BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

In re: Application for limited proceeding for recovery of incremental storm restoration costs related to Hurricanes Irma and Nate by Duke Energy Florida, LLC

Docket No. 20170272-EI

Dated: April 18, 2018

DUKE ENERGY FLORIDA, LLC'S RESPONSE TO
CITIZENS' FIRST REQUEST TO PRODUCE DOCUMENTS (NOS. 1-10)

Duke Energy Florida, LLC ("DEF"), responds to the Citizens of the State of Florida, through the Office of the Public Counsel's ("Citizens" or "OPC") First Request to Produce Documents (Nos. 1-10) as follows:

1. Capitalization Policy. Provide a copy of the Company's capitalization policy.

   Response: See the attached document bearing Bates Numbers 20170272-DEF-OPC-POD 1-1-00001 through 20170272-DEF-OPC-POD 1-1-0000199. The attachments are confidential; a redacted slip sheet is attached hereto and unredacted copies have been filed with the Florida Public Service Commission ("Commission") along with DEF's Notice of Intent to Request Confidential Classification dated April 18, 2018.

2. Storm Accounting Policies and Procedures. Provide a copy of the Company's storm restoration accounting policies and procedures and a copy of any instructions given to employees and/or contractors during mobilization and/or restoration.

   Response:

3. Studies. Provide any assessment and/or study performed by the Company and/or for the Company that estimates the amount of storm cost savings the Company was able to achieve because of the storm hardening program work performed prior to each of the respective storms.

   Response:

4. Studies. Provide any assessment and/or study performed by the Company and/or for the Company that identifies the damage that occurred to infrastructure where storm hardening work had not been performed yet.

Response: See the attached document bearing Bates Numbers 20170272-DEF-OPC-POD 1-4-00001 through 20170272-DEF-OPC-POD 1-4-000050.

5. Third Party Billings. For each of the seven storms, provide any third party billings for pole replacement, provide the supporting invoices for those amounts billed and any contracts associated with third party billings to the Company that detail pole replacement.

Response: Foreign owned poles represent only 1.4% of the total pole population in Duke Energy's inventory. Hurricane Irma damaged .2% of the total population; Hurricane Matthew damaged less than .02% of the population; the other five storms damaged less than .01% combined. The likelihood that there was an overlap of these population sets is marginal.

During a major restoration event, Duke Energy is focused on safely restoring service to its customers and does not track ownership of the poles requiring replacement due to the small possibility that the damaged pole was foreign owned. The administrative effort to deploy resources to every pole to determine ownership prior to replacement would extend the restoration process to an unacceptable level for both customer and company.

6. Contractors. For each of the seven storms, please provide by contractor the supporting invoices (including all supporting detail provided by the vendor) for invoices over $25,000.

Response:

7. Line Clearing. For each of the seven storms, please provide by line clearing contractor the supporting invoices (including all supporting detail provided by the vendor) for invoices over $25,000.

Response:

8. Employee Expenses. For each of the seven storms, please provide any invoices for charges over $5,000.

Response:

9. Other. For each of the seven storms, please provide any invoices for P Card charges over $7,500.

   Response:

10. Third-Party Reimbursement. Provide a copy of the contract with any third party that serves as the support for Duke billing third parties for replacement of poles..

    Response:

SUBMITTED this 18th day of April, 2018.

s/ Matthew R. Bernier

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CERTIFICATE OF SERVICE

I HEREBY CERTIFY that a true and correct copy of the foregoing has been furnished via electronic mail to the following this 18th day of April, 2018.

/s/ Matthew R. Bernier
Attorney

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QUESTION #1

ENTIRELY REDACTED

Bates Numbers:

20170272-DEF-OPC-POD 1-1-00001 through 20170272-DEF-OPC-POD 1-1-0000199

DUKE FL POLE FORENSICS SUPPORT REPORT

FINAL
ANALYSIS

DUKE ENERGY FLORIDA

accentureconsulting

20170272-DEF-OPC-POD 1-4-00001

TABLE OF CONTENTS

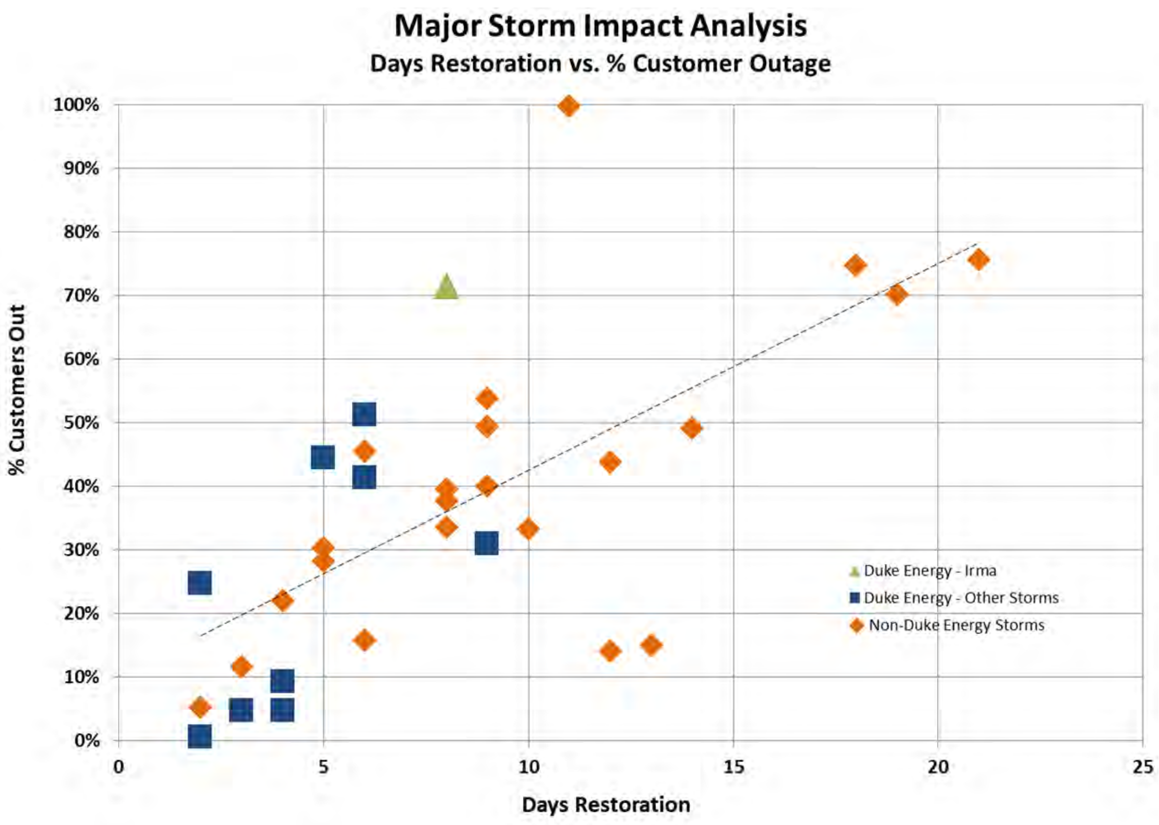
EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

- Hurricane Irma impacted Duke Energy Florida (DEF) service territory on September 10, 2017 as a Category 4 storm causing more than 70% of customers to lose power
- DEF collected forensic information on the broken poles in the early stages of the restoration and retained Accenture to conduct statistical and benchmark analysis using that data
- Accenture analysis focused on three key components:
  - **Benchmark Analysis** – leveraging "storm benchmark database" compared DEF performance against comparable storms
  - **Forensic Analysis** – using simple regression, multiple regression and multiple logistic analyses assessed the cause and effect of pole failures
  - **Storm Hardening Effectiveness** – applying visual and locational analysis evaluated the association of any broken poles to the hardening program established in 2006

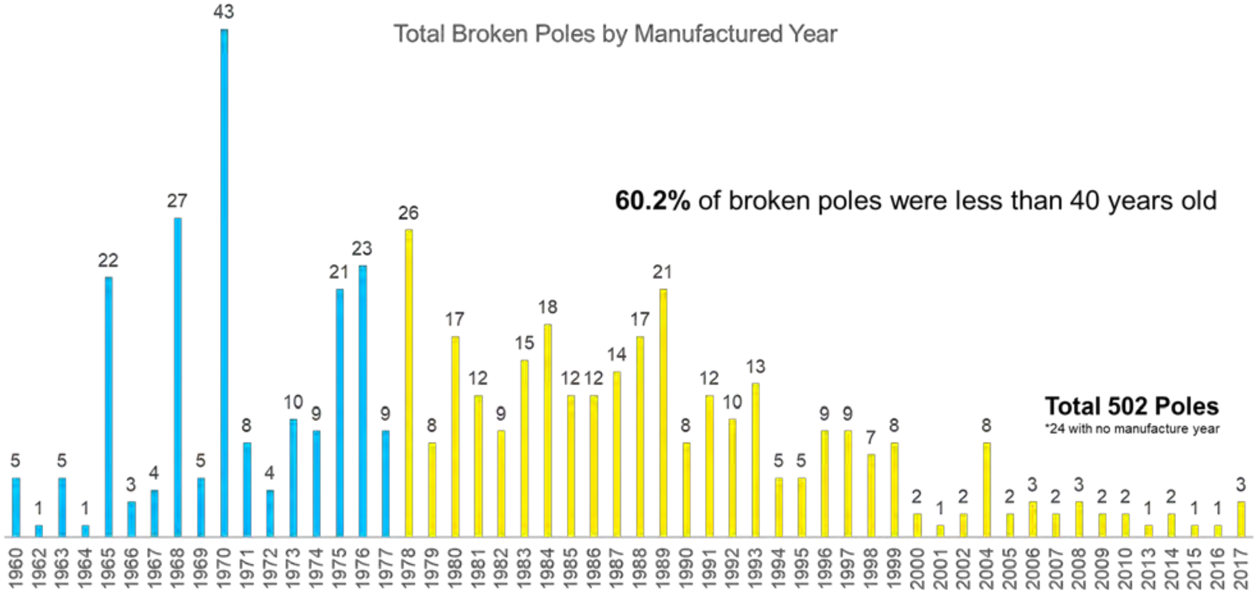
EXECUTIVE SUMMARY – BENCHMARK

- DEF deployed a large contingent of resources to this storm to ensure fast restoration
- DEF experienced less damage to its pole infrastructure when compared to similar events
- The number of poles replaced per customers out at peak was relatively low despite the high percentage of customers being affected
- DEF's Hurricane Irma restoration restored power to all customers faster than previous hurricane events as well as previous major storm events



EXECUTIVE SUMMARY – FORENSIC

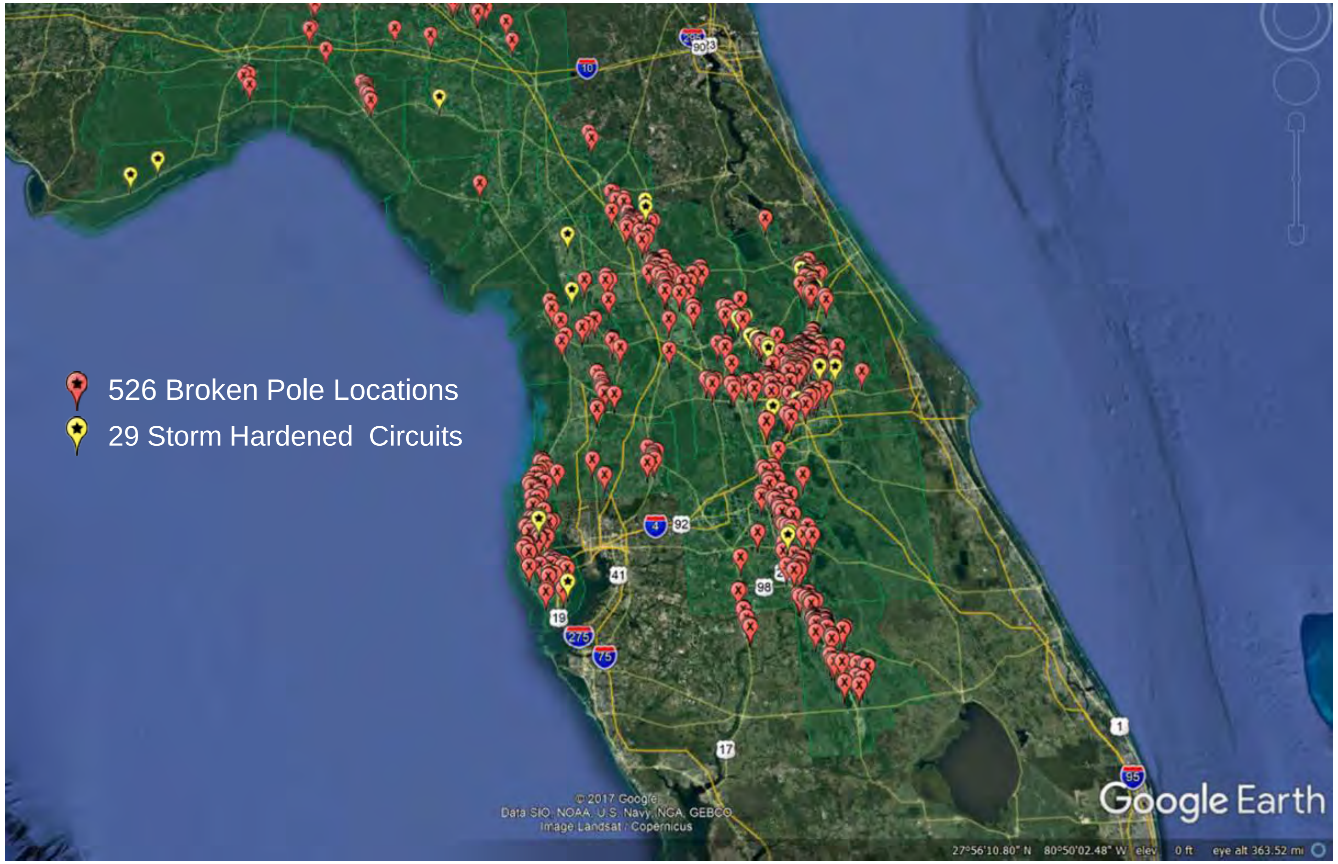
- Linear regression results indicated that age and pole height were correlated with failure rate.
- Multiple linear regression results suggested that the last inspection year and vegetation maintenance were not good indicators of pole failure rates.
- Results from both the simple and multiple analyses did not have a high correlation with the actual cause of pole failures. This suggests that other causal factors contributed to pole failures, e.g., damage to surrounding vegetation and additional loading on distribution facilities.
- The practice of conducting pole failure forensic analyses during major events is not yet widely used within the utility industry.



20170272-DEF-OPC-POD 1-4-00006

EXECUTIVE SUMMARY – SYSTEM HARDENING

- A forensic assessment of five hundred twenty-six (526) randomly selected poles was made across DEF's total broken pole population. None of these poles were a part of the 29 Storm Hardening projects.
- A separate assessment of twenty-nine (29) randomly selected Storm Hardening projects was made. No broken poles were identified.



