UNITIL ENERGY SYSTEMS, INC.

DIRECT TESTIMONY OF

SARA M. SANKOWICH

New Hampshire Public Utilities Commission

Docket No. 16-384

A. These variable factors will be minimized through extensive planning as well as field and management oversight. Hazard trees to be removed will be prioritized according to risk. The Company will engage in extensive interaction and advance notice to towns and the use of a specialized trained company representative for customer education and consent, and to promote the acceptance of the work. Advance planning and notice to a large vendor pool and timing of project and bid release will be used to minimize cost changes associated with competing work.

Q. Have any measurable benefits been realized since the implementation of the SRP work in 2012?

A. During the course of the initial pilot pruning and removal work in 2012, the Company was faced with a unique situation to test the work's response to a storm event. On October 29, 2012 Hurricane or "Super Storm" Sandy came up the east coast and affected the Company's New Hampshire service territory. At this time, one of the three storm pilot circuits was in the final stages of completion. Only a few customer tree removal negotiations and pruning spots remained. On the second circuit, pruning and removal was just beginning, and work had not started on the third circuit. This left the unique opportunity to study the effects on the worked and unworked circuits during one event. As rain and wind from Hurricane Sandy pelted the Seacoast area, the first circuit that had work completed held up remarkably well. The main line of the circuit experienced no events and many of the customers fed off this circuit did not experience a single interruption. A customer communication after the storm event, shown below, is representative of many emails, phone calls and Twitter "tweets" UES received and the customer experience during this storm event:

> *Just wanted to let you know how wonderful it was not to lose power during the hurricane. I believe it was directly attributable to all the tree cutting and trimming Unitil did especially in the Pollard Road and Westville Road area. My husband and I had our home built here thirty seven years ago....this is the first big storm that I can remember that power remained on!! I know there is no assurance this will be the norm but I think you all are striving hard to make it that way. Thanks so much!! -Plaistow, NH*

There was one tree-related event in the storm pilot area along the first circuit where a desired tree removal, still in discussion with an unsure homeowner, failed and contacted the phases. However, the tree was removed during the storm and those customers affected were restored quickly. The customers on this circuit experienced many of the benefits expected from the SRP.

The other two Storm Pilot circuits that had not had tree removal started faced more tree-related incidents and the main line of both of these circuits experienced tree-related troubles which led to substation lock-outs, longer outages for a larger number of customers in the area, and increased time and manpower to restore. I performed a field review directly after the storm event which demonstrated multiple tree failures along the Storm Pilot designated area. Two sideline tree failures on the mainline of the second circuit had been marked and approved for removal prior to the storm, but had not yet been removed. Had these removals been done prior to the storm event, associated reliability loss, damage, and cost would likely have been prevented.

In 2014 the Company was again able to test the SRP. On Wednesday November 27 through Thursday November 28, 2014 the Company's Capital region in New Hampshire experienced a heavy wet snow event that was forecasted as an EII 3 event with snow totals over 10 inches. During this event, the electric system experienced significant damage. However, there were limited tree related damage events on the portions that underwent storm resiliency work in 2013. To document and analyze the performance of these circuits, the Company employed a vendor to record vehicle mounted high definition video during restoration portions of the storm, after snowfall was completed. The video captures analysis and performance of the circuits and can be viewed in a Company's short film titled "SRP Video 2014,".

Q. Other than the benefits described above, are there any reliability improvements attributed to the SRP?

A. The Company has seen an overall reliability improvement related to tree-related outages over the past five years, as shown in Schedule SMS-1. While the Company would like to attribute this in large part to the SRP, it is difficult to distinguish this result from a number of other factors such as the vegetation management program, capital improvements, emergency response plan, and favorable weather conditions.

Q. What are the expected benefits of implementing the SRP?

A. The expected benefits of the SRP are, at the core level, improved reliability, improved customer service and satisfaction, reduced safety risks, and avoided costs during storm events. These benefits should be seen by the expected prevention of tree-related failures and subsequent electric incidents. This reduction in incidents reduces damage to the electric infrastructure and the need for crews to respond, in turn reducing overall storm restoration costs.

There are also more specific benefits, which drive the core benefits, expected from implementing the SRP. These include:

- Preserving municipal critical infrastructure
- Minimizing the dependence on mutual aid and off system resources
- Minimizing the total number of resources required to restore service
- Shortening the duration of major events
- Minimizing the overall cost of restoration
- Reducing economic loss to municipals, businesses, and customers
- Most cost-effective solution vs. other alternatives

Because of the design of the SRP, much of a municipality's critical infrastructure is included in the targeted circuitry. These areas are also most often the business centers for the municipality, and therefore include gas stations, restaurants and hotels. Preserving power during multiple-day events to both municipal infrastructure and business districts ensures functioning emergency service, and a place where residents can seek temporary warmth and shelter.

In addition, many states and regulatory jurisdictions have established standards for restoring power during major events, the competition for securing outside line resources has increased significantly and, as a result, resources have become both scarce and very expensive. Often, in order to secure an adequate amount of resources for a particular event, the Company has been required to reach outside of the New England area, adding travel time and additional cost. One way, however, to mitigate these escalating costs is to prevent the damage from occurring in the first place. Less damage translates into a reduced need for outside crews, which, in turn, lowers overall costs and shortens the duration of an event.

As electric utilities review various options to improve overall storm performance, the undergrounding of utility infrastructure is often mentioned, but quickly dismissed due to significant cost and impracticality. Implementation of an SRP may achieve similar performance to that of undergrounding at a fraction of the cost.

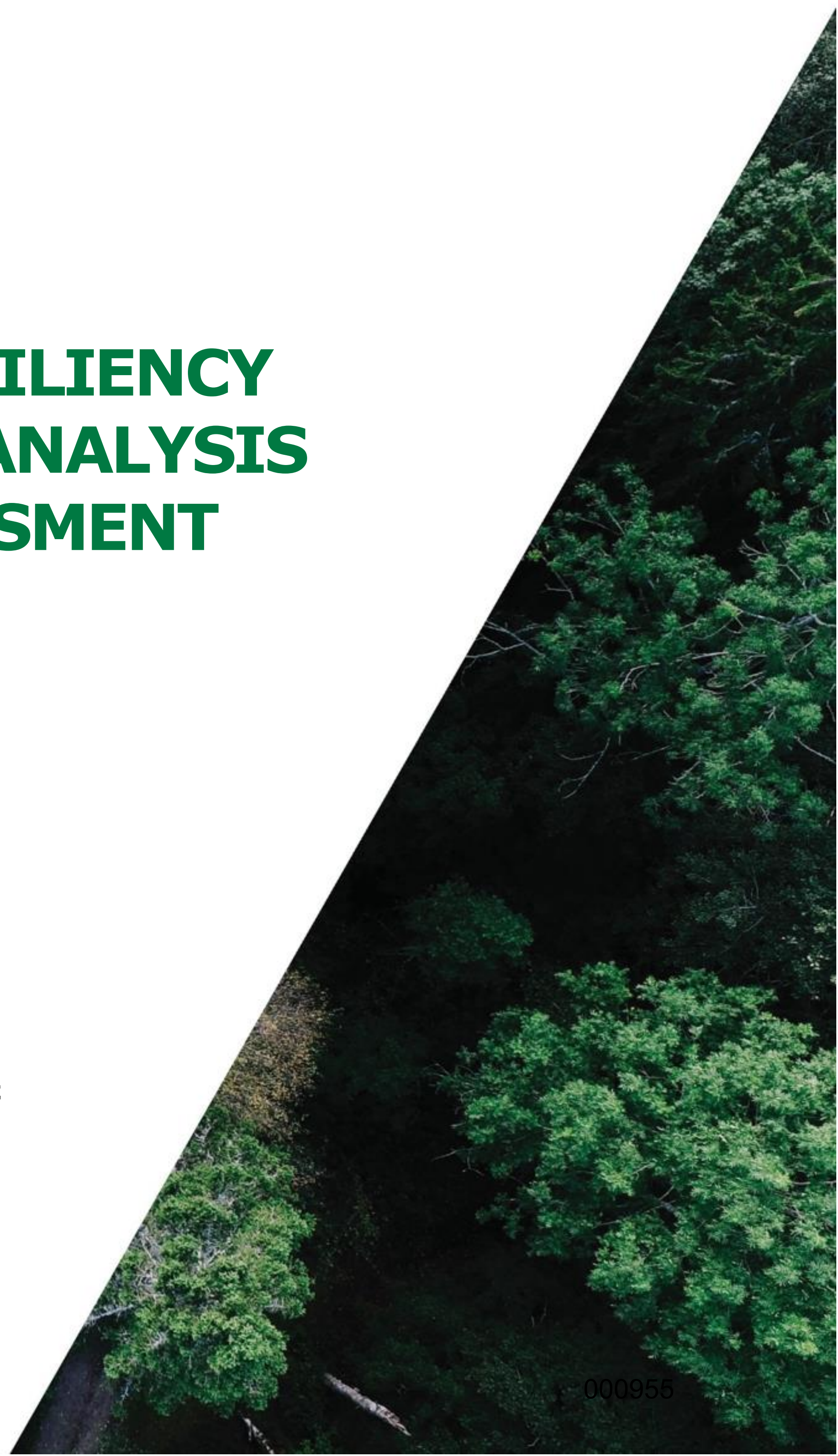
Municipalities and businesses have described the significant economic impact of losing power for multiple days. These natural disasters are very disruptive, result in a loss of business income and tax revenue, personal income loss, and increased costs to municipalities due to the requirements of providing emergency services, debris removal, and requiring overtime work for multiple departments. Any actions that help to minimize this disruption will provide some measure of economic relief.

Finally, customers have expressed concern with losing power for multiple days. Although it is impossible to prevent storm damage across the entire system, preserving power and minimizing damage for each municipality along its main business corridor as well as protecting its emergency critical infrastructure appears to offer significant promise as a means to assure safety and provide some measure of security during and after these extreme weather events.

Q. Has the Company drawn conclusions about the benefit of a storm resiliency program?

A. Yes. After reviewing the results of the storm hardening initiatives implemented in New Hampshire and Massachusetts, the Company concluded that the reliability effects, the

ECI Environmental Consultants



STORM RESILIENCY PROGRAM ANALYSIS AND ASSESSMENT

Prepared for:

Unitil
energy for life

SUBMITTED BY
Lakeside Environmental Consultants, LLC
D.B.A. Environmental Consultants (ECI)

12324 Hampton Way Dr.
Suite 104
Wake Forest, NC 27587
United States of America

August 3, 2020

Table of Contents

1.0 OVERVIEW

Unitil Corporation provides electric and gas operations in Maine, New Hampshire and Massachusetts, serving approximately 106,000 electric customers and 83,600 natural gas customers. Following Hurricane Sandy in 2012, which devastated large portions of the Northeast, Unitil was faced with restoring power to 69,000 electric customers.

