



VEGETATION MANAGEMENT
STORM PROTECTION PROGRAM
ANALYTIC SUPPORT REPORT

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1 Executive Summary

In 2019, the Florida Legislature enacted a law stating that each investor-owned electric utility (utility) must file a Transmission and Distribution Storm Protection Plan (SPP) with the Florida Public Service Commission (“FPSC”).¹ The SPP must cover the utility’s immediate ten-year planning period. Each utility must file, for Commission approval, an updated Storm Protection Plan at least every three years.² The SPP must explain the systematic approach the utility will follow to achieve the objectives of reducing restoration costs and outage times associated with extreme weather events and enhancing reliability.³ The FPSC later promulgated a rule to implement the SPP filing requirement.⁴ This rule went into effect in February of 2020.

Since damage from wind-blown vegetation is a major cause of outages during extreme weather conditions, the rule requires utilities to provide, for each of the first three years of the SPP, a description of its proposed vegetation management activities including:

- A. The projected frequency (trim cycle);
- B. The projected miles of affected transmission and distribution overhead facilities;
- C. The estimated annual labor and equipment costs for both utility and contractor personnel; and
- D. A description of how the vegetation management activity will reduce outage times and restoration costs in extreme weather conditions.⁵

TECO is proposing a VM Storm Protection Program that includes three distribution vegetation management initiatives:⁶

1. Four-year distribution vegetation management cycle
2. Incremental initiative to augment annual distribution trimming by targeting supplemental miles each year:
 - a. 400 miles in 2020
 - b. 500 miles in 2021
 - c. 700 miles in 2022 and beyond
3. Consolidate the gains of the baseline distribution cycle trim and supplemental trimming by introducing mid-cycle distribution vegetation inspections two years beyond each trim to prescribe additional distribution VM activities to:
 - a. Ensure fast-growing species are kept in check until the next scheduled trimming.
 - b. Remove troublesome species, hazard trees, and/or trees putting sensitive infrastructure at risk.

The mid-cycle initiative will be phased in with the inspections applied to the feeder portion of circuits starting in 2021, rolling out to full circuits (feeder and lateral) starting in 2023.

Beyond the day-to-day and storm benefits, the distribution portion of the VM Storm Protection Program is planned to scale up over time, moving from today’s complement of 196 field resources to a peak of 280 field resources across three years, and then settling into a steady-state number of approximately

¹ § 366.96(3), Fla. Stat.

² Document No 09233-2019 Filed on 10/7/2019 with the FPSC, 25-6.030 Storm Protection Plan, p. 1, lines 2-6

³ § 366.96(3), Fla. Stat. 1

⁴⁴ See R. 25-6.030, F.A.C.

⁵ Document No 09233-2019 Filed on 10/7/2019 with the FPSC, 25-6.030 Storm Protection Plan, p. 3, lines 10-17

⁶ The Vegetation Management Program also includes the baseline transmission trim cycles as well an incremental transmission vegetation management initiative, but those activities are outside of the scope of this report.

270 field resources. The phased rollout and associated resource load and budget are outlined in Table 1-1, below:

Table 1-1: Recommended Approach

	Baseline 4-Year Cycle	Supplemental Miles	Feeder Mid-Cycle	Lateral Mid-Cycle	Estimated Resource Load ⁷	Budget ⁸
2020	Yes	400	Pilot 1-5 Circuits	None	228	\$17.1M
2021	Yes	500	Inspect 60 Miles	None	257	\$20.0M
2022	Yes	700	Inspect 48 Miles	Pilot 1-5 Circuits	262	\$21.4M
2023	Yes	700	Inspect 46 Miles	Inspect 208 Miles	280	\$24.0M
2024	Yes	700	Inspect 45 Miles	Inspect 177 Miles	270	\$24.3M
2025	Yes	700	Inspect 96 Miles	Inspect 156 Miles	270	\$25.5M
2026	Yes	700	Inspect 60 Miles	Inspect 150 Miles	270	\$26.8M
2027	Yes	700	Inspect 45 Miles	Inspect 198 Miles	270	\$28.1M
2028	Yes	700	Inspect 52 Miles	Inspect 155 Miles	270	\$29.5M
2029	Yes	700	Inspect 54 Miles	Inspect 186 Miles	270	\$31.0M

These initiatives are projected to reduce day-to-day vegetation-caused customer interruptions by 21 percent and storm-related vegetation-caused outages by 29 percent relative to carrying out the 4-Year Trimming Cycle alone.

⁷ Resource projections from 2023 forward fluctuate with the specific blend of circuits that come up for mid-cycle trimming each year. 270 represents the average for these years, and TECO will manage the mid-cycle scope to match budget.

⁸ Budget reflects anticipated vegetation management costs for 1) the baseline 4-year cycle trim, 2) supplemental trim miles, 3) mid-cycle activities and 4) corrective maintenance. Excluded are the anticipated company-wide restoration costs associated with day-to-day outages and major storm events

2 Overview

TECO engages in 4-year distribution cycle trimming activities on an ongoing basis, working approximately one quarter of their overhead distribution system mileage every year. The goal is to trim tree limbs such that it will take four years before they can grow sufficiently to encroach on the clearances established for their lines. At various locations in the system, certain fast-growing tree species and/or right-of-way constraints on trimming result in isolated patches that may require attention between scheduled cycle trims. This often takes the form of Corrective Maintenance, where a crew is called out to address an impending issue on a specific tree because its limbs have grown too close to the line or because a tree, aided by the elements, makes contact with the lines and triggers an outage.

TECO continuously analyzes its vegetation management program using some of the industry's leading analytic tools. One of these tools is the Tree Trimming Model (TTM), originally developed by Davies Consulting (acquired by Accenture in 2017). Since the initial implementation of the model in 2006, TECO has continued to refine its program and update the tool's configuration using its growing set of historical spending and reliability performance data.

The TTM employs an analysis of day-to-day outages caused by vegetation, as well as a sampling of outages with unknown and weather cause codes which might be attributable to vegetation. TTM considers such outages in the context of the amount of time that has elapsed since the last time the trees on that circuit were trimmed. Universally, the analysis shows that outage volumes rise as a function of time since last trim, but the degree to which outages and their reliability impact escalate vary as a result of factors such as tree density, tree species, voltage, customer density, microclimate and a variety of others. In the configuration stages of the TTM modeling, circuits are grouped according to their similarity in terms of outage escalation and grouped separately as a function of how expensive it is to trim them, yielding a matrix of combinations of reliability and cost groupings. These expressions of cost and reliability, as a function of time, drive a ten-year prioritization aimed at getting the best day-to-day performance per dollar spent on trimming activities.

During extreme weather conditions, the proximity of limbs to lines and the cross-sectional area of vegetation upon which winds can exert force (referred to herein as the 'sail area') play a large factor in the degree of damage the electrical system will sustain due to vegetation-caused outages. Because the time elapsed since last trim is a direct driver of vegetation to conductor clearances when a storm arrives, the relationship between years since last trim, wind speed, and the extent of damage sustained has been studied and built into TTM's Storm Module. Using the trim list outputs of the TTM and an array of probable windspeeds for the Tampa area, the Storm Module predicts damage levels and associated restoration costs for typical years and can also project the impact of storms of specified magnitude.

Both TTM and the Storm Module address the effects of trimming circuits in their entirety, but some of TECO's proposed Vegetation Management initiatives are more targeted and address only portions of circuits in any given year. To accommodate this, Accenture crafted an Enhanced Storm Module for TTM to estimate the value derived from these targeted initiatives which change the state of only part of any given circuit at a time.

3 Approach

TECO used TTM and its storm modules to establish a set of baseline performance metrics associated with its four-year cycle, and then evaluated supplemental activities against that baseline:

- Supplemental trimming scenarios in which TECO targeted and trimmed an additional 100, 300, 500, 700 or 900 miles per year, and
- Mid-cycle activities whereupon circuits (either the feeder or the complete circuit) are inspected two years after their most recent trim, and follow-up vegetation management activities are prescribed to enhance both the day-to-day and extreme weather condition performance of the system.