20170272-DEF-OPC-POD 1-4-00007

OVERVIEW/ PURPOSE

OVERVIEW/PURPOSE

- Duke Energy Florida ("Duke FL") conducted a comprehensive analysis of forensic data on pole failures that the company collected in the aftermath of Hurricane Irma
- The purpose of the study is to determine the correlations and major causes of failure
- Accenture was retained to perform the analysis and performed the following tasks:
  - **Mobilized the Project**
    - Organize the available data into a single electronic database (table) to allow for analysis
    - Identify any gaps in the data and develop strategies to gather the missing information
  - **Performed Storm Benchmark Comparison**
    - Gather key statistics from the Duke FL response to Hurricane Irma
    - Identify the comparable events from Accenture's storm benchmarking database to compare against Duke FL's response
    - Conduct benchmark comparison and identify key metrics
    - Develop conclusions based on the benchmark analysis
  - **Conducted data analysis**
    - Define Duke FL's hypotheses
    - Conduct the regression analysis or apply other analytic methods to allow for statistically valid assessment of the correlations of the different factors
    - Identify the key drivers or pole failures and determine the overall cause and effect
    - Develop conclusions based on the statistical analysis
  - **Synthesize and Summarized**
    - Prepare a summary report that describes the methodology and conclusions based on the pole failure data analysis and the benchmark comparison

BENCHMARKING COMPARISON

METHODOLOGY/APPROACH

Two methods were used to collect data for benchmarking:

- Surveys
  - Duke FL provided metrics surrounding the restoration efforts of Hurricane Irma
  - Additional surveys were completed by other utilities for storms over the past 25+ years
  - The survey focused on three areas:
    - System Information
    - Storm Magnitude
    - Restoration Performance

- Historical/Archival Research
  - Additional research completed to enhance the benchmarking for restorations performed by other North American utilities that was not collected through surveys
  - These sources were collected from public filings with the commission and archival news feeds from the utility websites

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METHODOLOGY/APPROACH

- Identified similar category 1 – 4 hurricanes to perform the analysis of Duke FL's restoration efforts versus other utility companies captured in Accenture's storm benchmarking database from 1989 – 2017
- Highlighted restoration performances from Duke Energy and Progress Energy
- Accenture is using statistics that allow comparison without disclosing specific system information

DATA COLLECTION DEMOGRAPHICS

- 26 of 51 utilities included in the benchmarking
- 23 of 56 major events are included in the analysis
- 45 out of 119 unique restorations

Storm Type	Storm Name	Total
Hurricane Category 1	Fran	2
	Frances	2
	Hermine	1
	Hugo	1
	Humberto	1
	Irene	10
	Katrina	1
	Sandy	5
Hurricane Category 2	Elvis	1
	Georges	1
	Gustav	1
	Gustav + Ike	3
	Juan	1
	Isabel	2

Storm Type	Storm Name	Total
Hurricane Category 3	Ivan	2
	Jeanne	2
	Rita	2
	Wilma	1
Hurricane Category 4	Charley	2
	Hugo	1
	Irma	1
	Matthew	1
Hurricane Category 5	Floyd	1
Grand Total		**45**

Customers Served Range	# of Companies
0 – 500k	8
500k – 1 mil	2
1 mil – 1.5 mil	5
1.5 mil – 2 mil	2
2 mil – 2.5 mil	6
Over 2.5 mil	3
Grand Total	**26**

DATA COLLECTION
DUKE FL - IRMA STATISTICS

Company Information	
Total Number of Customers Served	1.8M
Total Overhead Distribution Line miles	18,000 miles
Total Underground Distribution Miles	14,000 miles

Storm Description	
Storm Name	Hurricane Irma
Storm Type	Hurricane
Storm Category	4
Start Date	September 10, 2017

Storm Damage Information	
Number of Customers Out at Peak	1,284,816
Number of Customers Out	1,738,030
Number of T&D Poles Replaced	2,271
Number of Transformers Replaced	1,106
Number of Conductor Feet Replaced	939,840 feet
Total Spans of Wire Down	> 26,000

Restoration Resources	
Total Line FTEs	7,500
Total Veg. Management FTEs	2,500
Total Damage Assessment Resources	2,408
Peak Number of Field Resources Deployed	12,500

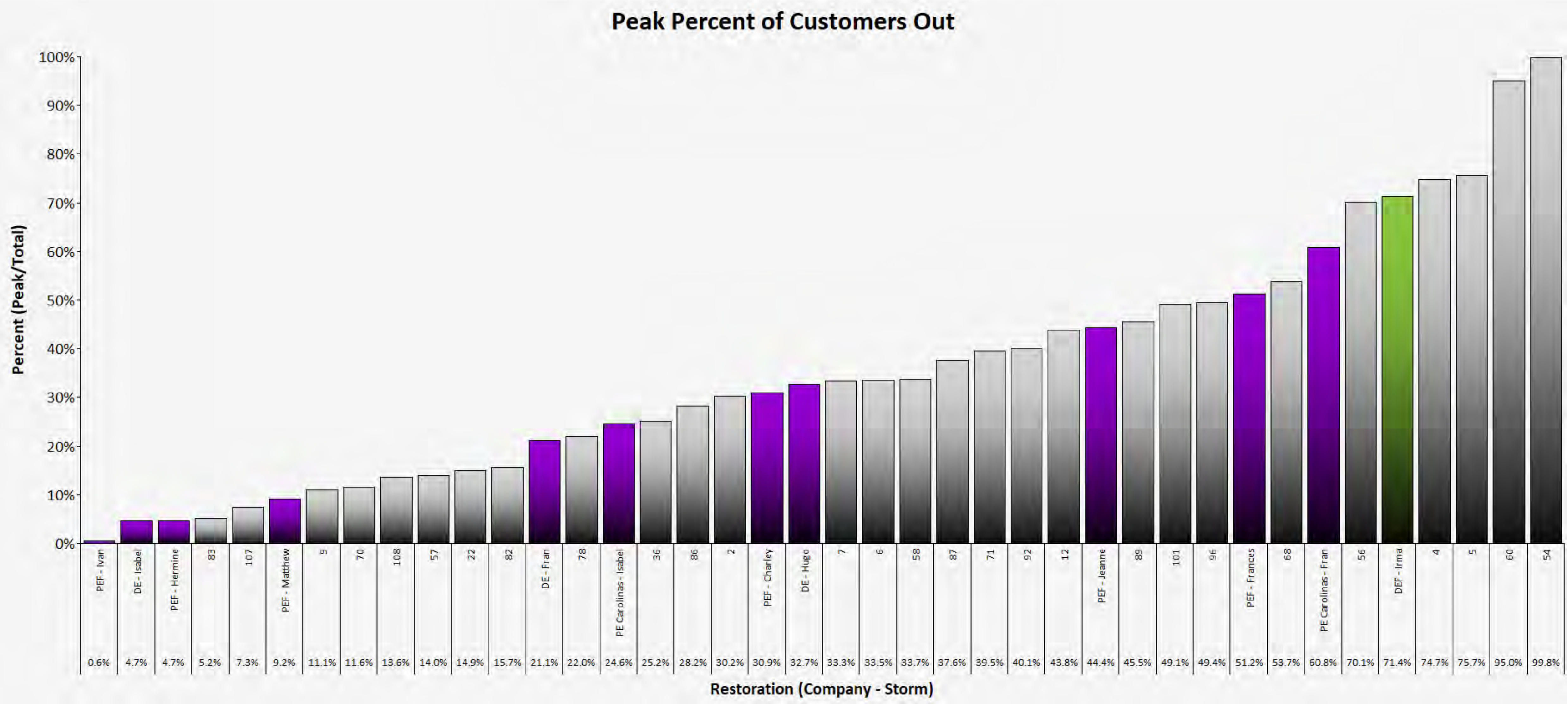
Restoration Duration	
Restoration Duration (# Days)	8 days

Restoration Costs	
Total Restoration Cost	$500M - $550M

Storm Drills	
Number of Storm Drills Per Year	1
Number of Table Top Exercises Per Year	2

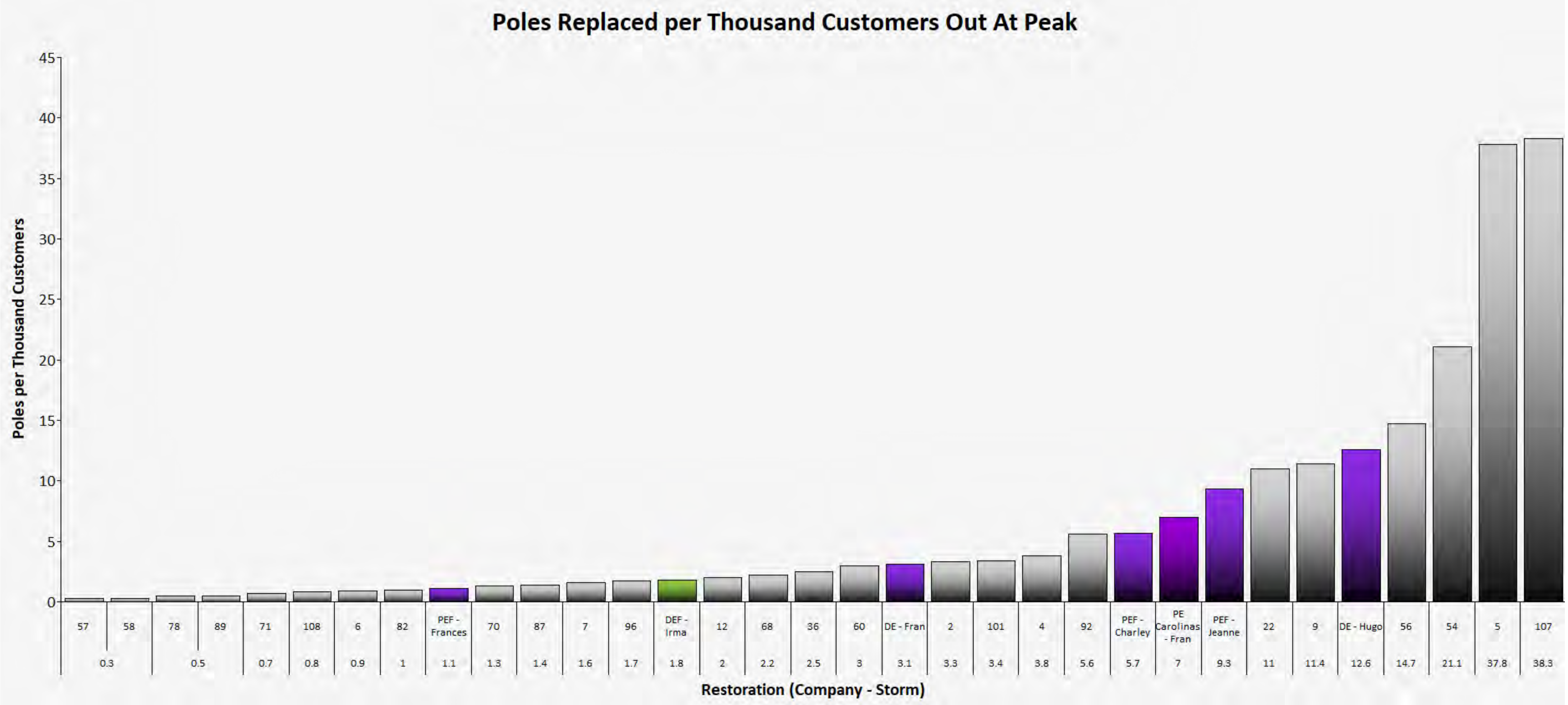
Vegetation Management	
Average Tree-Trimming Cycle	3yr backbone / 5yr branchlines

BENCHMARK RESULTS



20170272-DEF-OPC-POD 1-4-000015

BENCHMARK RESULTS



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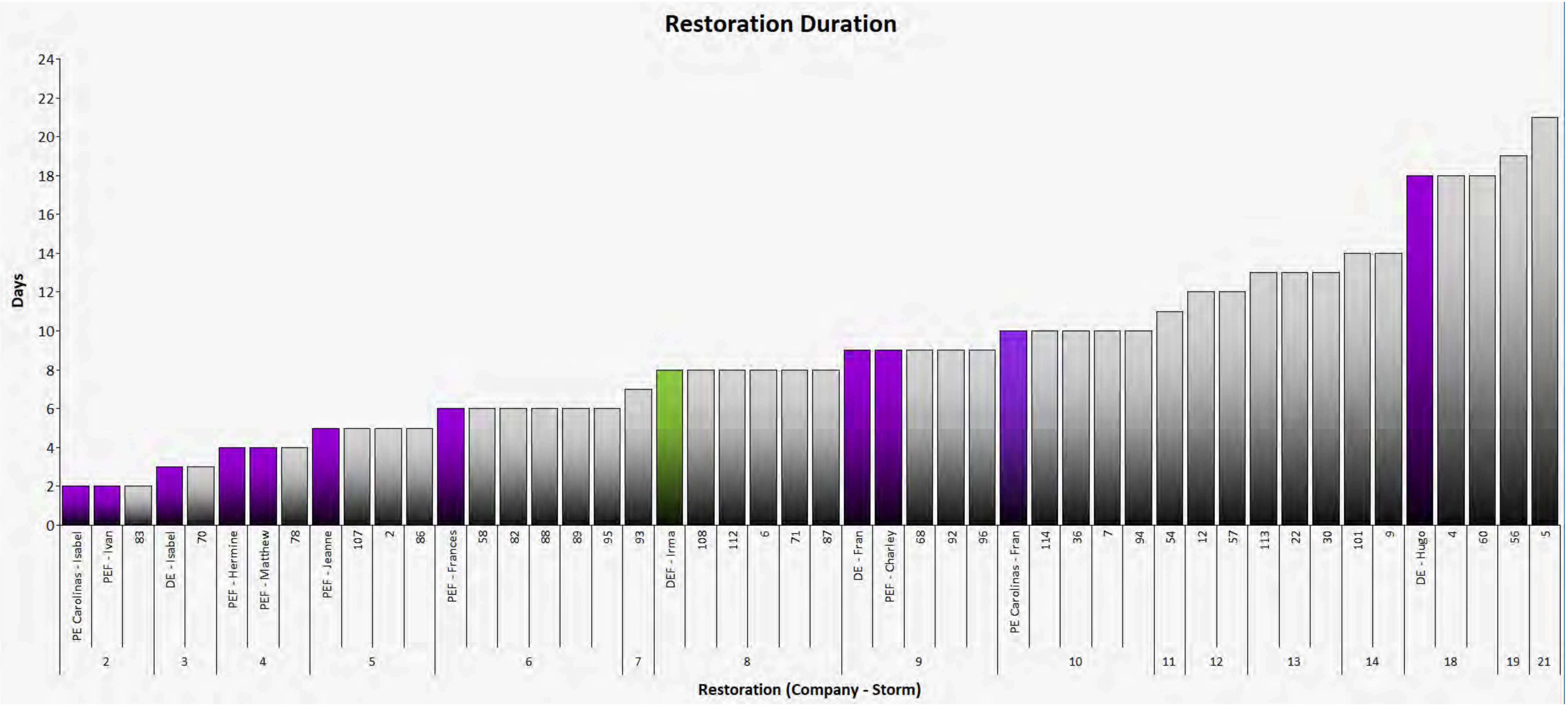
BENCHMARK RESULTS



