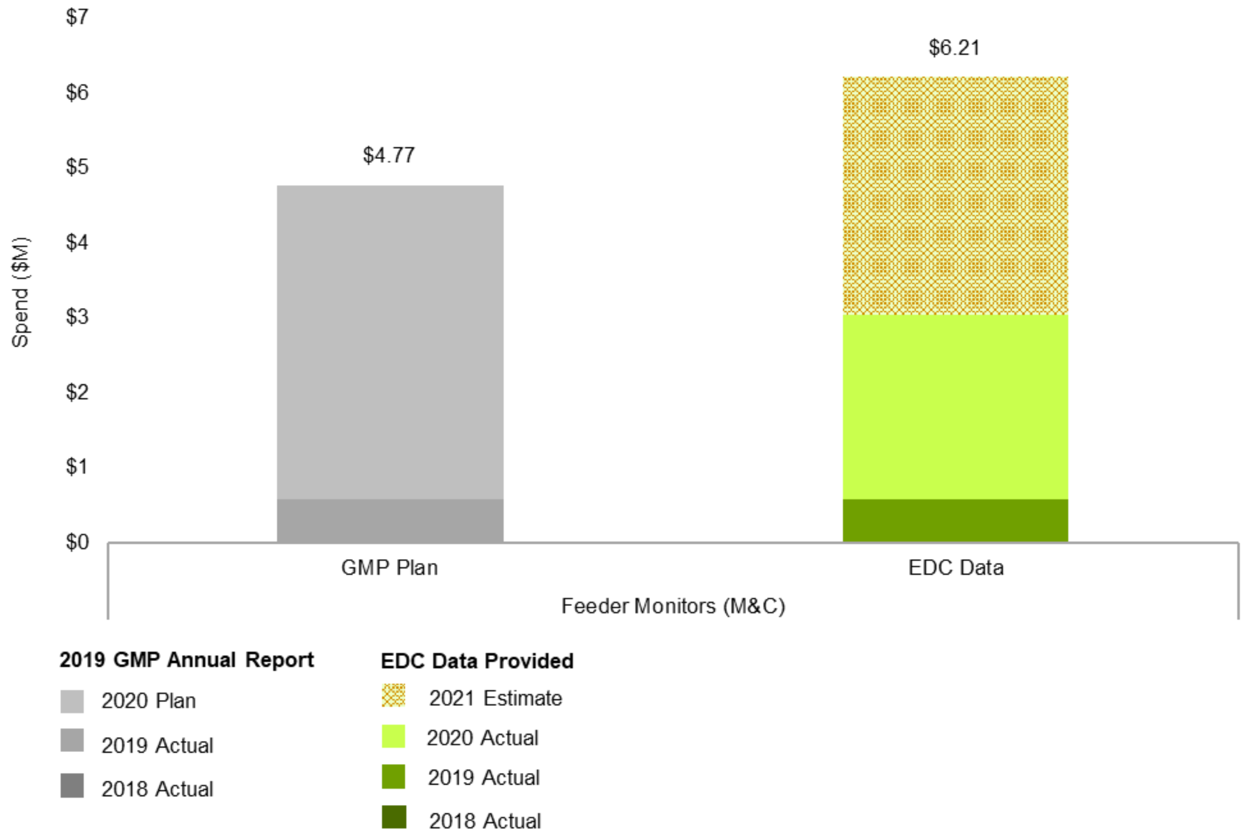
National Grid continued to make progress toward the plan. The devices that were anticipated to be deployed during PY2020 were in the construction phase at the end of the year and are scheduled to be completed in PY2021. Additionally, National Grid expanded the estimates to include deployment of additional feeder monitors during PY2021, bringing the 4-year total

[28] This includes the devices planned for 2021 that are not yet in Engineering/Design, Construction, or In-Service phases as of the end of PY 2020.

deployment beyond what was originally planned. The increase in the number of feeder monitors was driven by the need to install two sets of monitors on each feeder: one set of monitors at the head end (beginning of the feeder) and a second set of monitors where the circuit bifurcated or branched off in two different directions.

PY2020 spending was lower than planned. Figure 10 shows National Grid's planned versus actual spend over the 2018-2021 period. The EDC Data presented in Figure 10 is also shown in Table 27.

Figure 10. National Grid M&C Spend Comparison (2018-2021, $M)



Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

Table 27. National Grid M&C Plan and Actual Spend (2018-2021, $M)

	Feeder Monitors (M&C)
2018-2021 Total	**$6.21**
PY2021 Estimate	$3.18
PY2020 Actual	$2.46
PY2019 Actual	$0.57
PY2018 Actual	$0.00

Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

The spend in PY2020 slightly outpaced the unit deployment compared to the plan. This is largely due to the preparation and construction work initiated during PY2020 for units that will be deployed in PY2021. The total spend estimated for the 4-year term is just under $1.5 million higher than planned. This addition to the M&C budget is a result of shifting budget between Investment Areas as necessary to meet the GMP objectives by the end of the 4-year term. National Grid will use this additional budget for M&C to deploy more feeder monitors than planned.

The primary cause of deployment delays and shortfalls was COVID-19-related impacts. Due to the need for social distancing and reduced contact, the size and workload of the crews was reduced. These precautions ultimately slowed the deployment and necessarily pushed schedules later than originally planned. Furthermore, National Grid limited the planned outages—which are required to perform some of the work—that would impact residential customers, with the understanding that the pandemic caused more residential customers to work and attend school from their homes. Similarly, this delayed construction schedules and pushed portions of work into PY2021.

By the end of PY2020, these protocols were fine-tuned and National Grid gained momentum on the construction and commissioning of the feeder monitors. The work is expected to continue at an increased rate throughout PY2021 to deploy a total of over 200 feeder monitors by the end of the 4-year term.

3.2.3.4 Infrastructure Metrics Results and Key Findings

Table 28 presents the Infrastructure Metrics results through PY2020 for National Grid's feeder monitor deployment.

Table 28. National Grid PY2020 Infrastructure Metrics Findings

Infrastructure Metrics			Feeder Monitors (M&C)
GMP Plan Total, 2018-2020*		Devices	160
		Spend, $M	$4.77
EDC Data Total, 2018-2021		Devices	202
		Spend, $M	$6.21
IM-4	Number of devices or other technologies deployed through PY2020	# Devices Deployed	71
		% Devices Deployed	44%
IM-5	Cost for Deployment through PY2020	Total Spend, $M	$3.03
		% Spend	64%
IM-6	Deviation Between Actual and Planned Deployment for PY2020	% On Track (Devices)	43%
		% On Track (Spend)	59%
IM-7	Projected Deployment for the Remainder of the GMP Term	# Devices Remaining	131
		Spend Remaining, $M	$3.18

Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

Overall, National Grid's M&C progress is behind what was planned for PY2020. The shortfall was largely due to COVID-19-related impacts which limited and delayed construction timelines. National Grid expects to re-accelerate deployment of feeder monitors during PY2021. While the costs slightly outpaced the units deployed in PY2020, implying a slightly higher unit cost, the unit costs are still expected to track closely with the plans at the end of the 4-year period. By the end of PY2021, National Grid expects deployment to surpass the original plan.

3.2.4 Unitil

This section discusses Unitil's M&C investment progress through PY2020 and its projected PY2021 estimates.

3.2.4.1 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/ALF, 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 29 describes these technologies in greater detail.

Table 29. Unitil M&C Devices and Technologies

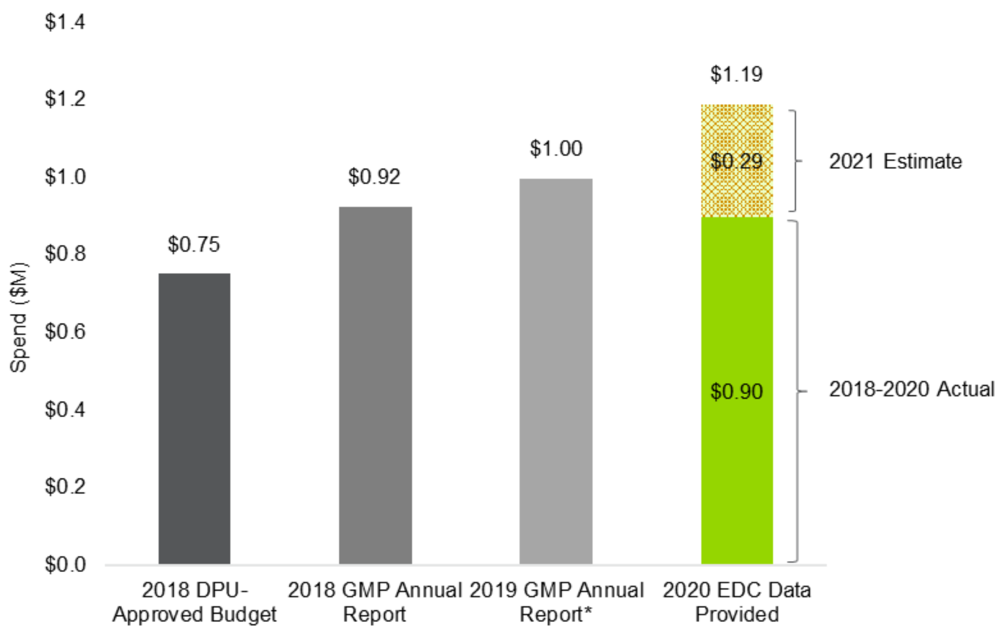
Investment Type	Description
Substation SCADA	The installation and interconnection of a SCADA terminal unit at the site, the establishment of communications between the terminal unit and the remotely located SCADA master system, and the associated programming to implement desired functions.
AMI-OMS Integration	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

3.2.4.2 M&C Deployment Plan Progression

Figure 11Figure 4 shows the progression of Unitil's M&C deployment plans from DPU-approval in 2018 through PY2020.

Figure 11. Unitil M&C Planned and Actual Spend Progression, $M



Source: Guidehouse analysis of DPU Order (May 10, 2018), 2018 and 2019 GMP Annual Reports, GMP Extension and Budget Report, and EDC Data

Unitil's plans for M&C investment have steadily increased between 2018 and 2020. The OMS Integration with AMI project has largely driven the increase in the cost estimate. The increase in costs associated with this project are related to: 1) updated labor costs between the original estimate and revised estimate; 2) increase in vendor involvement over original estimates; and 3) additional development time associated with the cloud-based solution. SCADA spending is also higher than expected in the early years of the plan primarily due to required equipment replacement to facilitate the M&C functionality required to support VVO.

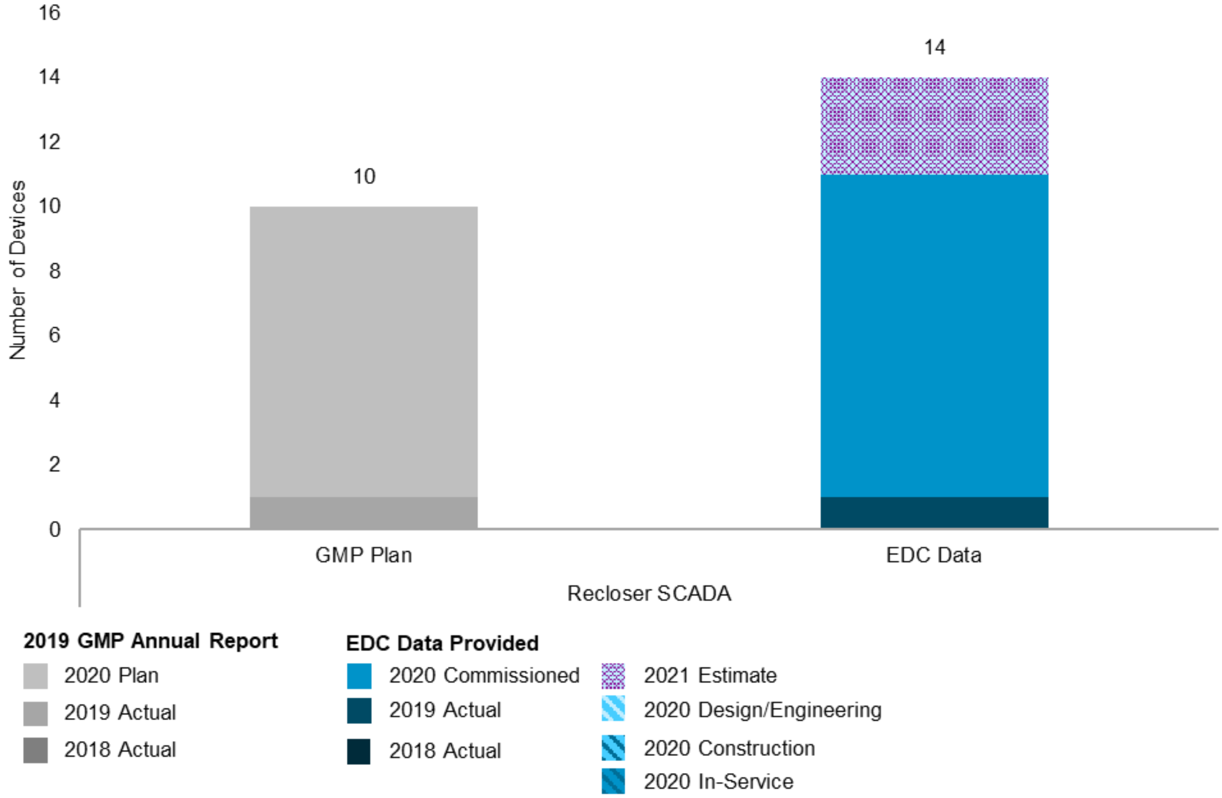
3.2.4.3 M&C Investment Progress through PY2020.