The effects of the supplemental trimming and mid-cycle initiatives build upon the base of the 4-year trimming cycle. For consistency of presentation throughout the document, all three are referred to herein as initiatives:

Table 3-1: Initiative Approach

Initiative	Name
1	Baseline 4-year Trimming Cycle
2	Supplemental Trimming
3	Mid-cycle Inspection & VM Activities

The effects of these initiatives are cumulative, in that any version of Initiative 2 requires that the baseline 4-year cycle to be in effect, and Initiative 3 would not be implemented without the baseline trim cycle and Initiative 2 in place. There are many different combinations of activities, any of which could serve as the company's VM program. The benefits of each possible activity can only be evaluated by comparing the benefits of different programs, or combinations of activities. Consequently, the team created different possible VM programs, each with a different set of component activities. The programs which appear in this document consist of component activities as follows:

Table 3-2: Program Nomenclature and Initiative Components

Program Name	Initiative 1 Component	Initiative 2 Component	Initiative 3 Component
Program 1	4-year cycle trim	n/a	n/a
Program 2 – 100	4-year cycle trim	100 Supplemental Miles	n/a
Program 2 – 300	4-year cycle trim	300 Supplemental Miles	n/a
Program 2 – 500	4-year cycle trim	500 Supplemental Miles	n/a
Program 2 – 700	4-year cycle trim	700 Supplemental Miles	n/a
Program 2 – 900	4-year cycle trim	900 Supplemental Miles	n/a
Program 3a – 700	4-year cycle trim	700 Supplemental Miles	Mid-cycle on feeders only
Program 3b – 700	4-year cycle trim	700 Supplemental Miles	Mid-cycle on whole circuits
Program 2 – 457	4-year cycle trim	Phased approach – 400 Supplemental Miles in 2020, 500 in 2021 and 700 in 2022 and beyond	n/a
Program 3ab - 457	4-year cycle trim	Phased approach – 400 Supplemental Miles in 2020, 500 in 2021 and 700 in 2022 and beyond	Phased approach – mid-cycle on feeders only in 2021 and 2022, mid-cycle on full circuits in 2023 and beyond

Upon finding an optimal endpoint, TECO examined the resource implications of the program and adapted the approach to phase in both the supplemental trimming initiative and the mid-cycle initiative to allow for a smooth transition into the program.

Prior to running the various scenarios, TECO engaged Accenture to refresh the TTM configuration and the various assumptions built into the TTM Storm Module. The configuration process and associated assumptions are captured in Section 6: Tree Trimming Model & Modules Configuration.

4 Storm Protection Initiatives Analysis

TECO and Accenture analyzed several vegetation management activities to determine an optimal level of supplemental trimming to reduce vegetation related outages during extreme weather events while continuing to minimize day-to-day vegetation related outages.

The following initiatives were considered:

Table 4-1: Vegetation Management Initiatives Analyzed

	Initiative Name	Initiative Description	Modeling Methodology
1	Baseline: 4-Year Effective Cycle	Trim 25% of TECO's overhead lines (~1,562 miles) annually.	Target 25% of the miles in each of TECO's 7 districts for trimming annually.
2	Supplemental Circuit Trimming	Trim an additional 100 – 900 targeted miles annually with a view to mitigating outage risk on those circuits most susceptible to storm damage	Five scenarios modeled – 100, 300, 500, 700 and 900 miles. Due to the nature of the algorithm and available targeting data, targeting is based on SAIFI performance in regular weather.
3a	Mid-cycle VM Initiative – Feeders Only	Add mid-cycle inspections to feeder portions of circuits (~35% of line miles) two years after trim, prescribing additional VM activities to a fraction of the trees inspected.	The TTM Enhanced Storm Module assumes that one quarter of the trees inspected will be targeted for re-trimming when inspected and promptly trimmed. As TTM works with miles of circuit rather than individual trees, this is modeled as one quarter of the feeder miles re-setting to trimmed in that year, while the remainder of the circuit continues to age. Within the model, the costs associated with day-to-day restoration, storm restoration, and corrective maintenance costs are re-calculated to reflect the new trim-age profile of the circuit.
3b	Mid-cycle VM Initiative – Full Circuits	Extend the inspection and prescribed activities described in Initiative 3a to the entire circuit. As with 3a, it is assumed that a fraction of the trees inspected will require mid-cycle VM activities.	As described above in Initiative 3a, TTM Enhanced Storm Module assumes one quarter of the entire circuit is re-trimmed at two years, with an impact on day-to-day restoration costs, storm restoration costs and corrective maintenance costs.

The Supplemental Circuit Trimming initiative seeks to reduce tree-caused outages by reducing the proximity between tree limbs and lines, as well as reducing trees' sail area which would otherwise cause them to sway or break as wind speed increases.

The Mid-cycle VM initiative focuses on some of the same proximity and sail area reduction efforts on the trees which grow the quickest and may encroach on lines despite the best efforts of the trimming cycle and supplemental trimming, as well as other activities to slow tree growth or eliminate hazard trees altogether.

4.1 Baseline Trim Cycle and Initiative 1 Variants

TECO and Accenture ran the company’s ongoing 4-year cycle trim through the model to project its full budget implications across seven categories of cost to form a baseline against which the incremental benefits of supplemental trimming activities can be measured. The associated costs are broken out as follows, along with indicators as to whether the cost component in question is part of the VM budget and whether the costs are associated uniquely with VM resources or, as in the case of outage restorations, extend further into the organization:

Table 4-2: Cost Categories

Cost Category	Applies to what resources?	Part of Storm Protection Program	Part of VM Budget?
Cycle Trimming	Vegetation	Yes	Yes
Supplemental Trimming	Vegetation	Yes	Yes
Mid-Cycle	Vegetation	Yes	Yes
Corrective Cost	Vegetation	No	Yes
Resource Premiums	Vegetation	Yes	Yes
Day to Day Restoration Costs	Line & Vegetation	No	No
Storm Restoration Costs	Line & Vegetation	No	No

Note that the anticipated spending levels for the two categories of restoration cost are driven by vegetation management decisions but are not part of the vegetation management budget. They are considered and presented within this analysis because the investments in enhancing vegetation management for the Storm Protection Plan should be offset by reductions in cost due to outage response.

In the baseline scenario, each service area is allotted one quarter of its mileage every year, or approximately 1,562 miles in total. Central, for example, accounts for one sixth of TECO’s overhead miles, and is afforded one sixth of the annual 1,562-mile budget as depicted below.

Table 4-3: Baseline 4-Year Effective Cycle Mileage Targets

Service Area	Mileage Target	Percentage
Central	260	16.6%
Dade City	93	6.0%
Eastern	209	13.4%
Plant City	310	19.8%
South Hillsborough	182	11.7%
Western	277	17.7%
Winter Haven	231	14.8%
Total	1,562	100.0%

In the supplemental trimming initiatives, one quarter of the supplemental miles is allocated across the service areas in the same proportions as the 4-year distribution trim cycle. The remainder of the miles are directed where they will deliver the greatest benefit. Thus, in a scenario where 400 supplemental miles were trimmed, 100 miles would be constrained with 16.6 occurring in Central, 6.0 miles in Dade City, 13.4 miles in Eastern, and so on with the remaining 300 miles of trimming directed to the areas where it would deliver the greatest benefit.

The costs for the baseline scenario and five variants of supplemental trimming, without mid-cycle, are plotted below:

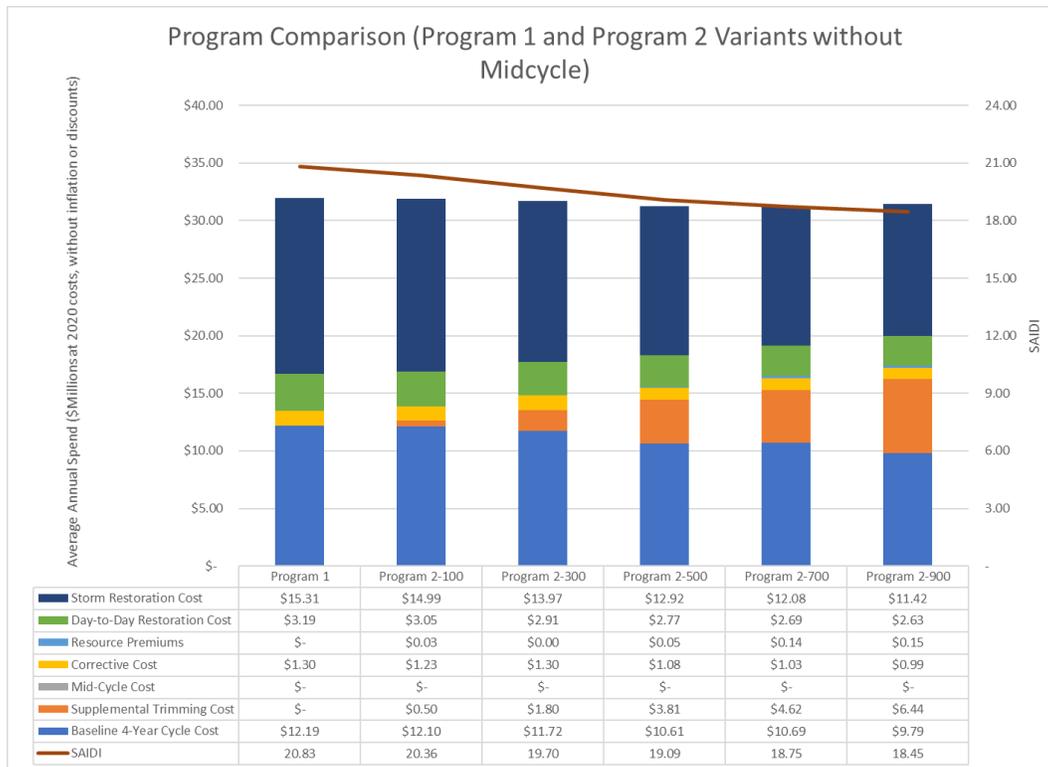


Figure 4-1: Program Comparison

The average annual vegetation management budget, without inflation, for these six options ranges from \$13.5M for the as-is 4-year trimming cycle to \$17.4M for the cycle plus 900 miles of supplemental trimming annually. Meanwhile the annual total restoration costs, which include all line work and vegetation management costs for storm restoration, trend in the opposite direction from \$18.5M for the baseline 4-year cycle to \$14.1M for the 900-mile variant. The total anticipated cost of the VM budget and restoration combined sits in a narrower range, at \$32.0M for the baseline 4-year cycle and \$31.25 M for the 500 and 700-mile variants.