In response to requests from customers and municipalities to improve service reliability and harden its electrical infrastructure against future storm events, Until Corporation developed a 10-year Storm Resiliency Program (SRP) to prevent power outages caused by trees and adjacent vegetation. The program's intent is to make the electric system more resilient to tree outages particularly during storm events. To accomplish this, Unitil sought ground-to-sky clearance to include the removal of trees and branches growing above electric wires, and incompatible trees growing underneath them.

The stated goals of the SRP fund as defined in the Electric Reconciliation Mechanism Filing in MA DPU 18-149 and NH DE 16-384 are as follows:

- reduce tree-related incidents and resulting customer interruptions;
- reduce municipality impact along critical portions of targeted lines in minor and major events;
- reduce overall cost of storm prep and response;
- improve restoration; and
- preserve municipal critical infrastructure.

To help quantify the impact of the Storm Resiliency Program, Unitil engaged GeoDigital in 2016 to utilize LiDAR data to assess the before trimming SRP condition and the after trimming SRP conditions of circuits maintained under this program. In 2019, Unitil requested an addition SRP Assessment utilizing the captured LiDAR data to focus on measuring the system reliability improvements and overall performance resulting from the Storm Resiliency Program, including the costs and benefits of Unitil's strategy to proactively identify and remove vegetation risk. To complete the assessment, Unitil engaged Environmental Consultants, LLC (d.b.a., ECI) as the lead consultant with OBI Partners providing operational reliability intelligence and data analysis.

2.0 ANALYSIS

The analysis focused on identifying and isolating where outage events occurred on circuits included in the SRP Program. This effort included the review of outages pre- and post-SRP completion. Outages were correlated to the available LiDAR data to identify vegetation conditions on the fault device to determine a more precise outage location to ensure proper alignment with SRP and non-SRP line sections. From this analysis, the impact of SAIDI and CAIDI for the Storm Resiliency Program could be estimated.

The following report discusses the process, results, and recommendations from ECI, and in part, leverages data derived by OBI Partners' performance analysis.

2.1 Utilizing Reporting Dashboards

Several standard reports and dashboard elements from OBI Partners Outage Management, Storm Management, and Vegetation Management solutions were used as a basis of the work for this analysis. Several of those components and their relationship can be seen in Figure 1.

The analysis tool was populated with Unitil's data to support this analysis effort. In addition to providing an information framework for this analysis effort, the platform was designed to be configured for automated updates and used for additional analysis, performance monitoring, and follow-up work initiation.

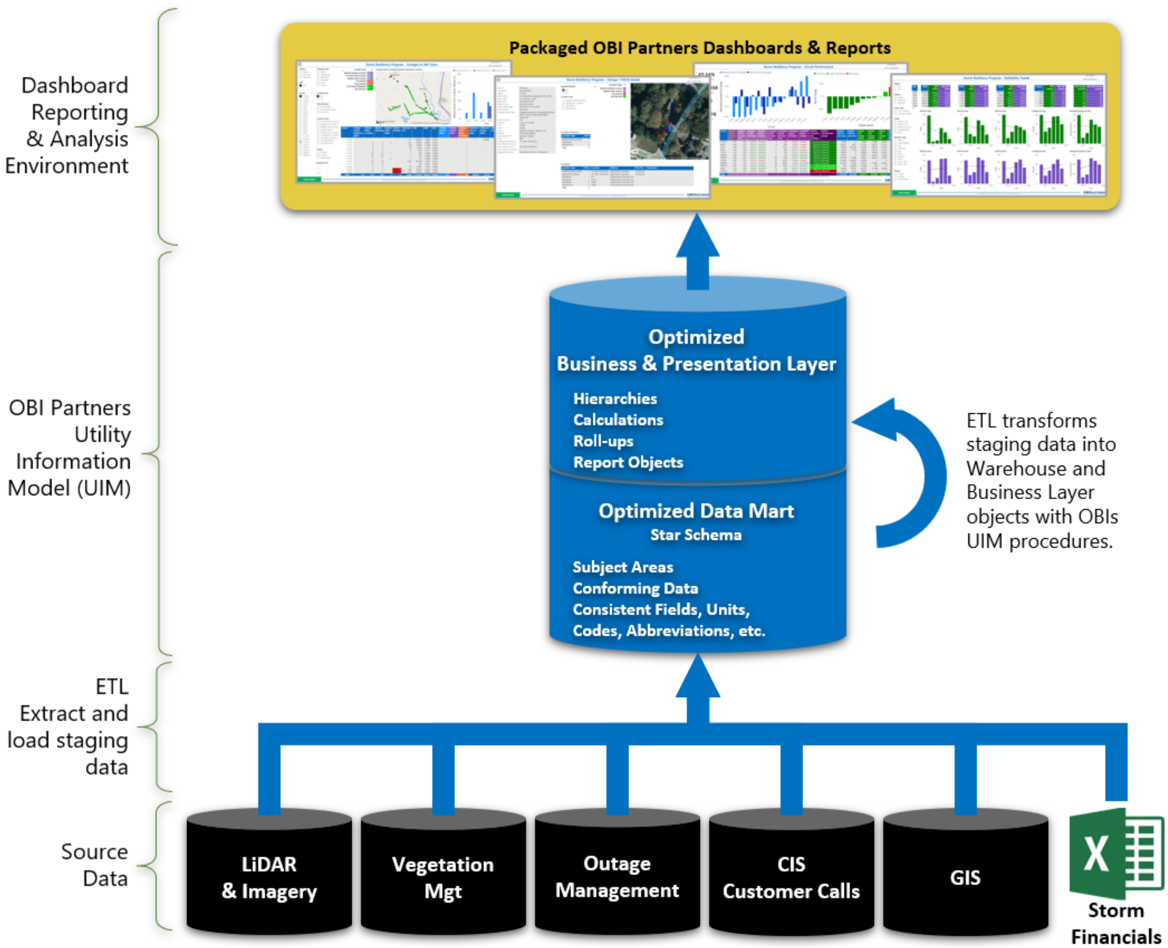


Figure 1 - OBI Partners - Utility Information Model Solution Overview

The platform standardized data via an Optimized Data Mart focusing on:

- Conforming data from disparate sources
- Standardizing data nomenclature and formats across the disparate sources
- Providing a single source of the truth
- Supporting machine data analytics
- Insulating the reporting environment from changes to source data and applications

The platform allowed Reporting and Analysis via an Optimized Business Layer by:

- Preparing data for users to support a broader range of technical skills and improve productivity
- Providing advanced calculations and roll-ups for reporting
- Simplifying the data environment for report builders and data analysts

2.2 Isolating Outage Events on SRP Circuits

Outage events were correlated to SRP Program circuits both spatially and temporally. This identified outages that occurred where SRP work was performed, and whether those outages occurred before or after the SRP work was completed. The figures below illustrate one selected circuit. Figure 2 shows outage events that occurred before SRP work was complete on the circuit. The symbology identifies those that are spatially related to where work was eventually completed and those that were not. Figure 3 shows outages that occurred after SRP work was complete along with SRP work locations.

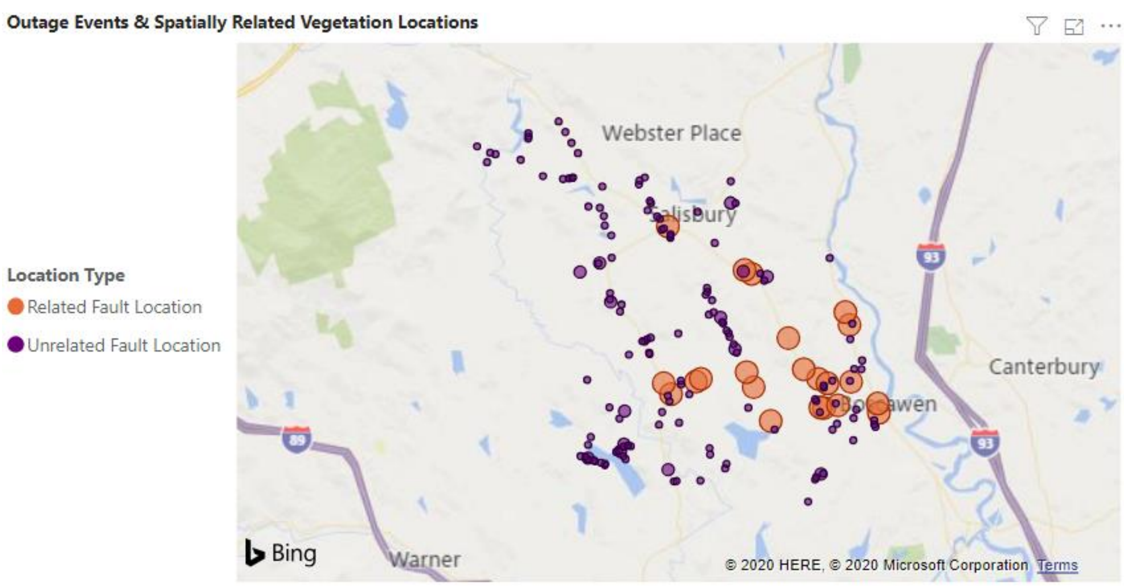


Figure 2- Outage Events Prior to Work Completion

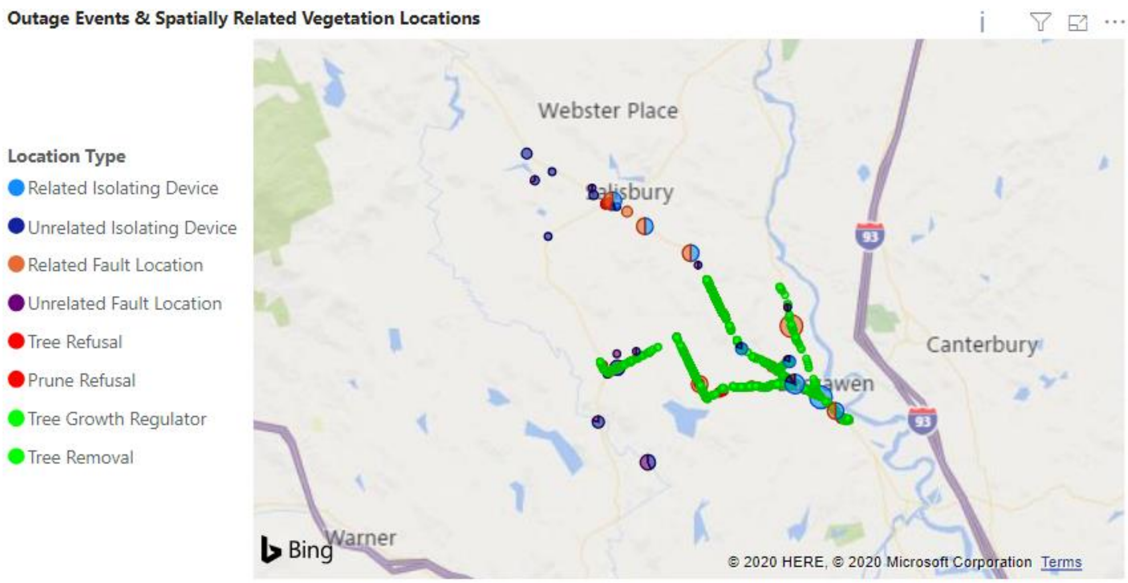


Figure 3- Outage Events After Work Completion

From a more detailed perspective, Figure 4 shows an individual outage fault location on this circuit, along with related SRP work locations. For the purposes of this analysis, to be related, those work locations had to be both; within a specific proximity and occur after work had been completed.