In PY2020, Unitil's progress toward substation SCADA retrofitting[29] and OMS/AMI integration tracked closely to the plan. Substation SCADA work was completed at three substations, and significant progress was made toward building out the OMS/AMI engine.

Figure 12 shows Unitil's planned versus actual device deployment progress over the 2018-2021 period. The EDC Data in Figure 12 is also shown in Table 30. The OMS/AMI integration plan is not quantified on a unit basis and so does not appear in the device deployment figures or tables. This investment is further discussed qualitatively below.

[29] Note the investment referred to as "Substation SCADA Retrofit" is labeled as "Recloser SCADA" in all figures and tables to align with the nomenclature of the DPU-approved device/technology types.

Figure 12. Unitil M&C Device Deployment Comparison (2018-2021)



Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

Table 30. Unitil M&C Plan and Actual Device Deployment (2018-2021)

	Recloser SCADA
2018-2021 Total	**14**
PY2021 Estimate[30]	3
Engineering/Design during PY2020	-
Construction during PY2020	-
In Service during PY2020	-
Commissioned in PY2020	10
Commissioned in PY2019	1
Commissioned in PY2018	-

Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

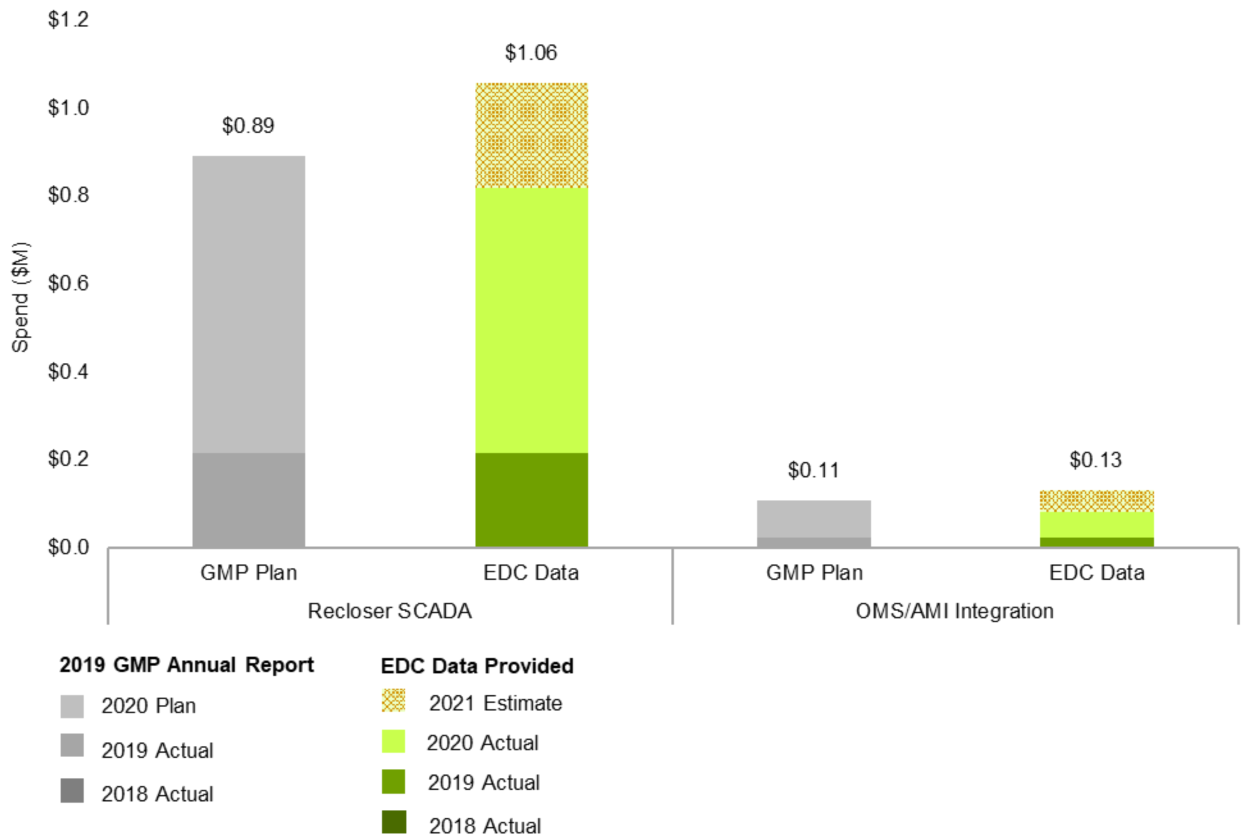
During PY2020, Unitil completed the work that rolled over from PY2019 in addition to all new work planned for PY2020. The investments were fully deployed at three substations. The details

[30] This includes the devices planned for 2021 that are not yet in engineering/design, construction, or in-service phases as of the end of PY2020.

of the work at each substation are discussed further below. Additionally, Unitil decided to move forward with adding SCADA to another substation in PY2021. By the end of PY2021, Unitil estimates the total substation SCADA retrofit completed will exceed the plans.

The PY2020 spend for both SCADA and OMS/AMI integration fell slightly below the plans primarily due to the complexity of data integration and resource constraints due to the pandemic. Unitil estimates the spending in PY2021 will make up the difference and then go beyond the plans due to the additional substation SCADA work and continued OMS/AMI integration work. Figure 13 shows Unitil's planned versus actual spend over the 2018-2021 period. The EDC Data presented in Figure 13 is also shown in Table 31.

Figure 13. Unitil M&C Spend Comparison (2018-2021, $M)



Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

Table 31. Unitil M&C Plan and Actual Spend (2018-2021, $M)

	Recloser SCADA	OMS/AMI Integration
2018-2021 Total	**$1.06**	**$0.13**
PY2021 Estimate	$0.24	$0.05
PY2020 Actual	$0.60	$0.06
PY2019 Actual	$0.22	$0.02
PY2018 Actual	-	-

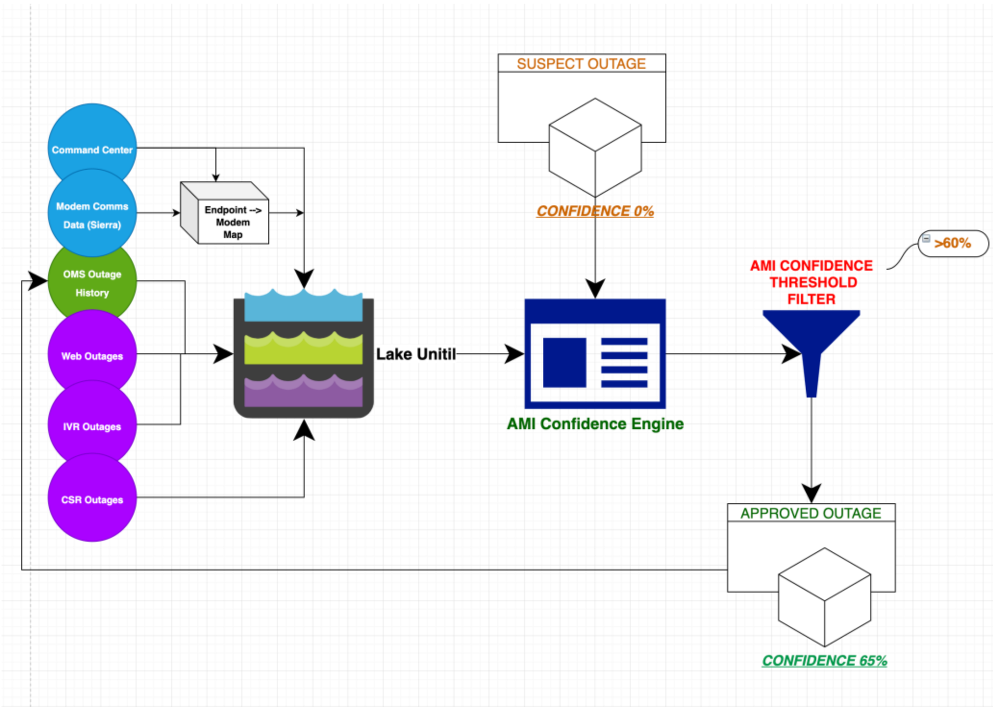
Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

The following sections discuss each technology in greater detail.

OMS/AMI Integration

Unitil spent the majority of PY2020 working toward completing phase 1 of the OMS/AMI integration. Phase 1 work includes developing and implementing the AMI confidence engine and filter. Figure 14 shows a schematic of the phase 1 work.

Figure 14. Phase 1 (Confidence Engine and Filter) Schematic



Source: Unitil

The plan to build out the engine leverages three types of data:

- Confirmed outage data from OMS, including past outage history
- Low level signal to noise data from collectors
- Weather and temperature data

Due to the complexity of data integration and resource constraints, the last two types of data were not integrated during PY2020. Building out the means to correlate signal to noise and weather and temperature data is included in the workplan for PY2021.

During PY2020, Unitil completed the correlation of OMS outages and hierarchical outage prediction. This included building out processes for loading and managing data, identifying communication gaps, and assigning confidence scores. A simple user interface was built and has the capability to simulate outages.

In addition to incorporating the signal to noise and weather and temperature data, the next steps for PY2021 include further building out the database, finalizing an initial version of the confidence engine, and developing the user interface.

Substation SCADA Retrofit

The substation SCADA retrofit initiative aims to upgrade existing SCADA or add new SCADA to distribution substations. Prior to initiating this work through the GMP, most substations had little to no SCADA. Where SCADA did exist, it was not capable of getting the analog quantities needed due to the lack of power quantities of voltage measurements.

This initiative supports the VVO deployment, which determined the timeline and workplan for the first few years of the GMP term. Work on the first substation began in PY2019, and the remaining work (completion of two additional substations) was completed during PY2020. In PY2021, Unitil expects to continue the substation SCADA work ahead of the VVO and ADMS deployment schedule.

Beyond 2021, Unitil expects to continue deploying substation SCADA at a rate of about one substation each year through around 2025. The work is largely prioritized by the impact, which includes metrics of substation size, load, and number of customers. The substation for PY2021, for example, was prioritized because it has three distribution circuits, while other remaining substations have only one or two circuits.

3.2.4.4 Infrastructure Metrics Results and Key Findings

Table 32 presents the Infrastructure Metrics results through PY2020 for the two technologies included in Unitil's M&C Investment Area.

Table 32. Unitil M&C: Infrastructure Metrics Summary

Infrastructure Metrics			Recloser SCADA	OMS/AMI Integration
GMP Plan Total, 2018-2020*		Devices	10	N/A
		Spend, $M	$0.89	$0.11
EDC Data Total, 2018-2021		Devices	14	N/A
		Spend, $M	$1.06	$0.13
IM-4	Number of Devices or Other Technologies Deployed through PY2020	# Devices Deployed	11	N/A
		% Devices Deployed	110%	N/A
IM-5	Cost for Deployment through PY2020	Total Spend, $M	$0.82	$0.08
		% Spend	92%	75%
IM-6	Deviation Between Actual and Planned Deployment for PY2020	% On Track (Devices)	111%	N/A
		% On Track (Spend)	90%	69%
IM-7		# Devices Remaining	3	N/A

	Projected Deployment for the Remainder of the GMP Term	Spend Remaining, $M	$0.24	$0.05

Source: Guidehouse analysis of 2019 GMP Annual Reports and 2020 EDC Data

Unitil’s progress in PY2020 was largely on track with plans. The total spend during PY2020 was slightly lower than anticipated, but these funds will be deployed in PY2021 to continue work on both substation SCADA retrofit and OMS/AMI integration. The substation SCADA retrofit work planned for PY2020 was completed, and additional work is scheduled for PY2021. The OMS/AMI integration work was more complex than anticipated, so portions of the work planned for PY2020 will be completed in PY2021; the work will then continue throughout PY2021 to develop additional capabilities and tools.

4. M&C Performance Metrics

Guidehouse's assessment of the Performance Metrics included Performance Metric data collection, data QA/QC, data analysis for each of the three EDCs, and determination of findings and conclusions from the analysis.

4.1 Data Management

This section discusses the data sources used for the Performance Metric evaluation and summarizes the Quality Assessment and Quality Control (QA/QC) steps, and selection of circuits used in the PY2020 analysis.

4.1.1 Data Sources

2020 Grid Modernization Plan Annual Report Appendix 1[31,32,33]: On April 1, 2021 each EDC submitted Appendix 1 along with its Annual Report. The Appendix 1 contains feeder-level data for all feeders within each EDC's territory. All PM-related data presented below are from these 2020 GMP Annual Report Appendices. These documents contain baseline and program year data for all circuits for each EDC. Key data from these Appendices that were utilized in this analysis include:

- Customer Counts
- Feeder Level SAIDI (CKAIDI) and SAIFI (CKAIFI) for the Plan Year and Baseline Years
- Number of Customers that Benefit from GMP Investments
- Average Protective Zone Size
- Main Line Customer Minutes of Interruption

Work Order Information: Circuit-level work order data was collected during the infrastructure metrics evaluation to understand the current status (e.g., Construction, Design, In-Service, Commissioned) of GMP investments. This work order data was used to determine when GMP investments were commissioned on each circuit with more granularity than is provided in the Appendix 1 data.