The side-by-side comparison of scenarios yields several insights:

- The introduction of supplemental trimming drives down the cost of the baseline four-year cycle. This is because the extra activity on the lines makes trimming the annual 1,562 miles less expensive each year since the tree limbs have had less time to grow and are neither as long nor as close to the lines as they would have been otherwise.
- The increases in cost associated with the Storm Protection Program 2 variants and associated resource premiums is offset by decreases in cost in the 4-year cycle trim, corrective maintenance, day-to-day restoration costs and storm restoration costs, up to the 500 to 700-mile range.
- Although difficult to see in Figure 4-1, the 500 mile and 700-mile programs yield the best overall average annual cost, which, due to diminishing returns, begins to trend back upwards starting with the 900-mile program. See Figure 4-2, below, for a view focused on total cost.
- Each supplemental increase in Program 2 yields an improvement in SAIFI and SAIDI, although the gains slow in the 500-mile to 700-mile range.

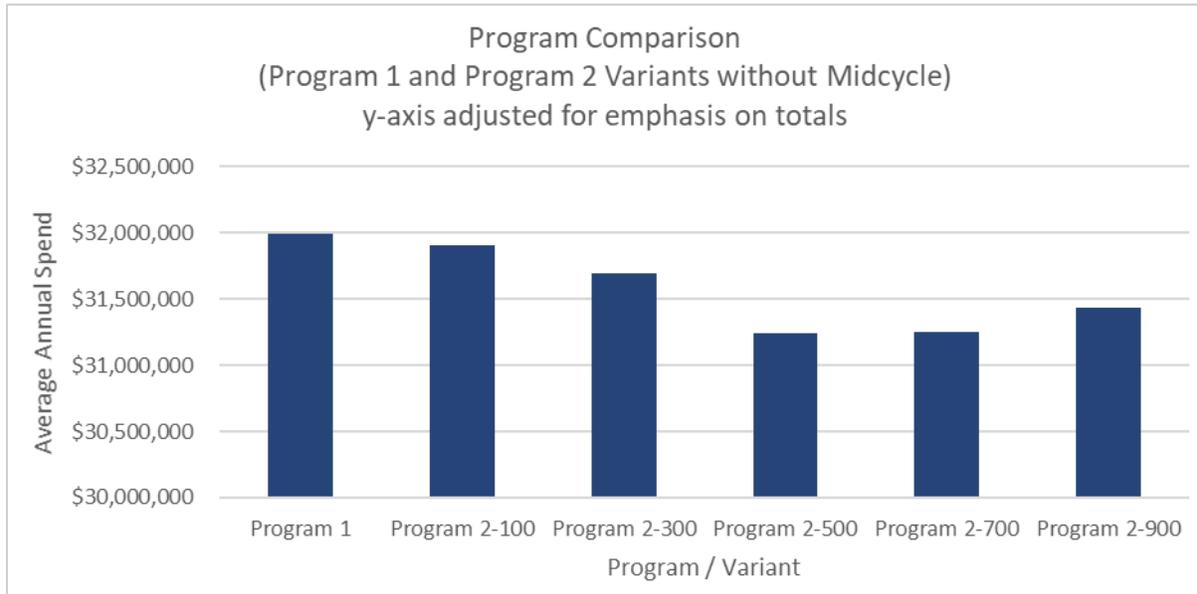


Figure 4-2: Program Comparison with Focus on Total Average Annual Spend

- While the 500 mile and 700-mile programs are in a virtual tie from an overall cost perspective, there is a clear advantage to the 700-mile program from the customer experience perspective. The 700-mile program drives 16 percent and 21 percent improvements in the ten-year average day-to-day and storm restoration costs, which are directly linked to customer interruptions. Across the ten-year span of the 500-mile program, these figures are 13 percent and 16 percent.

Table 4-4: 10-year Average Outage Restoration Improvements for Programs 2-500 and 2-700 Relative to Program 1

Cost Element	Program 1 Average 2020-2029	Program 2-500 Average 2020-2029	Program 2-700 Average 2020-2029	Improvement for Program 2-500	Improvement for Program 2-700
Day-to-Day Restoration	\$3.19 M	\$2.77 M	\$2.69M	13.2%	15.7%
Storm Restoration	\$15.31 M	\$12.92M	\$12.08M	15.6%	21.1%

4.2 Storm Protection Initiative 3a & 3b – Mid-cycle Inspection and VM Activities

Based on the results presented in Section 4.1, Initiatives 3a and 3b were analyzed in the context of Program 2-700, where 700 supplemental and targeted miles are trimmed each year. The average annual cost of the inspectors and VM resources for the mid-cycle initiatives was \$1.06M and \$4.05M, respectively, and they yielded a further 2.5 percent and 4.5 percent improvements to storm restoration costs from \$12.08M to \$11.77M and \$11.54M.

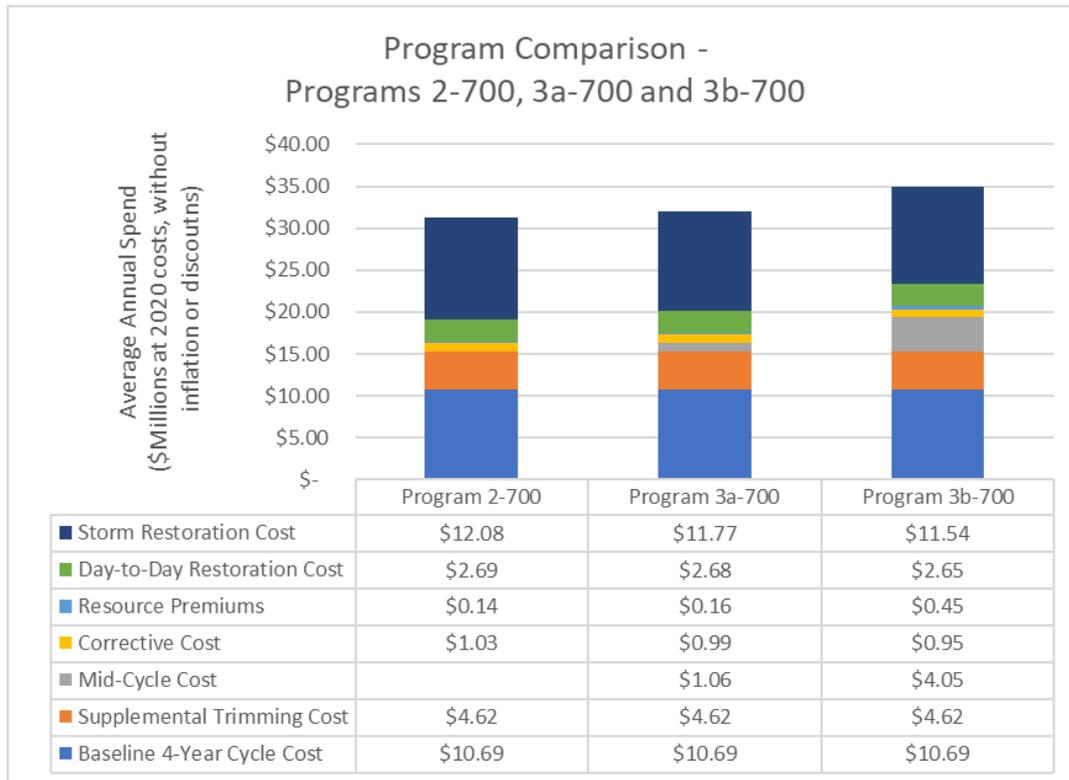


Figure 4-3: Storm Protection Program Mid-Cycle Comparison

Table 4-5: 10-year Average Outage Restoration Improvements for Programs 3a-700 and 3b-700 Relative to Program 2-700

Cost Element	Program 2-700 Average 2020- 2029	Program 3a- 700 Average 2020-2029	Program 3b- 700 Average 2020-2029	Improvement for Program 3a-700	Improvement for Program 3b-700
Storm Restoration	\$12.08M	\$11.77M	\$11.54M	2.6%	4.5%
Day-to-Day Restoration	\$2.69M	\$2.68M	\$2.65M	0.4%	1.5%

As noted previously, the modeling approach may not reflect the full value of the mid-cycle activities. While the Tree Trimming Model considers circuits in their entirety, the mid-cycle initiative would be targeted based on inspections and storm impact and is highly likely to yield greater benefits than what is reflected here. Also, some of the prescribed activities under the mid-cycle initiative, such as tree removals, will yield permanent and cumulative results not captured here. Simply put, it is believed that the benefits of the mid-cycle initiative will exceed what is shown here.

