IEEE Power & Energy Society

Resilience Value and Metrics

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17th International Conference on Probabilistic Methods Applied to Power System

IEEE PES Power & Energy Society®

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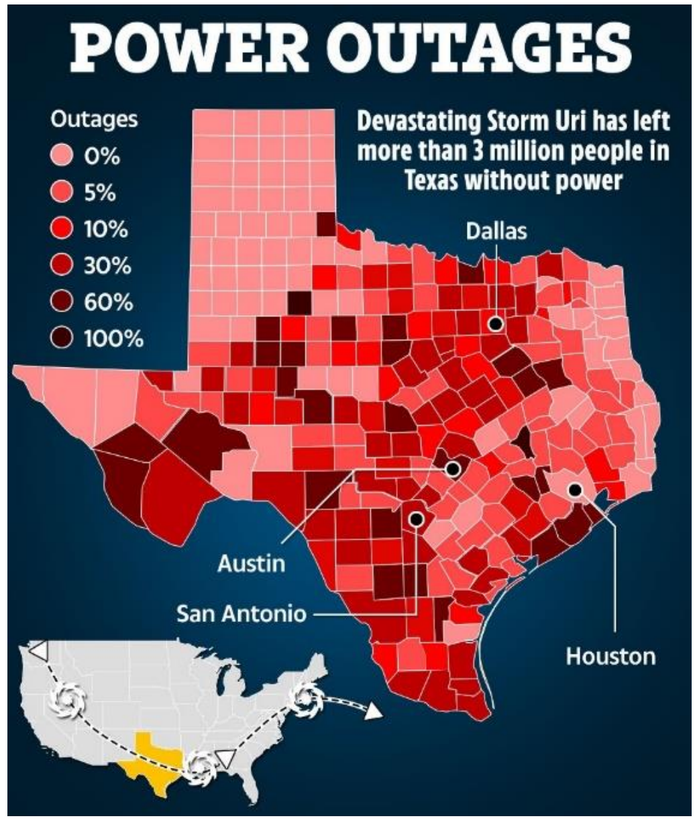
What is Grid Reliability?

Keep Lights On.

Texas Rolling Blackouts (Feb 15-17, 2021)

Frozen gas valve and high pressure pipe



Source: https://spectrum.ieee.org/, www.statesman.com

Challenges and Opportunities

- Increased Billion-Dollars Weather and Climate Disasters
- 1980, 3 events, cost $18B; 2020, 22 events, cost $121B

Superstorm Sandy (Oct 29, 2012) knocked out 50+ transmission lines in NY/NJ areas.

Hurricane Ida (Aug 26 – Sept 4, 2021) knocked out all transmission lines into New Orleans.

Does it mean
grid is not reliable?