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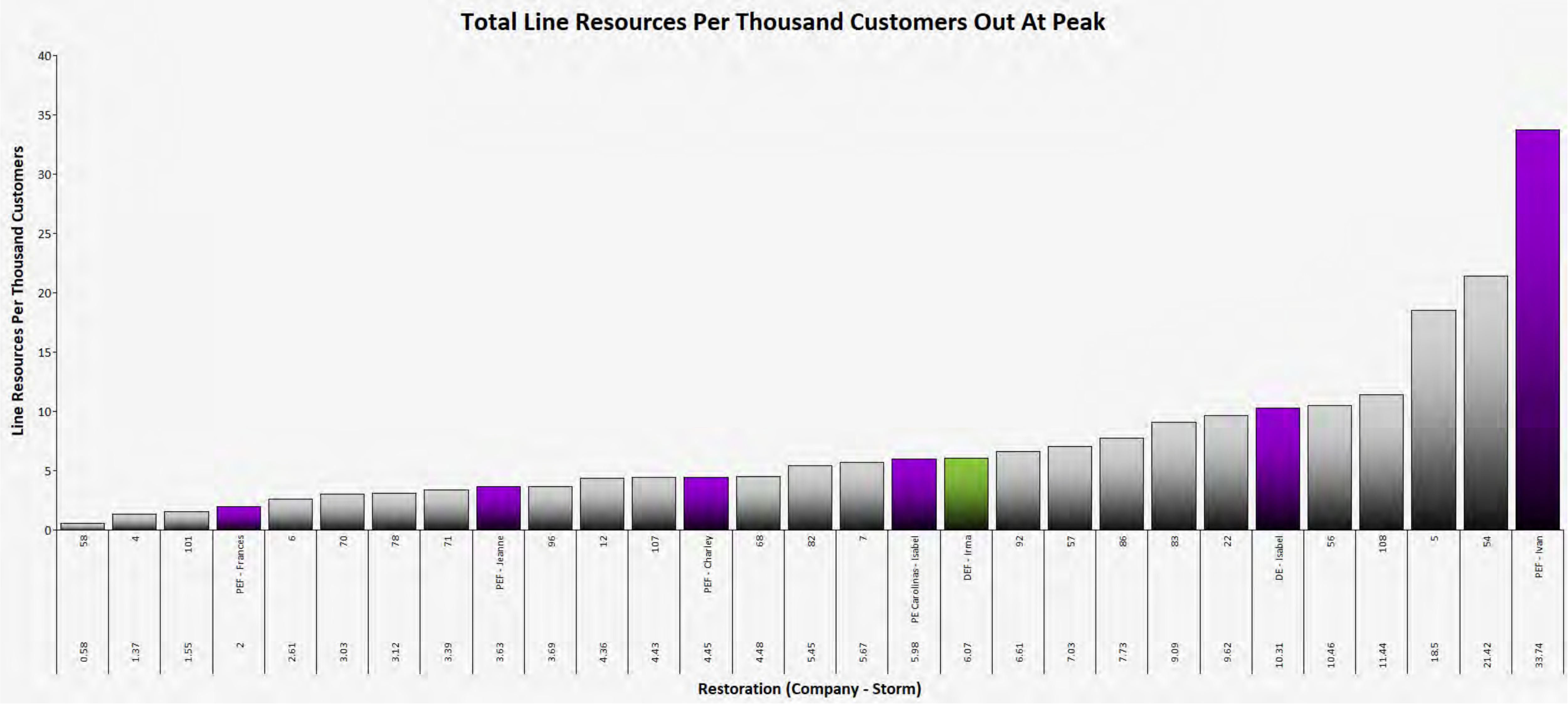
BENCHMARK RESULTS



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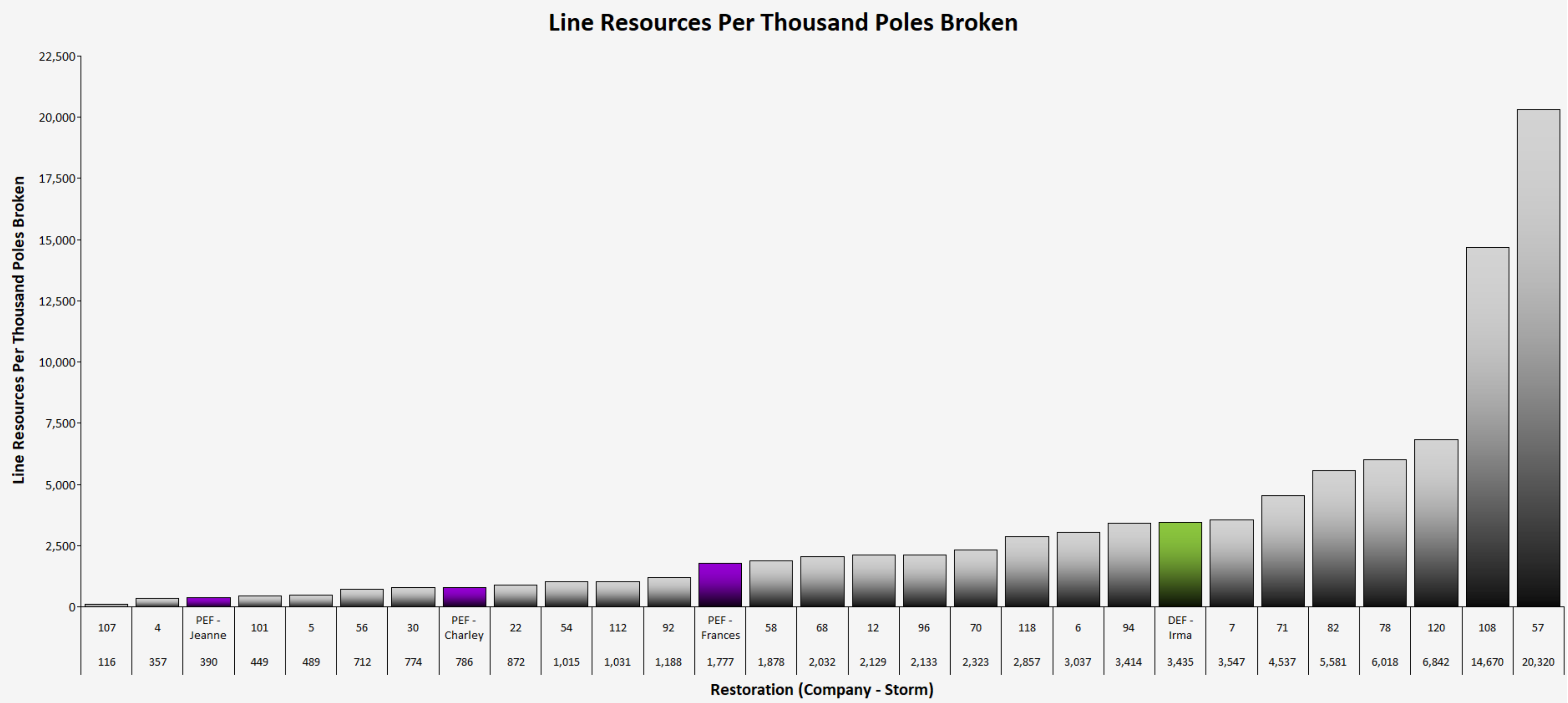
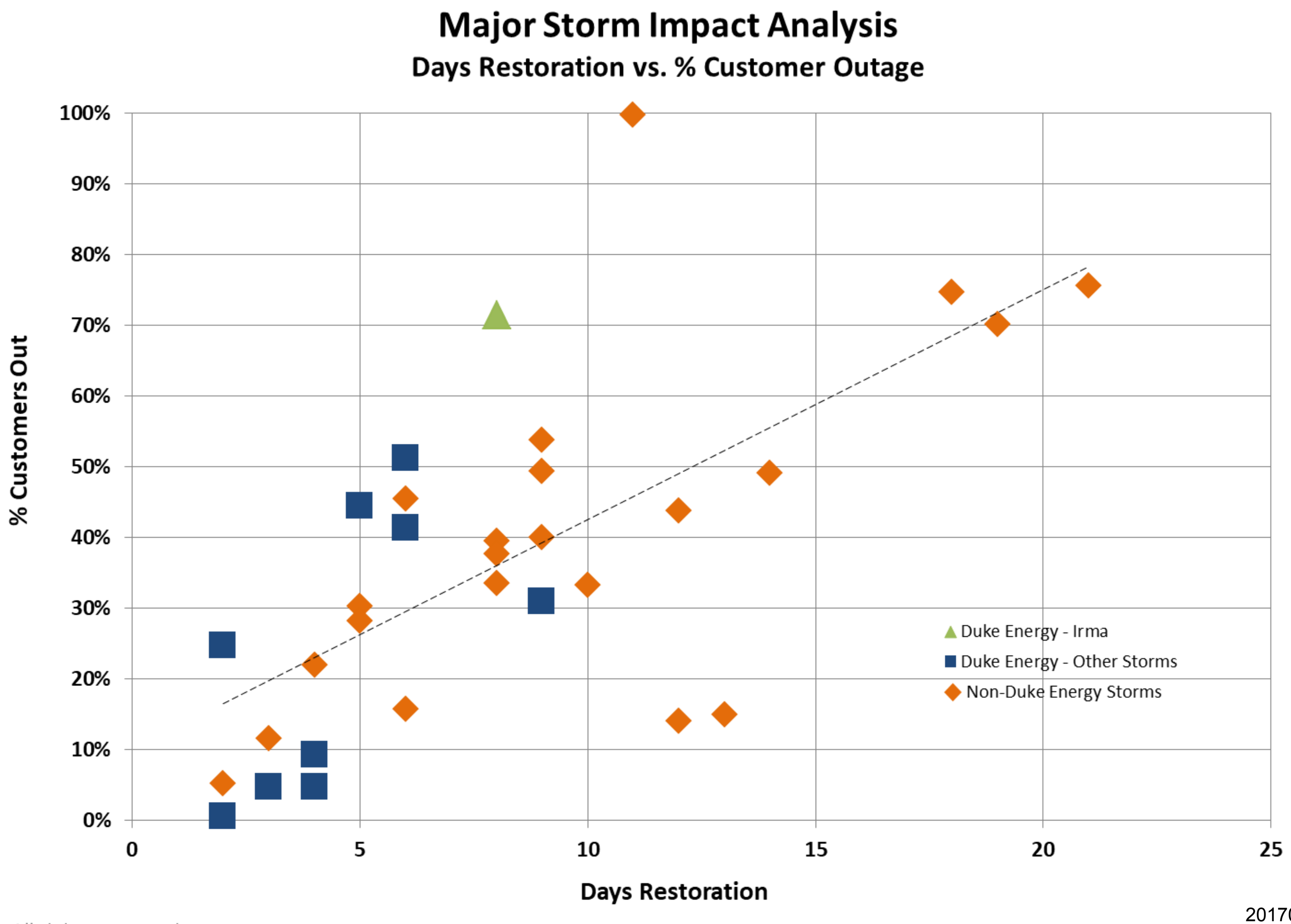
BENCHMARK RESULTS



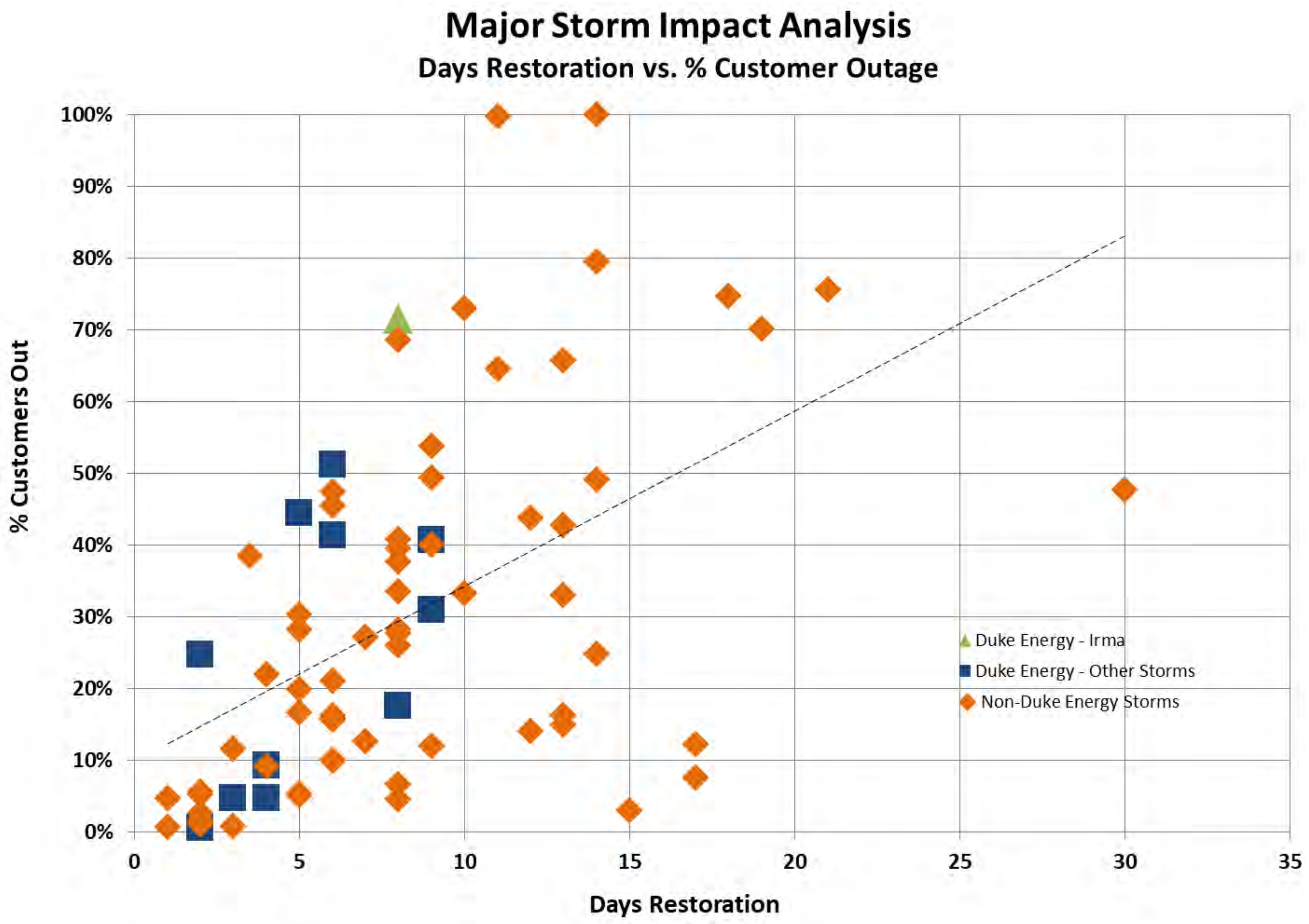
20170272-DEF-OPC-POD 1-4-000019

BENCHMARK RESULTS– ALL HURRICANES



20170272-DEF-OPC-POD 1-4-000020

BENCHMARK RESULTS– ALL RESTORATIONS



20170272-DEF-OPC-POD 1-4-000021

FINDINGS

Based on the high-level benchmark analysis:

- Duke Florida experienced less damage to its infrastructure when compared to similar events
  - Number of poles replaced per customers out at peak is relatively low despite the high percentage of customers being affected
  - This could indicate that the storm caused more of “wire” damage than “pole” failures, which can be interpreted that the infrastructure withstood the storm fairly well
- Duke Florida’s Hurricane Irma restoration cost per customer out and per pole replaced was higher but the company restored power to all customers faster than comparable events
  - In comparison to other hurricanes in Accenture’s database, The Company aggressively deployed a large contingent of resources for this storm.