4.3 Developing a Blended Strategy to Accommodate Resource Constraint

Resource impact is one final element to draw out of the Storm Protection Program 2 and Storm Protection Program 3a/3b analyses. The 500, 700, and 900-mile versions of Storm Protection Program 2 all incur cost premiums associated with the rapid increase in size to the workforce required. Programs

3a-700 and 3b-700 exacerbate the resource crunch. While the average annual VM budget (without inflation) for Program 2-700 (Baseline + 700 supplemental miles) is estimated at \$16.4M and would require an average of 220 resources to execute, the first year VM budget would be \$19.0M and require roughly 256 resources. With 196 resources in the field at present, the uptake of 60 workers in a single year would represent a very large challenge and require significant expenditure on overtime and premium incentives to achieve, particularly if the transition happens later in the year. Adding Initiative 3a or 3b simultaneously would further exacerbate the issue.

TECO is proposing instead to transition towards the 700-mile version of Initiative 2 over the course of three years by trimming 400 extra miles in 2020, 500 extra miles in 2021 and finally arriving at the 700-mile program in 2022. The mid-cycle initiative will also be introduced gradually, addressing feeders alone in the second and third years and moving towards inspecting full circuits in the fourth year and beyond as better data becomes available about the success of mid-cycle inspections and VM activities.

5 Recommendation

The recommended Vegetation Management Storm Protection Program (Program 3ab-457) consists of the following activities:

- 1) **Baseline Cycle:** continue the 4-year trimming cycle
- 2) **Supplemental trimming initiative:** scale up supplemental trimming miles by targeting an additional 400 miles in 2020, 500 miles in 2021, and 700 miles from 2022 going forward
- 3) **Mid-cycle VM initiative:** introduce mid-cycle inspections and associated targeted activities for the feeder portions of circuits in 2021, extending the inspections and prescribed activities to cover entire circuits from 2023 forward, with 60 miles inspected in 2021, 48 miles in 2022 and 254 miles in 2023 as the program rolls out to entire circuits.

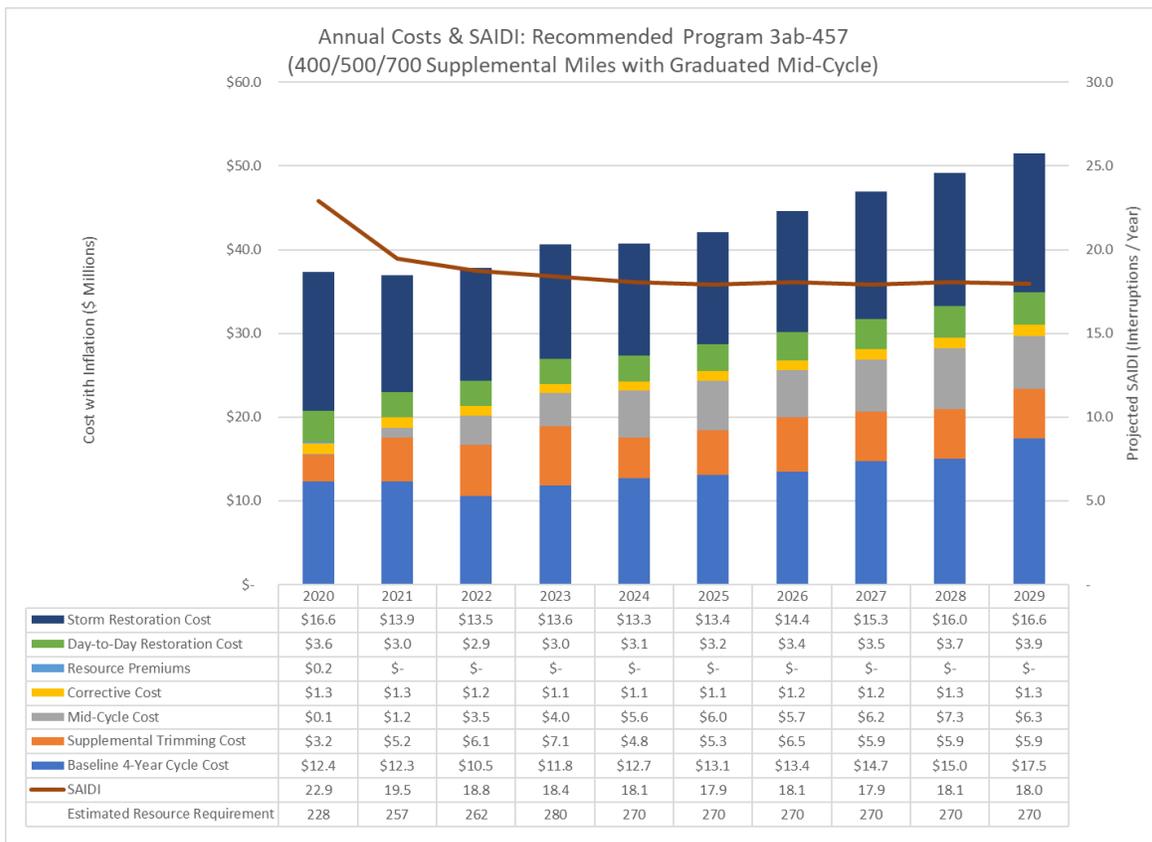


Figure 5-1: Annual Costs and SAIDI – Recommended VM Program

The VM Budget (SPP and Non-SPP) and Restoration Costs are summarized below:

Table 5-1: VM Storm Protection Program 3ab-457 Performance Characteristics

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Total VM Budget	\$17.1	\$20.0	\$21.4	\$24.0	\$24.3	\$25.5	\$26.8	\$28.1	\$29.5	\$31.0
Restoration Costs	\$20.3	\$17.0	\$16.5	\$16.6	\$16.4	\$16.6	\$17.8	\$18.8	\$19.7	\$20.5
Total VM-Influenced Costs	\$37.4	\$36.9	\$37.9	\$40.6	\$40.7	\$42.1	\$44.6	\$46.9	\$49.2	\$51.5

From a benefits perspective, two measures are worth exploring because the program takes a few years to establish: the overall ten-year average performance, and the future steady-state value taken in this case by considering the average of the last five years in the analysis. For the 10-year and 5-year end state averages, all years and cost elements are priced at 2020 rates, with no inflation.

Table 5-2: VM Storm Protection Program 3ab-457 Performance Characteristics

	10-Year Average			Future Steady-State (Average of Last Five Years)		
	Program 1	Program 2-457	Program 3ab-457	Program 1	Program 2-457	Program 3ab-457
SAIFI	0.229	0.195	0.193	0.227	0.184	0.181
SAIDI	20.8	18.9	18.8	20.7	18.2	18.0
Typical Storm Season	\$15.3 M	\$12.4 M	\$11.9M	\$15.1 M	\$11.4 M	\$10.7 M
65 mph Storm	\$16.6 M	\$14.0 M	\$13.3 M	\$16.3 M	\$13.2 M	\$12.4 M
85 mph Storm	\$37.1 M	\$31.3 M	\$29.8 M	\$36.5 M	\$29.6 M	\$27.6 M
105 mph Storm	\$69.9 M	\$59.0 M	\$56.1 M	\$68.7 M	\$55.7 M	\$52.1 M
125 mph Storm	\$117.9 M	\$99.5 M	\$94.6M	\$109.8 M	\$94.0 M	\$87.9 M

The proposed Program 3ab-457 is projected to improve SAIFI by 15.3 percent relative to the baseline 4-year cycle over the full period, or by 21.3 percent if just the final five years are considered. SAIDI improvement is 9.6 percent across ten years, or 14.0 percent in the future steady state. Storm performance improves by 22.2 percent across ten years, or 29.1 percent in the future steady state.

6 Tree Trimming Model & Modules Configuration

The Tree Trimming Model requires intermittent updates wherein the latest circuit configuration, trimming and outage history are employed to ensure the model is using the latest information available when targeting circuits for trimming. In addition, the storm module requires updates to a variety of cost and workforce assumptions to perform its functions correctly.

6.1 TTM Inputs and Assumptions

TTM requires three principal data sources:

- A complete inventory of the overhead circuits in the system, including circuit characteristics such as customer count, overhead mileage, and geographic coordinates;
- The outage database or databases; and,
- A history of trimming activity, preferably including start and end dates, costs, and covering multiple trims for each circuit.

6.1.1 Circuit List

A comprehensive list of circuits was obtained from TECO, which contained a total of 780 circuits.

Not all circuits and mileage were of interest, as TTM is only relevant to the overhead portion of circuits for which trimming is a regular concern. Ultimately, 709 “trimmable” circuits were included in the analysis, representing some 6,247 miles of overhead circuit length.