Bulk-Power System Reliability – US Congress Definition

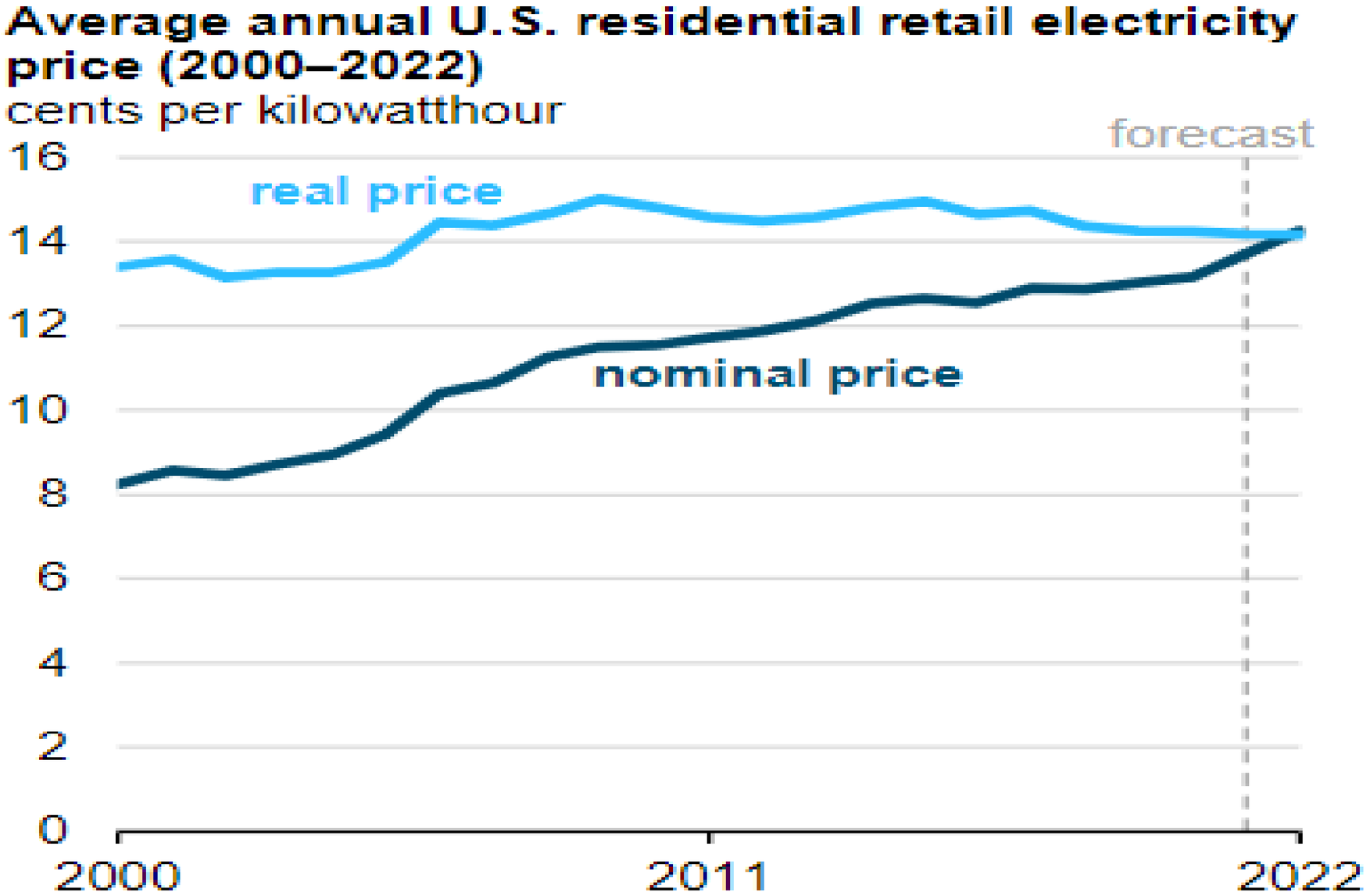
ALR – Adequate Level of Reliability

Operating the elements of the bulk-power system within equipment and electric system thermal, voltage, and stability limits so that instability, uncontrolled separation, or cascading failures of such system will not occur as a result of a sudden disturbance, including a cybersecurity incident, or unanticipated failure of system elements.

Adequate Level of Reliability (ALR) – Industry Definition

- The BES does not experience instability, uncontrolled separation, cascading, or voltage collapse under normal operating conditions and when subject to predefined disturbances.
- BES frequency is maintained within defined parameters under normal operating conditions and when subject to predefined disturbances.
- BES voltage is maintained within defined parameters under normal operating conditions and when subject to predefined disturbances.
- Adverse reliability impacts on the BES following low-probability disturbances (e.g., multiple contingences, unplanned and uncontrolled equipment outages, cybersecurity events, and malicious acts) are managed.
- Restoration of the BES after major system disturbances that result in blackouts and widespread outages is performed in a coordinated and controlled manner.
- BES transmission capability is assessed to determine the availability to meet anticipated BES demands during normal operating conditions and when subject to predefined disturbances.
- Resource capability is assessed to determine the BES's availability to meet anticipated BES demands during normal operating conditions and when subject to predefined disturbances.

Electricity Average Prices



https://www.eia.gov/todayinenergy/detail.php?id=51438

Reliability and Resilience

- “Adequate Level of Reliability” is commonly acknowledged as a system performance measure.