Service Quality Index (SQI) Filings[34]: During the PY2019 evaluation, the evaluation team used 2019 and historical SQI filings to cross-check for consistency with the data in the Appendix 1 filings. Because Unitil had not yet commissioned any M&C devices in PY2019, this QA/QC step was not performed for Unitil in the PY2019 evaluation. Thus, for the PY2020 evaluation, the evaluation team performed this consistency check for Unitil only.

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

[32] NSTAR Electric Company d/b/a Eversource Energy, Grid Modernization Plan Annual Report 2020. Submitted to Massachusetts DPU on April 1, 2021 as part of DPU 21-30. Note: Inconsistencies in calculations and definitions were discovered and Eversource updated the Appendix 1 in May 2021. The updates were provided to Guidehouse.

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

[34] Fitchburg Gas and Electric Light Company d/b/a Unitil, 2020 Service Quality Report. Submitted to Massachusetts DPU on March 1, 2021 as part of DPU 21-SQ-10

4.1.2 Data QA/QC Process

The evaluation team reviewed the Appendix 1 filings for completeness, accuracy, and alignment with the metrics set forward in the DPU Stamp Approved Metrics. The QA/QC process involved the following:

- Check that the change in CKAIDI/CKAIFI and average zone sizes were properly calculated using the Stamp Approved Metric's definition. Note: DPU Stamp Approved Metric Guidance defines this as "BASELINE – PROGRAM YEAR"
- Comparison of circuits with GMP investments in the Appendix 1 filing and the work order data collected during the Infrastructure Metric analysis.
- Comparison of PY2019 and PY2020 Appendix 1 filings to ensure baseline reliability data match.

During this QA/QC process, the evaluation team identified issues in both the Eversource and National Grid Appendix 1 filings that required adjustments and updates:

Eversource: A formula error for a portion of circuits in Eversource's SQI filing lead to inaccurate Appendix 1 CKAIDI/CKAFI values. Eversource updated the SQI filing and these updated values were used in the analysis below.

National Grid: The changes in CKAIDI/CKAIFI for several Nantucket circuits were calculated with an outdated data source. Additionally, National Grid discovered an error in the 2017 SQI filing, which resulted in the baseline CKAIDI/CKAIFI values being incorrect. National Grid updated both the 2017 SQI values and the Appendix 1 values for the Nantucket circuits and the evaluation team used the updated values for the analysis.

4.1.3 Circuit Selection

The key reliability metrics involving outage duration (CKAIDI) and frequency (CKAIFI) are annual metrics, and impacts to these metrics from GMP investments would only be seen if the investments were installed for sufficient time on a particular circuit to impact outages that drive these annual metrics. The approach most likely to detect metric impacts from the investments would be to wait until the investment had been commissioned for several full years on the circuit before attempting to understand its impact on these metrics. However, the evaluation team determined that the use of the technology for at least one-half of the full program year could provide insight into the impacts of the GMP investments.[35]

The evaluation team reviewed the installation and commissioning timing for the various investments to understand when during PY2020 the devices were installed. For the

[35] Equipment installed in the first half of the program year has at least half a year to fully operate and provide measurable reliability benefits to customers on a particular circuit, and using the half-year cutoff for circuit analysis also allows—on average—half the devices deployed in the program year to be included in the analysis. The evaluation team determined that this was a reasonable rule to use for exploring reliability impacts of the installed grid modernization devices, being mindful that many other factors affect these metrics, including weather, car strikes, and animal/bird interference.

CKAIDI/CKAIFI metrics (PM-12 and PM-13), circuits with *at least* a half year with the technology commissioned and in service were selected for inclusion in the analysis. This includes circuits with devices installed during 2018, 2019, as well as the first half of 2020. All circuits receiving M&C investments were included in the remaining performance metrics.

The evaluation team also identified a number of circuits for each EDC which had been reconfigured, split, or decommissioned between the baseline and program year. As a result of these changes, a comparison of CKAIDI/CKAIFI metrics was either not possible or deemed to be potentially misleading and these circuits were excluded from the analysis. Similar measures were taken to ensure that other performance metrics were calculated using a consistent circuit list between the baseline and the program year.[36]

The subsections below detail which circuits were included in the analysis for each EDC.

4.1.3.1 Eversource Circuits

Eversource commissioned M&C devices throughout PY2018, PY2019, and PY2020. Table 33 shows circuits with M&C devices commissioned through the first half of 2020. It also shows number of circuits not included in the analysis largely due to the reconfiguration of circuits between the baseline and PY2020, as discussed above. A similar percentage of M&C circuits were not included in the analysis for the same reasons.

Table 33. Eversource Circuits Included in Analysis

Eversource Circuits	System-Wide	M&C Commissioned Prior to H2 2020
Total Circuit Count	2,350	231
Circuits Included in Analysis	2,083	197
% of Total Circuits Included In Analysis	89%	85%

Source: Guidehouse analysis of GMP Annual Reports and EDC Data

4.1.3.2 National Grid Circuits

National Grid commissioned M&C Feeder Monitor devices throughout PY2019 and PY2020. Table 34 shows circuits with M&C devices commissioned through the first half of 2020. A majority of system-wide circuits and all M&C circuits were included in the analysis.

Table 34. National Grid Circuits Included in Analysis

National Grid Circuits	System-Wide	M&C Commissioned Prior to H2 2020
Total Circuit Count	1,123	25
Circuits Included in Analysis	1,069	25

[36] A comparison of system wide baselines between this report and the PY 2019 PM Evaluation Report shows only minor differences in the baseline circuit list, which is expected given changing customer counts and changes in circuit configurations.

% of Total Circuits Included In Analysis	95%	100%

Source: Guidehouse analysis of GMP Annual Reports and EDC Data

4.1.3.3 Unitil Circuits

Unitil began substation SCADA work in PY2020. Through the first half of 2020, Unitil commissioned the M&C investments on 4 circuits. As shown in Table 35, approximately 27% of all Unitil circuits lacked comparable data required for the analysis, as discussed above, and thus were not included in the analysis. This includes 1 of the four M&C circuits, resulting in 3 M&C circuits included in the analysis.

Table 35. Unitil Circuits Included in Analysis

Unitil Circuits	System-Wide	M&C Commissioned Prior to H2 2020
Total Circuit Count	44	4
Circuits Included in Analysis	32	3
% of Total Circuits Included In Analysis	73%	75%

Source: Guidehouse analysis of GMP Annual Reports and EDC Data

4.2 M&C Performance Metrics Analysis and Findings

Evaluation of the relevant performance metrics for each EDC is provided below. A summary of findings is presented first, followed by an overview of the analysis approach to facilitate understanding of the detailed results analysis. The analysis for each relevant metric is then provided, organized by EDC.

Results Summary: Table 36 provides a high-level summary of the results for each performance metric and EDC.

Table 36. Summary of Findings for M&C Investment Area

PM	Eversource	National Grid	Unitil
PM-12: Grid Modernization investments' effect on outage durations	Outage duration for M&C circuits for PY2020 was significantly longer than Baseline. However, this metric is not able to discern whether M&C investments impacted the annual reliability performance.*	Outage duration for M&C circuits for PY2020 was significantly longer than Baseline. However, this metric is not able to discern whether M&C investments impacted the annual reliability performance.*	Outage duration was slightly reduced for M&C circuits compared to the system average, but there is an insufficient number of devices installed to draw conclusions.

PM-13: Grid Modernization investments' effect on outage frequency	Outage frequency for M&C circuits for PY2020 was significantly higher than Baseline. However, this metric is not able to discern whether M&C investments impacted the annual reliability performance.*	Outage frequency for M&C circuits for PY2020 was significantly higher than Baseline. However, this metric is not able to discern whether M&C investments impacted the annual reliability performance.*	Outage frequency was slightly reduced for M&C circuits compared to the system average, but there is an insufficient number of devices installed to draw conclusions.
PM-UTL1: Customer Minutes of Outage Saved per Circuit	N/A – Unitil specific metric	N/A – Unitil specific metric	The OMS/AMI Integration is not complete; this metric cannot yet be evaluated.

*Program Year 2020 generally had much worse reliability performance on a system-wide basis across all three EDCs, and evidence suggests that this was due to the size and frequency of storm conditions throughout the year.
Source: Guidehouse Analysis

PY 2020 Reliability: CKAIDI and CKAIFI metrics for PY2020 were significantly worse than they were for the Baseline years (2015-2017). Evidence suggests that PY2020 was a bad storm year for all three EDCs, negatively impacting system-wide reliability performance including that of circuits with M&C installed.

A simple system-wide comparison between the baseline years (2015-2017) and PY2020 shows worse reliability performance in 2020 across all EDCs—without specific consideration of GMP investment (including M&C and ADA investments). As shown in Table 37, customer weighted average CKAIDI more than doubled for all 3 EDCs.

Table 37: Baseline vs PY2020 Reliability

EDC	CKAIDI/CKAIFI Metric	Baseline	PY2020
Eversource	Weighted Average CKAIDI	106	233
	Weighted Average CKAIFI	0.93	1.16
National Grid	Weighted Average CKAIDI	119	298
	Weighted Average CKAIFI	0.91	1.27
Unitil	Weighted Average CKAIDI	66	135
	Weighted Average CKAIFI	1.06	1.61

Note: Reliability data shown is without Excludable Major Events (EMEs).
Source: Guidehouse Analysis.

The CKAIDI and CKAIFI related metrics were also impacted when a number of significant storms did not meet the predefined criteria for an Excludable Major Event. For instance, Unitil notes that in 2020, 5 storm events with SAIDI greater than 7.5 minutes did not meet the EME criteria, while only 1 such event occurred during the baseline years 2015-2017. Likewise, National grid experienced 7 events in which specific circuits exceeded 5,000 total customer outage hours, but only 1 event met the criteria for an EME, and Eversource had no qualifying EMEs despite a number of significant storms. CKAIDI/CKAIFI values calculated without EMEs indicate noticeably worse performance compared to the baseline.

Analysis Approach: The following approach was developed to provide additional insight into the EDC Performance Metrics that were published by the EDCs in their PY2020 Annual

Reports, Appendix 1. The circuit-level data provided by the EDCs was used to evaluate the metrics. The evaluation approach has three elements:

1. Baseline and Program Year System-wide and M&C circuit comparisons: The evaluation team compared the baseline and program year data across the entire system and for circuits receiving M&C investments (see Section 4.1.3 for details). Statistical averages for these circuit groupings were used to make simple comparisons, and standard deviations were calculated to provide insight into the variability compared with the average values. For PM-12 (change in CKAIDI) and PM-13 (change in CKAIFI), the system-wide metric baseline was compared against the program year metric using reliability bins. This facilitates a general understanding of where the M&C investments fit into the context of the overall system metric performance and to compare changes in metrics for M&C circuits to those of system-wide circuits.

2. Before and after comparison**:** For PM-12 and PM-13, the program year performance was compared to the baseline performance for all circuits within the system. "Box-and-whisker" plots[37] are used to illustrate the distribution of data across the entire system and for circuits receiving M&C investments.[38]

3. Difference in differences: The difference in system-wide circuits change from baseline vs. M&C circuits change from baseline was calculated to understand if there is any discernable reliability improvement on the M&C circuits. This change is defined as "average metric for M&C circuits minus average metric for system-wide circuits."

The sections below leverage the three steps listed above to provide additional insights into the impacts of M&C investments. In addition, ancillary metrics are used for informative purposes. For clarity, a subset of those metrics are defined below.

- Weighted Average refers to the customer weighted average, e.g., CKAIDI or CKAIFI weighted by average annual number of customers on the circuit and averaged over circuits for the year. This is used alongside the Simple Average, e.g., simply averaging CKAIDI or CKAIFI values for the circuits for the year, to compare the extent to which higher customer count circuits were impacted by outages. A Weighted Average greater than a simple average indicates that circuits with higher customer counts were more impacted by outages. The weighted average is computed using 2017 customer counts for the baseline, and 2020 customer count for the Program Year.

- Standard Deviation of CKAIDI or CKAIFI values is computed to provide an indication of the variability in these metrics for the year(s) in question. A high value relative to the averages described above tends to indicate high variability and prevents us from drawing strong conclusions about changes in the average values.

[37] The "box-and-whisker" plot divides the sample into quartiles. The boxes show the 2nd and 3rd quartile in the sample. The lower and upper "whiskers" indicate 1.5 times the interquartile range (IQR) (difference between the start of the 2nd and the end of the 3rd quartile) or the maximum/minimum value within the range if it falls within 1.5x the IQR. The "x" indicates the sample average. Data points that fall outside 1.5x the IQR are not shown on the graph.

[38] Note that the DPU Guidance defines the change as "Baseline – Program Year" which means that positive values of this metric indicate reliability improvement—which may be counter intuitive as CKAIDI or CKAIFI metrics fall with improvement.

- % Zero is the proportion of circuits that had zero CKAIDI/CKAIFI in the 3 baseline years (for the baseline) or in 2020 (for the program year). This value for the baseline comprises circuits that have not experienced any outages in any of the 2015-2017 years, while this value for the program year comprises circuits that did not experience any outages in 2020. This value is included for informative reasons, as circuits that have experienced no outages in the program year provide no opportunity for the M&C investment to help improve reliability.