6.1.2 Performance Data

Circuit reliability performance data was gathered from TECO’s Distribution Outage Database (DOD). The analysis included outages from January 1, 2006 through November 26, 2019, thus accommodating at least thirteen years of data. Of interest were outages with the tree-related cause codes found in Table 6-1 below. The table indicates the number of events associated with each cause code, as well as the total customer interruptions (CI) and customer minutes of interruption (CMI).

Table 6-1: Tree-Related Cause Codes (January 1, 2006 - November 26, 2019)

Cause Code	Events	CI	CMI
Tree\Blew into Line	305	20,060	1,219,189
Tree\Non-Prev.	9,970	811,842	68,744,420
Tree\ Prev.	9,776	740,361	66,143,332
Tree\Grew into Line	1,644	110,815	8,404,342
Tree\Vines	5,984	210,380	7,476,754
Trees (Other)	436	22,815	1,879,906
Incorporated Unknown (25%)	2,732	162,248	10,206,418
Incorporated Weather (25%)	6,190	389,703	35,775,171
Grand Total	37,037	2,468,224	199,849,532

TECO also incorporated a portion of CIs and CMIs from outages with “Unknown” and “Weather” cause codes. From experience, Accenture has found with other utilities that a significant portion of such catch-all causes is, in fact, tree-related. Therefore, after conducting an internal analysis of trends in outage counts for these cause codes in relation to explicit tree cause codes, TECO determined that 25 percent was a reasonable proportion to include in the analysis.

Finally, certain outages were excluded from this analysis irrespective of the cause code. These included those adjustments specified and allowed in accordance with Rule 25-6.0455, Florida Administrative Code.

6.1.3 Trim Data

TECO records and maintains trim history that includes the following types of data:

- Circuit number;
- Trim start date;
- Trim completion date;
- Miles trimmed; and,
- Cost to trim the entire circuit.

Similar to the performance data, the analysis included trimming data from January 1, 2006 through November 26, 2019. The trim data was pared down to the outage data with the circuit number being the link between the two data sources. For analysis purposes, the circuit number and trim completion date (year and month of trim) of each circuit trim were incorporated in the analysis.

6.2 Reliability Performance Curve Development

6.2.1 Creating Circuit Performance Groups

Circuits were ordered according to historical performance. A total of seven groups were identified so that around 1,130 miles were represented in each group. Group 07 were the circuits that had zero tree-related outages from 2006-2019.

Table 6-2: CI Grouping Characteristics

Circuit CI Group	CI per Mile Criteria	Circuits	Miles
01	Greater than 649	164	1,117
02	Between 467 and 649	95	1,135
03	Between 277 and 467	131	1,136
04	Between 193 and 277	70	1,134
05	Between 104 and 193	101	1,132
06	Between 0.3 and 104	168	1,130
07	Less than 0.3	66	19

Table 6-3: CMI Grouping Characteristics

Circuit CI Group	CMI per Mile Criteria	Circuits	Miles
01	Greater than 55,483	159	1,130
02	Between 34,277 and 55,483	114	1,125
03	Between 22,485 and 34,277	114	1,107
04	Between 14,427 and 22,485	83	1,133
05	Between 8,340 and 14,427	87	1,152
06	Between 19.3 and 8,340	172	1,136
07	Less than 19.3	66	19

6.2.2 Circuit Performance Curve Fitting

Performance data points were derived using historical outage data, trim data, and circuit length data. Every outage was expressed as a number of CI or CMI per circuit mile and was plotted relative to the most recent time it was trimmed. Values for 12 consecutive individual months were rolled up to create year-based values, and these were plotted in MS Excel so that a curve could be fit to them.

Several conditions had to be satisfied in order to ensure that the data points were correct:

- Outage data was omitted in the months when a circuit was being trimmed.

- Outages were associated only to the most recent trim.
- Figure 6-1 below reflects the mileage into which the 12-month roll-up of CI or CMI is divided and represents the total mileage of the system or group of circuits. This ensures that in a situation where several circuits do not have any outages in a particular 12-month roll-up, those circuits were not disregarded, but rather served to appropriately pull the curve downward as part of the averaging process. This provided assurance that the resulting curves were representative of the overall CI or CMI per mile of circuits in the group and not just the CI or CMI per mile on circuits that happened to have outages.

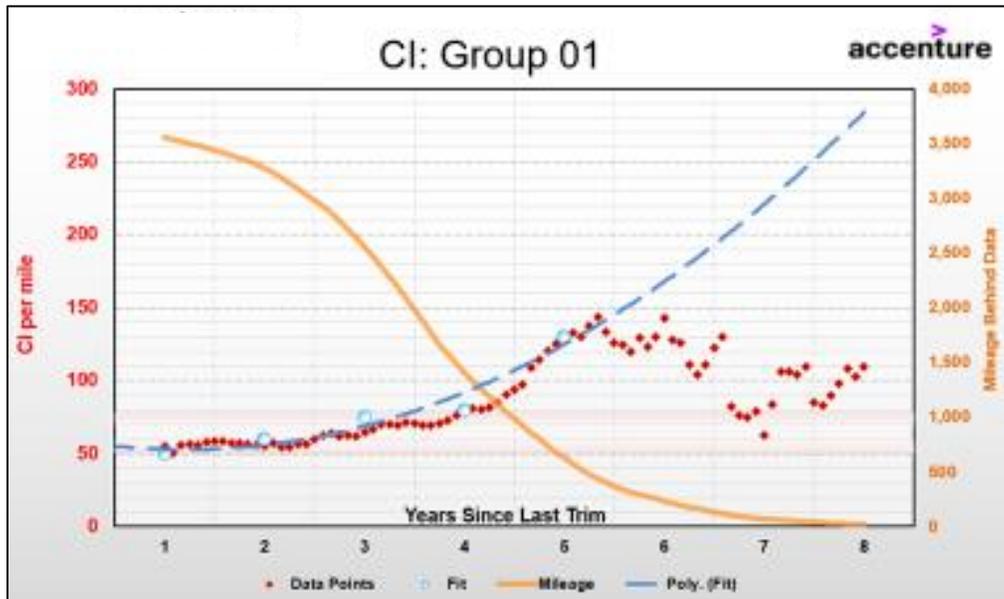


Figure 6-1: Example of Curve Fitting Analysis

A curve similar to that shown in Figure 6-1 was developed for each of the CMI groups, resulting in a total of fourteen curves, which are shown in Figure 6-2 and Figure 6-3 respectively. These curves provided the critical input required to compute the projected reliability associated with trimming each circuit. Eventually, the computed reliability values were used as the denominator to determine the cost-effectiveness score for circuits, which then served as the basis for their prioritization.

