IEEE Guide for Distribution Resiliency

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IEEE DRES Chapter Outline

The chapters aim to provide an understanding of resiliency, offer tools for utilities to study threats, quantify resilience metrics, and discuss system enhancements. It also includes case studies from five utilities across North America.

- Executive summary
- Electric distribution grid reliability and resiliency
- Literature review
- Grid resilience goals and objectives
- System resilience assessment methods: modeling, simulation and analysis
- Resilience metric
- Resilience improvement – infrastructure, operations and technology solutions
- Case studies

Resilience Guide Outline

Seven chapters, sub-sections for each chapters

- Link T&D_DSC_DResWGTF_Guide_Outline - Google Sheets
- Sub-groups for each chapters

CHAPTER	LEAD
CHAPTER 1: Literature Review	Masoud Davoudi
CHAPTER 2: Resilience Goal / Objectives	John Lauletta
CHAPTER 3: High Impact Weather / Storm Event Risk Identification	Ali Bidram
CHAPTER 4: Quantification of Resiliency	Shikhar Pandey
CHAPTER 5: System Modeling and Storm Simulation	Sarmad Hanif
CHAPTER 6: Infrastructure and Operational Improvements for Resilience	Julio Romero
CHAPTER 7: Case Study and Resiliency Study	Gary Huffman

Discussion guidance

All comments welcome today or later:

- Please provide constructive feedbacks
- Look to improve the metrics and content of the guide with ideas
- Please reach out to me if you want further discussion on Resilience and storm restoration strategies

What is Resiliency?

What is Resiliency?

FERC has proposed that resilience means the **"ability to withstand and reduce the magnitude and/or duration of disruptive events,** which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event."

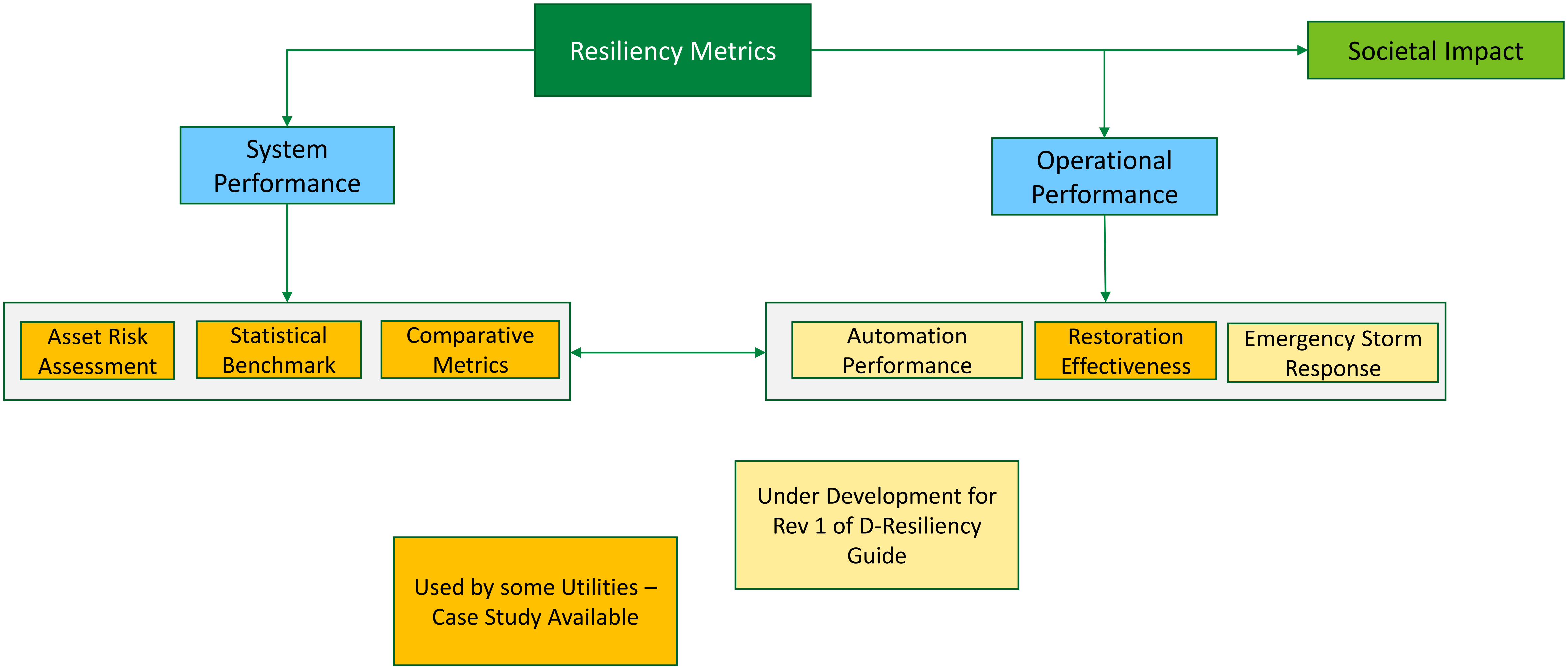
Credit: Utility Dive Feb 2, 2018 by Kate Konschnik and Brian Murray