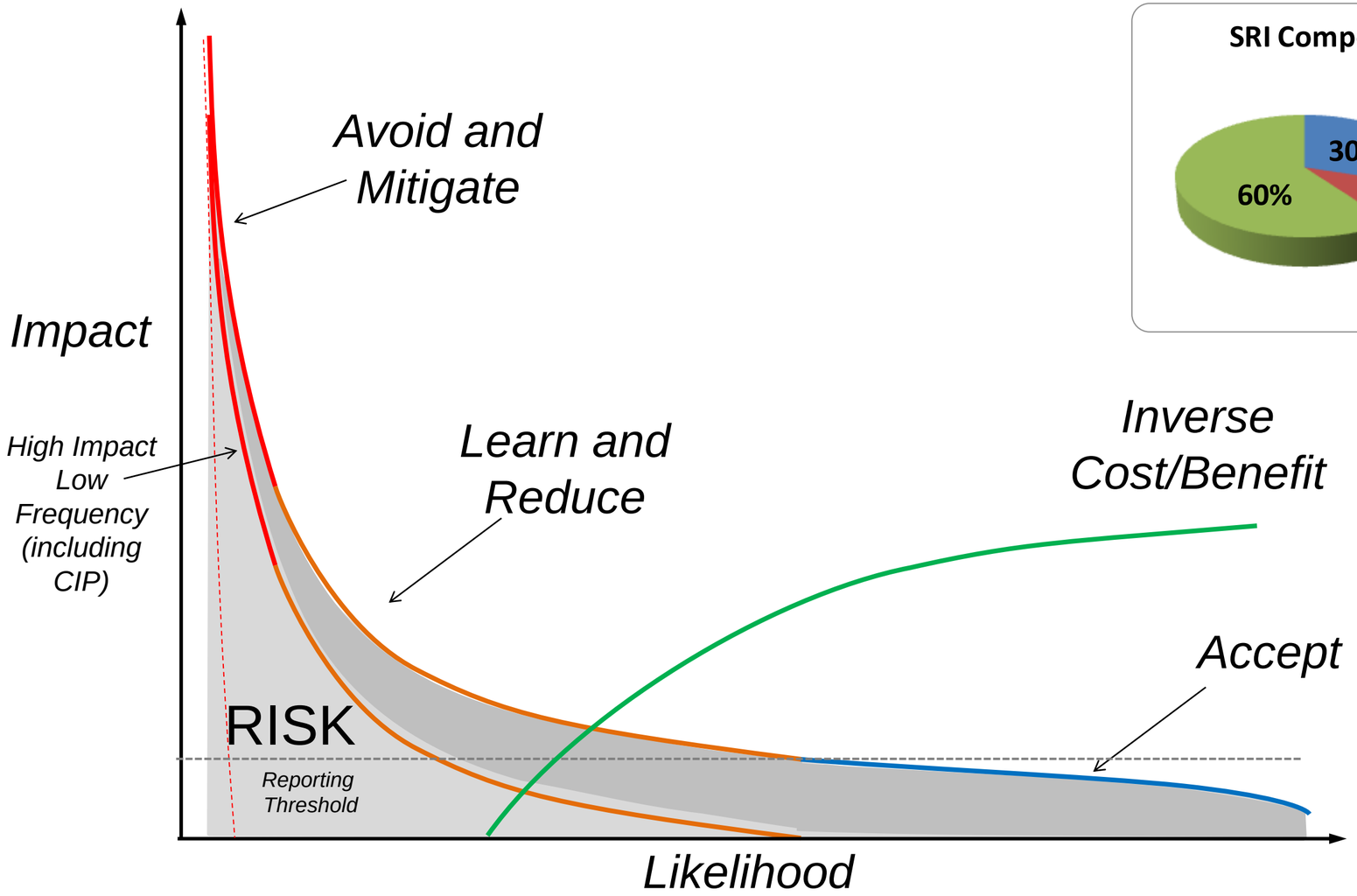
- Resilience is a system characteristic/capability encompassing all hazards and events, including high-impact low- probability events that are excluded from reliability calculations.