4.2.1 PM-12: Effect on Outage Duration (CKAIDI)

Metric PM-12, Reliability-Focused Grid Modernization Investments' Effect on Outage Duration (CKAIDI), provides insight on how GMP devices impact outage duration and will track the improvements over time. Per the DPU Stamp Approved GMP Performance Metrics Guidance:

> *This metric will compare the experience of customers on GMP DA-enabled circuits as compared to the prior three-year average for the same circuit. This metric will provide insight into how DA can reduce the duration of outages (by tracking and reporting) the following:*
>
> - *Circuit level SAIDI for the program year*
> - *Three-year average SAIDI for 2015, 2016, and 2017*
> - *Comparison of the current year SAIDI with the three-year historic average: AVERAGE(CKAIDI 2015, CKAIDI 2016, CKAIDI 2017) – PY CKAIDI = if greater than 0, positive impact*

The EDCs provided the circuit-level CKAIDI metric in their Appendix 1 filings. As discussed in Section 4.1.3, only circuits with M&C investments in the first half of 2020 and prior are included in the analysis. Analysis of this metric for each EDC is presented in the following subsections.

4.2.1.1 Eversource Analysis

The analysis of the CKAIDI metric for Eversource is presented in the subsection below.

System-wide and M&C circuit counts: Table 38 is structured with CKAIDI ranges, or "bins", to provide insight about the range of outage durations across circuits in the system, and to show where circuits selected for M&C investment fall within these bins. Approximately 35% of system wide and M&C circuits experienced no outages at all within the baseline period; this number increased to around 45% in PY2020.

An increase in system average CKAIDI from the baseline to PY2020 indicates decreased reliability at the system level. 2020 was a "worse" reliability year than the baseline as seen by the Weighted Average CKAIDI in Table 38, which is more than twice that of the baseline. This difference is primarily driven by the higher number of storms that disproportionately affected Eversource's MA Northern and MA Southern circuit divisions. The increase in outage duration can also be seen by looking at the higher number of circuits with CKAIDI greater than 450 in PY2020 compared with the same circuits during the baseline period.

The CKAIDI standard deviation also increased significantly, indicating increased variability in CKAIDI across circuits in the system. However, the standard deviation is on the same order of magnitude as the weighted average, providing some indication that the change in the weighted average is not simply statistical noise, but an actual degradation in performance during the program year. The customer weighted average CKAIDI is greater than the simple average, indicating that the circuits with longer outages tended to have above average number of customers.

Table 38. Eversource Baseline and PY2020 CKAIDI Distribution

Eversource M&C	2015-2017 Avg. CKAIDI (Baseline)				2020 CKAIDI (Program Year)			
	System-wide		M&C Circuits		System-wide		M&C Circuits	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
CKAIDI Statistics								
Total Circuits	2,083	2,083	197	197	2,083	2,083	197	197
% Zero	37%	37%	30%	30%	46%	46%	40%	40%
Weighted Average	134	106	90	86	238	238	419	419
Simple Average	80	63	67	63	129	129	253	253
Std. Dev.	136	103	102	87	288	288	441	441
Range								
0	777	778	60	60	966	966	78	78
0 - 50	491	535	58	58	358	358	27	27
50 - 150	448	491	56	58	300	300	31	31
150 - 250	182	166	12	11	133	133	10	10
250 - 350	84	63	7	7	95	95	7	7
350 - 450	44	27	2	2	59	59	4	4
450 - 550	20	10	1	1	34	34	5	5
550 - 650	13	3	0	0	30	30	5	5
650 - 750	9	5	0	0	16	16	1	1
750 - 850	9	3	1	0	22	22	6	6
850 - 950	3	1	0	0	11	11	4	4
950 - 1050	1	1	0	0	16	16	3	3
1050 - 1300	1	0	0	0	19	19	5	5
1300 - 1550	1	0	0	0	8	8	6	6
1550 - 1800	0	0	0	0	7	7	3	3
1800 - 2050	0	0	0	0	3	3	1	1
2050 - 3050	0	0	0	0	5	5	1	1
> 3050	0	0	0	0	1	1	0	0

Note: EME = excludable major events. CKAIDI of zero indicates circuit did not experience any outages.

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

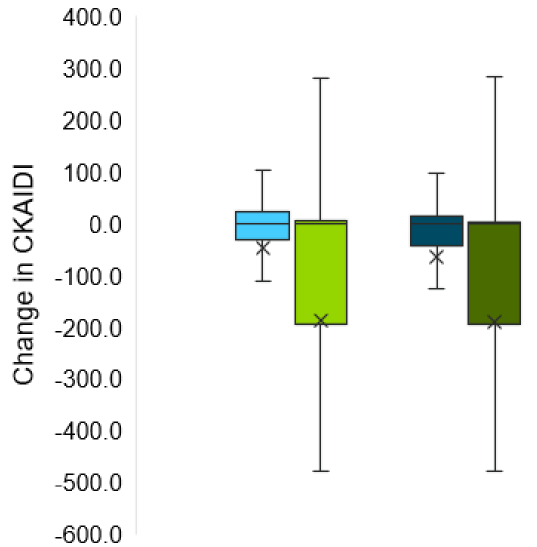
Before and after comparison: A simple graphical summary of the statistical change in CKAIDI is shown in This chart compares the difference in CKAIDI between baseline and Program Year 2020 for each circuit, for both the system-wide and the selected M&C circuits. The change shown below is calculated per the DPU Stamped Approved formula of Baseline CKAIDI – Program Year CKAIDI, so a positive change indicates improved performance in the Program Year.

Figure 15 uses the "box-and-whisker" format.[39] This chart compares the difference in CKAIDI between baseline and Program Year 2020 for each circuit, for both the system-wide and the selected M&C circuits. The change shown below is calculated per the DPU Stamped Approved

[39] The "box-and-whisker" plot divides the sample into quartiles. The boxes show the 2nd and 3rd quartile in the sample. The lower and upper "whiskers" indicate 1.5 times the interquartile range (IQR) (difference between the start of the 2nd and the end of the 3rd quartile) or the maximum/minimum value within the range if it falls within 1.5x the IQR. The "x" indicates the sample average. Data points that fall outside 1.5x the IQR are not shown on the graph.

formula of Baseline CKAIDI – Program Year CKAIDI, so a positive change indicates improved performance in the Program Year.

Figure 15. Impact in Outage Duration Performance Metric Results



	Change in System-wide CKAIDI w/ EMEs	Change in M&C CKAIDI w/ EMEs
Count	2,083	197
% No Change	35%	28%
Average Change in CKAIDI	-49	-187
Standard Deviation	276	419
Median Change in CKAIDI	0	0

	Change in System-wide CKAIDI w/o EMEs	Change in M&C CKAIDI w/o EMEs
Count	2,083	197
% No Change	35%	28%
Average Change in CKAIDI	-65	-191
Standard Deviation	272	416
Median Change in CKAIDI	0	0

Note: EME = excludable major events. Change in CKAIDI is reported as minutes and is calculated as defined by the DPU PM Guidance: 2015-2017 Avg. CKAIDI – 2020 CKAIDI = if greater than zero, positive impact.

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

The average system-wide CKAIDI increased in Program Year 2020 over the baseline. For the selected M&C circuits, CKAIDI increased significantly more than for system-wide circuits, indicating a worsening performance on the M&C circuits on average.[40] In particular, the bottom quartile of change for the M&C circuits is much larger than that for system-wide circuits, signifying that M&C circuits had a greater proportion of circuits with worse performance in 2020.

However, the standard deviation of the change in CKAIDI for each group is significantly larger—several times larger–than the average change in CKAIDI itself, providing an indication that the change in the average is of limited statistical significance, and not indicative of a clearly discernible trend in CKAIDI. As indicated above, there are many potential reasons for these changes and many factors impacting this metric. The impact of the M&C investment in operation is one of the factors but is not discernable using the metric itself.

Difference in differences: The differences in the change in CKAIDI (baseline to 2020) between the system-wide average and the average for circuits with M&C investments are shown in Table 39. The change in CKAIDI for circuits with M&C investments was substantially greater than the

[40] Note that the "whiskers" extend further for the circuits with M&C investments because there are fewer M&C circuits that experienced zero change in CKAIDI. As a result, the IQR range for these circuits is larger than the IQR range of the system-wide group.

system-wide circuits for both w/ EME and w/o EME data. Although the standard deviation for these samples is larger than the CKAIDI changes (as discussed above), 2020 was clearly a bad year for CKAIDI on M&C circuits. It is difficult to conclude how much positive (or negative) impact the M&C investments had on this metric for PY2020. Some of the reduced performance in the year is likely explained by the fact that many of the worse performing M&C circuits (as seen in the higher bins in Table 38) also have above average customer counts, increasing the customer weighted average CKAIDI for the year.

Table 39. Eversource CKAIDI Difference in Differences

	System-Wide Circuits	M&C Circuits	Difference in Differences (M&C - System-Wide)
Change in CKAIDI w/ EMEs	-49	-187	-138
Change in CKAIDI w/o EMEs	-65	-191	-125

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

Erosion of Baseline: As mentioned in section 4.1.3.1, 11% of Eversource system-wide circuits and 15% of Eversource M&C circuits had to be excluded from this metric, because circuits had been retired, reconfigured or split since 2017. The comparability of each circuit in the program year to its baseline, as defined in the DPU approved metric, depends on that circuit not having been reconfigured or significantly changed (e.g., a normally open switch between circuit segments is changed to operate as normally closed, changing the customer counts and outage measurements on that circuit). The number of circuits that are comparable between baseline and program year is reduced year over year as more circuits are reconfigured, leading to an erosion of metric baseline over time. In PY2020 only Eversource had M&C circuits that were excluded from analysis on this basis, but Guidehouse expects this issue to emerge for other EDCs in future years.

4.2.1.2 National Grid Analysis

The analysis of the CKAIDI metric for National Grid is presented in the subsection below.

System-wide and M&C circuit counts: Table 40 is structured with CKAIDI ranges, or “bins,” to provide insight about the range of outage durations across circuits in the system, and to show where circuits selected for M&C investment fall within these bins. There are a number of circuits with no outages at all within the baseline period; however, none of these circuits were targeted for M&C investments through 2020. The circuits receiving M&C investments had higher than average CKAIDI values, providing some indication that these less reliable and higher customer count circuits were targeted more for M&C investment.[41]

An increase in system average CKAIDI from the baseline to Program Year 2020 indicates decreased reliability at the system level. 2020 was a “worse” reliability year than the baseline as

[41] National Grid’s 2019 GMP Annual Report contains the following text about methodology of choosing circuits for GMP investments: *Preliminary Engineering was completed in order to assess and choose the highest areas of impact for feeder monitoring to be installed. These areas were typically categorized as feeders with large customer counts but low historical data.*

seen by the customer Weighted Average CKAIDI in Table 40, which is more than twice that of the baseline and is similar to observations about Eversource circuit performance above.

National Grid's unplanned significant outage data[42] indicates storm and high wind conditions accounted for 76% of system-wide customer outage hours but only 33% of circuit outage instances and 43% of all customers affected by outages. This points to a few events that caused prolonged outages, rather than shorter outages affecting a larger number of customers. The CKAIDI standard deviation also increased significantly, further highlighting the increased variability in CKAIDI across the system.

The 25 M&C circuits had higher weighted average CKAIDI values than the system-wide CKAIDI values in PY2020, indicating that these circuits performed comparatively worse. Customer-weighted average CKAIDI was higher for M&C circuits than the simple average for these circuits, indicating that outages impacted circuits with more customers. This data suggests that the circuits receiving M&C investments, feeder monitors in this case, were indeed larger and more difficult from a reliability perspective; however, it does not allow any direct conclusions about how the investment improved--or did not improve—reliability.

[42] Massachusetts DPU 21-SQ-11, submitted on March 1, 2021

Table 40. National Grid Baseline and PY2020 CKAIDI Distribution

National Grid M&C	2015-2017 Avg. CKAIDI (Baseline)				2020 CKAIDI (Program Year)			
	System-wide		M&C Circuits		System-wide		M&C Circuits	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
CKAIDI Statistics								
Total Circuits	1,069	1,069	25	25	1,069	1,069	25	25
% Zero[43]	3%	4%	0%	0%	17%	18%	4%	4%
Weighted Average	219	119	236	111	447	300	1,010	587
Simple Average	200	113	245	103	346	232	795	487
Std. Dev.	258	179	302	62	603	351	821	381
Range								
0	35	40	0	0	179	188	1	1
0 – 50	253	324	6	8	208	229	1	1
50 – 150	351	433	6	9	202	219	2	3
150 – 250	183	179	7	8	122	140	3	4
250 – 350	77	55	1	0	67	71	1	1
350 – 450	43	18	1	0	52	51	2	5
450 – 550	27	10	2	0	31	31	3	2
550 – 650	26	5	0	0	30	28	1	1
650 – 750	17	0	0	0	28	19	2	1
750 – 850	10	1	0	0	20	21	2	2
850 – 950	14	3	0	0	17	13	1	1
950 – 1050	5	0	0	0	12	8	0	0
1050 – 1300	23	0	2	0	25	23	1	1
1300 – 1550	4	0	0	0	27	15	1	2
1550 – 1800	0	0	0	0	8	8	1	0
1800 – 2050	1	0	0	0	11	2	1	0
2050 – 3050	0	0	0	0	23	3	1	0
> 3050	0	1	0	0	7	0	1	0

Note: EME = excludable major events. CKAIDI of zero indicates circuit did not experience any outages.