Proposed IEEE Definition

The capability of electric power ***distribution*** *systems to* ***deliver*** *electric energy to end-use customers by* ***avoiding interruptions and/or recovering this capability*** *following exposure to* ***naturally occurring high impact low frequency events.***

IEEE Distribution Resiliency Focus
Out of scope: BES, Cyber/Physical Security, Operational Events
Primary Focus: Extreme Weather Events, Natural Phenomenon

A Comprehensive Suite of Metrics



Note: These metrics are designed by the IEEE Distribution Resiliency Taskforce. They are currently in draft and will be refined.

Assets Risk Assessment

1. **Climate Vulnerability Studies**: Utilities are assessing risks from climate hazards to understand the impact on their assets.

Description	*Temperature, Heat and Humidity*	*Flooding*	*Wind and Ice*	*Wildfire*
Exposed Assets-At-Risk Properties	Thermal rating reduction, Accelerated asset degradation	Water-related equipment sensitivity, Corrosion, Soil Weakening	Wind and Ice Loading Tolerance, Vegetation Proximity	Fire-related equipment damage, Smoke on conductors, Soot accumulation over insulators, damaged insulators exhibiting high leakage currents, Vegetation Proximity

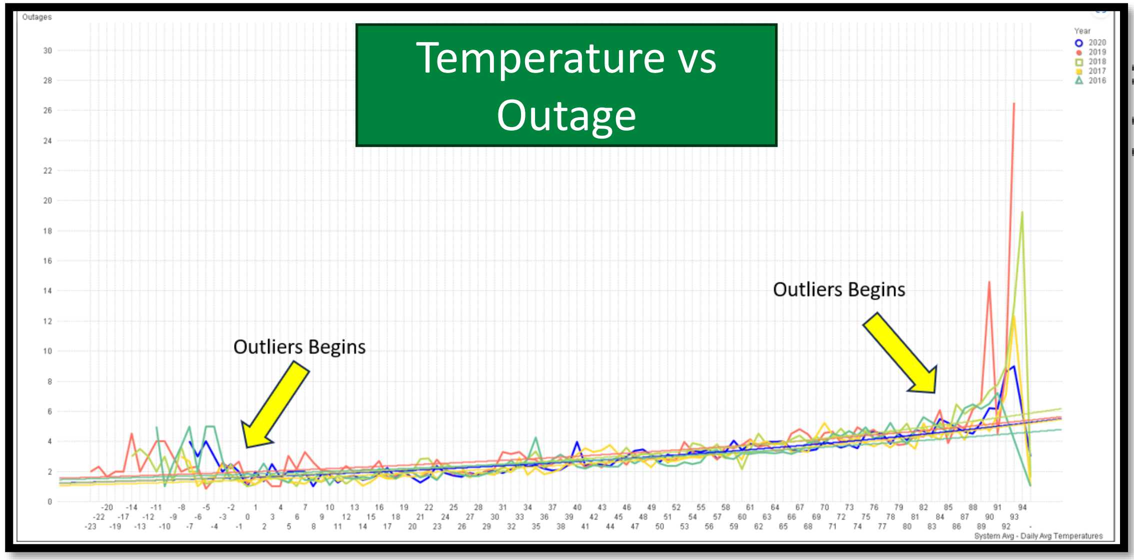
2. **Asset-Risk Assessment Metric**: Utilizes two matrices:
   - **Exposure Properties to Risk Matrix**: Identifies asset properties affected by climate change.
   - **Assets-to-Exposure Matrix**: Prioritizes asset strengthening based on risk levels (medium, high, low) against climate change variables.