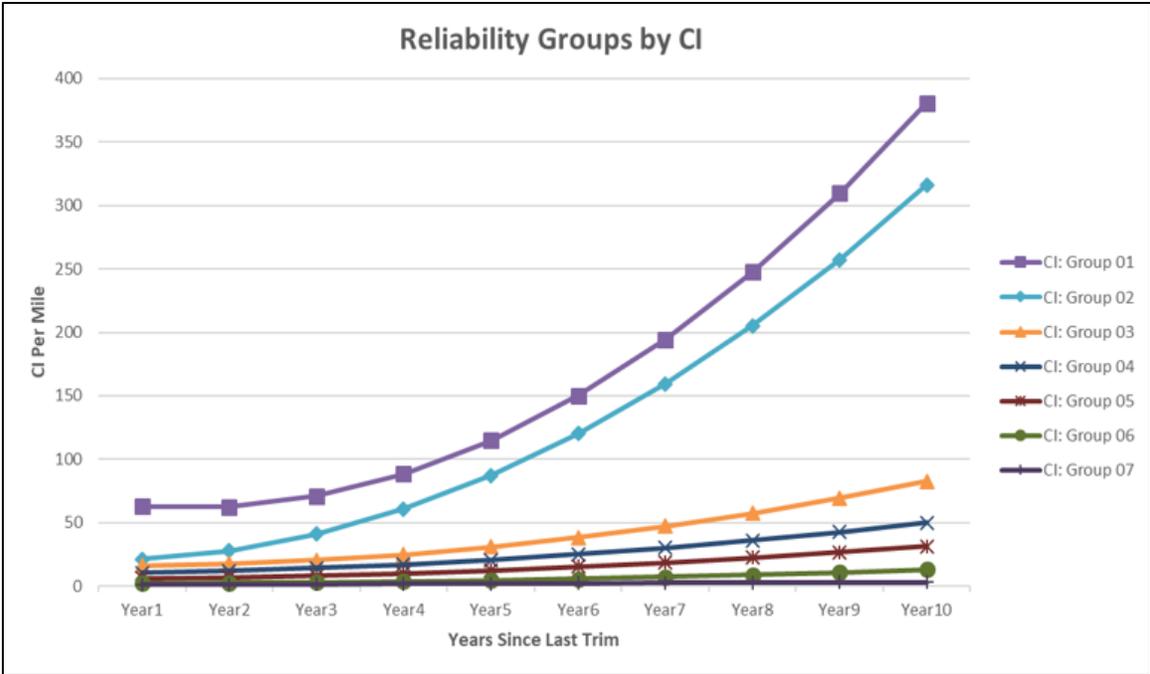


Figure 6-2: Customer Interruption (CI) Curve Groups

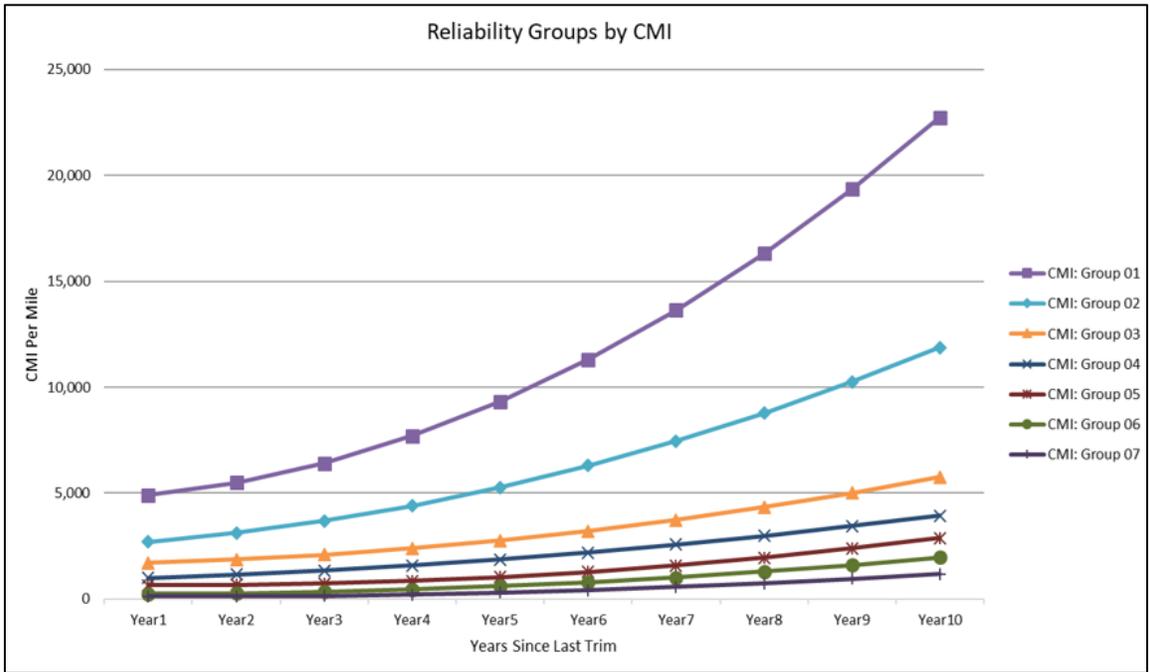


Figure 6-3: Customer Minute Interruption (CMI) Curve Groups

6.2.3 Cost Curves

Cost curves were the second factor in calculating the cost/benefit score of each circuit in TTM.

The shapes of the cost curves were based on a proprietary study called the Economic Impacts of Deferring Electric Utility Tree Maintenance by ECI⁹ that quantified the percentage increase in the eventual cost of trimming a circuit for each year that it is left untrimmed beyond the recommended clearance cycle. The findings of the ECI study are summarized in Figure 6-4 below. For instance, if the clearance cycle is three years, then waiting four years between trims will increase the cost per mile by 20 percent. Delaying trimming by another year will further inflate costs to 40 percent of the base cost and further increase it for subsequent years.

The ECI study only considered annual trimming cost increases between the recommended clearance cycle and up to a four-year delay. In generating a comprehensive cost curve that goes from one year since last trim onward, Accenture supplemented the percentages from the ECI study with two assumptions:

- Cost reduction from annual trimming – the percentage reduction from the clearance trim that will be achieved if the circuit was trimmed every year; and,
- Escalation – annual percentage increase in cost to be applied from the ninth year and beyond.

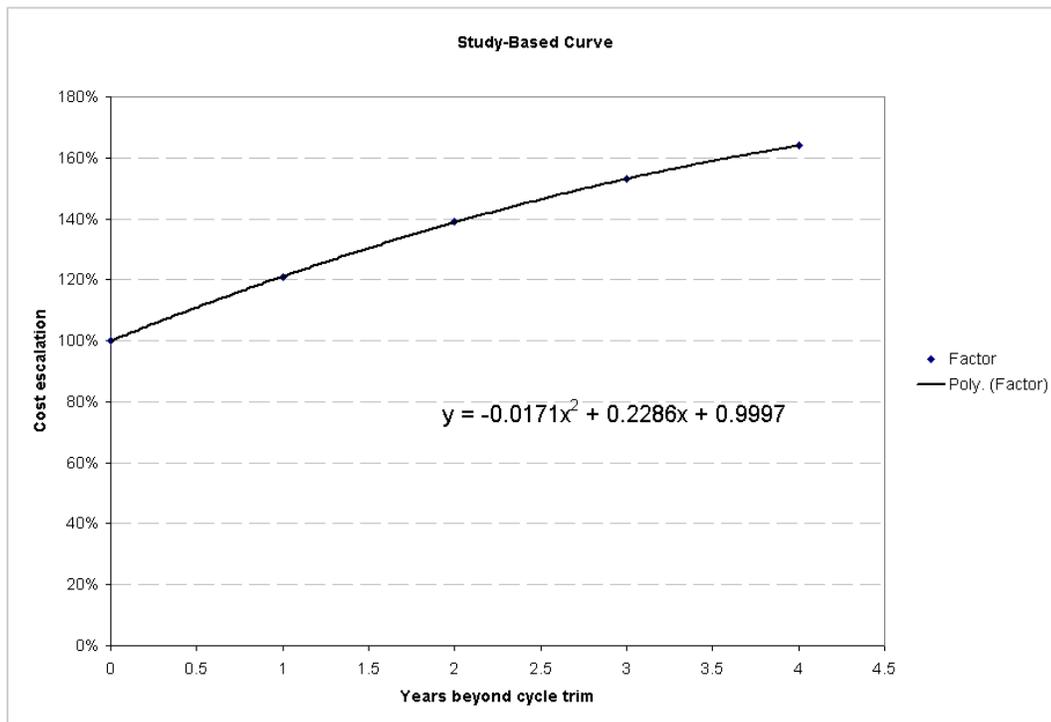


Figure 6-4: ECI Study-Based Cost Curve

The following section describes how such a cost curve methodology was applied to each cost group.

⁹ Browning, D. Mark, 2003, Deferred Tree Maintenance, Environmental Consultants Incorporated (ECI)

Similar to how the performance groups were created, circuits were ordered according to the average cost per mile. Initially a total of six groups were identified so that each had around 1,000 miles represented in each group. Group 01 ranged from \$7,600/mile to \$41,000/mile and it was important to further divide it into smaller groups due to the large range between costs. Ultimately, Group 01 was divided into 4 smaller groups so that the ranges were more reasonable. The same was true on the other side of the spectrum and the lowest cost group was split into two groups. Ultimately, circuits were grouped into 10 distinct groups as shown in the following table:

Table 6-4: Cost Grouping Characteristics

Circuit Cost Group	Cost per Mile Criteria	Circuits	Miles
01	Greater than \$25,000	14	79
02	Between \$15,500 and \$25,000	26	158
03	Between \$10,000 and \$15,500	42	225
04	Between \$7,600 and \$10,000	90	713
05	Between \$6,100 and \$7,600	103	1,088
06	Between \$5,000 and \$6,100	109	1,016
07	Between \$4,100 and \$5,000	91	1,037
08	Between \$3,300 and \$4,100	89	1,058
09	Between \$1,500 and \$3,300	116	896
10	Less than \$1,500	25	100

With this group information a curve was created for each using the average cost per mile in each group with an additional twenty-five percent increase on each. The additional twenty-five percent was added to adjust historical trimming costs to 2019 dollars. Since TECO is on a four-year effective trim cycle each cost group is anchored on Year 4 with its respective adjusted average cost per mile. The remaining points were determined using the expertise of TECO and Accenture:

- Years 1: A 35 percent reduction in average cost if TECO would return to a circuit a year later
- Years 2-3: Linear increase in spending from Year 1 to Year 4
- Years 5-8: Follow the cost escalation described in Figure 6-5.
- Years 9-10: A 5 percent increase for each year trimming is delayed

These datapoints and assumptions were used to fit a curve for each of the cost groups shown below:

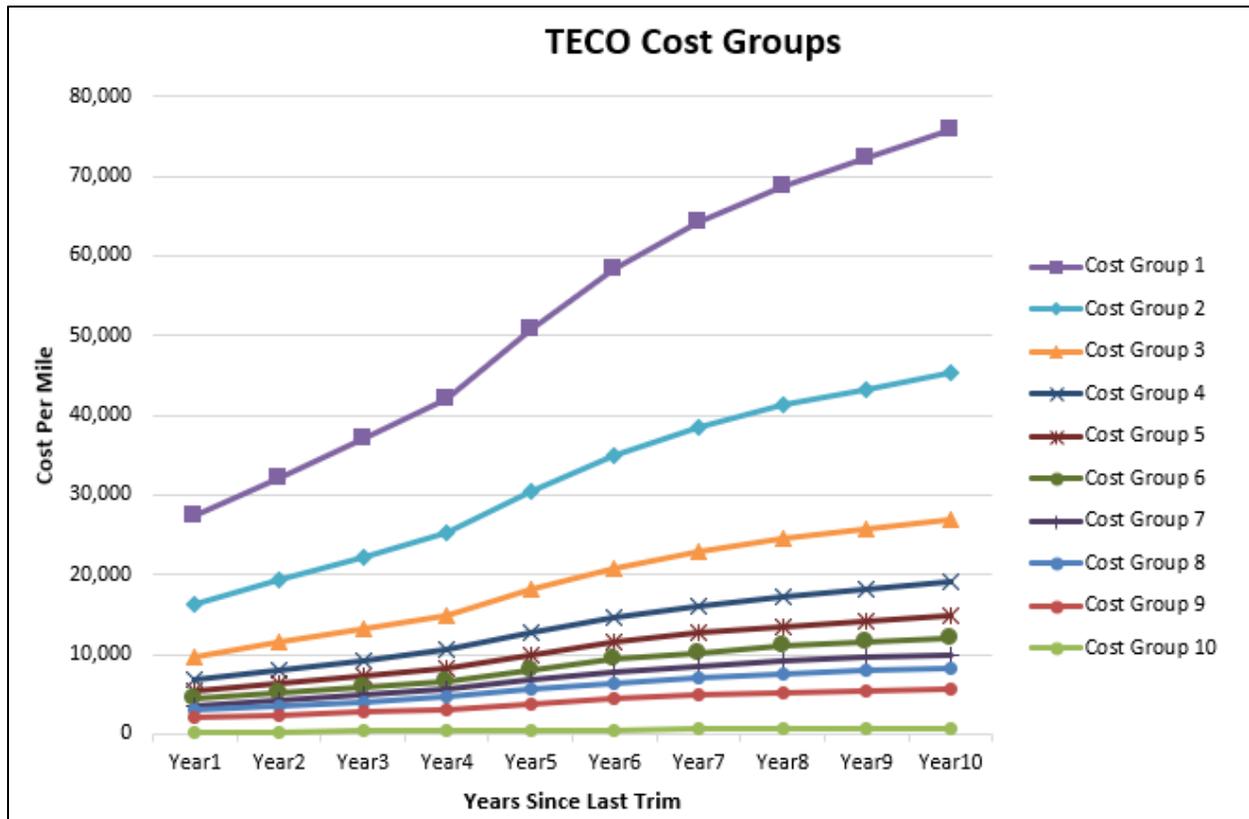


Figure 6-5: Cost Groups

TTM uses these curves to identify the estimated cost per mile to trim a circuit based on its year since last trim. These costs are in 2019 dollars and an estimated 5 percent inflation rate is used for subsequent trimming costs in future years.

6.3 Storm Module Inputs and Assumptions

Storm protection initiative cost and benefit modeling was accomplished using TTM and its associated Storm Module which have been used to prioritize trimming activities since 2006, and an Enhanced Storm Module to cover analyses not originally anticipated in the original Storm Module. The following cost implications were generated for each vegetation management activity considered:

Table 6-5: Storm Module Cost Assumptions

Cost	Cost Generator	Key Assumptions
Baseline: 4-Year Cycle Cost	TTM Core Module	<ul style="list-style-type: none"> • Cost curves (TTM Configuration Analysis) • Years since last trim (TECO records) • Proportional allocation of mileage across work areas
Supplemental Trimming Cost	TTM Core Module	<ul style="list-style-type: none"> • Cost curves (TTM Configuration Analysis) • Years since last trim (TECO records) • Proportional allocation of mileage across work areas for 25% of supplemental miles
Mid-Cycle VM Initiative Cost	TTM Enhanced Storm Module	<ul style="list-style-type: none"> • Cost premium for inspection and enhanced activities (SME Estimate) • Timing of mid-cycle activities (SME decision) • Proportion of circuit population targeted (SME decision – 2 scenarios) • Proportion of circuit targeted (SME decision)
Corrective Maintenance Tickets	TECO Subject Matter Expert Input	<ul style="list-style-type: none"> • Proportion of corrective maintenance tickets attributable to tree growth (TECO Records) • Relationship between tree growth corrective maintenance tickets and system effective cycle (SME estimate, past filings)
Premiums Associated with Attracting Additional Workforce	TTM Core Module	<ul style="list-style-type: none"> • VM budget (Cycle + Supplemental + Mid-Cycle + Corrective) • Straight and overtime loaded cost rates for VM crews (SME estimate) • Maximum organic growth rate of the VM workforce (SME estimate) • Productivity adjustment for training new VM resources (SME estimate) • Incentive costs for VM resources required beyond the organic growth capacity (SME estimate)
SAIDI-Driven Restoration Costs	TTM Storm Module	<ul style="list-style-type: none"> • Reliability outputs from TTM Core Module • Average cost to restore a CMI (SME estimate)
Storm Restoration Costs	TTM Storm Module	<ul style="list-style-type: none"> • Trim list from TTM Core Module • Storm damage calculation function • FEMA HAZUS windspeed return dataset

Cost	Cost Generator	Key Assumptions
		<ul style="list-style-type: none"> Average cost to restore in major event including mutual assistance (Irma Analysis, SME adjustment)

6.3.1 Baseline: 4-Year Cycle Costs

Routine cycle trimming costs are projected by the Tree Trimming Model based on curves derived in the model configuration stages.

Cycle targets are established by declaring a number of miles to trim each year. In the baseline four-year scenario, the budget was allocated such that each service area would be on its own four-year cycle.

6.3.2 Supplemental Trimming Costs

Supplemental trimming costs are projected by the Tree Trimming Model based on curves derived in the model configuration stages.

In all supplemental scenarios, each service area was guaranteed their allocation of one quarter of the supplemental miles, with the remaining three-quarters of the miles getting targeted to where they were most needed.

6.3.3 Mid-Cycle Costs

There are four key assumptions relating to mid-cycle trimming activities:

- The cost premium for inspection and targeted trimming relative to cycle activities
- The timing of mid-cycle activities
- The portions of circuits to target
- The fraction of trees which will require mid-cycle intervention

Inspection-based activities come at a premium. There is first the cost of patrolling and inspecting the lines before vegetation management activities are taken, which must then be loaded into the costs of performing the actions in question. Second, relative to regular maintenance trimming, there are cost inefficiencies to trimming selectively. In regular maintenance trimming, vegetation crews can trim multiple trees each time they set up their vehicle and raise the bucket. In selective trimming, the ratio of setup time to actual wood removal goes up, further increasing the per-unit cost. Based on an analysis of corrective maintenance tickets, the TECO subject matter experts estimated that mid-cycle trimming would cost 80 percent more on a per-tree basis than routine trimming.

Mid-cycle activities are timed to promote the best possible performance out of the routine trimming initiative. Based on TECO subject matter expert input and considering the intervals between trimming in the baseline and enhanced scenarios, two years was selected as the optimal time for a mid-cycle inspection and associated vegetation management activities.

Mid-cycle activities will have similar impact in terms of overall restoration effort in a major event whether they occur on the feeder or lateral. Activities on the feeder will, however, protect more

customers per tree outage avoided. With this in mind, TECO subject matter experts specified two possible scopes for Initiative 2 – feeder miles and all miles to be considered in that order.

The final component of scoping this cost was to predict the maximum number of trees to be targeted for mid-cycle activities as a result of the inspections. TECO subject matter experts estimated up to 25 percent of trees would grow sufficiently quickly to merit additional trimming prior to the next scheduled cycle trim. The analysis uses this figure but presumes that additional activities may be substituted for portions of the potential trimming, such as performing removals and the like, as long as the activities fit within the stipulated budget. As the cost per tree is 180% of regular trimming cost, and only 25 percent of trees can be targeted for mid-cycle activity, this should never amount to greater than 45% (180% * 25%) of the regular 4-year cycle budget.