Figure 4- Single Event Fault Location and Associated SRP Work Locations

The example above identifies three *Tree Removal* work locations and five *Tree Refusal* locations. These work activities occurred before the outage event, and because *Tree Refusals* existed in the immediate area of the fault location the outage was discounted from any outages that occurred in the work zone following SRP work. These outages were removed from the circuit performance data following SRP completion to avoid skewing circuit performance with non-preventable outage data.

2.3 Isolating Circuit Performance Both Before and After SRP

As mentioned in Section 2.2 above, the study identified all events that occurred before and after SRP work completion. Where data was available, the study looked at circuit performance from 2014 leading up to SRP, and the maximum number of years after SRP work was completed.

The data provided by Unitil included:

- Outages from 2014 through 2019
- SRP circuit work locations from 2015 through 2019 with sparse records for 2013 & 2014
- Storm data including storm name, storm timeframe, and storm costs for 2014 through 2019
- Other associated data such as; Poles and their locations from GIS, and Customers Calls, that were used along with the Outage and Work Location data.

Circuit performance using CMI, SAIDI, SAIFI, CAIDI, etc., was calculated for all circuits showing values and trends for SRP and Non-SRP circuits. Figure 5 shows results for all circuits.

Year	Events	CI	CMI	CMI/Event	SAIDI	SAIFI	CAIDI	Storm Events	Non-Storm Events	Storm CI	Non-Storm CI	Storm CMI	Non-Storm CMI	Storm CMI/Event	Non-Storm CMI/Event	Storm SAIDI	Non-Storm SAIDI	Storm SAIFI	Non-Storm SAIFI	Storm CAIDI	Non-Storm CAIDI
2014	989	146,679	51,651,912	52,226	482.23	1.37	352.14	202	787	58,365	88,314	28,390,034	23,261,878	140,544.72	29,557.66	265.05	217.18	0.5449	0.82	486.42	263.40
2015	414	54,040	4,030,715	9,736	37.63	0.50	74.59	39	375	6,629	47,411	530,285	3,500,430	13,597.05	9,334.48	4.95	32.68	0.0619	0.44	79.99	73.83
2016	600	55,161	8,653,598	14,423	80.79	0.51	156.88	175	425	30,862	24,299	6,624,725	2,028,873	37,855.57	4,773.82	61.85	18.94	0.2881	0.23	214.66	83.50
2017	966	146,244	40,088,479	41,499	374.27	1.37	274.12	408	558	92,453	53,791	34,190,638	5,897,841	83,800.58	10,569.61	319.21	55.06	0.8632	0.50	369.82	109.64
2018	1,061	123,830	35,632,465	33,584	332.67	1.16	287.75	299	762	56,331	67,499	25,012,156	10,620,309	83,652.70	13,937.41	233.52	99.15	0.5259	0.63	444.02	157.34
2019	715	61,026	12,573,404	17,585	117.39	0.57	206.03	364	351	26,369	34,657	8,473,167	4,100,237	23,277.93	11,681.59	79.11	38.28	0.2462	0.32	321.33	118.31

Figure 5 – SAIDI Performance Comparison – SRP and Non-SRP circuits

2.4 Evaluating Vegetation Condition Correlated with Outages

Fault locations related to SRP work were identified using outage detail data, including crew and dispatcher comments as well as customer call-in data. For the purposes of comparing circuit performance pre- and post-SRP work, it is crucial to only include those faults that were directly actionable by the SRP maintenance process. As such, faults that could be associated with customer refusals were excluded in the post-SRP analysis.

As with Figure 4 in Section 2.2 above, Figure 6 presents an additional outage example that occurred after SRP work was performed. The example shows several locations where *Tree Removals* occurred. The outage detail shows the outage occurred 11 months after the work was completed with no refusals or other impediments preventing SRP completion. Unlike the example in Figure 4, this outage did factor into post-SRP reliability metrics for the related circuit.

Event	184033
District	Fitchburg
Substation	Townsend #15
Feeder	F15W16
Storm Name	
Storm Level	
Begin Time	12/03/2019 13:24
Restore Time	12/03/2019 13:36
Project Date Range	07/01/2018 - 12/31/2018
Outage-Project Offset	11 months 3 days after project completion.
Customers Out	549
Duration	11 minutes
CMI	6,140
SAIDI	0.0573
Cause	Tree/Limb Contact - Broken Trunk
Weather	Snow
Failed Equipment	
Phase	ABC
Isolating Device	118-0002-0-00-00-03
Fault Device Comments	
Fault Location Pole Id	118-0008-0-00-00-03
Fault Location Comments	
Operator Comments	Tree on wire near pole 8 South Row Rd. Crews opened Recloser 118/2 removed the tree and closed Recloser 118/2.

Spatially Related

- [x] Yes
- [ ] No

Location Type

- [ ] Related Isolating Device
- [x] Related Fault Location
- [x] Tree Removal

Location Summary

Location Type	Units
Tree Removal	22
Total	**22**

Location Type
● Related Fault Location
● Tree Removal

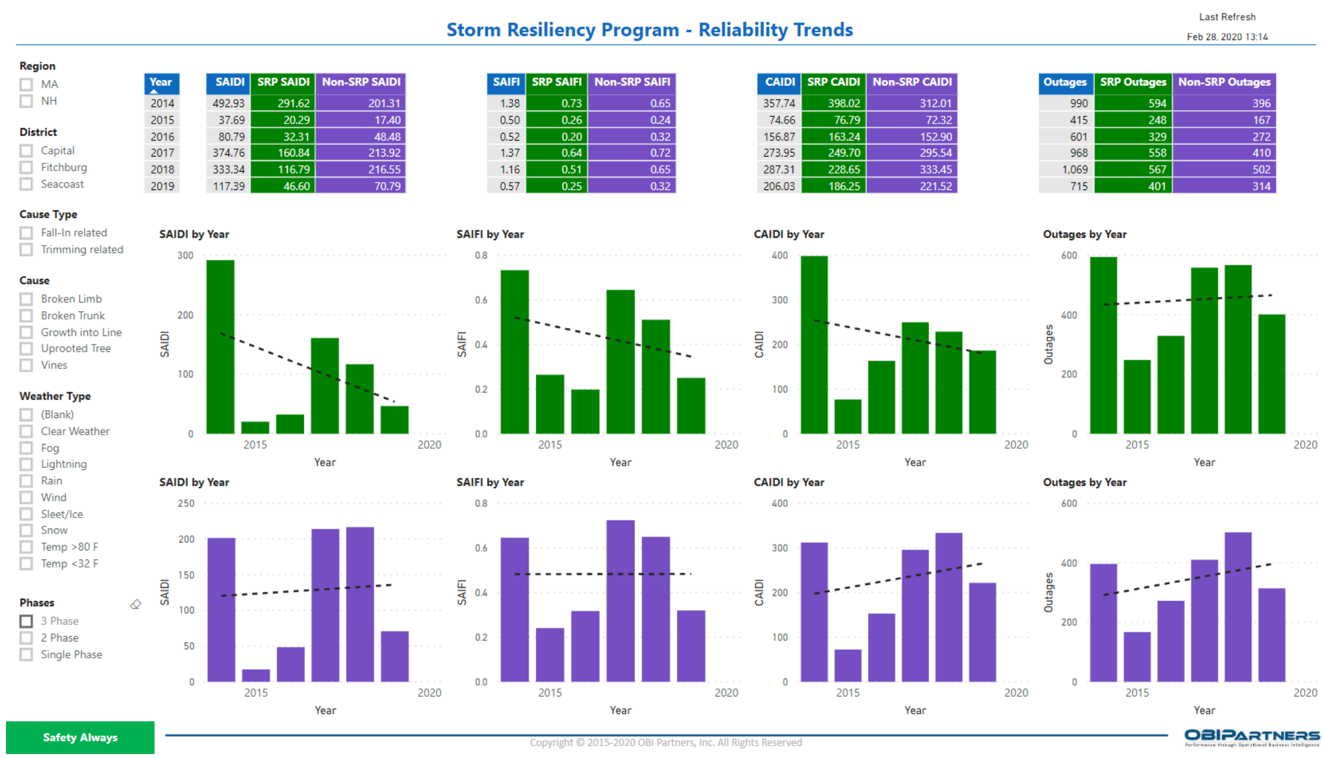
Locations

Location Type	Units	Location	Address	Pole Use	Comments
Related Fault Location	1	118-0008-0-00-00-03	S Harbor Rd, Townsend	Distribution	
Tree Removal	1	Pine	, MA		
Tree Removal	20	Pine	0 S Harbor Rd, Townsend MA		
Tree Removal	1	Pinw	0 S Harbor Rd, Townsend MA		
Total	**23**				

Figure 6 - Outage related to Tree Removals

2.5 Calculating SAIDI and CAIDI for the Storm Resiliency Program

SAIDI, SAIFI and CAIDI were calculated for the total SRP circuits and presented in Figure 7 and compared to pre- and post- SRP work. Additional metrics were defined and calculated to arrive at a circuit performance metric and projected reliability improvement. As illustrated in Figure 7, there is a clear improvement across the board for SRP completed circuits as compared to the circuits previous performance that positively affected the entire electrical network.