Equipment vs Threat	*Temperature, Heat and Humidity*	*Flooding*	*Wind and Ice*	*Wildfire*
Substation	High Risk	High Risk	Low Risk	Low Risk
Overhead Equipment	Medium Risk	Low Risk	High Risk	High Risk
Underground Equipment	High Risk	Medium Risk	Low Risk	Low Risk

Statistical Benchmark: Outages on Gray Sky days

Gray Sky Day: Focuses on robustness and the ability to withstand most weather events

- We established a statistical benchmark based on weather parameters and historical outages
- This benchmark tracks the system performance (of outages) during gray sky days



Yellow

- **Average temperature** between 80 and 85 degrees
- **Average temperature** between 0 and -5 degrees
- **Average sustained wind speed** between 25 and 30 MPH
- **Average of one-hour wind gust** between 25 MPH and 30 MPH
- **Average rainfall** between 0.75" and 1"
- **Lightning stroke count** between 3,000 and 6,000

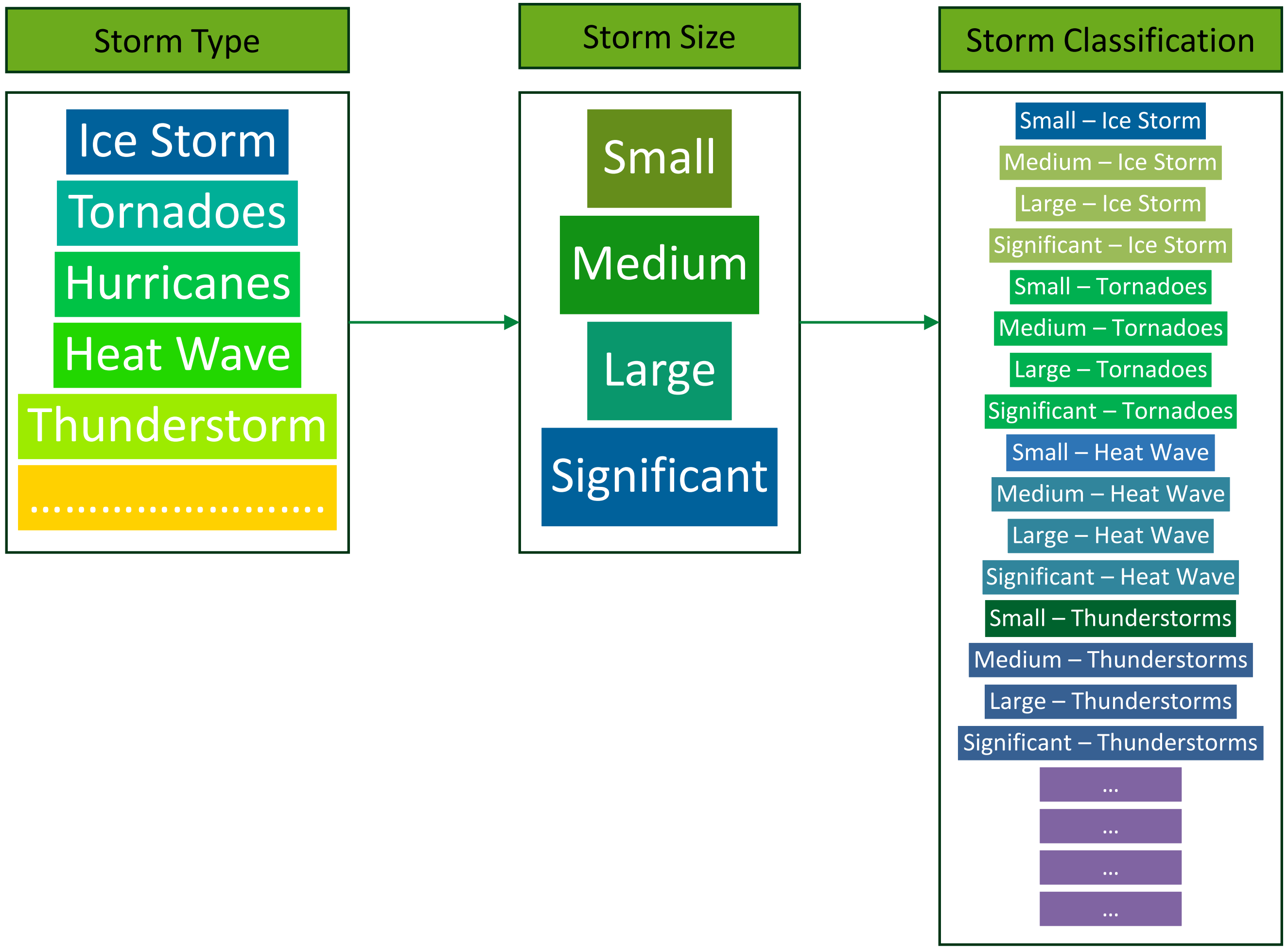
Orange

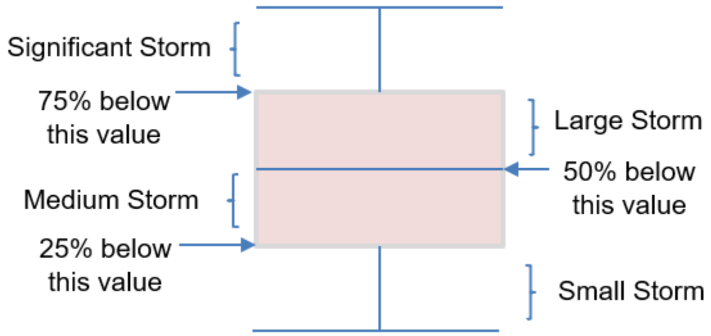
- **Average temperature** between 85 and 90 degrees
- **Average temperature** between -5 and -10 degrees
- **Average sustained wind speed** between 30 and 35 MPH
- **Average of one-hour wind gust** between 30 MPH and 35 MPH
- **Average rainfall** between 1" and 1.25"
- **Lightning stroke count** between 6,000 and 10,000

Red

- **Average temperature** greater than 90 degrees
- **Average temperature** less than -10 degrees
- **Average sustained wind speed** >= 35 MPH
- **Average of one-hour wind gust** >= 30 MPH
- **Average rainfall** greater than 1.25"
- **Lightning stroke count** greater than 10,000

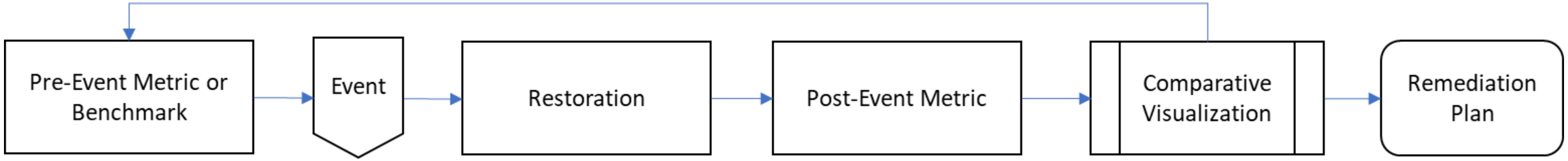
Storm Classification





It is Important to classify different storm categories to apply the metrics on.