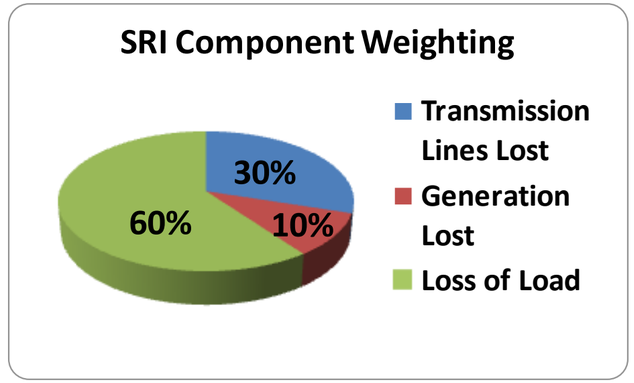
- Customers pay for “Adequate Level of Reliability” per grid codes or mandatory standards, not for resilience.

- There are no mandated resilience requirements at this time.

Measure Risk from Events

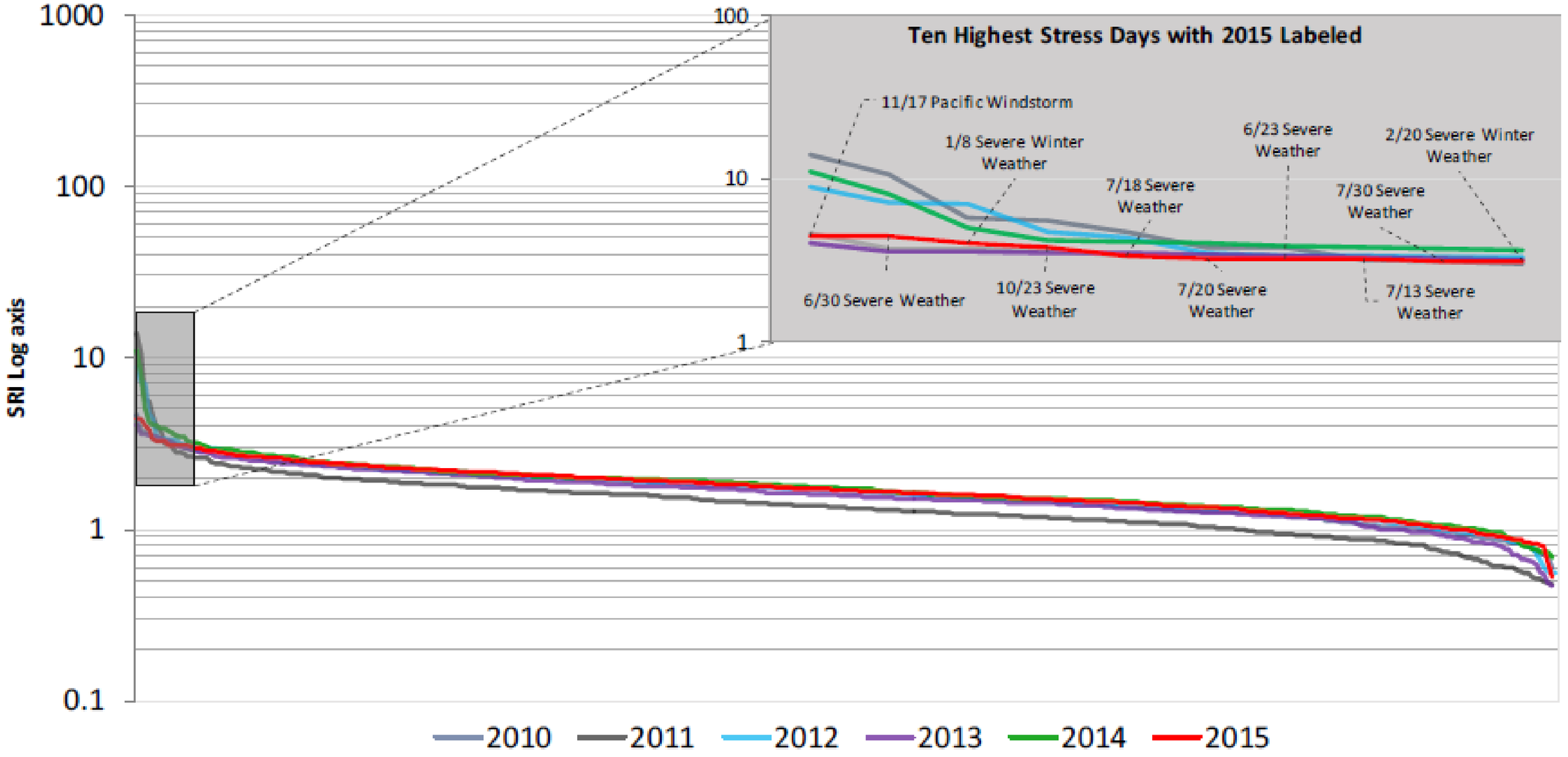
Severity Risk Index (SRI) Curve – "Stress" Indicator