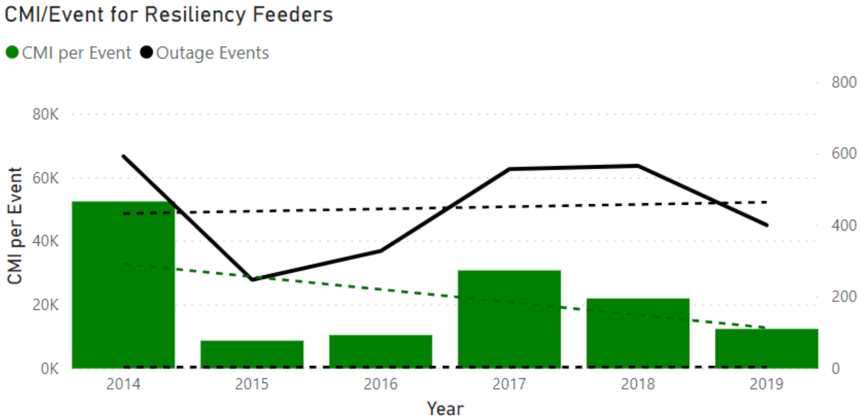


Year	SAIDI	SRP SAIDI	Non-SRP SAIDI	SAIFI	SRP SAIFI	Non-SRP SAIFI	CAIDI	SRP CAIDI	Non-SRP CAIDI	Outages	SRP Outages	Non-SRP Outages
2014	492.93	291.62	201.31	1.38	0.73	0.65	357.74	398.02	312.01	990	594	396
2015	37.69	20.29	17.40	0.50	0.26	0.24	74.66	76.79	72.32	415	248	167
2016	80.79	32.31	48.48	0.52	0.20	0.32	156.87	163.24	152.90	601	329	272
2017	374.76	160.84	213.92	1.37	0.64	0.72	273.95	249.70	295.54	968	558	410
2018	333.34	116.79	216.55	1.16	0.51	0.65	287.31	228.65	333.45	1,069	567	502
2019	117.39	46.60	70.79	0.57	0.25	0.32	206.03	186.25	221.52	715	401	314

Figure 7 - SAIDI, SAIFI, CAIDI for SRP and Non-SRP circuits

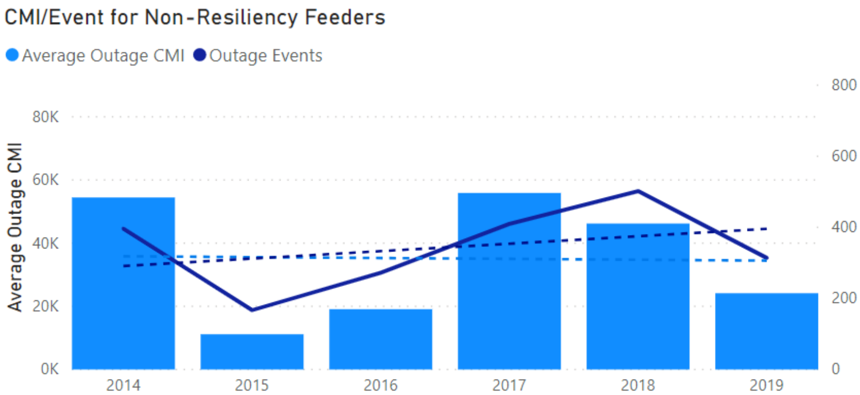
2.6 Additional Metrics used to determine SRP Performance

In addition to SAIDI, SAIFI and CAIDI, additional metrics were defined to get a further view of the results and impact of the SRP program. A Normalized CMI or CMI/Event analysis was performed to provide insight in the reduction of large main line events that may have hid multiple events occurring on laterals and services. From the charts below, SRP circuits had far lower CMI per event ratios than non-SRP circuits.



Resiliency Feeders

Year	CMI per Event	Events
2014	52,585	594
2015	8,765	248
2016	10,519	329
2017	30,873	558
2018	22,062	567
2019	12,447	401
Total	**26,547**	**2,697**



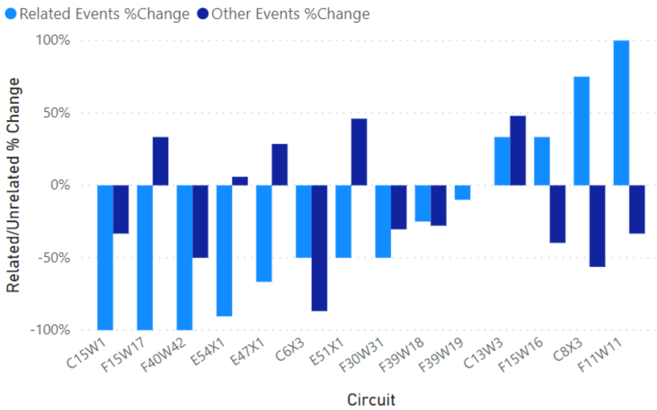
Non-Resiliency Feeders

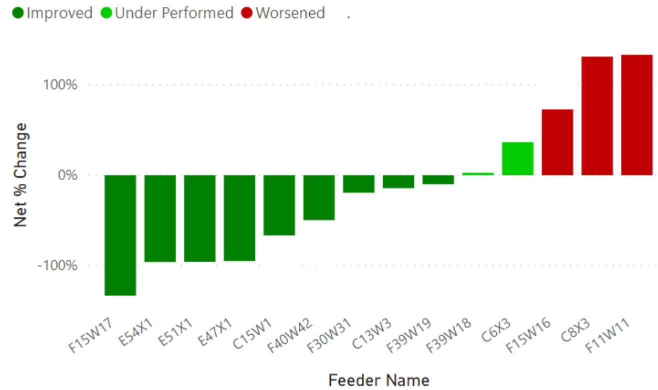
Year	CMI per Event	Events
2014	54,452	396
2015	11,159	167
2016	19,092	272
2017	55,886	410
2018	46,204	502
2019	24,147	314
Total	**39,937**	**2,061**

Figure 8 - Normalized CMI/Event Performance

Another metric designed to establish a performance rating and scale for each SRP circuit was based on the reduction of Events/Year and CMI/Year for those SRP circuits. Since the SRP program should result in fewer vegetation contacts, the outage event count should substantially decrease where work was performed, and associate CMI should also decrease.

Figure 9 shows the results of that analysis, illustrating which circuits had substantial reductions in outage events and associated CMI and which did not.





Circuit	Related Events Per Year Prior	Related Events Per Year Post	Related Events %Change	Related Events Change	Unrelated Events Per Year Prior	Unrelated Events Per Year Post	Unrealated Events %Change	Unrelated Events Change	Related Unrelated Net %Change	Related Unrelated Net Change	Related CMI Per Year Prior	Related CMI Per Year Post	Annual CMI Savings Simple	Annual CMI Savings Related	Annual CMI Savings Net	Annual CMI Savings Related %	Years Prior
F15W17	1.25	0.00	100.00 %	Decrease	2	2.00	33.33 %	Increase	-133.33 %	Improved	17,689	0	17,689	17,689	23,585	100.00 %	4
E54X1	3.50	0.33	90.48 %	Decrease	9	9.00	5.88 %	Increase	-96.36 %	Improved	176,551	1,851	174,700	159,737	170,122	90.48 %	2
E51X1	4.00	2.00	50.00 %	Decrease	11	15.33	46.03 %	Increase	-96.03 %	Improved	178,638	255,230	-76,592	89,319	171,549	50.00 %	2
E47X1	3.00	1.00	66.67 %	Decrease	7	9.00	28.57 %	Increase	-95.24 %	Improved	34,979	11,744	23,235	23,319	33,313	66.67 %	2
C15W1	1.00	0.00	100.00 %	Decrease	11	7.00	33.33 %	Decrease	-66.67 %	Improved	90,859	0	90,859	90,859	60,573	100.00 %	4
F40W42	0.50	0.00	100.00 %	Decrease	2	1.00	50.00 %	Decrease	-50.00 %	Improved	38,677	0	38,677	38,677	19,339	100.00 %	2
F30W31	4.00	2.00	50.00 %	Decrease	28	19.50	30.36 %	Decrease	-19.64 %	Improved	191,749	71,898	119,851	95,874	37,665	50.00 %	1
C13W3	5.25	7.00	33.33 %	Increase	37	54.00	47.95 %	Increase	-14.61 %	Improved	219,953	293,602	-73,649	0	0	0.00 %	4
F39W19	1.67	1.50	10.00 %	Decrease	28	28.00	0.00 %	Unchanged	-10.00 %	Improved	102,072	16,554	85,518	10,207	10,207	10.00 %	3
F39W18	0.67	0.50	25.00 %	Decrease	26	19.00	27.85 %	Decrease	2.85 %	Under Performed	663	82,495	-81,832	166	19	25.04 %	3
C6X3	1.00	0.50	50.00 %	Decrease	19	2.50	86.84 %	Decrease	36.84 %	Under Performed	82,496	35,741	46,755	41,248	30,393	50.00 %	1
F15W16	0.75	1.00	33.33 %	Increase	18	11.00	39.73 %	Decrease	73.06 %	Worsened	35,227	6,140	29,087	0	0	0.00 %	4
Total											1,197,949	933,398	264,551	567,095	556,765	47.34 %	

Figure 9 - Circuit Performance Relative to SRP

By calculating the percent change for the events and related normalized CMI a reasonable avoided annual CMI, or Annual CMI Savings, for each circuit was calculated.

Circuit	Related Events %Change	Related Events Change	Annual CMI Savings Related	Annual CMI Savings Related %	Years Prior	Years Post	LDT CMI Savings Related
F15W17	100.00 %	Decrease	17,689	100.00 %	4	1	17,689
E54X1	90.48 %	Decrease	159,737	90.48 %	2	3	479,211
E51X1	50.00 %	Decrease	89,319	50.00 %	2	3	267,957
E47X1	66.67 %	Decrease	23,319	66.67 %	2	3	69,957
C15W1	100.00 %	Decrease	90,859	100.00 %	4	1	90,859
F40W42	100.00 %	Decrease	38,677	100.00 %	2	3	116,031
F30W31	50.00 %	Decrease	95,874	50.00 %	1	4	383,496
C13W3	33.33 %	Increase	0	0.00 %	4	1	0
F39W19	10.00 %	Decrease	10,207	10.00 %	3	2	20,414
F39W18	25.00 %	Decrease	166	25.04 %	3	2	332
C6X3	50.00 %	Decrease	41,248	50.00 %	1	4	164,992
F15W16	33.33 %	Increase	0	0.00 %	4	1	0
Total			567,095	47.34 %			1,610,938

Figure 10 - Circuit Performance - Annual CMI Savings

The results for 14 SRP circuits, which had associated outage data for one year prior, and one-year post work completion produced a combined 47 percent annual CMI savings. Those 14 circuits had an average of 2.5 years of data pre- and post-work completion with one to four years minimum and maximum. The annual CMI savings were calculated to be ~567K CMI, with total CMI savings post work completion being ~1.6M customer minutes of interruption (from Figure 10 above).

This annual CMI saving of (~1.6M) along with a cost per CMI analysis was used to calculate a reasonable internal savings in dollars as well as external savings to Unitil's customers from avoided revenue losses based on the Interruption Cost Estimate (ICE) calculator, developed by Lawrence Berkeley National Laboratory and Nexant, and funded by the Department of Energy.

To arrive at a Cost/CMI, the costs associated with individual storms was used to calculate a reasonable cost per CMI value. The Cost/CMI utilized individual cost for each storm event as identified by Unitil. Multiple methods were used due to the wide range of values associated with each storm event (4¢ to $2k per CMI). Methods considered included simple outlier exclusion, averages by storm category, regional averages, and trends over time. The metric deemed most reasonable to calculate a Cost/CMI was the average of the mid-quartile Cost/CMI (see Table 1).