Comparative Metrics



Metric	Attributes	Historical Benchmark	Current Event Records	Performance Assessment
Storm Strength Comparison	Wind Speed	70 mph	80 mph	Increased wind speed, correlates with longer outages
	Precipitation	2 inches	3 inches	Higher precipitation, potential cause for disruptions
Flood Comparison – Substations/Underground Equipment	Substation Outages due to Flood	5 incidents	3 incidents	Improved resilience, fewer outages
	Underground Equipment Outages due to Flood	10 incidents	12 incidents	Slight increase, review flood mitigation strategies
Square Miles Impacted/Customer Density	Square Miles Impacted	50 sq miles	60 sq miles	Larger area impacted, reassess preparedness
	Customer Density	1,000 customers/sq mile	1,200 customers/sq mile	Higher density, more significant impact
Pole Damage Comparison	Pole Damage Incidents	15 incidents	20 incidents	Increased incidents, consider reinforcement strategies
Equipment Damage Comparisons	Equipment Damage Incidents	30 incidents	52 incidents	Increased incidents, proactive maintenance strategy
Construction Man Hours to Restore Hardened vs. Non-Hardened	Construction Man Hours - Hardened	500 hours	450 hours	Improved efficiency, hardening measures effective
	Construction Man Hours - Non-Hardened	1,200 hours	1,400 hours	Increased time, need for further hardening measures
Smart Grid Performance	Smart Grid - Interruptions Avoided	300 incidents	350 incidents	Improvement, smart grid enhancing resilience
Equipment Comparison (Substation /Distribution)	Hardened Substation (Outages)	80,000	60,000	Improved performance, effective hardening measures
	Non-Hardened Substation (Outages)	86,667	125,333	Increased, monitor for further hardening
	Hardened Distribution (Outages)	106,667	155,333	Big increase, analysis needed
	Non-Hardened Distribution (Outages)	126,667	185,333	Increased vulnerability, consider reinforcement
Restoration Comparison to Prior Events	Restoration - 24 hrs	60% restored	55% restored	Slight delay, assess resource allocation
	Restoration - 48 hrs	85% restored	80% restored	Similar delay, possible need for more resources
	Restoration - 72 hrs	95% restored	92% restored	Minor delay, review efficiency
	Total Restoration Days	5 days	5.5 days	Slight increase, investigate specific challenges

Example on Comparative Metrics Application

$$\text{X-Parameter Performance Ratio (X-PR)} = \frac{\text{Incidents Avoided}}{\text{Incidents Avoided} + \text{Sustained Incidents}}$$

- Take a circuit that has 200 poles and historically experiences 20% of them being damaged during significant storms.

$$\text{Historical Pole Damage metric} = \frac{(200-40)}{(200-40)+(40)} = \mathbf{0.8}$$

- Event 1 affects 25% of the poles Event 2 affects 5% of the poles.

$$\text{Event 1 Pole Damage metric} = \frac{(200-50)}{(200-50)+(50)} = \mathbf{0.75}$$

$$\text{Event 1 Pole Damage Ratio} = \frac{(0.75)}{(0.8)} = \mathbf{0.94}$$

$$\text{Event 2 Pole Damage metric} = \frac{(200-10)}{(200-10)+(10)} = \mathbf{0.95}$$

$$\text{Event 2 Pole Damage Ratio} = \frac{(0.95)}{(0.8)} = \mathbf{1.19}$$

Ratio less than unity indicates system performance less favorable than historical; whereas the event ratio greater than unity indicates performance favorable than historical benchmark.

Automation/Hardening Performance

$$\text{Automation /Hardening Performance Ratio (APR)} = \frac{\text{Avoided Customer Interruption (CI) by Automation}/\textit{Hardening}}{\text{Avoided CI by Automation}/\textit{Hardening} + \text{Sustained CI}}$$

Aspect	Key Points
Perfect Resilience Scenario	Automation Performance **Ratio of 1** signifies perfect resilience, ensuring uninterrupted service and high customer satisfaction.
Factors Influencing the Ratio	**Automation Mechanisms:** Impact on outage prevention. **Sustained Outages**: Causes like equipment failure or external disruptions.
Real-World Implications	**Case Studies**: Successful automation in outage prevention. **Challenges**: Areas where automation needs improvement.
Trends Over Time	**Historical Analysis**: Trends in Automation Performance Ratio and automation strategies. **Continuous Improvement**: Informing ongoing efforts.
Comparisons with Other Metrics	**Comprehensive Resilience**: Alignment with other metrics. **Interconnected Nature**: Holistic understanding of grid resilience.
Operational Considerations	**Response Times**: Speed of detection, decision-making, and execution. **Adaptability**: Handling different disturbances.
Scalability and Adaptability	**Scalability Challenges**: For larger grid systems. **Technological Advances**: Enhancing automation systems.
Practical Applications	**Decision-Making Support**: Helps in prioritizing investments. **Customer Impact**: Improved service reliability through outage prevention.