FORENSICS ANALYSIS

METHODOLOGY

Analyze **broken pole data** through visualizations

Compare **broken pole data to distribution wood pole inventory** to identify factors that contributed to pole failure

Use **regression analyses** to test the correlations between potential pole failure factors and the rate of pole failure by circuit

Factors Considered:

- wind
- gust
- manufactured year
- pole height
- last inspection date
- vegetation level

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ASSUMPTIONS

- ✓ All data used including Broken Pole Forensics, GIS Inventory and Inspection data provided by Duke Energy
- ✓ Used Equip_ID and Cust_Data_ID to integrate Broken Pole Forensics, GIS Inventory and Inspection data
- ✓ Assumed that GIS contains a full inventory of Duke owned poles
- ✓ **526** broken wood poles were included in the forensic analysis out of a total of 2,130 distribution poles that were broken during the event
- ✓ Poles that had incomplete data were excluded from this population

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DATA COLLECTION

Broken Poles Included in Forensic Analysis

2,130 Total Broken Distribution Poles

687 Total Unique Broken Poles Sampled
— **114** Broken Poles not Duke, not Distribution, or not made of wood =

573 Distribution Broken Poles

- 47 Not Matched to GIS data =

526 Broken Poles Total
471 Broken Poles with Forensic Data

Pole Inventory – Duke Florida

1,083,388 Total Unique Pole Records

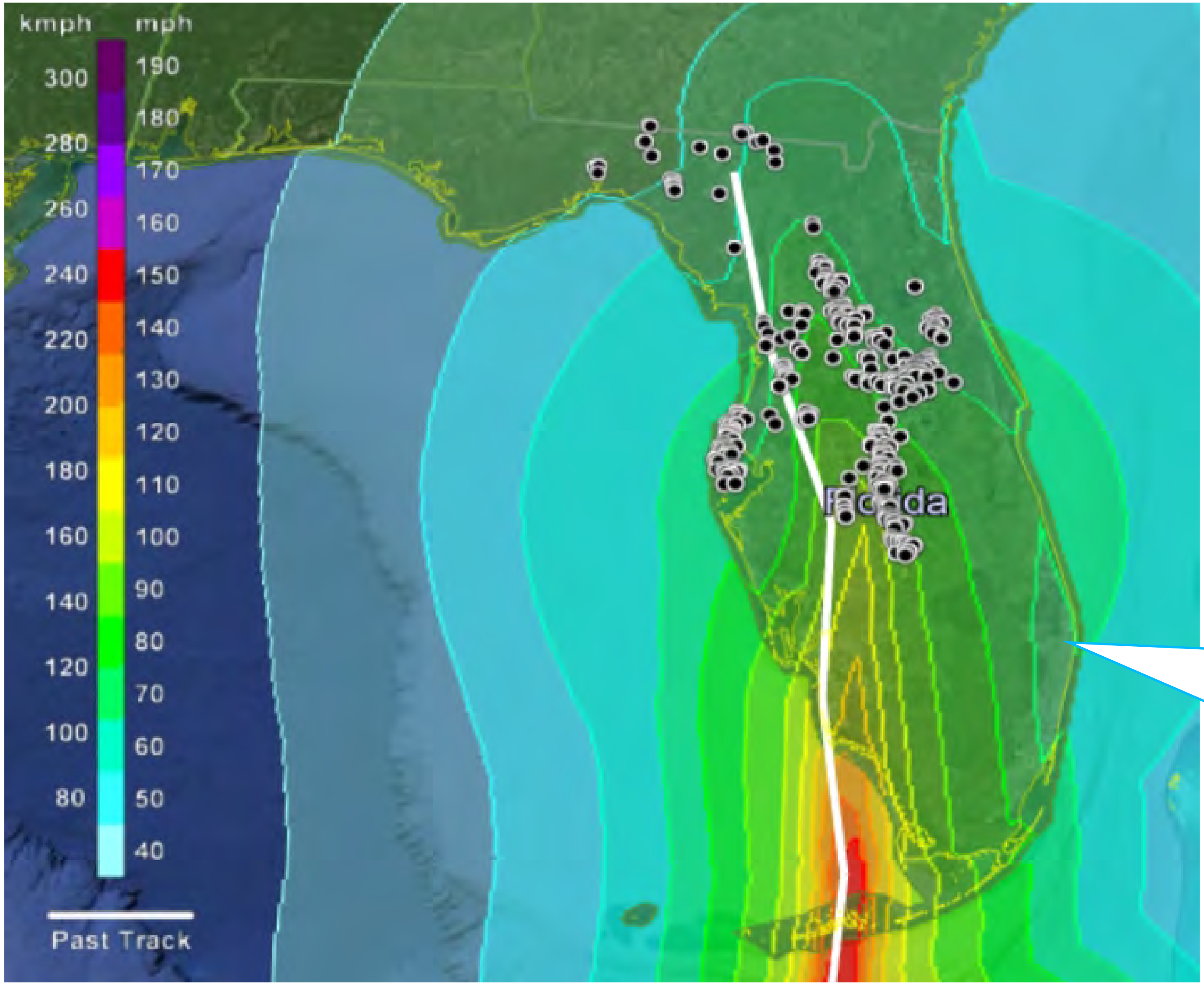
— **257,655** Transmission
— **99,469** Not Wood
— **624** Non Duke =

725,640 Total Distribution wood poles

20170272-DEF-OPC-POD 1-4-000026

BROKEN POLE VISUALIZATIONS

DUKE ENERGY. FLORIDA



https://data.humdata.org/dataset/hurricane-irma-windspeed

526 Broken Poles

Irma Path
9/11 12am – 12pm

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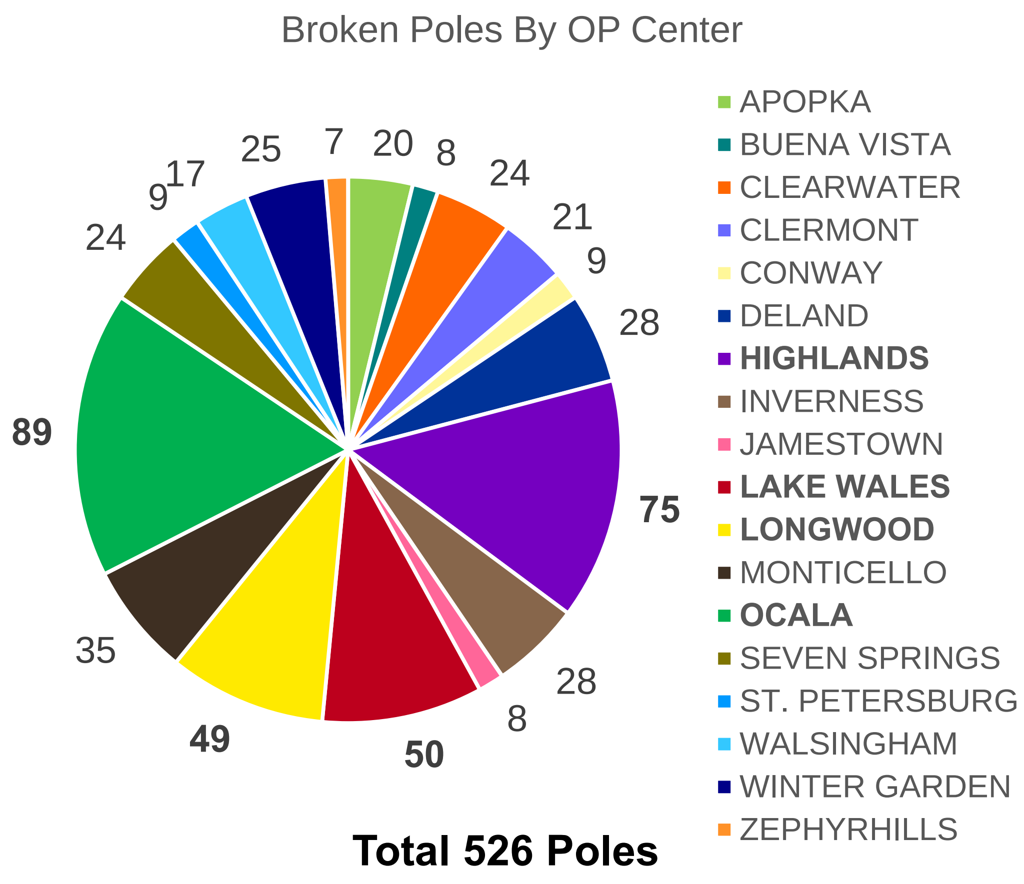
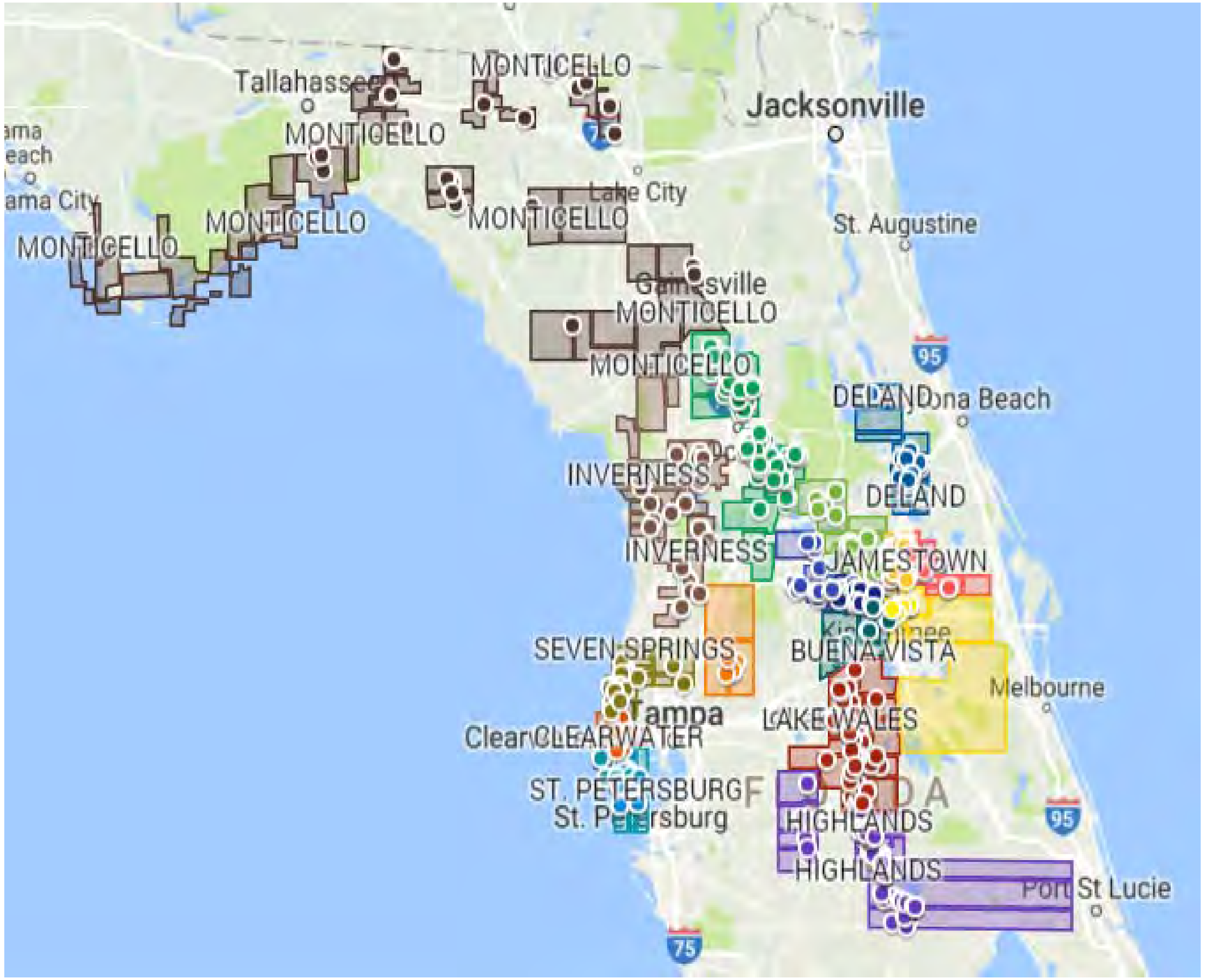
BROKEN POLE VISUALIZATIONS

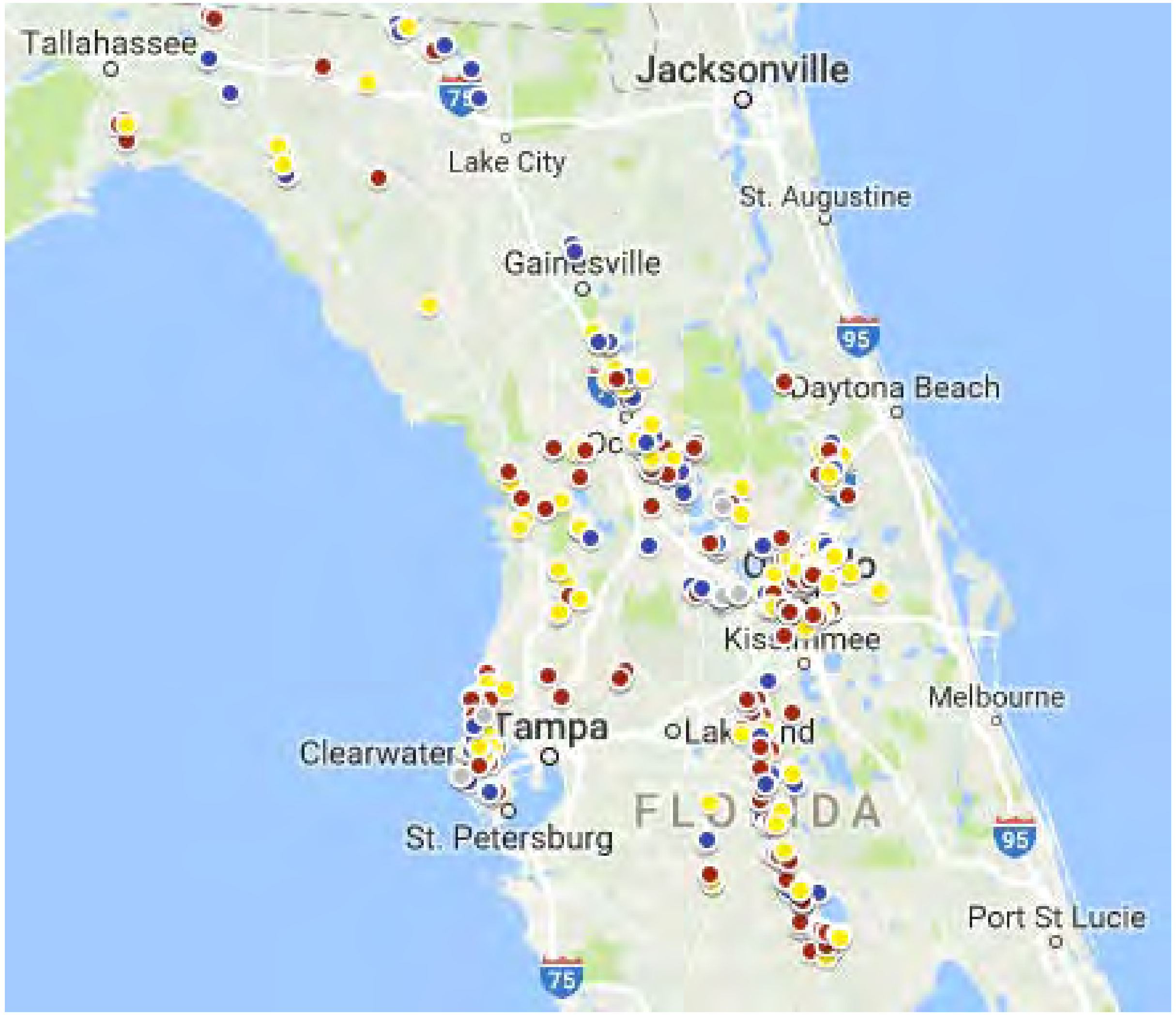




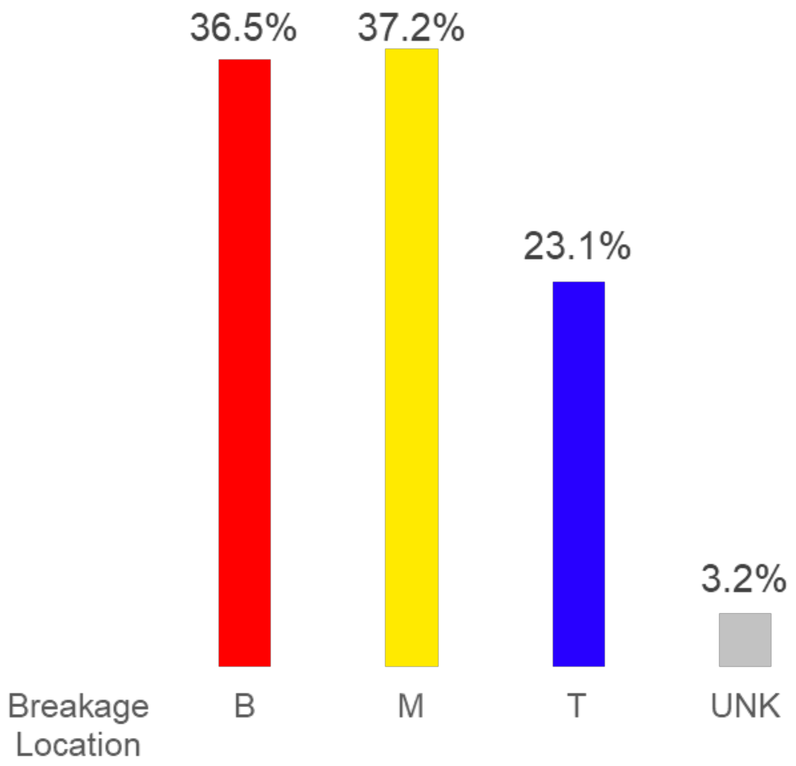
50% of broken pole data came from **Ocala**, **Highlands**, **Lake Wales** and **Longwood** OP Centers