Table 1: Unitil Storm Cost/CMI Example Utilizing 2nd and 3rd Quartile Storm Info.

Storm Name	Region	Level	Outage Events	CMI	Storm Cost	Cost/CMI	Quartile	Storm CMI	Cost
Thunderstorm Event (November 3rd, 2018)	MA	Mod	28	506,187	$48,868	$0.10	2	506,187	$48,868
Thunderstorm Event (September 6th, 2014)	MA	Mod	18	427,646	$55,596	$0.13	2	427,646	$55,596
Snow Event (March 31st, 2017)	NH	Mod	61	1,419,671	$197,931	$0.14	2	1,419,671	$197,931
Thunderstorm Event (May 4th, 2018)	NH	Min	39	1,575,462	$228,761	$0.15	2	1,575,462	$228,761
Wind Event (October 30th, 2017)	MA	Min	24	213,942	$31,152	$0.15	2	213,942	$31,152
Thanksgiving Storm Cato (November 26th, 2014)	MA	Mod	53	1,373,149	$289,768	$0.21	2	1,373,149	$289,768
T-Storm/Microburst (July 18th, 2016)	NH	Min	14	1,124,745	$243,879	$0.22	2	1,124,745	$243,879
Winter Storm Grayson (January 4th, 2018)	NH	Min	19	366,659	$147,046	$0.40	2	366,659	$147,046
Winter Storm Riley (March 2nd, 2018)	NH	Min	26	334,469	$153,712	$0.46	2	334,469	$153,712
Winter Storm Skylar (March 13th, 2018)	NH	Nor	12	64,641	$31,722	$0.49	2	64,641	$31,722
Winter Storm Grayson (January 4th, 2018)	MA	Min	8	44,471	$25,607	$0.58	2	44,471	$25,607
Thunderstorm Event (November 3rd, 2018)	NH	Nor	17	54,495	$41,257	$0.76	2	54,495	$41,257
Snow Event (February 13th, 2014)	NH	Min	6	208,511	$159,605	$0.77	2	208,511	$159,605
Wet Snow (February 15th, 2017)	NH	Nor	1	82,569	$63,630	$0.77	3	82,569	$63,630
Winter Storm (February 12th, 2017)	NH	Nor	1	30,008	$24,780	$0.83	3	30,008	$24,780
Snow Storm (December 26th, 2016)	MA	Nor	11	27,418	$27,432	$1.00	3	27,418	$27,432
Noreaster (December 29th, 2016)	NH	Min	14	185,991	$211,166	$1.14	3	185,991	$211,166
Wind Event (February 15th, 2015)	NH	Min	11	211,209	$285,854	$1.35	3	211,209	$285,854
Winter Storm Riley (March 2nd, 2018)	MA	Min	14	64,985	$118,973	$1.83	3	64,985	$118,973
Thunderstorm (July 30th, 2015)	MA	Nor	3	7,410	$19,924	$2.69	3	7,410	$19,924
Thunderstorm Event (July 17th, 2018)	NH	Nor	5	27,210	$85,017	$3.12	3	27,210	$85,017
Wind Event (March 29th, 2016)	NH	Nor	7	29,144	$93,209	$3.20	3	29,144	$93,209
T-Storm Event (June 19th, 2017)	NH	Nor	5	10,818	$35,958	$3.32	3	10,818	$35,958
Wind Storm (February 25th, 2019)	NH	Min	2	84,895	$303,387	$3.57	3	84,895	$303,387
Wind Event (March 12th, 2014)	NH	Nor	6	9,943	$36,670	$3.69	3	9,943	$36,670
							Total	**8,485,648**	**$2,960,904**
								$Cost/CMI	**$0.35**

Eliminating the upper- and lower-25 percent values produced 35¢ per CMI for an internal savings of ~$563K (~1.6M CMI x 35¢ = ~$563K) and external savings of ~$4M for those 14 circuits. ECI believes the savings will be similar in magnitude for the remaining SRP circuits were adequate data was not provided, or those circuits a currently in the process of being worked, yielding two to three times these savings.

2.7 Benefit Analysis

ECI reviewed the analysis results produced to support a cost benefit analysis and recommendations.

2.7.1 Overall SRP Benefits

ECI reviewed the vegetation management programs for both Unitil-New Hampshire and Unitil-FG&E in 2010. ECI found that tree density in both operational areas to be in the upper quartile of tree densities (New Hampshire-154 trees per mile and FG&E-137 trees per mile) when compared to other utilities throughout the United States (avg. 96 trees per mile). Beginning in 2012, Unitil began a focused Storm Resiliency Program (SRP) to address tree-caused outages. At the core of this program, Unitil began to address overhang removal and additional brush/tree removal on critical line sections impacting the largest portion of their customer base.

Trees overhanging the conductors have been shown to increase customer outages during major ice storm events (Guggenmoos, 2007). As such many utilities in ice prone areas have adopted processes to remove overhanging limbs on priority lines. Priority lines are generally defined as those line sections that if they were to fail, will impact all the customers on that circuit (e.g. feeder backbone) or those line sections deemed to feed critical customers (e.g. industrial, commercial, police, fire, etc.).

The data analysis was used to validate the improvement trends between SRP and non-SRP circuits utilizing the Unitil tree-outage data between 2014 and 2019. Total tree-related outages trends for all weather events and storm only were reviewed for all phases and for three-phase only. The results are presented here in Figure 11 through Figure 16.

The six trend graphs show a clear improvement trend in SRP circuit performance for SAIDI, SAIFI, and CAIDI as compared to the non-SRP circuit performance. The increase seen in Outages by Year for all phases are due to increases in tree-caused outages (including increased weather-related events) on the single-phase portion of the circuits that were not maintained as part of the SRP program. The largest improvements in SRP circuit performance can be seen in the graphs for three-phase only performance (Figure 12) particularly during storm events (Figure 14).

Last Refresh
Mar 10, 2020 09:49

Storm Resiliency Program - Reliability Trends

Region
- MA
- NH

District
- Capital
- Fitchburg
- Seacoast

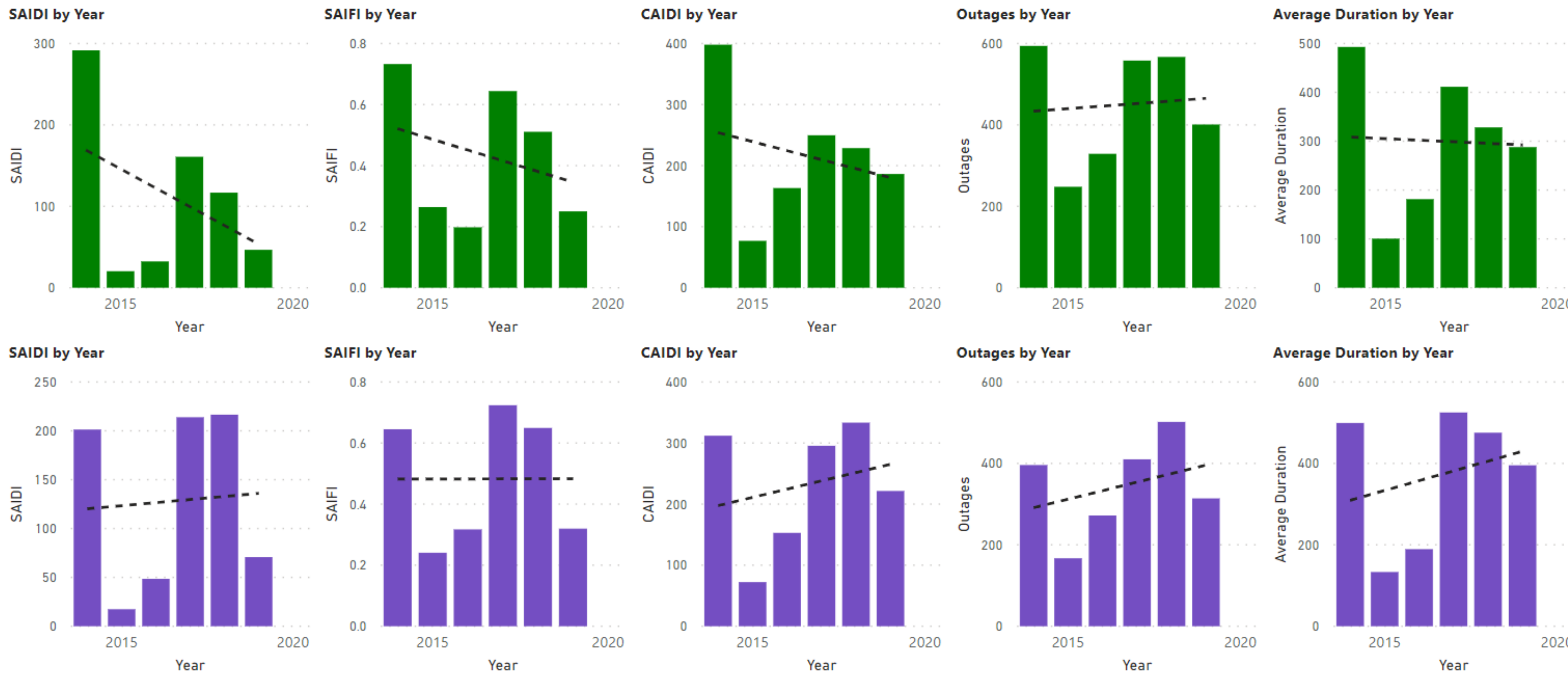
Cause Type
- Fall-In related
- Trimming related

Cause
- Broken Limb
- Broken Trunk
- Growth into Line
- Uprooted Tree
- Vines

Weather Type
- (Blank)
- Clear Weather
- Fog
- Lightning
- Rain
- Wind
- Sleet/Ice
- Snow
- Temp >80 F
- Temp <32 F

Phases
- 3 Phase
- 2 Phase
- Single Phase

Year	SAIDI	SRP SAIDI	Non-SRP SAIDI	SAIFI	SRP SAIFI	Non-SRP SAIFI	CAIDI	SRP CAIDI	Non-SRP CAIDI	Outages	SRP Outages	Non-SRP Outages	SRP Average Duration	Non-SRP Average Duration
2014	492.93	291.62	201.31	1.38	0.73	0.65	357.74	398.02	312.01	990	594	396	493	499
2015	37.69	20.29	17.40	0.50	0.26	0.24	74.66	76.79	72.32	415	248	167	101	133
2016	80.79	32.31	48.48	0.52	0.20	0.32	156.87	163.24	152.90	601	329	272	181	189
2017	374.76	160.84	213.92	1.37	0.64	0.72	273.95	249.70	295.54	968	558	410	411	525
2018	333.34	116.79	216.55	1.16	0.51	0.65	287.31	228.65	333.45	1,069	567	502	328	475
2019	117.39	46.60	70.79	0.57	0.25	0.32	206.03	186.25	221.52	715	401	314	288	395