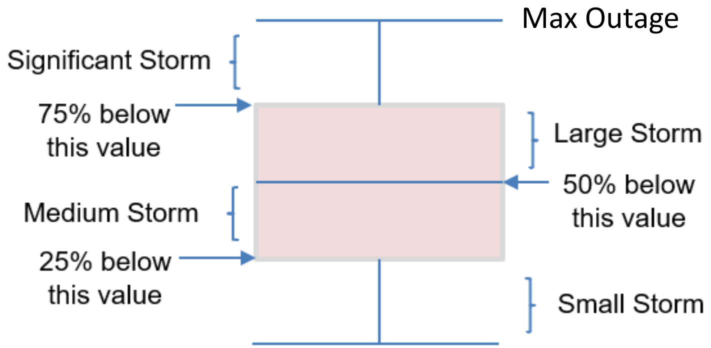
Restoration Effectiveness

Calculation:

1) For each storm in a calendar year, calculate the ratio of customers without power for more than 12 hours and total customer interruptions (CI) including customers automatically restored (ACI) through smart switch operations (DA devices), community energy storage, and microgrids (does not include substation reclosing events) – measured in %

$$\textbf{Storm Event: } x = \frac{\sum \text{Customers Without Power for More Than } Z \text{ Hours}}{Sustained\ CI + ACI \ \text{Automation or Hardening}}$$

2) Based on number of interruptions (storm outages), categorize each storm event significant, large, medium, or small
3) Determine if X is greater than or equal to the threshold value (Y) for the category.
4) If X < Y, storm met expectations. If X >= Y, storm did not meet expectations

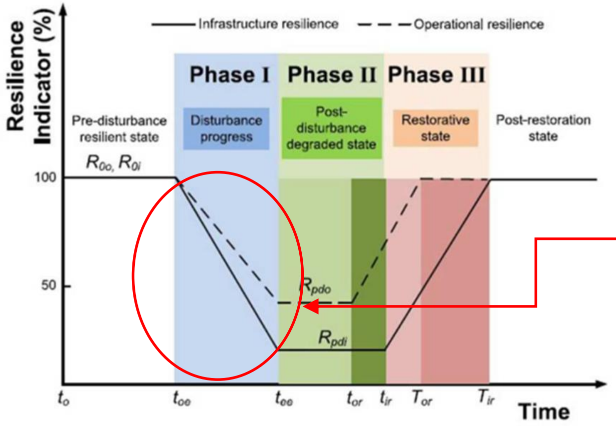


Threshold "Y" is calculated based on data analytics of small, medium, large, and significant size storm with 5 year moving average data. Details are explained in IEEE distribution resiliency guide.