20170272-DEF-OPC-POD 1-4-000028

BROKEN POLE VISUALIZATIONS



- **37.2%** of poles broke in the middle



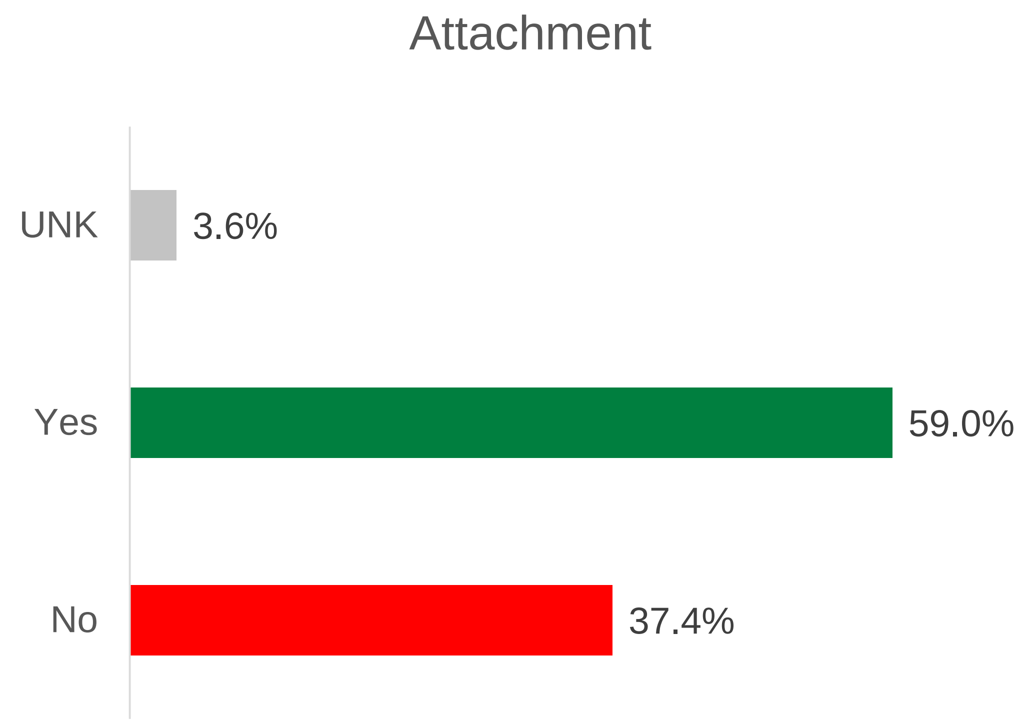
Total 471 Poles

***66 poles that broke at the bottom did not have reject status information**

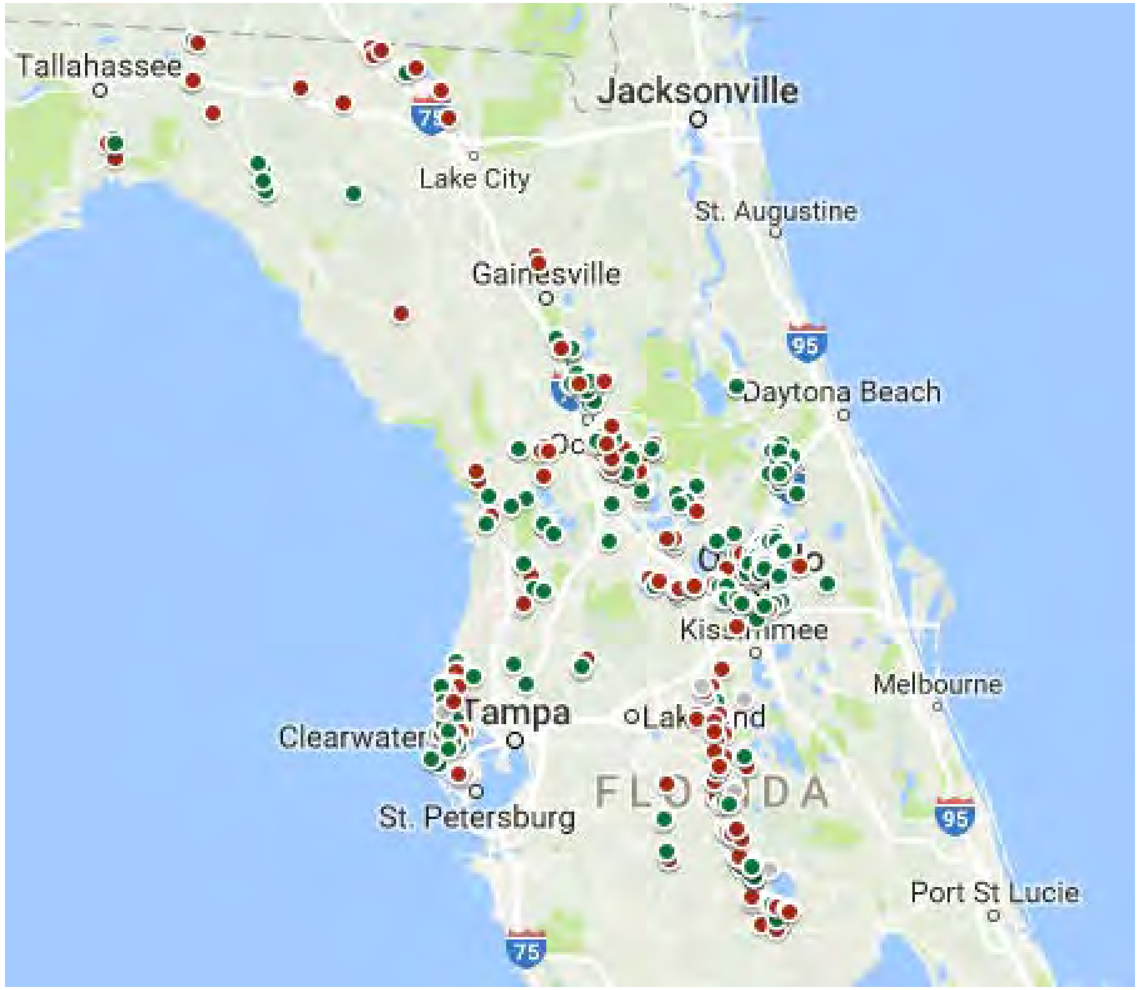
20170272-DEF-OPC-POD 1-4-000029

BROKEN POLE VISUALIZATIONS

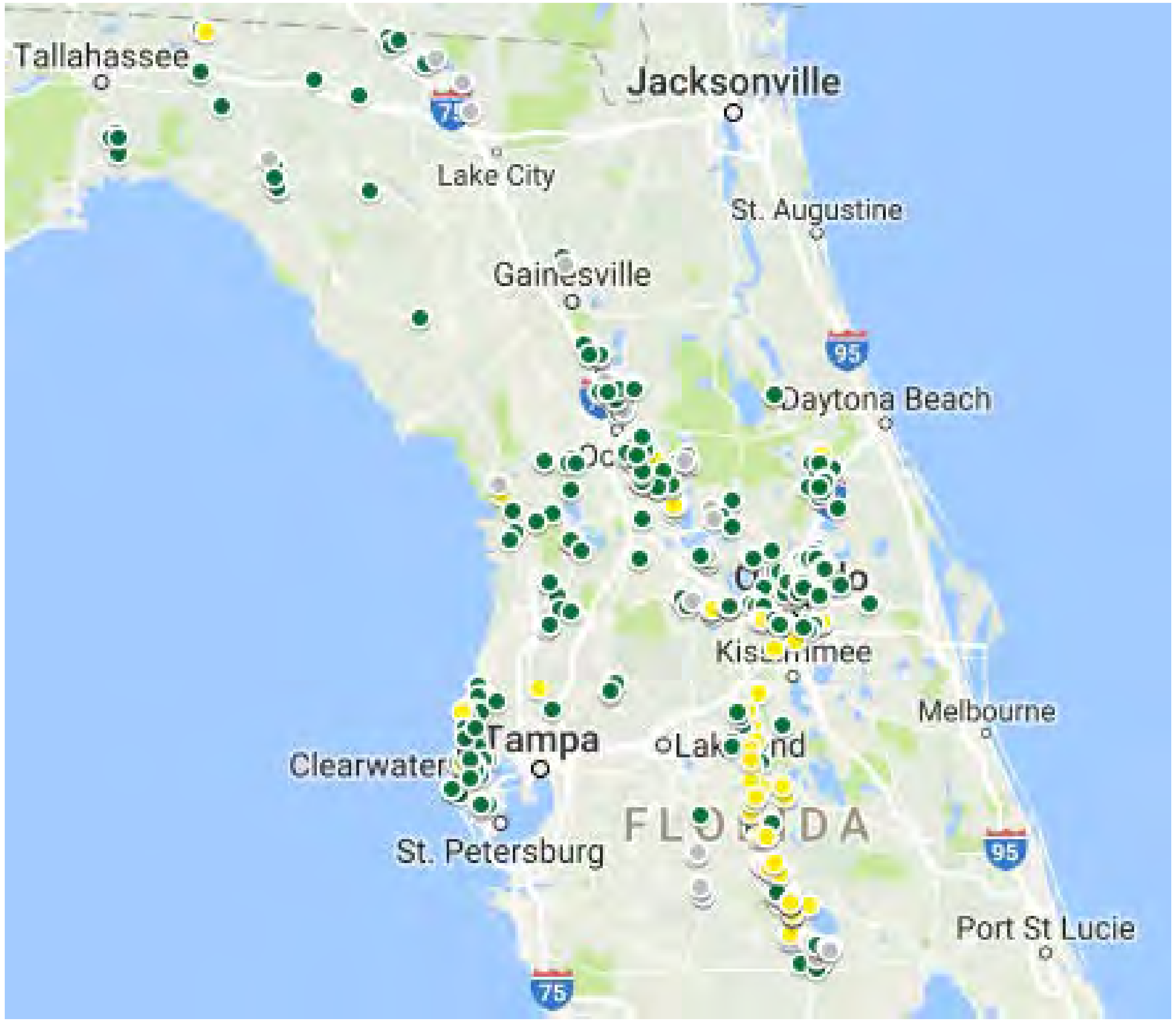
59% of broken poles had an attachment



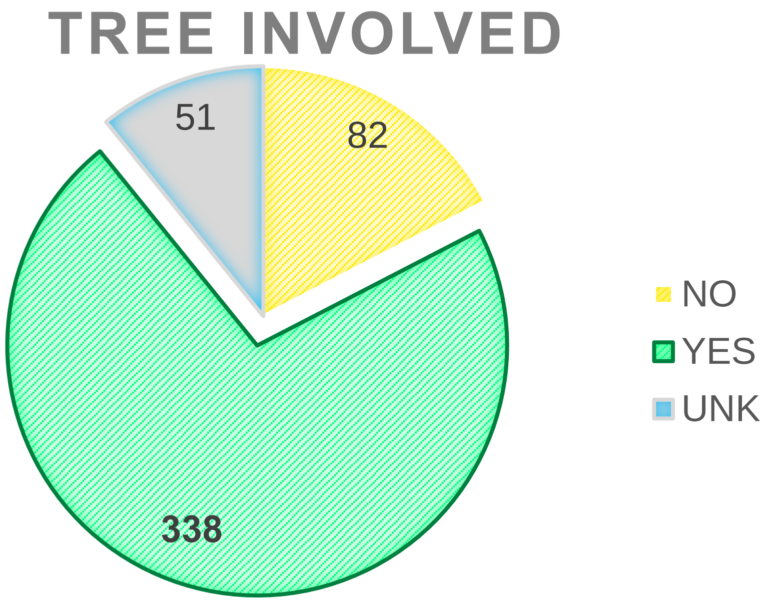
Total 471 Poles



BROKEN POLE VISUALIZATIONS



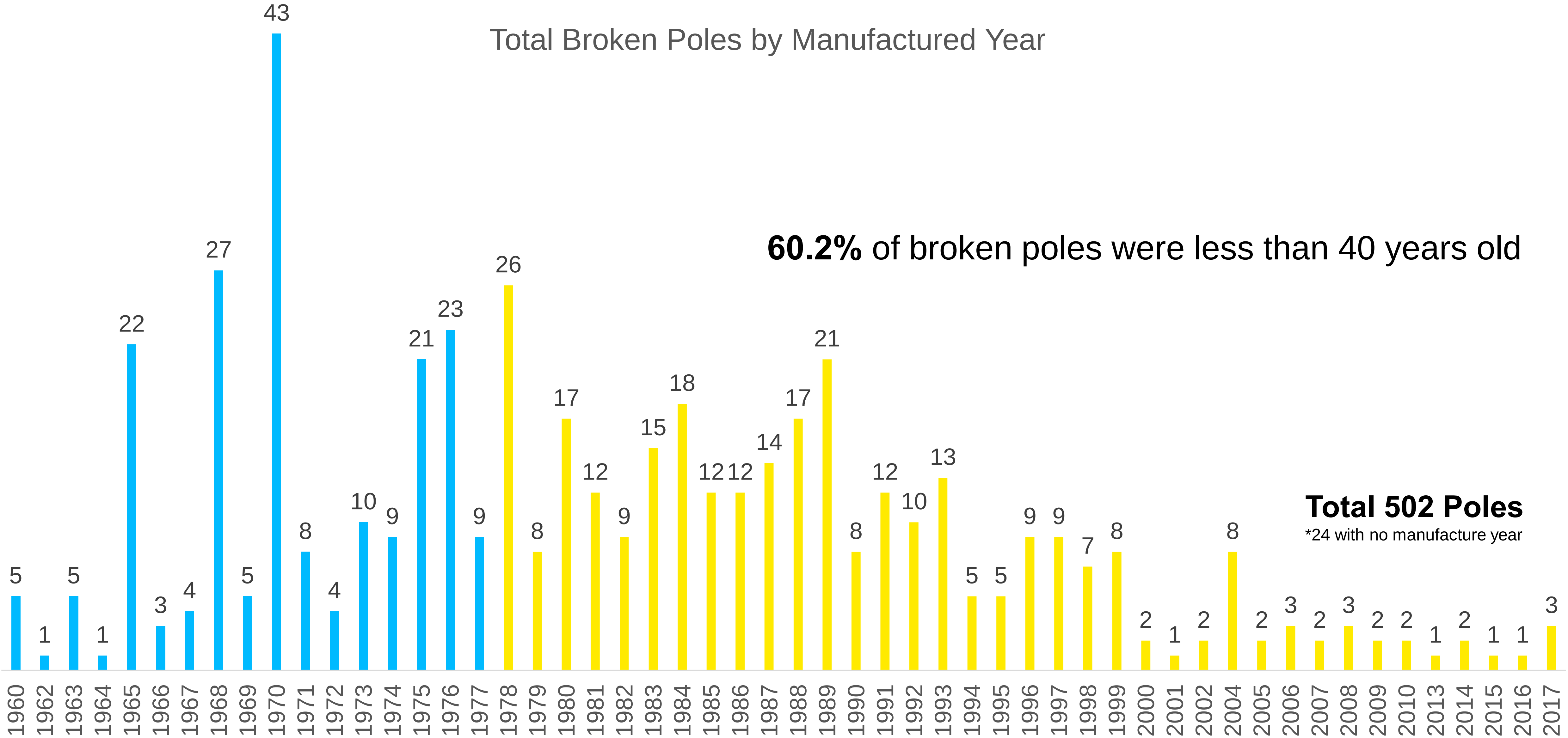
71.8% of broken poles had a tree involved