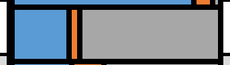
Severity Risk Index – "Stress" Level

North American Annual Daily Severity Risk Index (SRI) Sorted Descending



https://www.nerc.com/pa/RAPA/PA/Pages/default.aspx

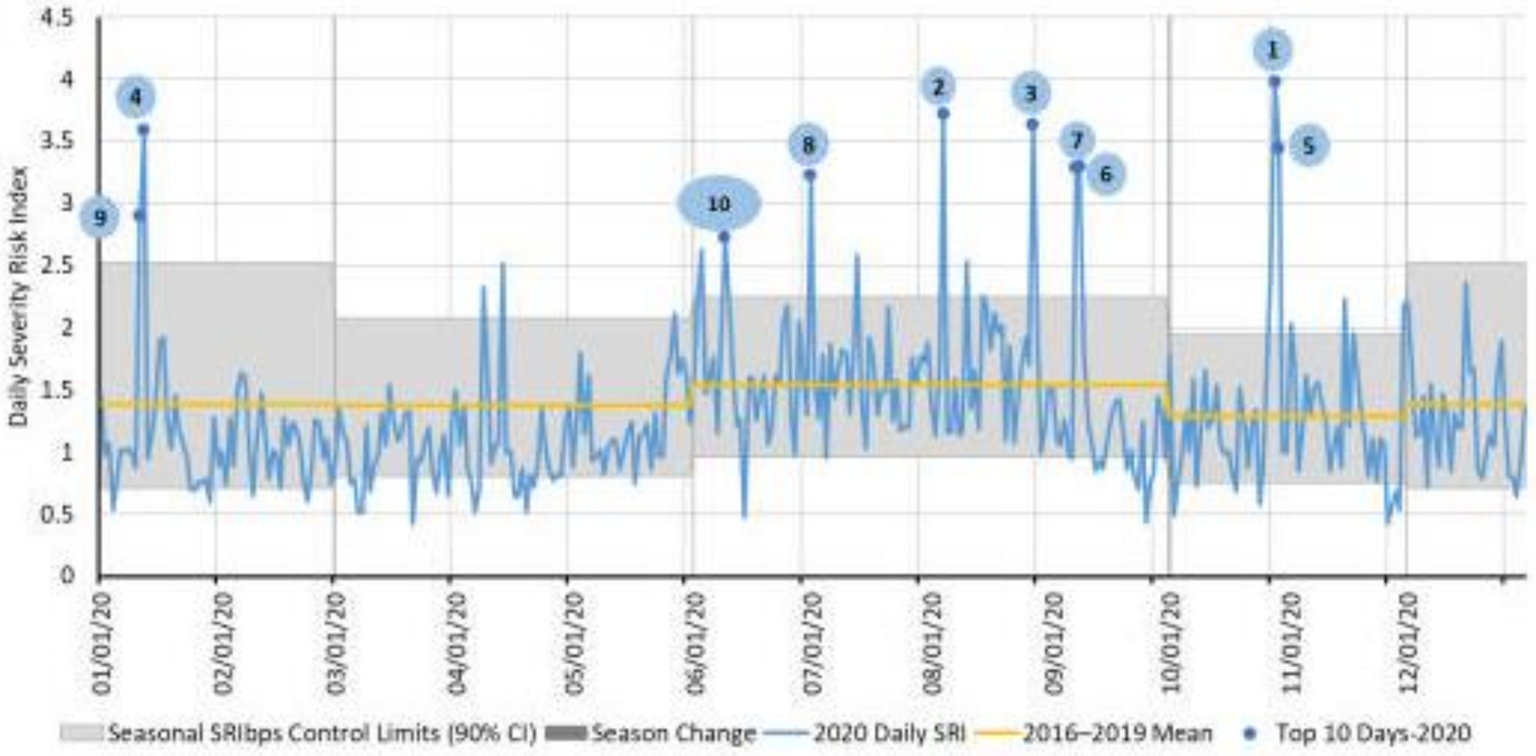
Top 10 Severity Risk Index Days (2008-2015)