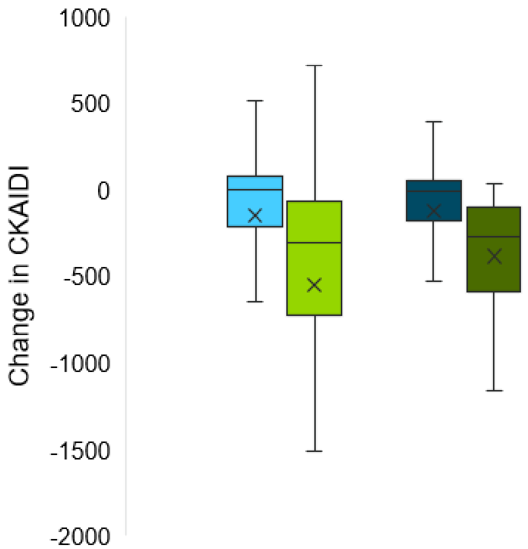
Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

Before and after comparison: A simple graphical summary of the statistical change in CKAIDI is shown in Figure 16 below, which uses the “box-and-whisker” format.[44] This chart compares the difference in CKAIDI between baseline and PY 2020, for both the system-wide and the selected M&C circuits. The change shown below is calculated per the DPU Stamped Approved formula of Baseline CKAIDI – Program Year CKAIDI, so a positive change indicates improved performance in the Program Year.

[43] The % Zero value shows the proportion of circuits that have experienced zero outages throughout the entire baseline (2015-2017) or program year period.

[44] The “box-and-whisker” plot divides the sample into quartiles. The boxes show the 2nd and 3rd quartile in the sample. The lower and upper “whiskers” indicate 1.5 times the interquartile range (IQR) (difference between the start of the 2nd and the end of the 3rd quartile) or the maximum/minimum value within the range if it falls within 1.5x the IQR. The “x” indicates the sample average. Data points that fall outside 1.5x the IQR are not shown on the graph.

Figure 16. Impact in Outage Duration Performance Metric Results



	Change in System-wide CKAIDI w/ EMEs	Change in M&C CKAIDI w/ EMEs
Count	1,069	25
% No Change	3%	0%
Average Change in CKAIDI	-145	-551
Standard Deviation	630	893
Median Change in CKAIDI	0	-302

	Change in System-wide CKAIDI w/o EMEs	Change in M&C CKAIDI w/o EMEs
Count	1,069	25
% No Change	3%	0%
Average Change in CKAIDI	-119	-383
Standard Deviation	378	364
Median Change in CKAIDI	-7	-270

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

On average, the system wide circuits experienced an increase in CKAIDI from the baseline to 2020, showing worsening performance overall. The close to 0 median change value indicates that half of all system wide circuits showed either improved, no difference, or slightly decreased performance in 2020 over the baseline. The below-median average change value signifies, again, that the overall decreased performance is driven by a smaller subset of circuits with significantly higher CKAIDI in 2020. For M&C circuits, the average change in CKAIDI was worse than system average, as shown by the X's in the diagram and discussed above.

Difference in differences: The differences in the change in CKAIDI between the system-wide average and the average for circuits with M&C investments are shown in Table 41. The change in CKAIDI for circuits with M&C investments was significantly greater than the system wide circuits. As discussed above, this illustrates that the M&C circuits performed considerably worse than the system average, for both EME and non-EME outages: although they fared significantly worse when EMEs were included. Again, this data does not provide any clear indication of how the M&C investments themselves performed, as it is not possible to isolate the outage duration impacts using this metric.

Table 41. National Grid CKAIDI Difference in Differences

	System-Wide Circuits	M&C Circuits	Difference in Differences (M&C - System-Wide)
Change in CKAIDI w/ EMEs	-145	-551	-405
Change in CKAIDI w/o EMEs	-119	-383	-264

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

4.2.1.3 Unitil Analysis

The analysis of the CKAIDI metric for Unitil is presented in the subsection below.

Unitil only had 3 qualifying M&C circuits meeting the selection criteria. Table 42 provided an overview of circuit performance during the baseline period and Program Year 2020.

Table 42. Unitil Baseline and PY2020 CKAIDI Distribution

Unitil M&C	2015-2017 Avg. CKAIDI (Baseline)				2020 CKAIDI (Program Year)			
	System-wide		M&C Circuits		System-wide		M&C Circuits	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
CKAIDI Statistics								
Total Circuits	32	32	3	3	32	32	3	3
% Zero[45]	3%	6%	0%	33%	6%	22%	0%	33%
Weighted Average	175	66	243	78	254	136	339	165
Simple Average	140	53	190	46	223	133	226	103
Std. Dev.	94	35	71	36	245	218	126	75

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

The M&C circuits have similar or somewhat higher CKAIDI values than the system wide circuits for both the baseline and 2020. As with other EDCs, the circuit performance in 2020 decreased compared to the baseline. It should be noted that the chosen baseline years for 2015-2017 represent Unitil's historical best performance of all time (since 2008). Again, this metric does not allow determination of the specific effect of M&C investment on the CKAIDI metric.

4.2.2 PM-13: Effect on Outage Frequency (CKAIFI)

Metric PM-13, Reliability-Focused Grid Modernization Investments' Effect on Outage Frequency (CKAIFI), provides insight on how GMP devices impact outage frequency and will track the improvements over time. Per the DPU Stamp Approved GMP Performance Metrics Guidance:

> *This metric will compare the experience of customers on GMP DA-enabled circuits as compared to the prior three-year average for the same circuit. This metric will provide insight into how DA can reduce the frequency of outages (by tracking and reporting) the following:*
>
> - *Circuit level SAIFI (CKAIFI) for the program year*
> - *Three-year average SAIFI (CKAIFI) for 2015, 2016, and 2017*
> - *Comparison of the current year SAIFI (CKAIFI) with the three-year historic average: AVERAGE(CKAIFI 2015, CKAIFI 2016, CKAIFI 2017) – PY CKAIFI = if greater than 0, positive impact*

The EDCs have provided the CKAIFI metric in their Appendix 1 filings. As discussed in Section 4.1.3, only circuits with M&C investments in the first half of 2020 and prior are included in the analysis. Analysis of this metric for each EDC is presented in the following subsections and the

[45] The % Zero value shows the proportion of circuits that have experienced zero outages throughout the entire baseline (2015-2017) or program year period.

presentation structure aligns closely with that used with the previous metric (PM-12: Impact on Outage Duration).

4.2.2.1 Eversource Analysis

The analysis of the CKAIFI metric for Eversource is presented in the subsection below.

System-wide and M&C circuit counts: Table 43 is structured with CKAIFI ranges, or “bins”, to provide insight about the range of outage durations across circuits in the system, and to show where circuits selected for M&C investment fall within these bins. Approximately 35% of system wide and M&C circuits experienced no outages at all within the baseline period; this number increased to around 45% in PY2020.

An increase in system average CKAIFI from the baseline to PY2020 indicates decreased reliability at the system level in 2020. However, the percentage difference in CKAIFI between the baseline and PY2020 is not as large as the difference in CKAIDI. Thus, the average frequency of customer outages did not increase as much as the average duration did in 2020, again indicating longer outages affecting larger numbers of customers per circuit.

The CKAIFI standard deviation also increased, indicating increased variability in CKAIFI across system circuits. However, the standard deviation is on the same order of magnitude as the weighted average, providing some indication that the change in the weighted average is not simply statistical noise, but an actual degradation in performance during the program year. The customer weighted average CKAIFI is significantly greater than the simple average, indicating that the circuits with more frequent outages tended to have above average number of customers.

Table 43. Eversource Baseline and PY2020 CKAIFI Distribution

Eversource M&C	2015-2017 Avg. CKAIFI (Baseline)				2020 CKAIFI (Program Year)			
	System-wide		M&C Circuits		System-wide		M&C Circuits	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
CKAIFI Statistics								
Total Circuits	2,083	2,083	197	197	2,083	2,083	197	197
% Zero	38%	38%	30%	30%	48%	48%	40%	40%
Weighted Average	1.0	0.9	0.8	0.8	1.2	1.2	1.2	1.2
Simple Average	0.5	0.5	0.6	0.5	0.6	0.6	0.7	0.7
Std. Dev.	0.7	0.7	0.6	0.6	1.0	1.0	1.0	1.0
Range								
0	782	783	60	60	993	993	79	79
0 - 0.25	206	212	21	21	279	279	21	21
0.25 - 0.75	520	536	58	58	162	162	24	24
0.75 - 1.25	266	273	30	31	281	281	31	31
1.25 - 1.75	153	159	14	14	106	106	15	15
1.75 - 2.25	90	70	11	10	90	90	8	8
2.25 - 2.75	35	27	1	2	56	56	6	6
2.75 - 3.25	17	14	2	1	47	47	6	6
3.25 - 3.75	9	7	0	0	26	26	5	5
3.75 - 4.25	3	2	0	0	16	16	0	0
4.25 - 4.75	1	0	0	0	10	10	0	0
4.75 - 5.25	0	0	0	0	9	9	1	1
5.25 - 5.75	0	0	0	0	4	4	1	1
5.75 - 6.25	0	0	0	0	2	2	0	0
6.25 - 6.75	0	0	0	0	1	1	0	0
6.75 - 7.25	0	0	0	0	0	0	0	0

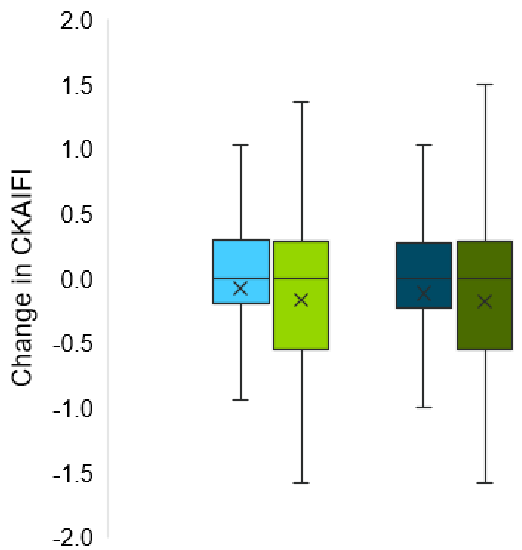
7.25 - 7.75	0	0	0	0	0	0	0	0
> 7.75	1	0	0	0	1	1	0	0

Note: EME = excludable major events. CKAIFI of zero indicates circuit did not experience any outages.

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

Before and after comparison: A simple graphical summary of the statistical change in CKAIFI is shown in Figure 17 below, which uses a "box-and-whisker" format.[46] This chart compares the difference in CKAIFI between baseline and Program Year 2020 for each circuit, for both the system-wide and the selected M&C circuits. The change shown below is calculated per the DPU Stamped Approved formula of Baseline CKAIFI – Program Year CKAIFI, so a positive change indicates improved performance in the Program Year.

Figure 17. Impact in Outage Frequency Performance Metric Results



	Change in System-wide CKAIFI w/ EMEs	Change in M&C CKAIFI w/ EMEs
Count	2,083	197
% No Change	35%	28%
Average Change in CKAIFI	-0.1	-0.2
Standard Deviation	0.9	0.8
Median Change in CKAIFI	0.0	0.0

	Change in System-wide CKAIFI w/o EMEs	Change in M&C CKAIFI w/o EMEs
Count	2,083	197
% No Change	35%	28%
Average Change in CKAIFI	-0.1	-0.2
Standard Deviation	0.9	0.8
Median Change in CKAIFI	0.0	0.0

Note: EME = excludable major events. Change in CKAIFI is calculated as defined by the DPU PM Guidance: 2015-2017 Avg. CKAIFI – 2020 CKAIFI = if greater than zero, positive impact.

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

The average system-wide CKAIFI changed very little in PY2020 relative to the baseline period. For the selected M&C circuits, CKAIFI increased slightly more than for system-wide circuits indicating a slight worsening of performance on the M&C circuits on average.[47] However, the standard deviation of the change in CKAIFI for each group is significantly larger—several times

[46] The "box-and-whisker" plot divides the sample into quartiles. The boxes show the 2nd and 3rd quartile in the sample. The lower and upper "whiskers" indicate 1.5 times the interquartile range (IQR) (difference between the start of the 2nd and the end of the 3rd quartile) or the maximum/minimum value within the range if it falls within 1.5x the IQR. The "x" indicates the sample average. Data points that fall outside 1.5x the IQR are not shown on the graph for visualization purposes.

[47] Note that the "whiskers" extend further for the circuits with M&C investments because there are fewer M&C circuits that experienced zero change in CKAIFI. As a result, the IQR range for these circuits is larger than the IQR range of the system-wide group..

larger–than the average change in CKAIFI itself, providing an indication that the change in the average is of limited statistical significance, and not indicative of a clearly discernible trend in CKAIFI. There are many potential reasons for these changes and many factors impacting this metric. The impact of the M&C investment in operation is one of the factors but is not discernable using the metric itself.

Difference in differences: The differences in the change in CKAIFI (baseline to 2020) between the system-wide average and the average for circuits with M&C investments are shown in Table 44. The change in CKAIFI for circuits with M&C investments was slightly greater than the system-wide circuits for both w/ EME and w/o EME data. However, the standard deviation for these samples is much larger that the CKAIFI changes indicating that the difference is likely not statistically significant and is more probably a factor of randomness in the metric data than any type of trend. It is difficult to conclude how much positive (or negative) impact the M&C investments had on this metric for Program Year 2020.