Total 471 Poles

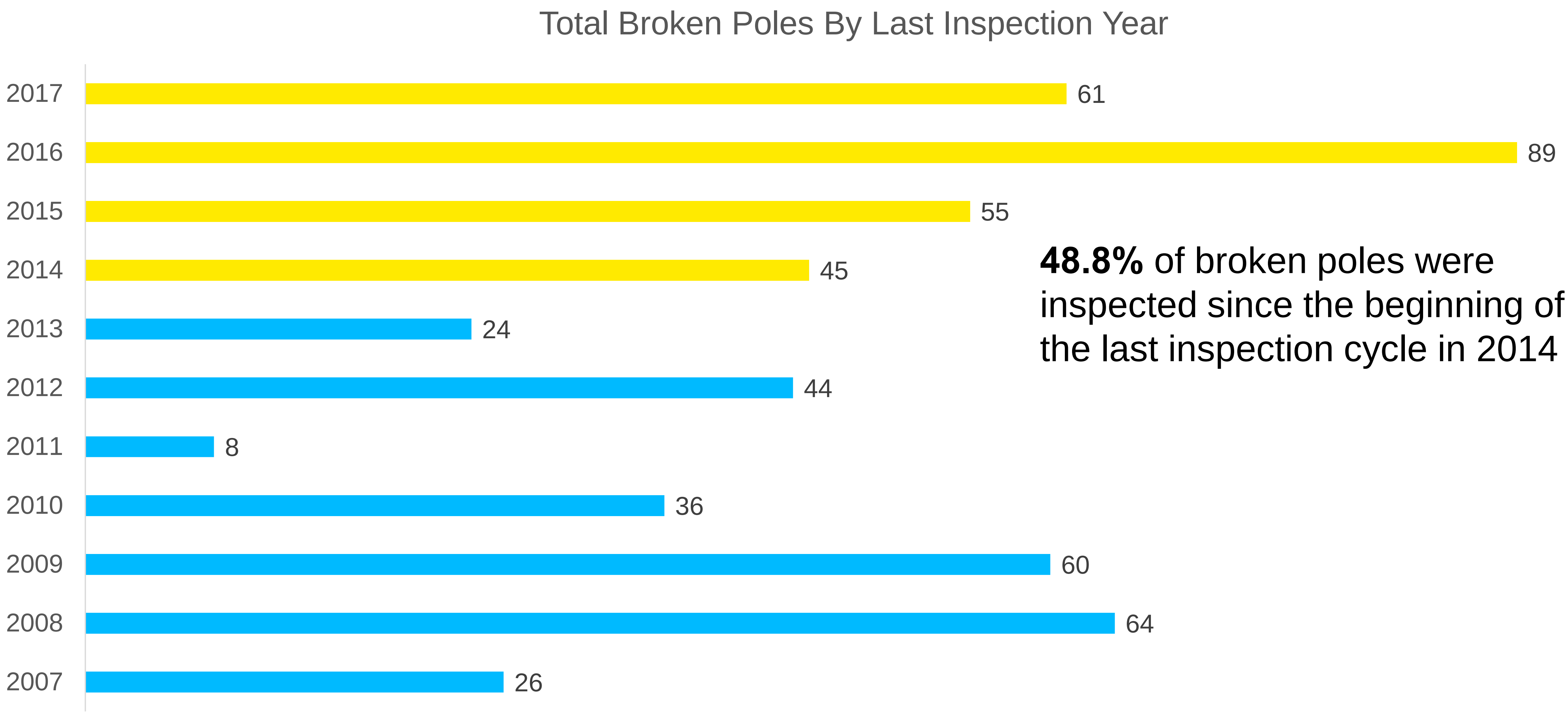
20170272-DEF-OPC-POD 1-4-000031

BROKEN POLE VISUALIZATIONS



20170272-DEF-OPC-POD 1-4-000032

BROKEN POLE VISUALIZATIONS



48.8% of broken poles were inspected since the beginning of the last inspection cycle in 2014

Total 512 Poles

*14 with no inspection year

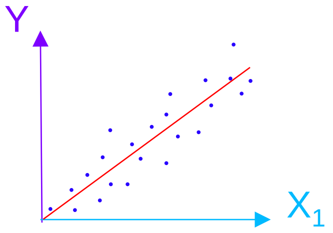
20170272-DEF-OPC-POD 1-4-000033

INTRO TO REGRESSION ANALYSES

Regression analysis is a way of mathematically determining the relationship between two or more variables. In our analysis we employ three types of regression analyses.

Type of Regression | **Model Design** | **Why we use it**

Simple Linear Regression



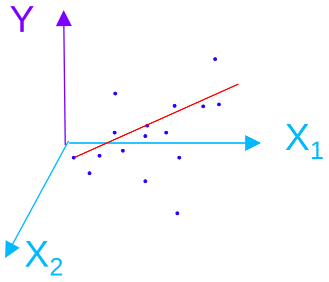
Y = Intercept + Correlation * X_1 + Error

Y = Percent Pole Failure by Circuit

X_1 = Pole Failure Factor (wind, gust, manufactured year, last inspection, off cycle)

- Determine correlation between each individual pole failure factor and pole failure rate

Multiple Linear Regression



Y = Intercept + Correlation * X_1 + Correlation * X_2+ …+ Error

Y = Percent Pole Failure by Circuit

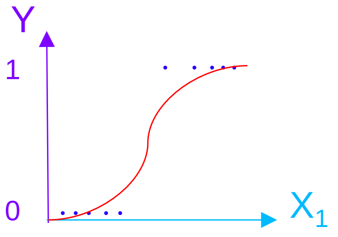
X_1 = Pole Failure Factor i.e. wind speed

…

X_n = Pole Failure Factor i.e. max off cycle

- Consider the impact of the combination of all pole failure factors on percent pole failure rate
- Determine which factors compared to others have the most predictive power

Multiple Logistic Regression



$\text{Log}\left(\frac{Y}{1-Y}\right)$ = Intercept + Correlation * X_1 + Correlation * X_2+ …+ Error

Y = Likelihood of failing with tree involved

X_1 = Pole Failure Factor i.e. wind speed

…

X_n = Pole Failure Factor i.e. attachment

- Given that a pole fails, determine what factors were contributed to it having a tree involved

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INTERPRETING REGRESSION RESULTS

There are multiple measures we can look at to understand the results of linear regression, including the **Correlation Coefficient Estimate**, associated **P Values**, and **R^2 Value**. Consider the example below:

Example Results:

Y = Intercept + **Correlation** * X_1 +…+ Error

Y = Percent Pole Failure by Circuit
X_1= Pole Failure Factor i.e. Avg Pole Height

	Estimate	P Value
Intercept	1.734e-03	0.00025***
Avg Pole Height	**-2.979e-05**	**0.01267***

Correlation Coefficient Estimate – This value denotes the relationship between the potential pole failure factor and pole failure rate. A positive value indicates that factor and pole failure are directly related (i.e. taller poles are associated with a higher pole failure rate). A negative value indicates that the factor and pole failure are inversely related (i.e. taller poles are associated with a lower pole failure rate).

P Value – The P value of a correlation coefficient estimate helps us understand how confident we can be in the correlation coefficient estimate. In our regression analysis, it is the probability that we falsely determine a correlation between the pole failure factors and pole failure rate with our sample data, given that there is no correlation. A small p value (typically <0.05) indicates a statistically significant correlation coefficient estimate.

In our results if:

P <.05 the p value is marked with a '*'
P < .01 the p value is marked with a '**'
P < .001 the p value is marked with a '***'

R^2 Value – The R^2 value is a measure that is used to determine how well the regression model fits the observed data set. It is the proportion of variance in percent pole failure that is explained by the model. R^2 values range from 0-1. The closer this value is to 1, the higher the model's predictive power of observed pole failure rates.

POLE FAILURE FACTORS CONSIDERED

In our regression analysis, we measure the following pole failure factors against the **average percent pole failure by circuit**.

Factor (by circuit)	Description	Minimum	Maximum	Median	Sample
Max Wind (mph)	Maximum wind speed experienced by a pole on the circuit measured from the closest weather center	15.8	70.2	41.4	1,215 circuits
Max Gust (mph)	Maximum gust speed experienced by a pole on the circuit measured from the closest weather center	20	88.6	58.4	1,083 circuits
Avg Manufactured Year	Average manufactured year by circuit	1963	2014	1987	1,235 circuits
Avg Height (ft.)	Average pole height by circuit measured in feet	16	52	39	1,269 circuits
Avg Last Inspection Year	Average pole last inspection year from consolidated inspection data	2007	2017	2013	1,249 circuits
Vegetation Management	Off cycle circuits given a value of 1. On cycle circuits given a value of 0.	0	1	0	1,248 circuits

SIMPLE LINEAR REGRESSION: MAX WIND

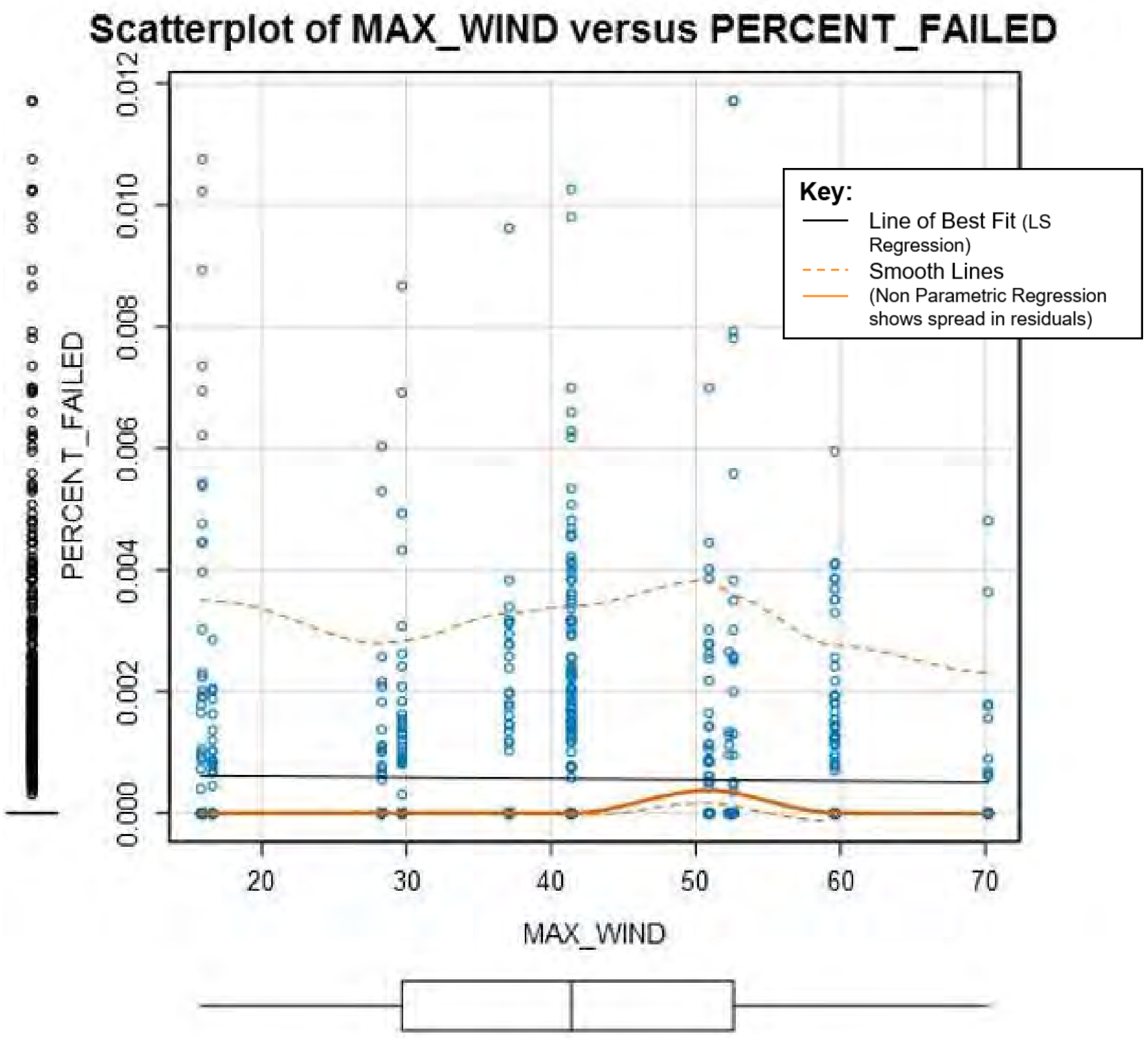
Data Summary

Variable	Min	Max	Median	Sample Size
Max Wind (x)	15.8 mph	70.2 mph	41.4 mph	1,215 circuits
Percent Failed (y)	0.000	0.012	0.000	

Results

	Estimate	P Value
Intercept	6.498e-04	2.97e-08***
Max Wind	-2.038e-06	0.44725

- No statistically significant relationship between max wind experienced by a circuit and pole failure rate (P = 0.44725 >0.05)
- Data suggests other factors contributed to distribution pole failure



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SIMPLE LINEAR REGRESSION: MAX GUST