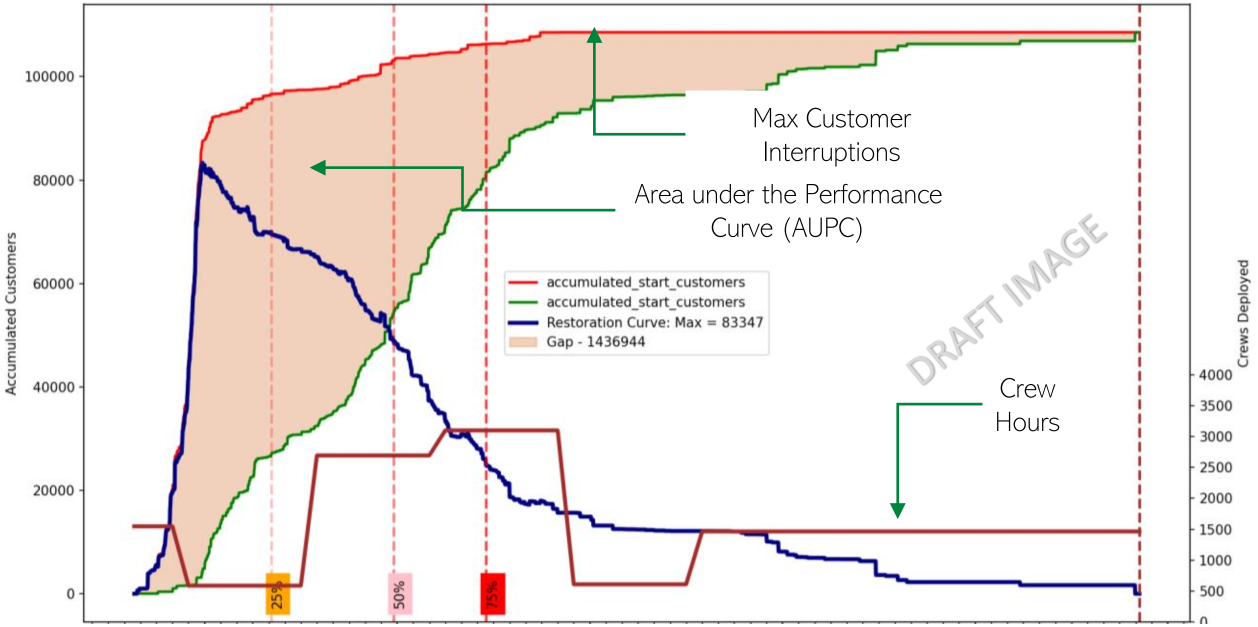
Emergency response effectiveness

Factors:

- **Total Outages** – Intensity of the storm [Non-controllable]
- **Max Customer Interruptions** – Indicator of crew efforts in curbing maximum degradation
  - Semi-Controllable – better human performance, lower CI.
  - But for severe events where all outages happen at the head end of the chart, there will be significant lag in start of restoration by crews
- **Area under the Restoration Curve** – Indicator tracking restoration efforts vs emerging outages. Smaller the area under the curve better restoration performance [Controllable – Better human performance, lower AUPC]
- **Crew Hours** – Total hours spent on the field by crew [Controllable – Better human performance, lower crews needed for 100% restoration]
- **Storm duration**
- **Full restore time** – Controllable but already captured by AUPC



If Customer Interruptions is the resilience indicator in this figure, then the operational resilience is enabled by restoration efforts, both automated and by crew work



Sample Calculations for 9 storms

- Wide range – compression required. Use Log scale

ERF = $\log\left(\frac{AUPC}{CI} . \frac{CrewHours}{Outages}\right)$

Insights:

- Lower crew
- Lower max customer Interruptions
- Lower AUPC

Customers Interruptions	AUPC	Outages	Crew Hours	ERF
96,570	2,765,000	1,513	227,257	3.63
61,021	3,590,000	921	82,764	3.72
49,107	4,164,000	966	58,118	3.71
4,424	4,204,136	195	65,030	5.5
112,134	8,160,396	2,184	190,774	3.8
65,920	9,717,651	723	150,944	4.49
11,983	9,910,036	411	52,344	5.02
18,502	10,145,170	291	48,933	4.96
83,347	11,582,114	930	81,456	4.09

Takeaways and Next Steps

- ComEd has been utilizing two metrics, restoration effectiveness and Gray Sky day, since 2020.
- These metrics have allowed ComEd to concentrate on system enhancements and improvements in resiliency.
- Through the IEEE Distribution Resiliency Working Group, three other utilities have adopted the restoration effectiveness and Gray Sky day metrics for their systems.
- 4 Utility Case study is included in the guide. 3 more are in the works.
- The final draft of the guide will be submitted for review and ballot at IEEE JTCM in January 2025.

Regulators and stakeholders continue to use the IEEE 1366 metrics (the SAIDI sisters) to assess the impact of resilience events.

Thank you