Table 44. Eversource CKAIFI Difference in Differences

	System-Wide Circuits	M&C Circuits	Difference in Differences (M&C - System-Wide)
Change in CKAIFI w/ EMEs	-0.1	-0.2	-0.1
Change in CKAIFI w/o EMEs	-0.1	-0.2	-0.1

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

Erosion of Baseline: As mentioned in section 4.1.3.1, 11% of Eversource system-wide circuits and 15% of Eversource M&C circuits had to be excluded from this metric, because circuits had been retired, reconfigured or split since 2017. The comparability of each circuit in the program year to its baseline, as defined in the DPU approved metric, depends on that circuit not having been reconfigured or significantly changed (e.g., a normally open switch between circuit segments is changed to operate as normally closed, changing the customer counts and outage measurements on that circuit). The number of circuits that are comparable between baseline and program year is reduced year over year as more circuits are reconfigured, leading to an erosion of metric baseline over time. In PY2020 only Eversource had M&C circuits that were excluded from analysis on this basis, but Guidehouse expects this issue to emerge for other EDCs in future years.

4.2.2.2 National Grid Analysis

The analysis of the CKAIFI metric for National Grid is presented in the subsection below.

System-wide and M&C circuit counts: Table 45 is structured with CKAIFI ranges, or “bins”, to provide insight about the range of outage durations across circuits in the system, and to show where circuits selected for M&C investment fall within these bins. There are a number of circuits with no outages at all within the baseline period; however, none of these circuits were targeted for M&C investments through 2020.

An increase in system average CKAIFI from the baseline to Program Year 2020 indicates decreased reliability at the system level. 2020 was a “worse” reliability year than the baseline as seen by the customer weighted average CKAIFI in Table 45. The CKAIFI standard deviation also increased significantly, indicating increased variability in CKAIFI across the system.

The 25 M&C circuits had higher weighted average CKAIFI values than the system-wide CKAIDI values in PY2020, indicating that these circuits performed comparatively worse. Customer-weighted average CKAIFI was higher for M&C circuits than the simple average for these circuits, indicating that outages impacted circuits with above average number of customers. This data suggests that the circuits receiving M&C investments, feeder monitors in this case, were indeed larger and more difficult from a reliability perspective; however, it does not allow any direct conclusions about how the investment improved—or did not improve—reliability.

Table 45. National Grid Baseline and PY2020 CKAIFI Distribution

National Grid M&C	2015-2017 Avg. CKAIFI (Baseline)				2020 CKAIFI (Program Year)			
	System-wide		M&C Circuits		System-wide		M&C Circuits	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
CKAIFI Statistics								
Total Circuits	1,069	1,069	25	25	1,069	1,069	25	25
% Zero[48]	3%	4%	0%	0%	17%	18%	4%	4%
Weighted Average	1.0	0.9	1.0	0.9	1.5	1.3	2.3	1.9
Simple Average	0.9	0.8	0.9	0.8	1.1	1.0	2.0	1.8
Std. Dev.	0.6	0.6	0.5	0.4	1.2	1.1	1.5	1.3
Range								
0	35	41	0	0	179	188	1	1
0 - 0.25	121	140	3	3	191	215	2	2
0.25 - 0.75	371	400	7	9	132	134	3	3
0.75 - 1.25	300	280	8	9	205	225	1	6
1.25 - 1.75	152	134	6	3	98	91	6	4
1.75 - 2.25	59	52	1	1	101	91	4	2
2.25 - 2.75	21	15	0	0	44	41	1	0
2.75 - 3.25	8	5	0	0	42	28	1	3
3.25 - 3.75	2	1	0	0	17	13	1	1
3.75 - 4.25	0	0	0	0	24	16	3	1
4.25 - 4.75	0	0	0	0	15	17	0	2
4.75 - 5.25	0	0	0	0	13	6	1	0
5.25 - 5.75	0	1	0	0	3	3	0	0
5.75 - 6.25	0	0	0	0	3	1	1	0
6.25 - 6.75	0	0	0	0	2	0	0	0
6.75 - 7.25	0	0	0	0	0	0	0	0
7.25 - 7.75	0	0	0	0	0	0	0	0
> 7.75	0	0	0	0	0	0	0	0

Note: EME = excludable major events. CKAIFI of zero indicates no outages occurred.

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

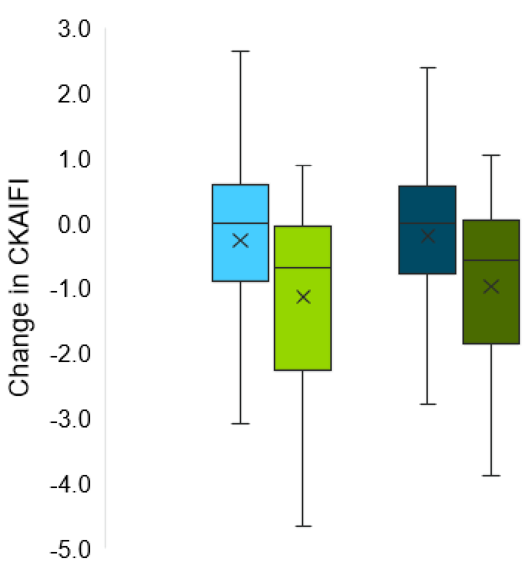
2020 had significantly more circuits with multiple outages when compared to the baseline. In particular, the tail of the bin distribution is much longer, indicating that many more customers had greater than 2 outages occur. One positive note is that 17% of circuits experienced no outages, despite the increased number of storms. This aligns with the expectation that there was greater variability in customers' outages for 2020, with some customers experiencing no

[48] The % Zero value shows the proportion of circuits that have experienced zero outages throughout the entire baseline (2015-2017) or program year period.

outages while others noticeably more. This trend did not hold for the selected M&C circuits, which on average experienced approximately 2 outages.

Before and after comparison: A simple graphical summary of the statistical change in CKAIFI is shown in Figure 18 below, which uses a "box-and-whisker" format.[49] This chart compares the difference in CKAIFI between baseline and Program Year 2020 for each circuit, for both the system-wide and the selected M&C circuits. The change shown below is calculated per the DPU Stamped Approved formula of Baseline CKAIFI – Program Year CKAIFI, so a positive change indicates improved performance in the Program Year.

Figure 18. Impact in Outage Frequency Performance Metric Results



	Change in System-wide CKAIFI w/ EMEs	Change in M&C CKAIFI w/ EMEs
Count	1,069	25
% No Change	3%	0%
Average Change in CKAIFI	-0.3	-1.1
Standard Deviation	1.2	1.4
Median Change in CKAIFI	0.0	-0.7

	Change in System-wide CKAIFI w/o EMEs	Change in M&C CKAIFI w/o EMEs
Count	1,069	25
% No Change	3%	0%
Average Change in CKAIFI	-0.2	-1.0
Standard Deviation	1.1	1.3
Median Change in CKAIFI	0.0	-0.6

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

The system-wide CKAIFI changed only slightly from the baseline to PY2020. The magnitude of the difference in baseline and PY2020 CKAIFI was greater for M&C circuits (-1.1 with EMEs, -1.0 without EMEs), indicating a worsening performance on the M&C circuits on average.[50] The below-median average change value signifies, again, that the overall decreased performance is driven by a smaller subset of circuits with significantly higher CKAIFI in 2020. For M&C circuits, the average change in CKAIFI was worse than system average, as shown by the X's in the diagram and discussed above.

[49] The "box-and-whisker" plot divides the sample into quartiles. The boxes show the 2nd and 3rd quartile in the sample. The lower and upper "whiskers" indicate 1.5 times the interquartile range (IQR) (difference between the start of the 2nd and the end of the 3rd quartile) or the maximum/minimum value within the range if it falls within 1.5x the IQR. The "x" indicates the sample average. Data points that fall outside 1.5x the IQR are not shown on the graph for visualization purposes.

[50] Note that the "whiskers" extend further for the circuits with M&C investments because there are fewer M&C circuits that experienced zero change in CKAIFI. As a result, the IQR range for these circuits is larger than the IQR range of the system-wide group..

Difference in differences: The differences in the change in CKAIFI between the system-wide average and the average for circuits with M&C investments are shown in Table 46. The change in CKAIFI for circuits with M&C investments was worse than the circuits without M&C investments. Again, this data does not provide any clear indication of how the M&C investments themselves performed, as it is not possible to isolate the outage duration impacts using this metric.

Table 46. National Grid CKAIFI Difference in Differences

	System-Wide Circuits	M&C Circuits	Difference in Differences (M&C - System-Wide)
Change in CKAIFI w/ EMEs	-0.3	-1.1	-0.9
Change in CKAIFI w/o EMEs	-0.2	-1.0	-0.8

Note: Due to rounding error, manual calculations of Difference in Differences will not precisely match calculated numbers provided in this table.

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

4.2.2.3 Unitil Analysis

The analysis of the CKAIFI metric for Unitil is presented in the subsection below.

Unitil only had 3 qualifying M&C circuits meeting the criteria. Table 47 provides an overview of circuit performance during the baseline period and Program Year 2020.

Table 47. Unitil Baseline and PY2020 CKAIFI Distribution

Unitil M&C	2015-2017 Avg. CKAIFI (Baseline)				2020 CKAIFI (Program Year)			
	System-wide		M&C Circuits		System-wide		M&C Circuits	
	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs	w/ EMEs	w/o EMEs
CKAIFI Statistics								
Total Circuits	32	32	3	3	32	32	3	3
% Zero[51]	3%	6%	0%	33%	6%	22%	0%	33%
Weighted Average	2.0	1.1	2.6	1.1	2.8	1.6	2.2	1.0
Simple Average	1.6	0.8	1.9	0.7	2.2	1.3	1.7	0.6
Std. Dev.	0.9	0.5	0.7	0.5	1.7	1.4	0.6	0.5

Source: Guidehouse analysis of 2020 GMP Annual Report Appendix 1

The M&C circuits have slightly higher CKAIFI values than the system wide circuits in the baseline and slightly lower CKAIFI values than system-wide circuits in Program Year 2020. As with other EDCs, the system-wide circuit performance in 2020 decreased compared to the baseline, but the CKAIFI for the M&C circuits slightly improved (0.2 with EMEs, 0.1 without EMEs). However, due to the small sample size, limited conclusions can be drawn about any trends or impacts of M&C based on this metric.

[51] The % Zero value shows the proportion of circuits that have experienced zero outages throughout the entire baseline (2015-2017) or program year period.

4.2.3 PM-UTL1: Unitil Reliability-Related Metric: Customer Minutes Saved per Outage

This metric tracks the time savings realized from faster AMI outage notification compared customer outage call. The metric seeks to quantify the impacts of Unitil's OMS/AMI integration through the reduced customer of minutes of interruption. The OMS/AMI work has not been completed, so this metric cannot yet be analyzed.

5. M&C Case Studies

Six case studies were performed for the M&C investment area: three for Eversource, two for National Grid and one for Unitil. The case studies illustrate the operation and impacts of the GMP devices installed through PY 2020. The analyses were based on information from EDCs including OMS data, one-line diagrams, SCADA data, switching orders and discussions with EDCs. However, Guidehouse made certain reasonable assumptions to reconstruct the precise details of an outage event in cases where not all information was available.

5.1 Data Management

Case studies were performed using data from the outage management system (OMS), switching orders, SCADA data, circuit topology maps, one-line diagrams, and interviews with the EDCs. The outage data contains details of outage events, such as location, timing, and customers affected, that were integral to understanding the role of the GMP device in resolving the outage. The One-Line Diagrams helped support the analysis by using visualization to better understand the operation of the relevant devices during the outage event. Supplemental information was obtained from the EDCs in some cases to reconstruct the details of an event.

5.2 Case Study 1: Eversource Recloser SCADA (Circuit 38A1)

5.2.1 Background

This case study illustrates how SCADA capability helped to reduce the outage duration required to make emergency repairs on a distribution pole. In this case, an emergency repair was needed to avoid an imminent equipment failure in Ashfield, Massachusetts. Eversource took a 3-minute outage to 296 customers to perform the repair. Guidehouse estimates that without the GMP M&C investment, a 70-minute outage would have been needed to perform the same repair, due to crew travel time. Eversource leveraged GMP-funded SCADA capability on a pole top recloser to achieve this reduction in customer outage duration.

5.2.2 Event Description

On March 16, 2020 at 8:07 PM, Eversource learned that an insulator pin had come loose from a distribution pole so that 23kV live wire was in direct contact with the pole. PI data shows wire was likely smoking or burning. This could have caused a short-circuit or pole fire. Repair had to be performed urgently but was relatively simple; crew had to re-attach the insulator pin to the pole. The pole was a buck-arm junction construction (see Figure 19 for an example) with wires crossing in multiple directions, meaning the line had to be deenergized to perform work safely. Eversource notified customers in advance of the outage.

Eversource had commissioned SCADA functionality at a nearby pole-top recloser as part of the GMP M&C program. Eversource operators used the SCADA functionality to remotely open the recloser, deenergizing the work area. Crews performed the repair in 3 minutes and notified operators when the line was ready to be energized. Operators then used SCADA to remotely close the recloser and restore circuit to normal conditions. 296 customers lost power for 3 minutes.