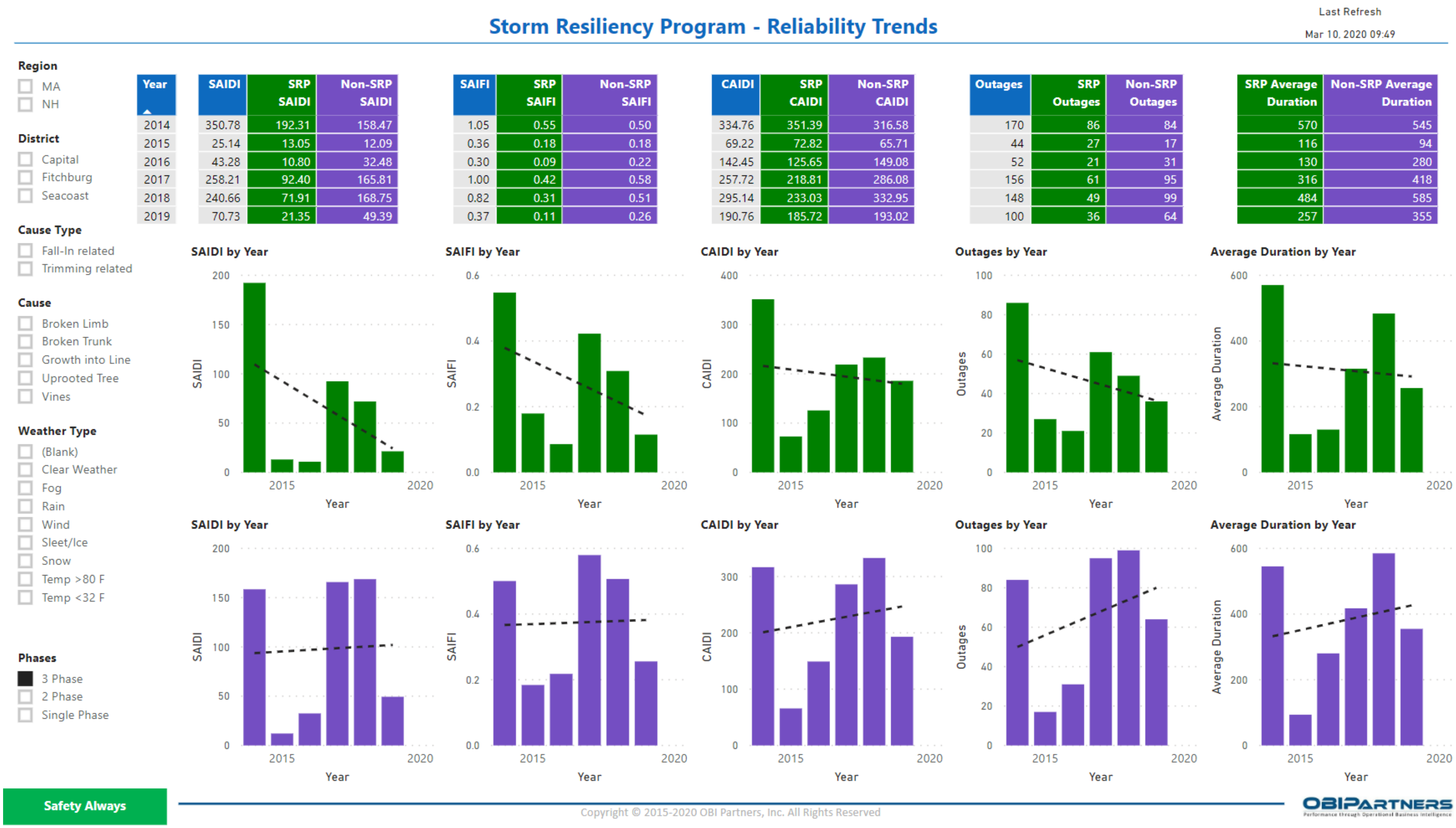


Safety Always

OBIPARTNERS

Figure 11 - SRP vs. Non-SRP Circuit Performance for All Phases and All Weather Events

The figure above shows that when considering all outages, the SRP circuits outperformed the Non-SRP circuits based on all indices.



Year	SAIDI	SRP SAIDI	Non-SRP SAIDI	SAIFI	SRP SAIFI	Non-SRP SAIFI	CAIDI	SRP CAIDI	Non-SRP CAIDI	Outages	SRP Outages	Non-SRP Outages	SRP Average Duration	Non-SRP Average Duration
2014	350.78	192.31	158.47	1.05	0.55	0.50	334.76	351.39	316.58	170	86	84	570	545
2015	25.14	13.05	12.09	0.36	0.18	0.18	69.22	72.82	65.71	44	27	17	116	94
2016	43.28	10.80	32.48	0.30	0.09	0.22	142.45	125.65	149.08	52	21	31	130	280
2017	258.21	92.40	165.81	1.00	0.42	0.58	257.72	218.81	286.08	156	61	95	316	418
2018	240.66	71.91	168.75	0.82	0.31	0.51	295.14	233.03	332.95	148	49	99	484	585
2019	70.73	21.35	49.39	0.37	0.11	0.26	190.76	185.72	193.02	100	36	64	257	355

Figure 12 - SRP vs. Non-SRP Circuit Performance for Three-Phase Only and All Weather Events

The figure above shows that when considering three-phase outages, the SRP circuits also outperformed the Non-SRP circuits based on all indices.

Storm Resiliency Program - Reliability Trends

Last Refresh
Mar 10, 2020 09:49

Region
- [ ] MA
- [ ] NH

District
- [ ] Capital
- [ ] Fitchburg
- [ ] Seacoast

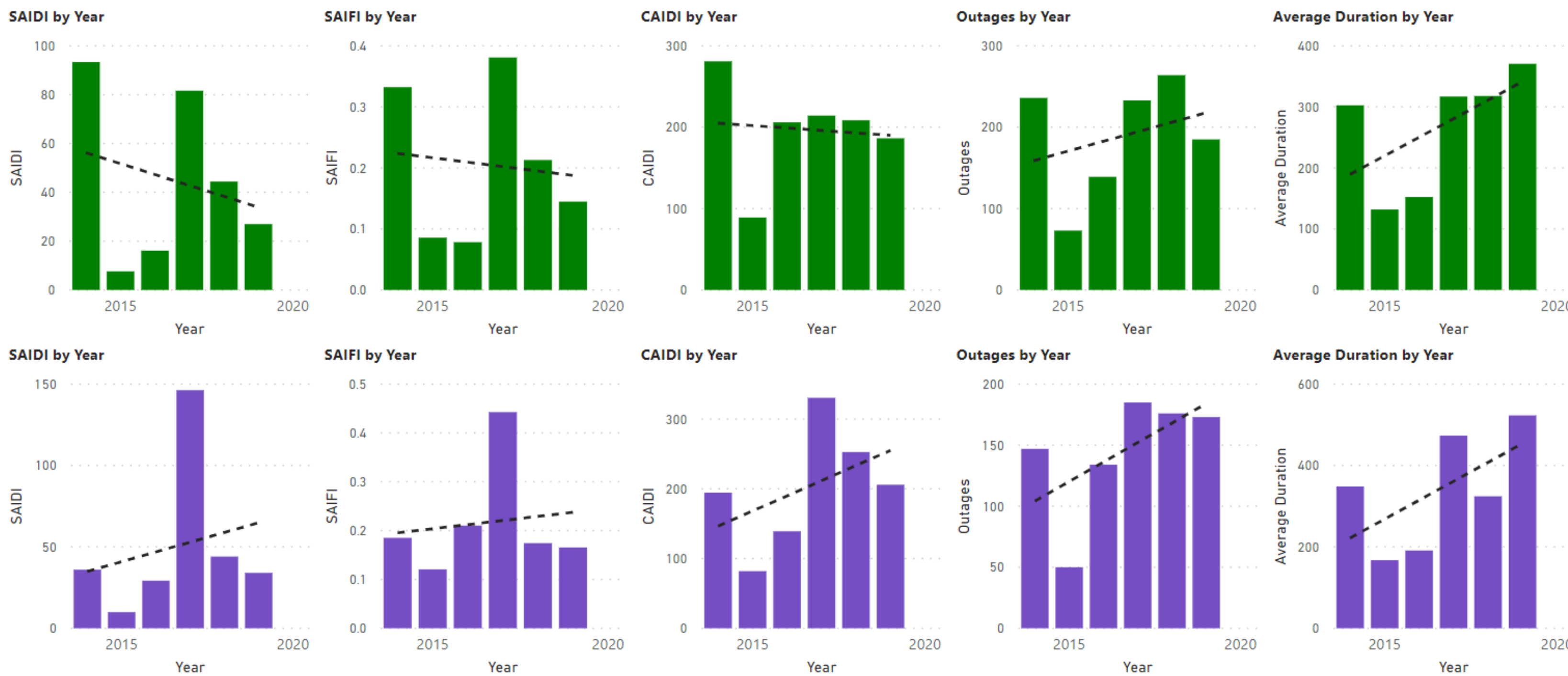
Cause Type
- [ ] Fall-In related
- [ ] Trimming related

Cause
- [ ] Broken Limb
- [ ] Broken Trunk
- [ ] Growth into Line
- [ ] Uprooted Tree
- [ ] Vines

Weather Type
- [ ] (Blank)
- [ ] Clear Weather
- [ ] Fog
- [ ] Lightning
- [ ] Rain
- [x] Wind
- [x] Sleet/Ice
- [x] Snow
- [ ] Temp >80 F
- [ ] Temp <32 F

Phases
- [ ] 3 Phase
- [ ] 2 Phase
- [ ] Single Phase

Year	SAIDI	SRP SAIDI	Non-SRP SAIDI	SAIFI	SRP SAIFI	Non-SRP SAIFI	CAIDI	SRP CAIDI	Non-SRP CAIDI	Outages	SRP Outages	Non-SRP Outages	SRP Average Duration	Non-SRP Average Duration
2014	129.39	93.39	36.00	0.52	0.33	0.19	250.01	280.98	194.42	383	236	147	303	349
2015	17.50	7.62	9.88	0.21	0.09	0.12	84.83	88.98	81.88	123	73	50	132	167
2016	45.35	16.12	29.23	0.29	0.08	0.21	157.22	206.01	139.07	273	139	134	152	191
2017	227.90	81.61	146.29	0.82	0.38	0.44	276.72	214.27	330.45	418	233	185	317	474
2018	88.47	44.42	44.05	0.39	0.21	0.17	228.41	208.57	252.63	440	264	176	318	324
2019	61.01	26.98	34.03	0.31	0.14	0.17	196.73	186.42	205.76	358	185	173	371	523