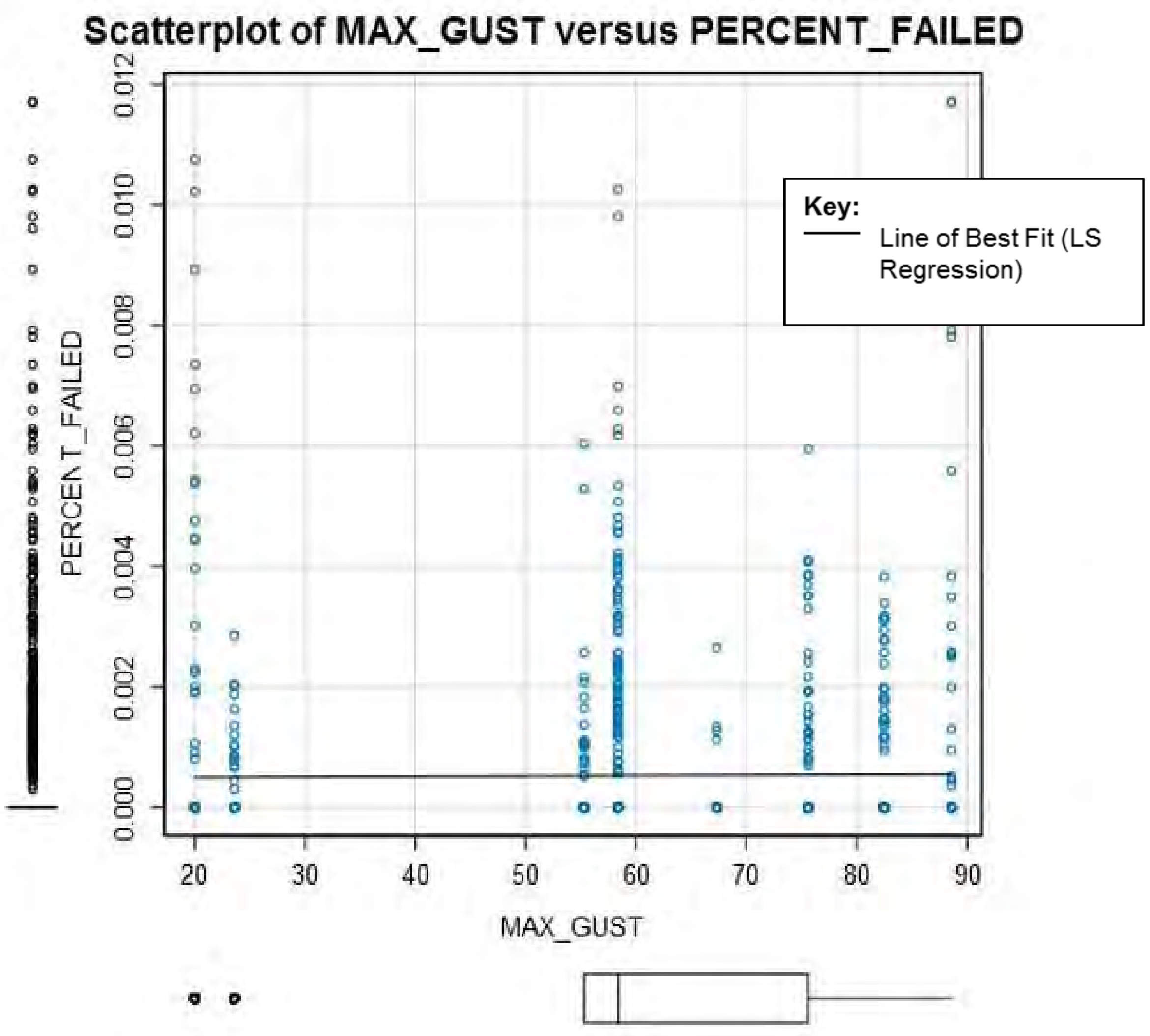
Data Summary

Variable	Min	Max	Median	Sample Size
Max Gust (x)	20 mph	88.6 mph	58.4 mph	1,083 circuits
Percent Failed (y)	0.000	0.012	0.000	

Results

	Estimate	P Value
Intercept	4.836e-04	0.00016***
Max Gust	7.601e-07	0.71111

- No statistically significant relationship between max gust experienced by a circuit and percent pole failure (P = 0.71111 >0.05)
- Data suggests other factors contributed to distribution pole failure



SIMPLE LINEAR REGRESSION: AVG MANUFACTURED YEAR

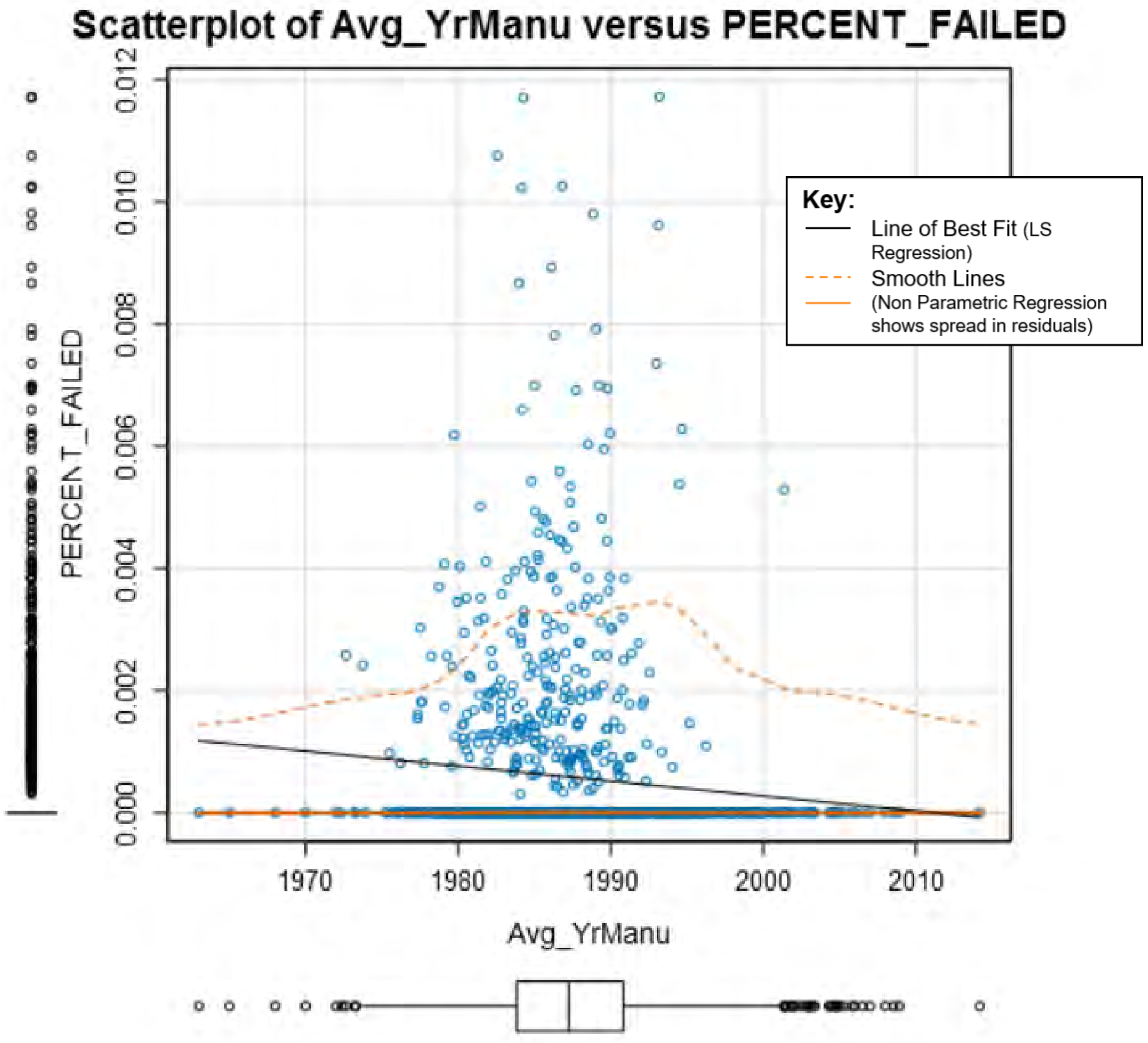
Data Summary

Variable	Min	Max	Median	Sample Size
Avg Manufactured Year (x)	1963	2014	1987	1,235 circuits
Percent Failed (y)	0.000	0.012	0.000	

Results

	Estimate	P Value
Intercept	4.925e-02	0.00043***
Avg Manufactured Year	-2.449e-05	5e-04***

- There is a statistically significant relationship between average manufactured year of a circuit and percent pole failure. (P = 0.0005 <0.05)
- Data suggests circuits with newer poles on average are associated with lower pole failure rates*.



*Note: This analysis does not consider reinforcement of older poles.

SIMPLE LINEAR REGRESSION: AVG POLE HEIGHT

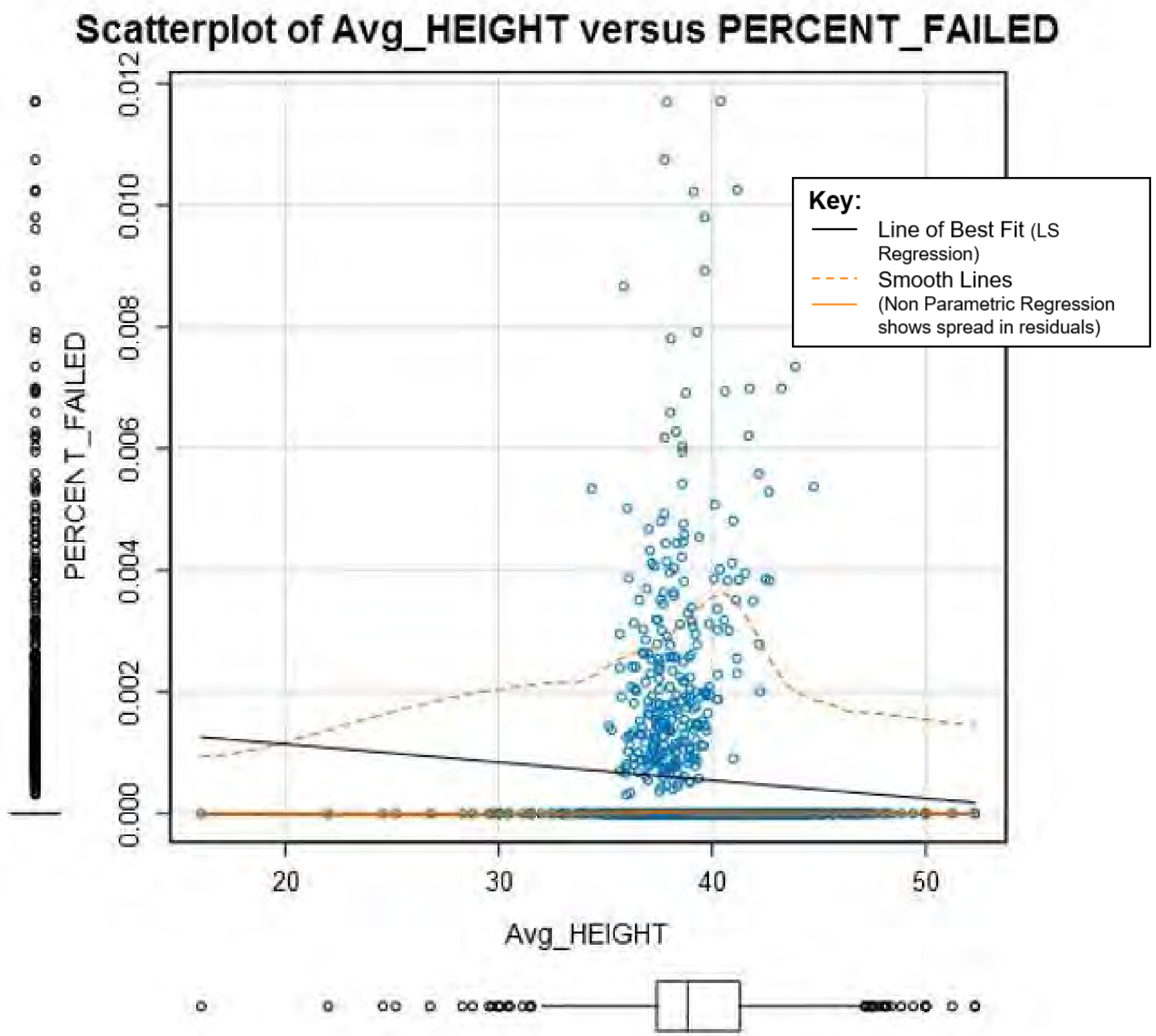
Data Summary

Variable	Min	Max	Median	Sample Size
Avg Pole Height (x)	16 ft.	52 ft.	39 ft.	1,269 circuits
Percent Failed (y)	0.000	0.012	0.000	

Results

	Estimate	P Value
Intercept	1.734e-03	0.00025***
Avg Pole Height	-2.979e-05	0.01267*

- There is a statistically significant relationship between average pole height of a circuit and percent pole failure. (P = 0.01267 <0.05)
- Data suggests circuits with taller average pole heights are associated with lower pole failure rates.



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SIMPLE LINEAR REGRESSION: AVG LAST INSPECTION YEAR

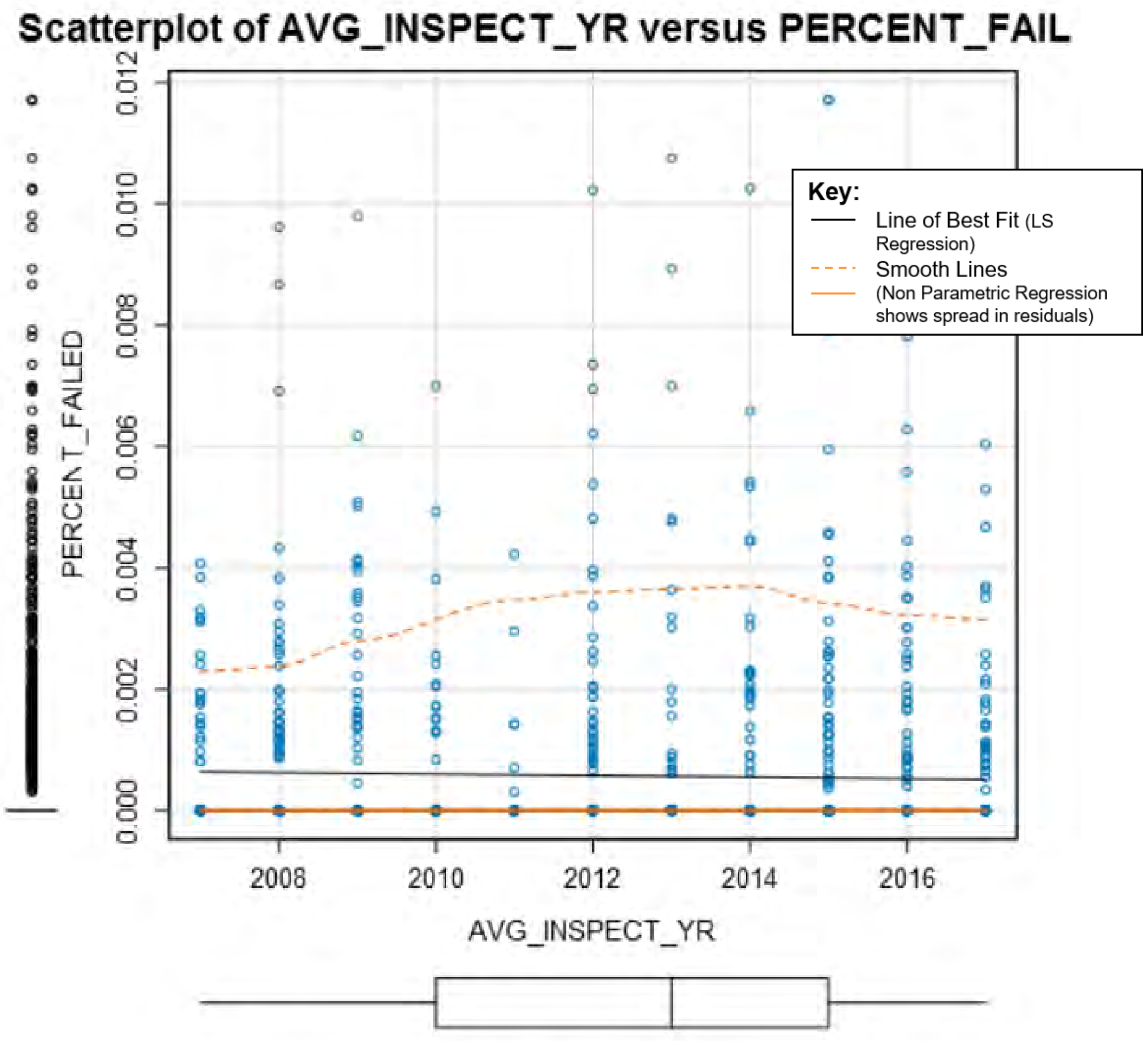
Data Summary

Variable	Min	Max	Median	Sample Size
Avg Inspection Year (x)	2007	2017	2013	1,249 circuits
Percent Failed (y)	0.000	0.012	0.000	