Date	NERC SRI and Weighted Components				G/T/L	Weather Influenced Verified by OE-417	Rank	Event Type	Region
	SRI	Weighted Generation	Weighted Transmission	Weighted Load Loss					
9/8/2011	13.97	1.19	0.80	11.98		No	1	Southwest Blackout	WECC
1/7/2014	11.14	9.80	0.94	0.40		Yes	2	Polar Vortex	RF, Texas RE,SERC
2/2/2011	10.75	3.00	0.48	7.27		Yes	3	Cold Weather Event	Texas RE
6/29/2012	8.87	2.62	1.37	4.88		Yes	4	Thunderstorm Derecho	RF, NPCC, MRO
1/6/2014	8.02	6.66	1.16	0.20		Yes	5	Polar Vortex	RF, Texas RE,SERC
10/30/2012	7.17	2.91	3.36	0.90		Yes	6	Hurricane Sandy	NPCC, SERC
10/29/2012	7.04	2.05	1.78	3.21		Yes	7	Hurricane Sandy	NPCC, SERC
4/27/2011	5.78	1.89	3.53	0.36		Yes	8	Tornadoes, Severe Storm	SERC
8/28/2011	5.56	0.79	1.59	3.18		Yes	9	Hurricane Irene	NPCC, RF
1/4/2008	5.25	1.25	0.82	3.18		Yes	10	Pacific Windstorm	WECC

Top 10 Severity Risk Index Days (2016-2020)