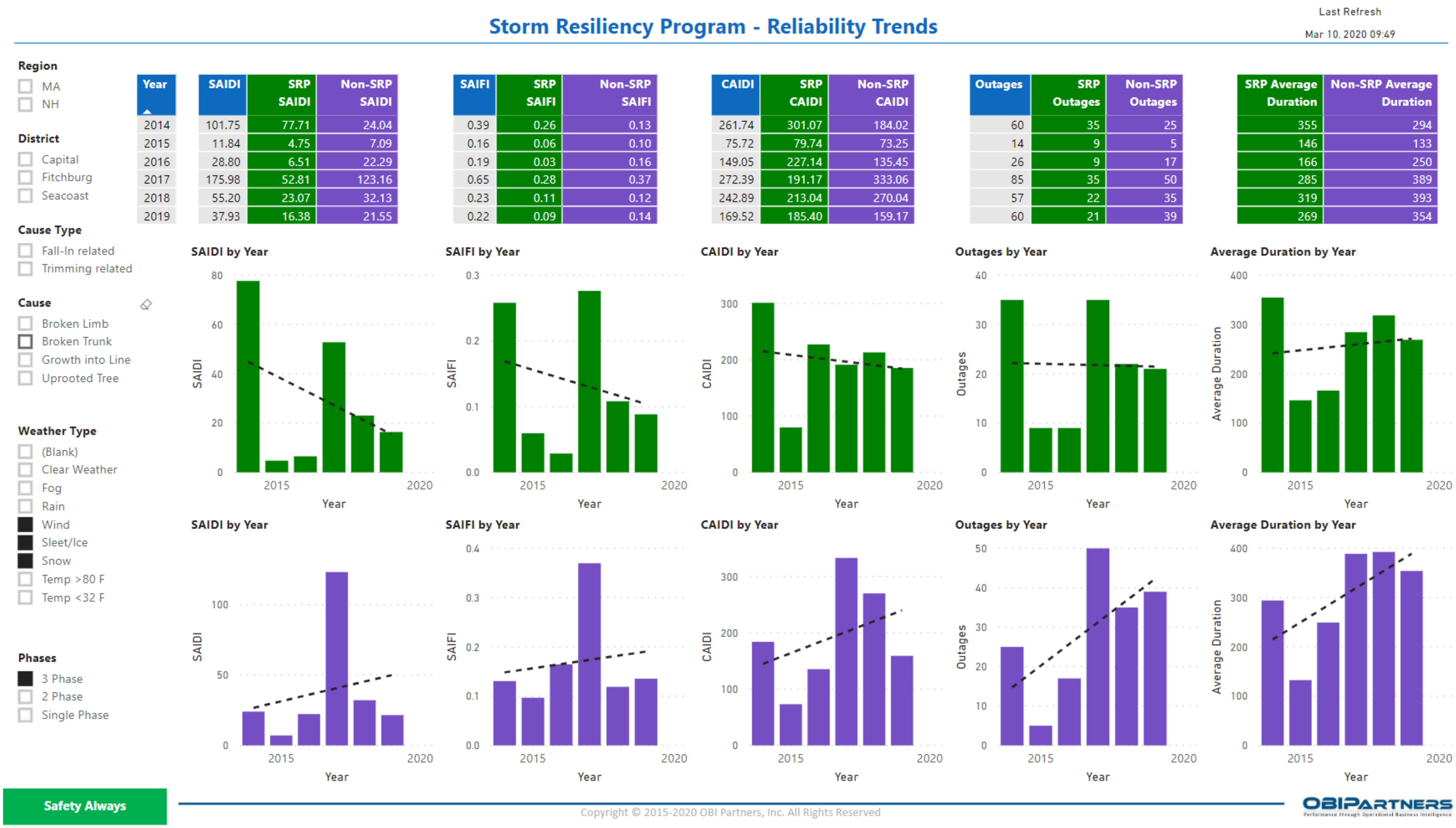


Safety Always

OBIPARTNERS
Performance through Operational Business Intelligence

Figure 13 - SRP vs. Non-SRP Circuit Performance for All Phases and Storm Only Events

The figure above shows that when considering all outages under storm conditions, the SRP circuits outperformed the Non-SRP circuits based on all indices.



Year	SAIDI	SRP SAIDI	Non-SRP SAIDI
2014	101.75	77.71	24.04
2015	11.84	4.75	7.09
2016	28.80	6.51	22.29
2017	175.98	52.81	123.16
2018	55.20	23.07	32.13
2019	37.93	16.38	21.55

SAIFI	SRP SAIFI	Non-SRP SAIFI
0.39	0.26	0.13
0.16	0.06	0.10
0.19	0.03	0.16
0.65	0.28	0.37
0.23	0.11	0.12
0.22	0.09	0.14

CAIDI	SRP CAIDI	Non-SRP CAIDI
261.74	301.07	184.02
75.72	79.74	73.25
149.05	227.14	135.45
272.39	191.17	333.06
242.89	213.04	270.04
169.52	185.40	159.17

Outages	SRP Outages	Non-SRP Outages
60	35	25
14	9	5
26	9	17
85	35	50
57	22	35
60	21	39

SRP Average Duration	Non-SRP Average Duration
355	294
146	133
166	250
285	389
319	393
269	354

Figure 14 - SRP vs. Non-SRP Circuit Performance for Three-Phase Only and Storm Only Events

The figure above shows that when considering three-phase outages under storm conditions, the SRP circuits <u>substantially</u> outperformed the Non-SRP circuits based on all indices.

Storm Resiliency Program - Reliability Trends

Last Refresh
Mar 10, 2020 09:49

Region
- MA
- NH

District
- Capital
- Fitchburg
- Seacoast

Cause Type
- Fall-In related
- Trimming related

Cause
- Broken Limb
- Broken Trunk
- Growth into Line
- Uprooted Tree
- Vines

Weather Type
- (Blank)
- Clear Weather
- Fog
- Lightning
- Rain
- Wind
- Sleet/Ice
- Snow
- Temp >80 F
- Temp <32 F

Phases
- 3 Phase
- 2 Phase
- Single Phase

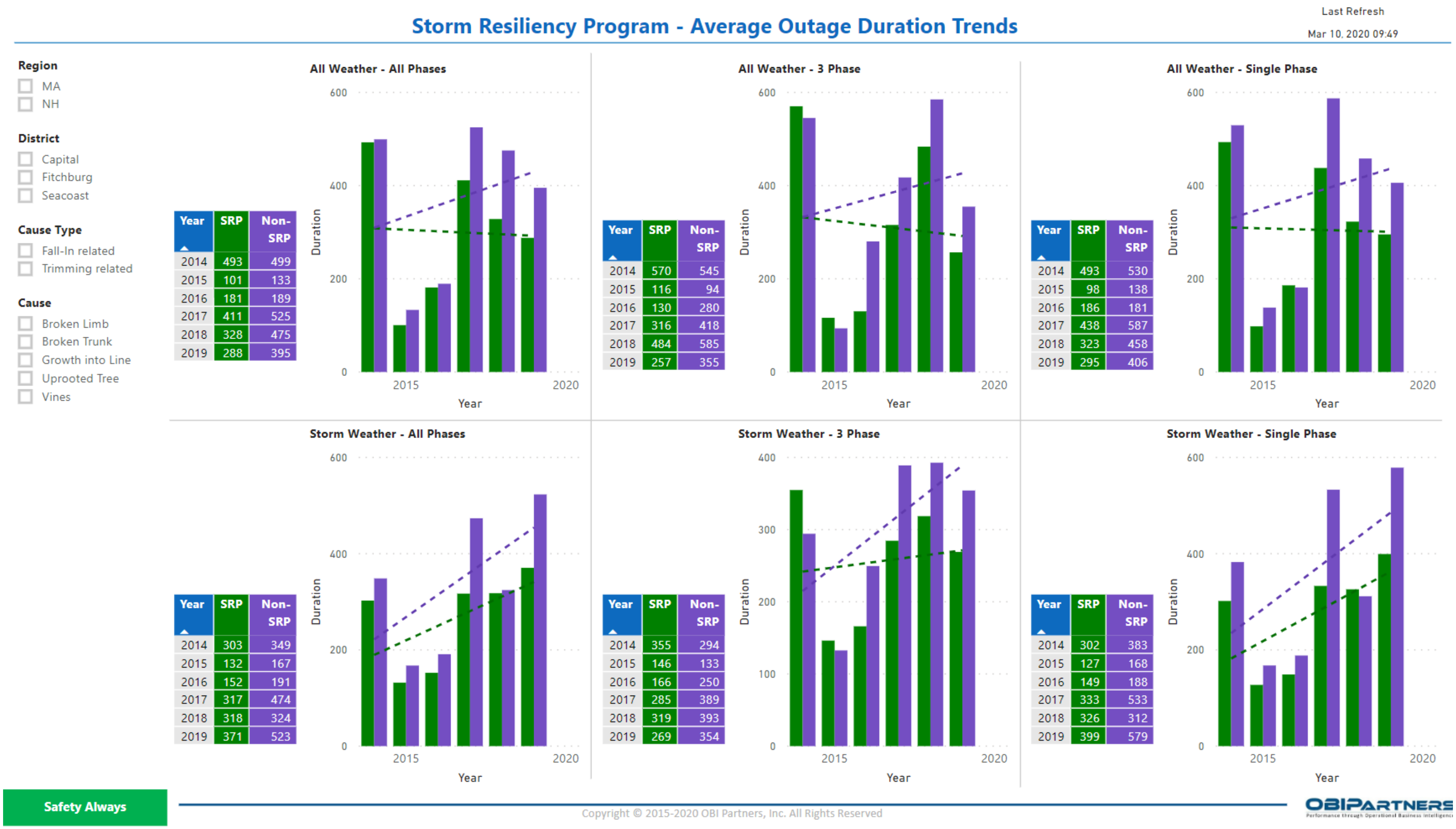
Year	SAIDI	SRP SAIDI	Non-SRP SAIDI	SAIFI	SRP SAIFI	Non-SRP SAIFI	CAIDI	SRP CAIDI	Non-SRP CAIDI	Outages	SRP Outages	Non-SRP Outages	SRP Average Duration	Non-SRP Average Duration
2014	20.58	11.18	9.40	0.09	0.05	0.03	236.61	213.07	272.38	296	187	109	302	383
2015	2.36	1.51	0.85	0.02	0.01	0.01	109.13	110.15	107.37	91	54	37	127	168
2016	11.15	6.91	4.24	0.06	0.04	0.03	175.71	184.33	163.28	223	121	102	149	188
2017	32.26	22.09	10.18	0.10	0.07	0.03	335.47	313.90	394.27	290	180	110	333	533
2018	26.45	17.99	8.45	0.11	0.08	0.03	230.55	221.23	253.23	360	231	129	326	312
2019	16.67	9.20	7.47	0.06	0.04	0.02	257.52	213.68	344.61	280	154	126	399	579

Safety Always

OBIPARTNERS
Performance through Operational Business Intelligence

Figure 15 - SRP vs. Non-SRP Circuit Performance for Single-Phase Only and Storm Only Events

The figure above shows that when considering single phase outages under storm conditions, the SRP circuits tracked along the Non-SRP circuits as would be expected since they did not receive any enhanced trimming. Additionally, the increase in the Outage count for the SRP circuits that are in contrast to the reduction in outages for the three-phase SRP circuits from the prior figure, are likely due to previously unaccounted nested outages on laterals and services.