Results

	Estimate	P Value
Intercept	2.629e-02	0.33208
Avg Inspection Year	-1.278e-05	0.34264

- No statistically significant relationship between average last inspection year of a circuit and percent pole failure (P = 0.34264 >0.05)
- Data suggests other factors contributed to distribution pole failure



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SIMPLE LINEAR REGRESSION: VEGETATION MANAGEMENT

DUKE ENERGY. FLORIDA

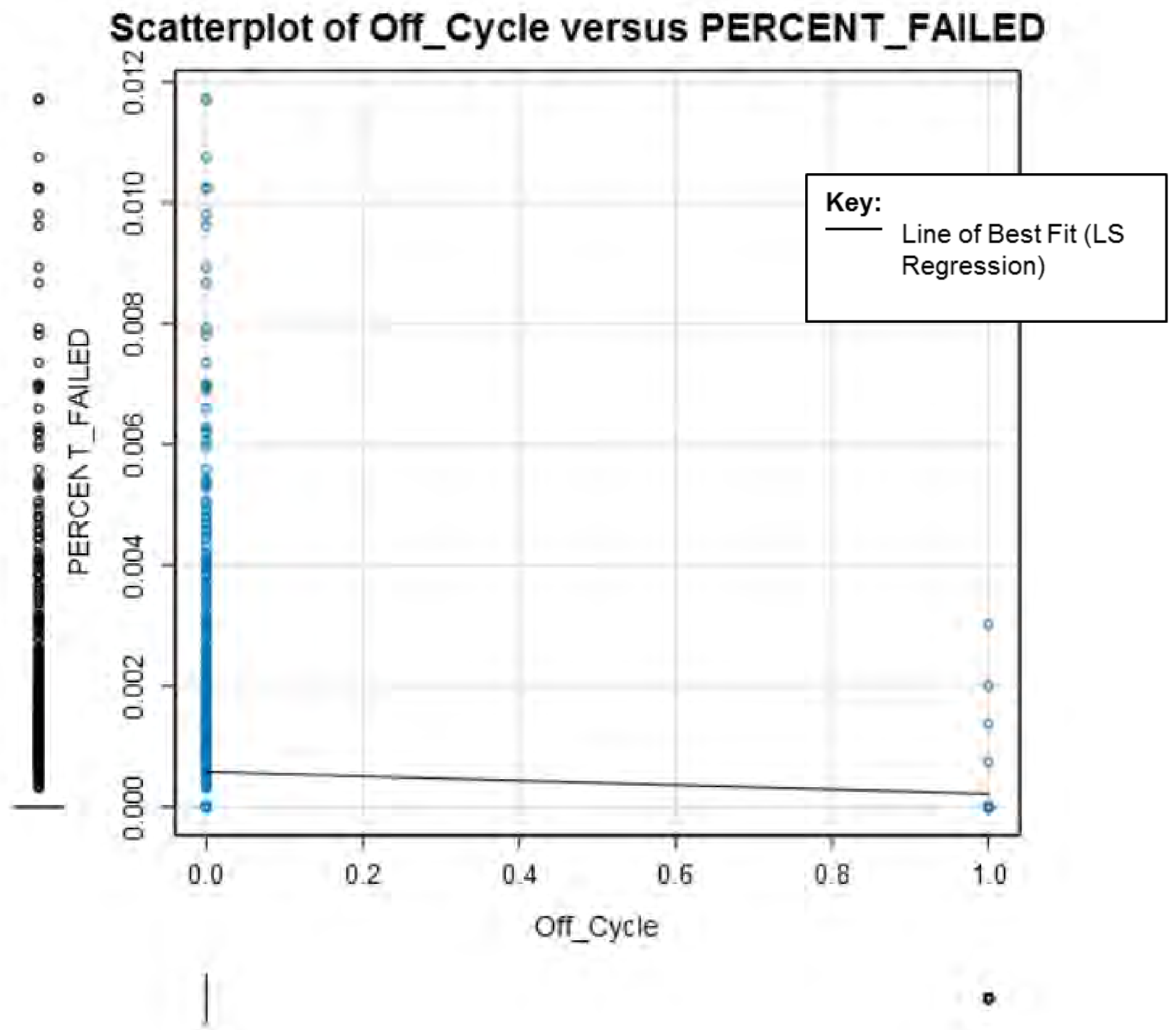
Data Summary

Variable	Min	Max	Median	Sample Size
Off Cycle* (x)	0	1	0	1,248 circuits
Percent Failed (y)	0.000	0.012	0.000	

Results

	Estimate	P Value
Intercept	0.0005788	<2.2e-16***
Off Cycle	-0.0003623	0.15662

- No statistically significant relationship between whether or not the vegetation maintenance of a circuit is on cycle or off cycle and the percent pole failure. (P = 0.157 >0.05)
- Data suggests other factors contributed to distribution pole failure.



*Note: This survey does not provide an assessment of degrees of off-cycle trimming, and other aspects of the VM program, (i.e., hot spot trimming and periodic inspections that are performed to ensure that reliability is not at risk).

MULTIPLE LINEAR REGRESSION ON ALL POLE DATA

Percent Failure By Circuit ~ Wind + Gust + Manufactured Yr. + Height + Last Inspection Yr.+ Max Off Cycle

Factor	Minimum	Maximum	Median	Sample Size	Estimate	P Value
Max Wind	15.8 mph	70.2 mph	41.4 mph	1,187 circuits	-1.731e-05	0.00254**
Max Gust	20 mph	88.6 mph	58.4 mph		7.011e-06	0.0794
Avg Manufactured Year	1963	2014	1987		-3.439e-05	0.00051***
Avg Height	22 ft.	55 ft.	39 ft.		-8.495e-06	0.59495
Avg Last Inspection Year	2007	2017	2013		3.038e-05	0.07384
Vegetation Management	0	1	0		-1.292e-04	0.6689

Results: While the correlations between max wind and average manufactured year versus pole failure rate are statistically significant, these factors are not the only contributors to pole failure.

- Higher average max winds are found to be associated with lower percent failure rates (P=0.0025<0.05). Circuits that have newer poles on average are also associated with a lower percent failure rates (P=0.00051<0.05).
- Gust, Height, Inspection Year and Vegetation Maintenance do not have statistically significant correlation coefficient estimates, suggesting that they are not highly correlated with pole failure rate by circuit.
- The Adjusted R^2 value of the model is 0.01619. Thus only 1.62% of the variation in observed pole failure rates by circuit is explained by our model. This indicates that other factors contributed to pole failure than those included in the model.
- Differing results from simple regression analysis can be explained by difference in samples as well as potential correlation between explanatory variables.

OPTIMIZED MULTIPLE LINEAR REGRESSION ON ALL POLE DATA

Percent Failure By Circuit ~ Wind + Gust + Manufactured Yr. + Inspection Yr.

Factor	Minimum	Maximum	Median	Sample Size	Estimate	P Value
Max Wind	15.8 mph	70.2 mph	41.4 mph	1,187 circuits	-1.696e-05	0.00292**
Max Gust	20 mph	88.6 mph	58.4 mph		7.023e-06	0.07857
Avg Manufactured Year	1963	2014	1987		-3.737e-05	2e-05***
Avg Last Inspection Year	2007	2017	2013		3.165e-05	0.0603

Results: When optimizing the previous multiple linear regression model, the best predictors of pole failure are max wind and gust, along with the average manufactured year and inspection year.

- Again, higher average max winds are found to be associated with lower percent failure rates (P=0.003<0.05). Circuits that have newer poles on average are associated with a lower percent failure rates (P=0.00002<0.05).
- Adjusted R^2 value is 0.01767. Thus only 1.77% of variation in percent pole failure is explained by the model, still suggesting that there are other explanatory variables not captured.

MULTIPLE LOGISTIC REGRESSION ON BROKEN POLE DATA

Failure by Tree ~ Max Wind + Manufactured Year + Height + Last Inspection + Breakage Location + Attachment

Factor	Minimum	Maximum	Median	Sample Size	Estimate	P Value
Max Wind (mph)	15.8	70.2	37.1	384 poles	-0.04031	9e-05***
Manufacture Year	1960	2017	1980		0.01710	0.17221
Height (ft.)	30	55	40		-0.1005	0.00029***
Last Inspection Year	2007	2017	2012		-0.10610	0.01527*
Breakage Location (T=3, M=2, B=1)	1	3	2		0.08490	0.65284
Attachment (Y=1, N=0)	0	1	0		1.55611	1e-05***

Results:

- When considering the above factors on the likelihood that a failed pole had a tree involved; max wind, height, last inspection year, and attachment are statistically significant factors.
- Poles with attachments were more likely to fail by mode of tree.

RESULTS SUMMARY: REGRESSION

Simple

- Max wind, max gust, average last inspection year and off cycle vegetation maintenance did not have a statistically significant correlation with pole failure rate by circuit.
- Circuits with a taller average pole height were more likely to have a lower pole failure rate.
- Circuits with newer poles were associated with lower pole failure rates.

Multiple

- Average pole manufactured year and max wind speed were the best indicators of pole failure rate by circuit.
- Circuits with older poles were associated with higher pole failure rates.
- Circuits that experienced lower wind speeds were associated with higher pole failure rates. This counterintuitive result could be due to the difficulties collecting wind data at all pole locations.
- Pole height, inspection year, and vegetation management level are likely not good indicators of pole failure.

Overall

- Simple regression and multiple regression models did not have high predictive power of pole failure rates, suggesting that there are unaccounted for explanatory factors captured in the error term of our models.
- **Model Improvements:**
  - Potential explanatory factors to consider further would be vegetation density, height and proximity of vegetation to distribution facilities, rainfall, reject status and wind direction, etc.
  - Improve wind data accuracy (gust, wind, GPS related data)
  - Consistent data across all poles for all fields/ Confirm randomized sampling

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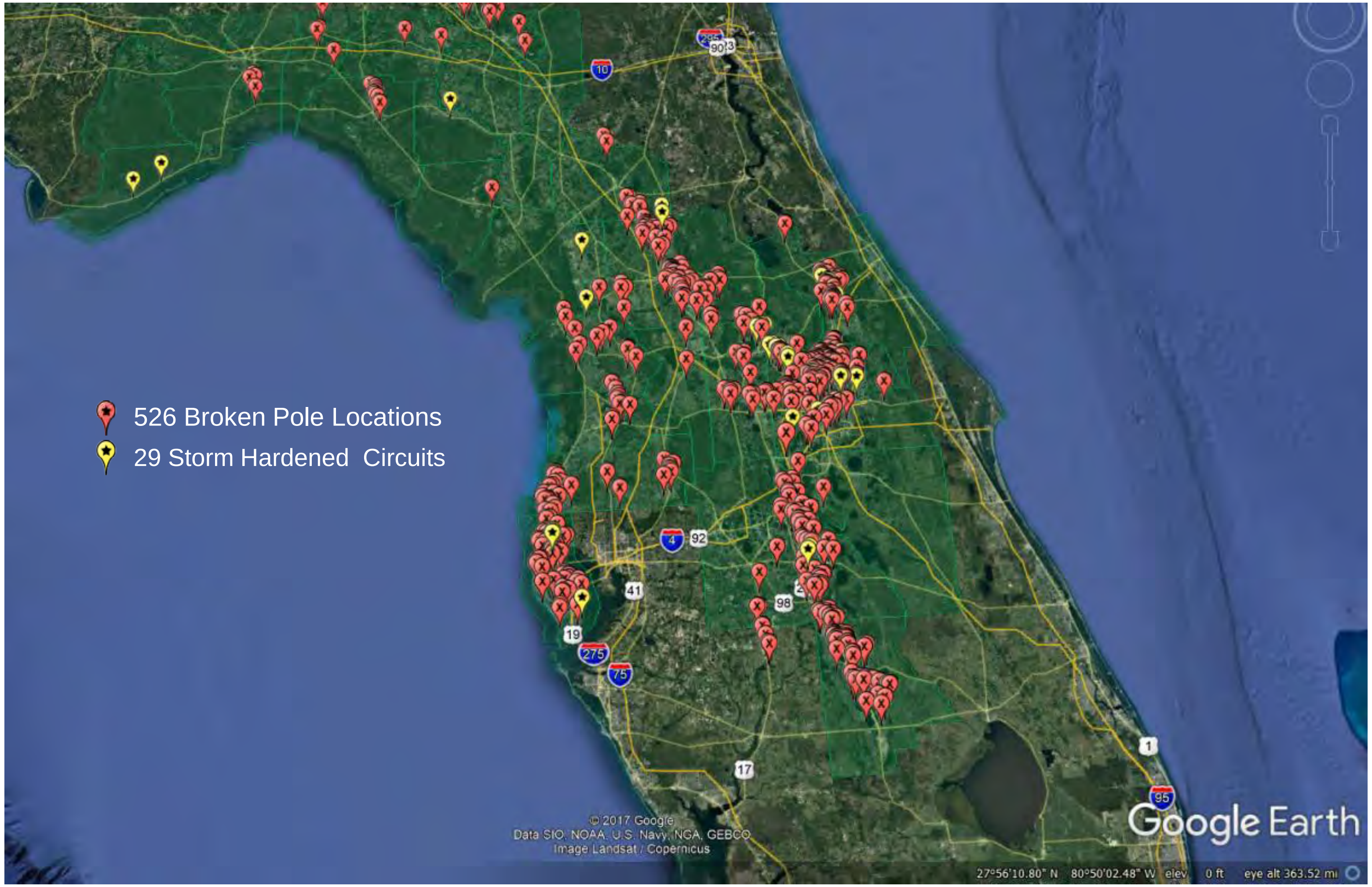
STORM HARDENING

METHODOLOGY/APPROACH

- Duke FL performed storm hardening on a number of distribution line sections since 2006
- Determined if any poles that failed during Hurricane Irma were a part of the storm hardened circuits by:
  - Mapping broken poles that were reviewed by the forensics team
  - Overlaying storm hardened projects
  - Identifying if any broken poles were a part of the storm hardened projects

DATA COLLECTION

- A sample set of broken pole data was collected by Duke FL's forensics team
- This information included:
  - EQUIP ID
  - POLE TAG
  - ADDRESS
  - DAMAGE COMMENTS
  - Birth Year
  - Last Inspect
  - Where did pole break? Top (T), Middle (M), Base (B)
  - Was Tree Involved?
  - ATTACHMENTS (Y/N)
  - EQUIPMENT(STA,RCL,SCT)
  - POLE BRACED?
  - OP CTR
- Matched broken pole data within GIS system to associate Latitude and Longitude coordinates
- Identified 29 storm hardening projects and mapped them with the broken pole data set



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RESULTS SUMMARY: SYSTEM HARDENING ANALYSIS

- A forensic assessment of five hundred twenty-six (526) randomly selected poles was made across DEF’s total broken pole population. None of these poles were a part of the 29 Storm Hardening projects.
- A separate assessment of twenty-nine (29) randomly selected Storm Hardening projects was made. No broken poles were identified.
- Initial findings led the team to believe there was one pole that failed in the North Central Zone, Mercers Fernery Rd storm hardening project, but further analysis showed it was not a part of the project

North Central - Mercers Fernery Rd

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