6.3.4 Corrective Costs

TECO responds to approximately 4,000 corrective maintenance tickets annually, of which one third are related to tree limbs growing too close to the wires. The remainder are related to various forms of capital work, moving lines to accommodate construction, and the like. In total, the corrective maintenance tickets currently amount to \$1.3 million per year, with TECO trimming to a four-year cycle. In prior filings, TECO estimated that moving from a three-year to a four-year cycle would result in a 30 percent increase in corrective maintenance tickets. Conversely, moving from four years back to three years would effectively revert the current \$1.3 million budget to \$1.0 million, or a roughly 23 percent reduction. Postulating that all growth-related tickets (33 percent) would be eliminated in a two-year cycle, the team fit a curve and generated a set of assumptions as follows, relative to the baseline 4-year scenario:

Table-6-6: Cost Assumptions by Effective Cycle

Effective Cycle (years)	Cost Reduction	Resulting Cost
4.00	0.0%	\$1.30M
3.75	7.0%	\$1.21M
3.50	13.0%	\$1.13M
3.25	18.5%	\$1.06M
3.00	23.0%	\$1.00M
2.75	26.7%	\$0.95M
2.50	29.6%	\$0.91M
2.25	31.7%	\$0.89M
2.00	33.0%	\$0.86M

6.3.5 Resource Premium Costs

Experience has shown that there is a limit to the rate at which TECO can expand its workforce without incurring some degree of premium cost. To account for this, the TTM Storm Module estimates the number of resources that would be required to do the Trimming, Mid-cycle and Corrective work in an

assumed 2,000-hour work year, and applies a number of cost adjustment factors if that amount is significantly higher than the current size. Cost Premium calculations consider the maximum number of resources that can be added in a given year without offering overtime or a per diem premium, and the assumed productivity of new resources in their first year.

6.3.6 Day-to-Day Restoration Costs

A key output of the Tree Trimming Model is the anticipated reliability performance of the system due to vegetation-caused outages in each year of the analysis. The reliability predictions are produced through TTM's CI and CMI configuration curves, which are derived on the basis of several years of outage and tree trimming data.

Outages trigger restoration costs through the use of the dispatch function, line crews and tree crews. The average cost for responding to an outage is estimated at \$1,300 and the calculated average number of customers interrupted per vegetation outage is 65, resulting in an estimated average cost per CI due to tree-caused outages of twenty dollars.

Annual restoration costs are estimated multiplying the SAIFI values generated by TTM by the number of customers served by TECO, and in turn multiplying that product by the estimate of \$20 per customer interrupted.

6.3.7 Storm Restoration Costs

The TTM Storm Module projects storm restoration costs per year using a function which determines the fraction of customers who will experience power loss based on wind-speed experienced and the number of years since the circuit was last trimmed, an amalgam of annual windspeed probabilities derived from FEMA's Hazards-US dataset and an estimate of restoration cost per customer derived from TECO's recent experience with Hurricane Irma.

The TTM Storm Module's central equation is based on a study conducted in southern Florida around 2005 which determined that wind-driven tree outages are influenced by the length of time since last trim. The equation accepts as parameters the wind speed experienced and the number of years since the circuit was last trimmed. The equation returns a percentage which is then applied to the number of customers served by the circuit to come up with an estimate of customers interrupted. In cases of extremely high winds (150 mph and up) and long intervals since last trim, the equation can return values above 100 percent, which is taken to mean that while only 100 percent of the customers on a circuit will be interrupted, the effort to restore them will go beyond the usual cost per customer due to the multitude of damage locations on the circuit.

		Years Since Last Trim					
		1	2	3	4	5	6
Wind Gusts (3 second sustained @10m elevation)	40	0.39%	0.48%	0.83%	1.21%	1.68%	2.08%
	45	0.27%	0.69%	1.18%	1.73%	2.32%	2.96%
	50	0.38%	0.94%	1.61%	2.37%	3.18%	4.06%
	55	0.50%	1.23%	2.13%	3.15%	4.24%	5.40%
	60	0.65%	1.63%	2.79%	4.09%	5.50%	7.01%
	65	0.82%	2.07%	3.53%	5.20%	6.99%	8.91%
	70	1.03%	2.58%	4.43%	6.48%	8.74%	11.13%
	75	1.27%	3.18%	5.43%	7.99%	10.74%	13.69%
	80	1.54%	3.88%	6.61%	9.69%	13.04%	16.61%
	85	1.84%	4.63%	7.93%	11.63%	15.64%	19.93%
	90	2.19%	5.49%	9.42%	13.80%	18.57%	23.66%
	95	2.57%	6.46%	11.07%	16.23%	21.84%	27.82%
	100	3.00%	7.54%	12.92%	18.93%	25.47%	32.45%
	105	3.47%	8.72%	14.93%	21.92%	29.48%	37.56%
	110	3.99%	10.03%	17.19%	25.20%	33.90%	43.19%
	115	4.56%	11.46%	19.63%	28.79%	38.73%	49.35%
	120	5.18%	13.02%	22.32%	32.71%	44.01%	56.07%
125	5.86%	14.72%	25.23%	36.98%	49.74%	63.38%	
130	6.59%	16.58%	28.38%	41.59%	55.95%	71.29%	
135	7.38%	18.54%	31.78%	46.58%	62.66%	79.84%	
140	8.23%	20.68%	35.44%	51.95%	69.88%	89.04%	
145	9.15%	22.98%	39.38%	57.72%	77.64%	98.93%	
150	10.13%	25.44%	43.60%	63.90%	85.95%	109.52%	
155	11.17%	28.06%	48.10%	70.50%	94.84%	120.84%	
160	12.29%	30.87%	52.91%	77.55%	104.31%	132.91%	

Figure 6-6: Expected Damage by Wind Gusts for a Given Year Since Last Trim

The windspeed probabilities employed by the TTM Storm Module are derived from wind speed return values calculated by FEMA in their Hazards-US (HAZUS) package. HAZUS provides a geographically specific listing of windspeeds that can be expected to return to a given location every year, 10 years, 20 years, 50 years, and so on through 1,000 years based on an analysis of tropical storm tracks over several decades. Those data points are transformed to point probabilities for individual windspeeds, from which expectations for given ranges are calculated. The TTM Storm Module is loaded with probabilities every 10 miles from 55 miles per hour through 195 miles per hour, representing the probability of seeing windspeeds in the 50-60 mile per hour range, 60-70 mile per hour range and so on through to the 190-200 mile per hour range.

With an estimate of the expected number of customers to experience outages due to extreme weather events established, the final step is to multiply by the expected cost to restore customers. In Accenture's storm benchmark database, storm restoration is calculated based on total cost per customers out at peak. As illustrated below, while TECO experienced a grand total of about 328,000 customers out from Hurricane Irma, the number of customers out simultaneously was 213,000, as many quick wins are achieved early through switching and the restoration of substation and transmission issues. Approximately two thirds of this peak value are believed to be tree-caused.

7 Work Plan

7.1 Baseline Summary

Work Area	2020		2021		2022		2023	
	Miles	Customers	Miles	Customers	Miles	Customers	Miles	Customers
CENTRAL	260.3	43,997	262.1	44,336	260.0	51,889	260.1	52,612
DADE CITY	93.3	4,618	80.1	2,308	107.8	5,541	90.8	3,015
EASTERN	212.4	30,524	210.1	34,845	208.8	35,717	208.6	27,808
PLANT CITY	311.9	16,511	308.9	16,875	309.7	22,055	311.4	12,296
SOUTH HILLSBOROUGH	178.3	16,775	176.1	26,999	181.4	14,380	184.5	18,196
WESTERN	279.3	67,510	279.5	60,773	277.0	64,125	278.2	59,307
WINTER HAVEN	227.0	26,391	237.9	9,676	228.4	16,338	230.7	25,762
Total	1,562.6	206,326	1,554.6	195,812	1573.0	210,045	1,564.2	198,996

7.2 Supplemental Summary

Work Area	2020		2021		2022		2023	
	Miles	Customers	Miles	Customers	Miles	Customers	Miles	Customers
CENTRAL	77.9	21,357	159.1	29,226	113.5	20,418	127.1	19,538
DADE CITY	99.9	5,208	6.2	484	127.6	5,578	44.9	681
EASTERN	99.8	18,598	153.3	12,341	72.9	8,794	149.8	18,918
PLANT CITY	76.7	9,702	25.2	2,443	202.2	8,347	31.1	3,579
SOUTH HILLSBOROUGH	15.3	2,264	20.5	2,427	20.2	3,236	138.9	28,399
WESTERN	15.7	3,926	82.8	13,024	112.4	20,376	155.8	27,165
WINTER HAVEN	16.8	1,277	63.1	5,063	43.2	5,784	53.2	7,950
Total	402.3	62,332	510.2	65,008	692.0	72,533	700.8	106,230

7.3 Mid-cycle Summary

Work Area	2020		2021		2022		2023	
	Miles Inspected	Customers	Miles Inspected	Customers	Miles Inspected	Customers	Miles Inspected	Customers
CENTRAL	0.0	0	48.6	17,262	36.0	9,488	176.8	25,321
DADE CITY	0.0	0	2.8	1,293	5.1	904	0.0	0
EASTERN	0.0	0	17.3	4,730	34.5	12,007	115.3	16,234
PLANT CITY	0.0	0	18.0	8,234	12.0	7,191	231.0	12,380
SOUTH HILLSBOROUGH	0.0	0	51.7	16,233	23.0	13,900	82.1	3,925
WESTERN	0.0	0	58.8	27,318	53.3	19,073	171.2	27,479
WINTER HAVEN	0.0	0	45.9	20,663	32.1	14,565	241.5	7,779
Total	0.0	0	243.1	95,733	196.0	77,128	1017.9	93,118