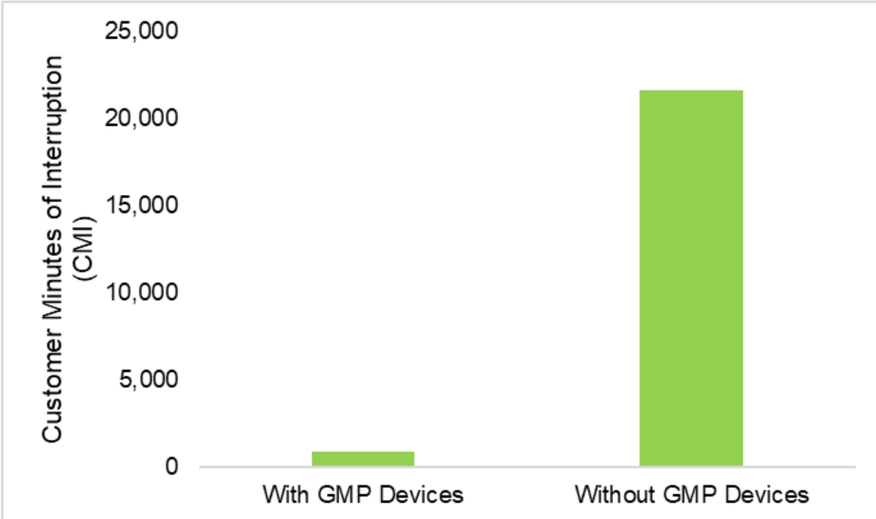
Figure 19: Illustrative example of a buck-arm junction pole

Source: California Public Utilities Commission. www.cpuc.gov.ca

5.2.3 Benefit of Grid Modernization Investment

This case study illustrates how a GMP M&C device was used to shorten customer outage duration during a grid maintenance event. Without SCADA, Eversource crews would have had to travel to the nearby recloser, manually open the recloser to deenergize the line, travel to the job site to perform repairs, and then return to the recloser to restore power. Guidehouse estimates it would have taken 70 minutes of outage to 296 customers to perform 3 minutes of repair work. The resulting savings in customer minutes of interruption (CMI) are shown in Figure 20. (Note CMI = number of customers interrupted *times* duration of interruption in minutes.)

Figure 20. Benefit of Grid Modernization Device in Reducing Customer Minutes of Interruption



Source: Guidehouse

5.3 Case Study 2: Eversource Microprocessor Relay (Circuit 30B4)

5.3.1 Background

This case study evaluates how an advanced microprocessor relay effectively captured data during a major system outage. The outage occurred during a snowstorm in December 2020, when a transmission line tripped and caused a substation outage. 2,609 customers in the town of Pittsfield in Western Massachusetts lost power for nearly an hour. Eversource had commissioned a GMP-funded microprocessor relay device at one of the affected circuits (30B4). The microprocessor relay operated correctly and reported information properly to the SCADA system and then from the SCADA system to the historical PI database. This information is valuable to Eversource for purposes of verifying correct equipment operation and post-event analysis.

5.3.2 Event Description

On December 12, 2020 at 7:39 AM, a 115 kV transmission line tripped and reclosed during a snowstorm in Western Massachusetts. The transmission line trip and reclosure resulted in a bus outage at the Oswald Substation. The substation event affected several distribution circuits and about 2,600 customers lost power for just under an hour. One of the circuits, 30B4 in Pittsfield, had a microprocessor installed as part of the Grid Modernization Program. Historical data in the PI database shows that the microprocessor relay correctly reported data as shown in

Table 48. The table also shows how the data can be useful for event analysis, grid operation and planning.

Table 48: Data Reported by Microprocessor Relay

Data Type	Benefit
Breaker Trip Times	Can be used to verify feeder breaker is tripping at the correct speed or if maintenance is required. A slow tripping breaker will cause "over-tripping" resulting in potential customer outages.
Phase Current in Real-Time	Can be used to verify feeder is not overloaded and within design standards. Enables Engineers and Planners to take corrective action before an over-load or phase imbalance can cause an outage.
Fault Current Level	In analyzing a main-line outage, the level of fault current is critical. The fault current level can be used to determine why a protective device operated, and the proper settings for equipment.
Power Factor and kVAR	The feeder 30B4 has 1.5 MW of solar located at Silver Springs. The reporting of power factor / KVAR supports and verifies the impact of the PV in real-time. An improper power factor could result in poor power quality to customers.
Three Phase Voltage Readings	Can be used to verify the voltage provided to the customer is within the acceptable range. Voltage recording also supports the installation of solar by indicating whether the real or reactive power support is required.
Transmission Outage Detection	Although the outage was cause by a transmission line event, the distribution microprocessor relay recorded the time of the outage event, the loss of three phase voltage and the loss of three phase current.

Source: Guidehouse

5.3.3 Benefit of Grid Modernization Investment

The review of the date determined the microprocessor relay was in service, operated correctly and reported information properly to SCADA and PI Historian database. Advance microprocessor relays are effective at capturing data during a major system event, such as a power outage or other equipment operation. As outlined above, the data made available by the microprocessor relay has benefits for outage response and post-event investigation. The data could aid in an investigation into the cause of the event which could be used to reduce the duration of an outage or a reoccurrence. On regular days, the data can be used to verify proper grid operation and support the integration of solar and distributed generation on the distribution grid.

5.4 Case Study 3: Eversource Recloser SCADA (Circuit 19J1)

5.4.1 Background

This case study event took place on August 4, 2020, when Tropical Storm Isaias brought 60 mph wind gusts and caused power outages to nearly 250,000 Massachusetts customers.[1] The case study describes how GMP-funded M&C investments and other non-GMP M&C devices were used to gain better visibility into real-time grid operation. The outage was caused by a vehicle colliding with a pole and breaking an overhead wire in Huntington in Western Massachusetts.

Circuit 19J1 is a long, rural circuit serving 1,561 customers including critical customers in Montgomery and Huntington, Massachusetts. Eversource had commissioned three M&C devices and two ADA devices on circuit 19J1. There are also other non-GMP M&C devices that were utilized during the outage events.

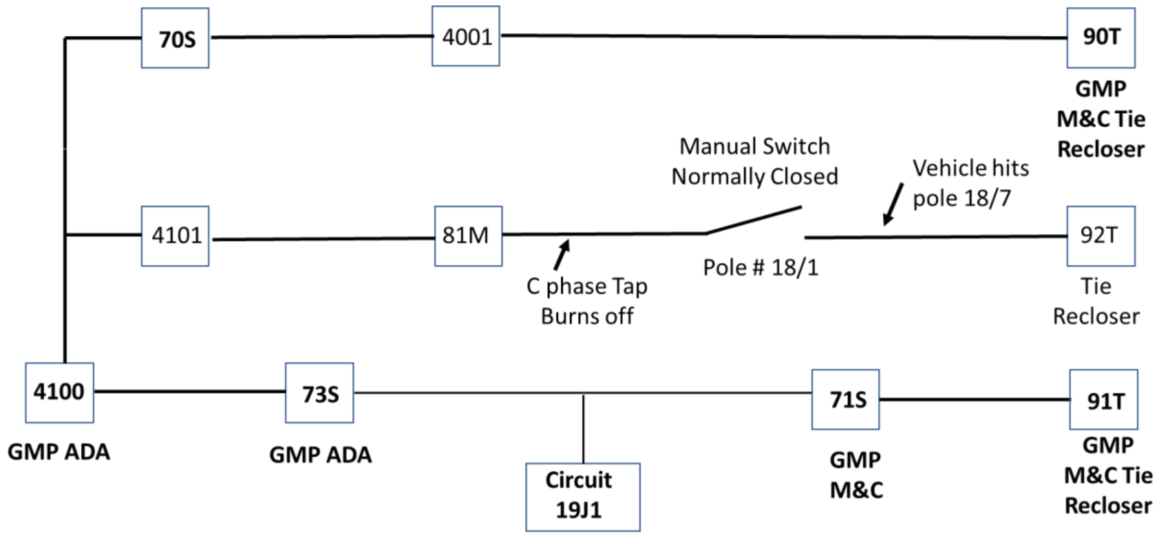
5.4.2 Event Description

On August 4, 2020 at 8am, a vehicle collided with a pole at the location shown in Figure 21. The pole carried 3-phase 23 kV mainline overhead wire. The vehicle accident caused one of the three phases to burn open at a nearby pole location.

The following switching sequence took place:

- Eversource operators determined that the fault location was downstream of the GMP ADA recloser 4100.
- Eversource operators used SCADA to open GMP ADA recloser 4100 remotely via supervisory switching.
- The opening of 4100 correctly triggered an automated loop scheme downstream. Recloser 81M opened and 92T closed. Recloser 70S opened and 90T closed, so that the maximum number of customers downstream of 70S were now supplied from an alternate source of power. 70S and 90T are GMP M&C devices.
- After about 12 minutes, Eversource operators determined that the fault was downstream of the sectionalizing device 81M. They remotely opened 81M and 92T to further isolate the fault location to a smaller zone.
- Once the damage location was isolated, operators closed 4100 using SCADA capability, restoring power to 405 customers between 4100, 81M, and 70S.
- After 67 minutes, crews manually opened a switch at pole #18/1 to isolate the fault zone even further, restoring 209 customers.
- 19 customers (to the right of 18/1) experienced a longer outage while crews replaced the pole and completed repairs.

Figure 21. One-Line Diagram



Source: Guidehouse analysis of Eversource One-Line Diagram

5.4.3 Benefit of Grid Modernization Investment

This case study illustrates the benefit of M&C in giving operators visibility into the automated operation of grid devices. The SCADA capability of 90T and 70S helped operators ensure that the automated loop and operated and power was restored to customers. Operators also used SCADA to open 4100 remotely, a GMP ADA device, avoiding a circuit outage to 1,561 customers.

5.5 Case Study 4: National Grid Feeder Monitor (Circuit 14-65L3)

5.5.1 Background

This case study describes how National Grid used a feeder monitor to improve circuit voltage and service quality to East Bradford customers. In 2020, National Grid commissioned a feeder monitor at the East Bradford circuit 14-65L3 as part of its GMP M&C investment program. The feeder monitor collects current, voltage and other power quantities for this circuit and brings the data back in near real time to SCADA screens in the operations control center.

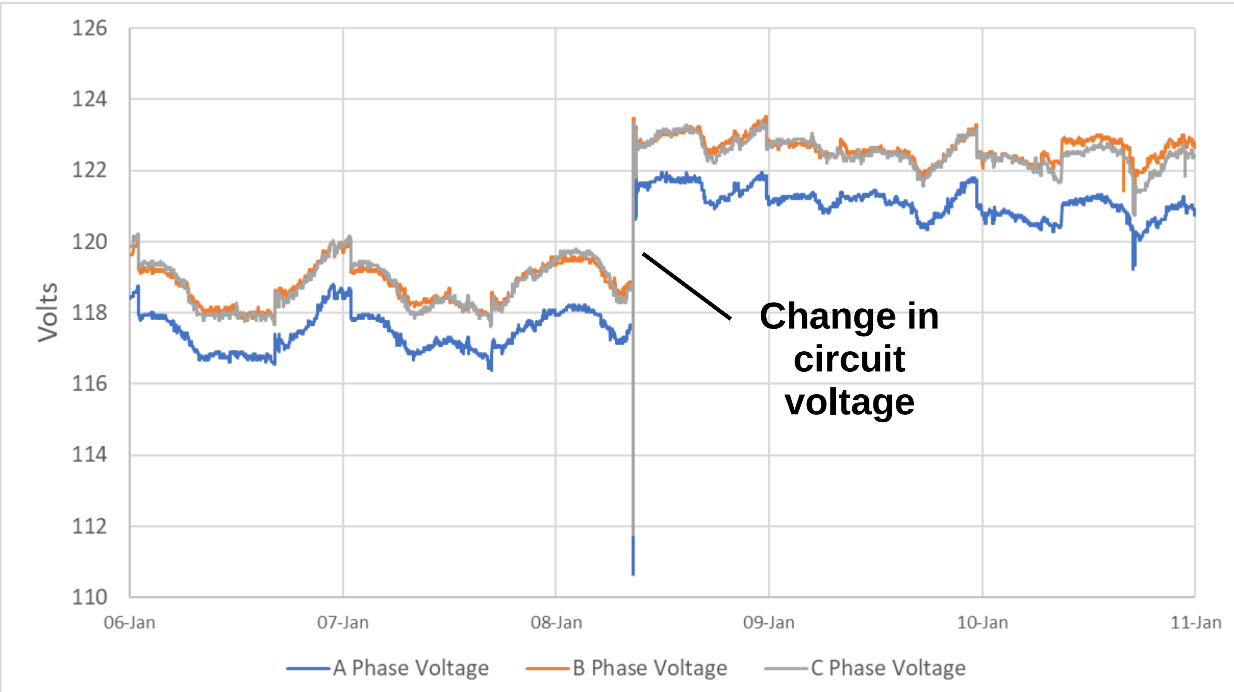
5.5.2 Event Description

In December 2020, a commercial customer served by the circuit, the East Bradford Ski Resort, reported low voltage issues. Ski season had just started on December 19 and the Ski Resort was an important part of the local economy especially in the pandemic year.