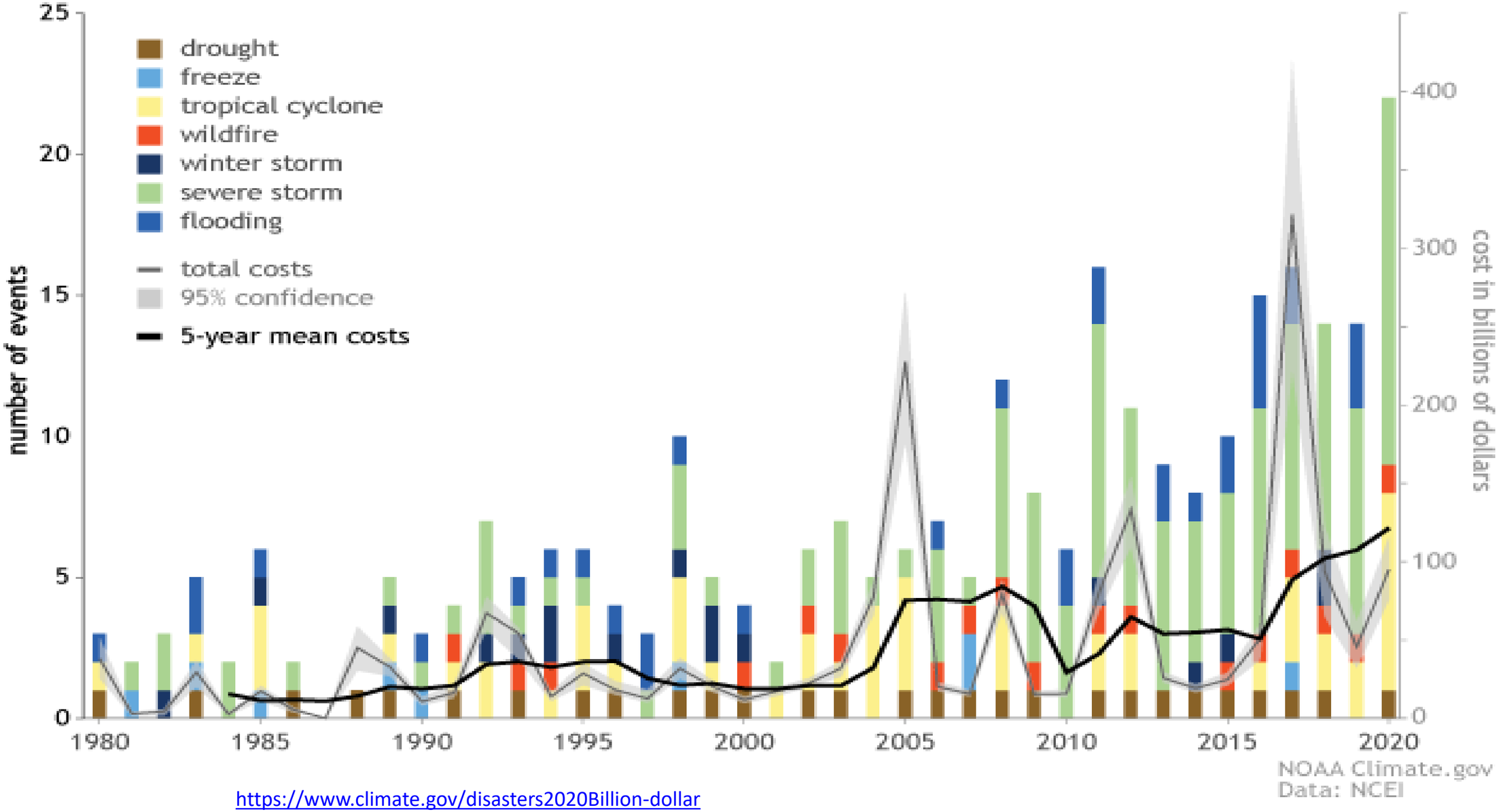
Rank	Date	SRI and Weighted Components				Event Type (*Weather Influenced)	Regional Entity
		SRI	Weighted Generation	Weighted Transmission	Weighted Load Loss		
1	September 14, 2018	4.33	1.34	0.46	2.53	Hurricane Florence*	SERC
2	March 2, 2018	4.22	0.90	0.41	2.90	Winter Storm Riley*	NPCC
3	January 2, 2018	4.06	3.81	0.15	0.10	Winter Storm Grayson*	SERC, RF, MRO, NPCC, Texas RE
4	November 15, 2018	4.05	1.85	0.25	1.95	Winter Storm Avery*	RF, NPCC
5	**October 28, 2020**	**3.98**	**1.22**	**2.06**	**0.71**	**Ice Storm* and Hurricane Zeta***	**Texas RE, MRO, SERC**
6	**August 4, 2020**	**3.72**	**1.22**	**0.77**	**1.73**	**Hurricane Isaias***	**SERC, RF, NPCC**
7	October 11, 2018	3.70	0.98	0.53	2.19	Hurricane Michael*	SERC
8	**August 27, 2020**	**3.63**	**1.52**	**0.51**	**1.60**	**Hurricane Laura***	**MRO, SERC, Texas RE**
9	May 1, 2017	3.59	1.76	0.31	1.53	Unrelated coincidental generator outages	SERC, RF
10	**January 12, 2020**	**3.59**	**0.63**	**0.92**	**2.04**	**Arctic outbreak and extreme cold* Nor'easter***	**WECC NPCC, RF, SERC**

Top 10 Severity Risk Index Days (2020)