All Weather - All Phases

Year	SRP	Non-SRP
2014	493	499
2015	101	133
2016	181	189
2017	411	525
2018	328	475
2019	288	395

All Weather - 3 Phase

Year	SRP	Non-SRP
2014	570	545
2015	116	94
2016	130	280
2017	316	418
2018	484	585
2019	257	355

All Weather - Single Phase

Year	SRP	Non-SRP
2014	493	530
2015	98	138
2016	186	181
2017	438	587
2018	323	458
2019	295	406

Storm Weather - All Phases

Year	SRP	Non-SRP
2014	303	349
2015	132	167
2016	152	191
2017	317	474
2018	318	324
2019	371	523

Storm Weather - 3 Phase

Year	SRP	Non-SRP
2014	355	294
2015	146	133
2016	166	250
2017	285	389
2018	319	393
2019	269	354

Storm Weather - Single Phase

Year	SRP	Non-SRP
2014	302	383
2015	127	168
2016	149	188
2017	333	533
2018	326	312
2019	399	579

Figure 16 – SRP vs. Non-SRP Average Outage Duration Comparisons

The figure above shows a comparison of Average Outage Durations for SRP and Non-SRP circuits related to various weather conditions and phases. The Average Outage Duration under all circumstances is lower for SRP circuits than Non-SRP circuits, with three-phase outages in storm conditions showing a significant difference in both the trend and average duration minutes. Additionally, the significant SRP based improvement is also validated by comparing storm condition three-phase against single-phase duration trends and duration minutes.

2.7.2 Cost/Benefit Analysis

Utilizing the estimated annual CMI avoided estimate of 567,095 (from Figure 10) for the 14 circuits studied, it can be roughly estimated that the cumulative CMI avoided for the 31 New Hampshire SRP circuits completed to date as well as the 11 Massachusetts completed SRP circuits totaled approximately 1.7M per year. It can therefore be assumed that the additional 22 remaining SRP circuits will produce an additional 891K CMI avoided per year or a total of 2.9M CMI avoided per year for all 74 planned SRP circuits going forward.

Utilization of cost per CMI of 35¢, which represents the mid-quartile cost per storm CMI for both New Hampshire and Massachusetts, is estimated to be a conservative estimate of what Unitil may expect. The total direct (internal) cost avoided to Unitil is estimated to be approximately $1.02M per year (35¢ per CMI x 2.9M CMI avoided) for all 74 planned SRP circuits once complete.

Total SRP spend for the 42 circuits completed through 2019 totals $13.44M or approximately $39,308.85 per mile complete. It is estimated that the completion of all 74 planned SRP circuits will cost approximately $18.76M total or $1.88M per year assuming a total 10-year completion timeframe. It is obvious that the internal cost avoided alone falls short of justifying the SRP program expenditures. However, when considering the total cost avoided, it is important to include external costs. External cost avoidance includes items such as lost revenue, customer dissatisfaction, lost production hours to business and industry and other societal costs.

Using the annual SAIDI, SAIFI and CAIDI savings (Figure 17) with the Interruption Cost Estimate (ICE) calculator, the following **external** savings results for New Hampshire was estimated:

Circuit	Related Events Per Year Prior	Related Events Per Year Post	Related Events %Change	Related Events Change	CMI Per Year Prior	Annual CMI Savings %	Related CI	Annual CMI Savings	Annual SAIDI Savings	Annual SAIFI Savings	Annual CAIDI Savings
C6X3	1.00	0.50	50.00 %	Decrease	82,496	50.00 %	2,251.00	41,248	0.28	0.0038	27.71
C8X3	1.00	1.75	75.00 %	Increase	9,325	0.00 %	4,131.00	0	0.00	0.0000	0.00
E47X1	3.00	1.00	66.67 %	Decrease	34,979	66.67 %	1,219.00	23,319	0.31	0.0043	34.85
E51X1	4.00	2.00	50.00 %	Decrease	178,638	50.00 %	7,791.00	89,319	1.60	0.0235	32.77
E54X1	3.50	0.33	90.48 %	Decrease	176,551	90.48 %	2,049.00	159,737	1.59	0.0089	85.53
F11W11	0.50	1.00	100.00 %	Increase	19,071	0.00 %	1,099.00	0	0.00	0.0000	0.00
F15W16	0.75	1.00	33.33 %	Increase	35,227	0.00 %	2,739.00	0	0.00	0.0000	0.00
F15W17	1.25	0.00	100.00 %	Decrease	17,689	100.00 %	709.00	17,689	0.22	0.0022	33.26
F30W31	4.00	2.00	50.00 %	Decrease	191,749	50.00 %	5,823.00	95,874	0.35	0.0080	8.66
F39W18	0.67	0.50	25.00 %	Decrease	663	25.04 %	1,342.00	166	0.00	0.0000	0.29
F39W19	1.67	1.50	10.00 %	Decrease	102,072	10.00 %	3,353.00	10,207	0.10	0.0009	3.36
F40W42	0.50	0.00	100.00 %	Decrease	38,677	100.00 %	739.00	38,677	0.18	0.0017	26.17
Total					1,197,949	47.34 %	46,429.00	567,095	5.20	0.0588	269.79

Figure 17 - Circuit Performance - Annual Reliability Savings

General inputs:	State = **New Hampshire**	Residential Customers = **90,000**	Non-Residential = **17,000**
Analysis Values:	Annual SAIFI Savings = **0.0588**	Annual SAIDI Savings = **5.20**	Annual CAIDI Savings = **269.79**

ICE data inputs and results:

Inputting SAIFI of **0.0588** and of SAIDI of **5.20**

Results in ICE calculated CAIDI of ***88.4*** and savings of ***$1.246M*** Total Annual External Savings

Inputting SAIFI of **0.0588** and CAIDI of **269.74**

Results in ICE calculated SAIDI of ***15.9*** and savings of ***$3.187M*** Total Annual External Savings

Inputting SAIDI of **5.20** and CAIDI of **269.74**

Results in ICE calculated SAIFI of ***0.019*** and savings of ***$1.030M*** Total Annual External Savings

SAIFI	SAIDI	CAIDI	#Residential	#Non-Residential
0.0588	5.2	88.4	90,000	17,000

New Hampshire

Interruption Cost Estimates

Sector	# of Customers	Cost Per Event (2016$)	Cost Per Average kW (2016$)	Cost Per Unserved kWh (2016$)	Total Cost (2016$)
Residential	90,000	$5.68	$6.64	$4.51	$30,081.66
Small C&I	16,564	$890.96	$308.49	$209.38	$867,762.20
Medium and Large C&I	436	$13,612.74	$75.24	$51.06	$348,987.20
All Customers	**107,000**	**$198.17**	**$104.06**	**$70.63**	**$1,246,831.06**

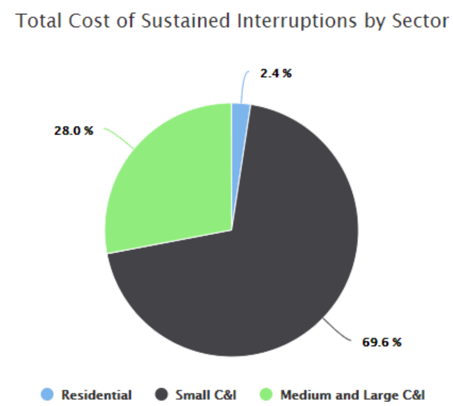


Figure 18 - ICE Calculator Result

Extrapolating calculations performed utilizing the ICE model, the **external** only cost avoided will yield between $5.44M and $16.85M per year for all 74 planned SRP circuits. The internal and external total cost avoided therefore, is estimated to be between $6.46M and $17.87M per year. Net cost avoided after funding the SRP program will yield between $4.58M and $15.99M per year.

3.0 SUMMARY

The benefits of a well-structured and targeted ground-to-sky maintenance program are well documented. As supported by the Unitil SRP analysis, it is estimated that Unitil will avoid approximately 2.9M CMI per year for the 74 SRP planned circuits and a net cost avoided (after fully funding the current SRP program) between $4.58M and $15.99M per year. ECI recommends that Unitil be allowed to continue their current SRP program with funding to continue that program into the future to help ensure the continued reduction in tree-related outages.

ECI believes Unitil could augment the Storm Resiliency Program and continue to reduce storm damage and impact on customers by utilizing a similar platform as established for this analysis to define best SRP circuit segment candidates using Outage Data, LiDAR data, additional GIS data and vegetation work data.

4.0 RECOMMENDATIONS

4.0 General Recommendations

The General Recommendations listed below are provided by ECI to support the findings of this report.

- Unitil should continue its current SRP program on the currently planned 74 circuits. The data analysis demonstrates an estimated 2.9M CMI avoided per year and a net internal/external cost avoided (after fully funding the SRP program) between $4.58M and $15.99M per year.
- Unitil should request additional future funding to continue the SRP program and complete the remaining 74 circuits not currently planned.
- Additional data that may be available for work performed in the early years of the SRP Program should be used to derive SRP locations from earlier periods to expand the current analysis.
- Utilize additional LiDAR data to support the identification of re-growth or worsening tree conditions, to begin developing future predictive models to provide outage probabilities and "hot spots".
- Utilize historic outage concentrations with facility data and LiDAR data to determine high impact and high ROI circuit segments to prioritize future SRP work locations.
- Perform weather analysis based on available weather station data across the Unitil system to develop correlation models between wind speed and tree damage.
- The **LiDAR** data provided valuable insight about vegetation conditions and was critical in correlating data from Outage Management and GIS to determine event cause. Continued usage of LiDAR and Imagery to inspect outage causes will help Unitil to refine their understanding of events and work more proactively to prevent outages.

5.0 LITERATURE CITED

1. Guggenmoos, S. (2007). Increased Risk of Electric Service Interruption Associated with Tree Branches Overhanging Conductors. Transmission & Distribution World, Penton Media, Inc., June 2007, New York, NY.
2. Interruption Cost Estimate (ICE) calculator, developed by Lawrence Berkeley National Laboratory and Nexant, and funded by the Department of Energy.

[THIS PAGE INTENTIONALLY LEFT BLANK]