National Grid used the feeder monitor to evaluate the voltage issue and determine corrective action. Before the feeder monitor, National Grid had no telemetry outside the substation. It would have tweaked substation voltage (using a load tap changer) through trial-and-error to adjust customer voltages downstream. Now, it used the feeder monitor readings to verify circuit voltages in near real time.

The feeder monitor readings (Figure 22) showed that voltage readings on the circuit were ranging from 117-119V. National Grid changed the substation LTC settings and coordinated with the operations control center to ensure the voltages out on the circuit were in the desired range (120-123 V). Figure 22 shows the feeder monitor readings before and after the adjustment of substation LTC settings.

Figure 22. Feeder Monitor readings show improvement in voltage delivered to customers



Source: Guidehouse analysis of National Grid data

5.5.3 Benefit of Grid Modernization Investment

This case study illustrates how a GMP device was used to confirm circuit conditions and ensure high quality service delivery to customers. Before the feeder monitor, National Grid only had telemetry from within the substation or had to install temporary telemetry at various locations. It relied on customer feedback to deduce circuit voltage conditions, needing multiple customer touchpoints and resulting in suboptimal customer experience. Correcting a low voltage issue would have required more time and resources, potentially involving repeat trips to the substation and a longer-duration impact to ski activity.

With the feeder monitor, National Grid was able to correct the issue using near real time monitoring and with greater accuracy. As a result, the ski resort experienced minimal impact to the ski season. Guidehouse estimates that all 1,941 customers on the circuit benefited from the improved voltage profile, including 10 critical customers. The East Bradford circuit currently has 79 distributed solar generation units connected. In the future, feeder monitors may be used to keep circuit loads and voltages in check as solar generation can be expected to cause distribution voltage fluctuations.

5.6 Case Study 5: National Grid Feeder Monitor (Circuit 11W83)

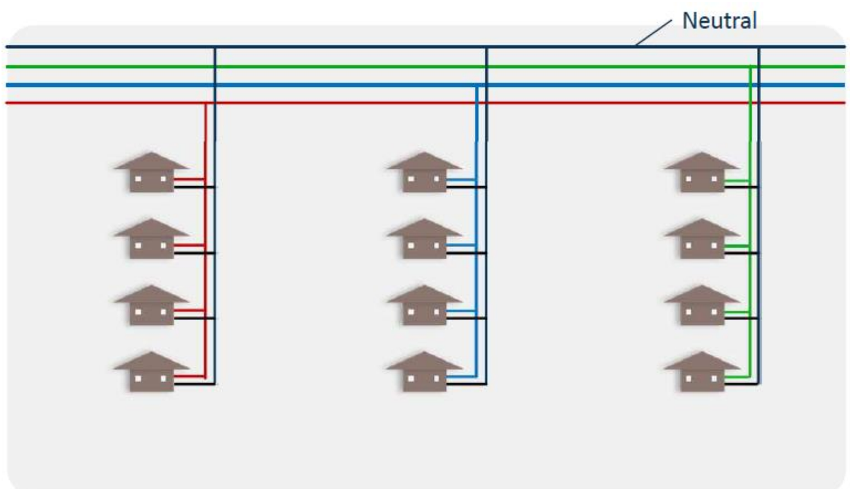
5.6.1 Background

This case study describes how feeder monitor data was used by National Grid to predict a likely overloading condition and proactively plan to avoid it, saving cost and possible customer outage time. In 2020, National Grid commissioned a feeder monitor at the Swansea circuit 11W83 in the Fall River area as part of its GMP M&C investments. The feeder monitor collects voltage, current and other power quantities for this circuit and brings the data back in near real time to SCADA screens in the operations control center.

5.6.2 Event Description

National Grid used the feeder monitor to achieve balanced feeder loading and avoid a forecasted overload that would probably result in a power outage. Figure 23 shows a schematic of how distribution feeders are designed to tap single-phase service from a three-phase main line. Over time, many more customers may get connected to one phase than another, leading to imbalanced load. Utilities must periodically balance feeder loading to ensure service quality to customers and avoid asset over-utilization.

Figure 23. Schematic of residential single-phase customers serviced from a three-phase distribution line. The amount of load on each phase is roughly balanced in this diagram.



Source: Enerdynamics, The Electrical Distribution System

Before the feeder monitor was commissioned, National Grid had limited information about the loading on each individual phase, making it difficult to determine if an overload would be occurring on any of the three phases. In late 2020, National Grid used initial data reported by the feeder monitor to develop a load flow model in Cyme. The data allowed National Grid to confirm that the station meter was connected to the B phase but was providing no information on the other two phases. Using the feeder monitor readings, National Grid determined that sections of the overhead line were close to the maximum current rating and would be at risk of overloading in 2021, as shown in Figure 24. An overload could lead to an outage for the 2,920 customers served by the feeder, most likely during the summer peak hours. Switching customers to nearby feeders was not an option as those were also heavily loaded. To avoid the potential power outage, National Grid performed load balancing and proactively upgraded sections of the overhead line to a higher rating before the summer peak season.

Figure 24. National Grid used feeder monitor readings to predict overloading on an overhead line at Swansea

Feeder	Normal Limiting Element	Normal Element Specifics	SN Rating (Amps)	Emergency Limiting Element	Emergency Element Specifics	SE Rating (Amps)	Actual Load				Projected Load					
							2019		2020		2021			2022		
							Amps	%SN	Amps	%SN	Spot Loads	Amps	%SN	Spot Loads	Amps	%SN
11W83	OH Line	1/0 Cu (+80A)	395	OH Line	1/0 Cu (+80A)	505	367	93%	365	92%		394	100%	-40	363	92%

Source: National Grid

5.6.3 Benefit of Grid Modernization Investment

This case study illustrates how a GMP device was used to monitor grid health and predict an overload before it happened. Outages resulting from overloads typically last longer and cost more than planned outages, because emergency work often involves overtime pay and less pre-planning. Planned repairs are also preferable because customers are notified in advance and can be scheduled at a less disruptive time than, say, the hottest hours of summer when overloads are most likely to occur.

Going forward, National Grid should continue to use M&C capabilities to monitor and maintain this circuit, especially given the 291 DER units currently connected to it. National Grid should also continue to use other feeder monitors to balance other heavily loaded circuits with high DER penetration.

5.7 Case Study 6: Unitil Substation SCADA (Beech Street)

5.7.1 Background

This case study describes how GMP-funded M&C investments helped to reduce customer outage durations during a windstorm in Fitchburg, Massachusetts, part of northern Worcester County. Strong winds caused tree damage to a 69 kV transmission line, causing a major outage affecting 27,541 customers on various circuits in Fitchburg. Unitil had commissioned SCADA monitoring and control capability at three substations in Fitchburg, one using GMP funds. In this case, the GMP-funded SCADA device allowed Unitil to restore power to 3,662 customers 15 minutes quicker than if crews had performed manual switching. The other two SCADA devices also helped to reduce outage durations.

Previously, in case of an outage event, Unitil's field workforce would have to travel to a substation to manually deenergize equipment, perform repairs and then return to the substation to energize equipment, a time-consuming process. Guidehouse determined that Unitil implemented necessary workforce training and procedural changes to ensure that Unitil workforce was ready to utilize SCADA devices when an outage occurred. These steps included:

- Information awareness meeting with field workers
- Written documentation provided to each field worker on the locations of the newly installed M&C equipment
- Review and validation of the switching and tagging safety procedures to ensure they support the Grid Mod Investments

5.7.2 Event Description

On March 26, 2021, at 7:02pm, strong winds severed a tree trunk which made contact with a 69 kV overhead transmission line in Fitchburg. The transmission line tripped, causing 27,541 customers on various circuits to lose power immediately. Due to the nature of the damage and the location of the fault, a significant amount of system switching at various locations was needed to restore all customers. Unitil used SCADA capability to operate grid devices remotely at the following substation locations:

- Beech Street (GMP-funded M&C device)
- Sawyer Passway
- Wallace Road

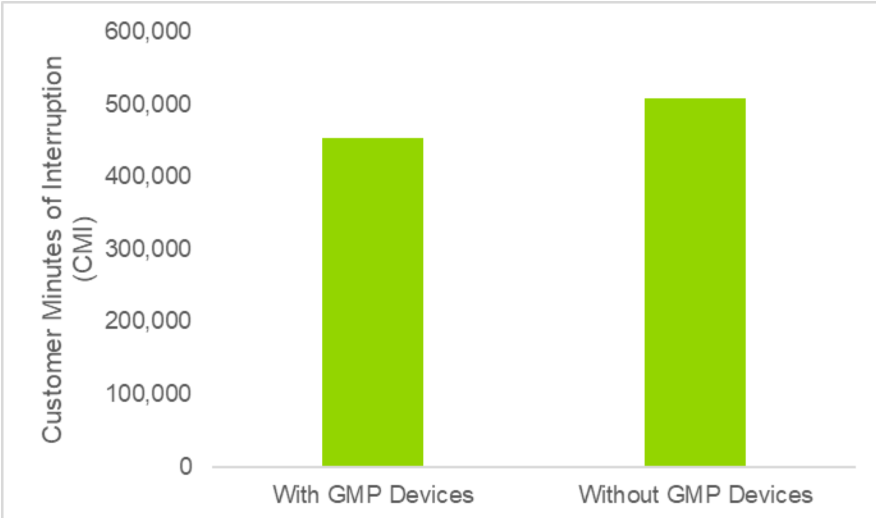
5.7.3 Benefit of Grid Modernization Investment

This case study illustrates the benefit of GMP devices in reducing customer outage durations during a major outage event. Without SCADA, crews would have been required to travel to manually deenergize and energize equipment. Unitil estimates that SCADA capability allowed Unitil to reduce customer outage times as follows:

- SCADA operation at Beech Street substation (GMP-funded M&C device) – avoided 15 minutes of outage for 3,662 customers
- SCADA operation at Sawyer Passway substation – avoided 25 minutes of interruption to 3,025 customers
- SCADA operation at Wallace Road substation – avoided 37 minutes of interruption to 790 customers

Without GMP M&C investment, 3,662 customers would have experienced an additional 15 minutes of outage. The resulting savings in customer minutes of interruption (CMI) are shown in Figure 25.

Figure 25. Benefit of Grid Modernization Devices in Reducing Customer Minutes of Interruption



Source: Guidehouse analysis

6. Recommendations

Several recommendations are provided below based on the analysis and summaries made during the PY 2020 Evaluation process.

1) The CKAIDI and CKAIFI reliability related Performance Metrics as defined have deficiencies in measuring the effectiveness of Grid Modernization Investments. Many factors unrelated to the Grid Modernization investments will affect these metrics in any given year, and it is not possible to distinguish among these factors using the metrics. For example, the variation in storm activity between years can cause significant changes in these metrics, as apparently happened in PY2020. The need for three years of baseline data also excludes circuits that have been reconfigured.

    a. Recommendation: Continue to track these Performance Metrics, but to establish other methods of isolating the specific impacts of Grid Modernization investments.
    b. Recommendation: Additional Performance Metrics should be explored to determine if it is possible to capture the actual reliability performance attributable to the investments. Exploration could include:
        i. Reviewing the data and techniques necessary to understand the relationship between circuit reliability and weather conditions, vegetation management cycles and other reliability drivers that are independent of the grid modernization investments.
        ii. Expanding the use of case studies to cover a greater proportion of the investments—more outage cases examined on more circuits (see Recommendation 4a below).
        iii. Leveraging new processes and collecting data to more efficiently perform outage case studies, and perhaps extrapolate these results to a broader set of circuits to understand investment performance with more certainty.
        iv. Comparing number of customers out and customer minutes of interruption (CMI) that occurred, with the number of customers out and CMI that would have occurred without Grid Modernization investments.

2) The use of currently defined CKAIDI and CKAIFI reliability related Performance Metrics—which are circuit level metrics—has increasing challenges over time as circuits get re-configured or retired and new circuits are constructed. The comparability of each circuit in the program year to its baseline depends on that circuit not having been reconfigured or significantly changed (e.g., a normally open switch between circuit segments is changed to operate as normally closed, changing the customer counts and outage measurements on that circuit). The number of circuits that are comparable between baseline and program year is reduced year after year as more circuits change due to ongoing operation of the system.

    a. Recommendation: Explore metrics that are robust to these operating changes to help ensure that Grid Mod investment assessment based on these metrics are not misleading, and that they are able to better capture the impact of the investment.

3) Current metrics do not provide an understanding of how M&C and ADA investments facilitate easier interconnection, or more capacity, of DER added to the system

    a. Recommendation: Consider developing additional metrics and/or performing pilot projects that utilize the installation of ADA and M&C investments at DER locations to understand the value or benefits that are provided. This would provide actual data on the effectiveness of these investments to support DER integration.

4) Case studies show detailed functioning and impact of GMP devices, and they are proving to be a useful tool in understanding the effectiveness of the Grid Modernization investments. Based on case studies performed, the M&C investment is yielding reliability and service delivery benefits to customers for each of the EDCs.

    a. Recommendation: Continue to perform case studies in future evaluations, and increase the use of case studies where practicable, to analyze the mitigation of customer outages and help determine the effectiveness of Grid Modernization investments in improving reliability and service delivery.

    b. Recommendation: Continue the deployment of M&C technologies as part of the Grid Modernization Program and continue to monitor progress (including through amended or additional metrics to be determined by the Department).