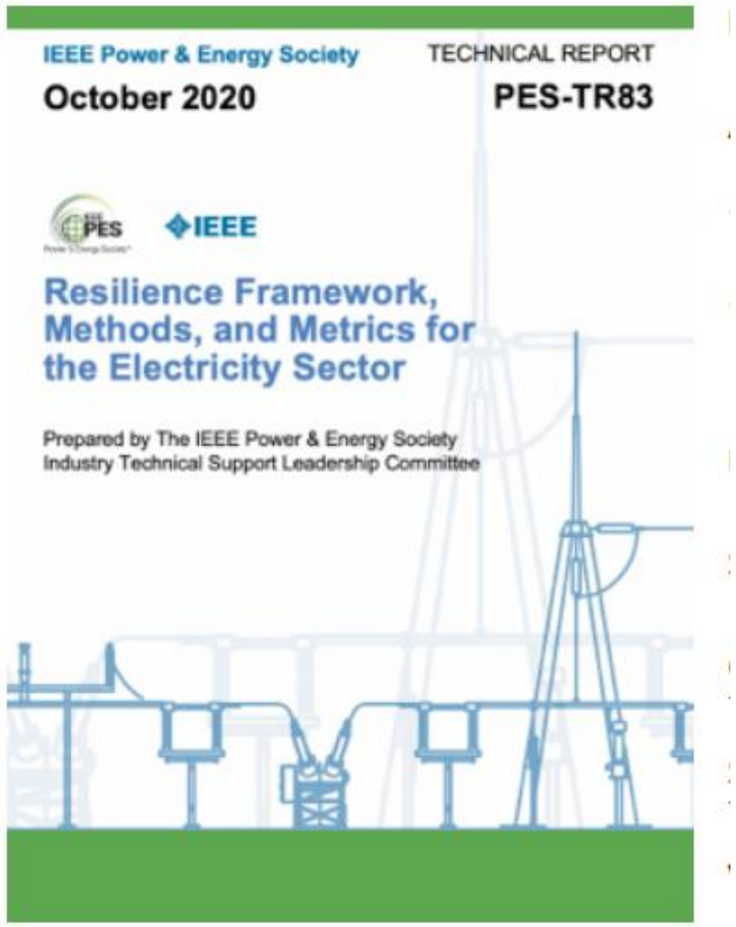
Rank	Date	Event Type (*Weather Influenced)	Regional Entities
1	October 28	Ice Storm* and Hurricane Zeta*	Texas RE, MRO, SERC
2	August 4	Hurricane Isaias*	SERC, RF, NPCC
3	August 27	Hurricane Laura*	MRO, SERC, Texas RE
4	January 12	Arctic outbreak and extreme cold,* Nor'easter*	WECC NPCC, RF, SERC
5	October 29	Hurricane Zeta*	MRO, RF, SERC
6	September 8	Wild fires*	WECC
7	September 7	Wild fires*	WECC
8	July 1	Unrelated coincidental generator outages	WECC, MRO, RF, SERC, NPCC
9	January 11	Arctic outbreak and extreme cold,* thunderstorms*	WECC MRO
10	June 9	Tropical Storm Amanda: Cristobal*	WECC, RF, SERC

U.S. Economic Losses Due to Natural Disasters Exceeding $1B in Damages per Year (1980 – 2020)



https://www.climate.gov/disasters2020Billion-dollar

IEEE/PES Technical Report - Resilience Framework, Methods, and Metrics for the Electricity Sector (TR83)



- Provide unbiased, independent technical assessment on various technologies
- Share leading trends and global best practices
- Educate members of the industry
- Attract highly qualified students to the field
- Develop standards

https://resourcecenter.ieee-pes.org/publications/technical-reports/PES_TP_TR83_ITSLC_102920.html

PES Resource Center 2021 Top Downloads

	Title	Type
1	Resilience Framework, Methods, and Metrics for the Electricity Sector	Technical Report
2	Impact of Inverter Based Generation on Bulk Power System Dynamics and Short-Circuit Performance	Webinar & Tech. Report
3	Simulation of 100% Inverter-Based Resource Grids with Positive Sequence Modeling	Webinar
4	IEEE PES Resilience Framework, Methods, and Metrics for the Electricity Sector IEEE PES-TR83 Webinar - Part I	Webinar Video
5	Protection of Wind Electric Plants	Technical Report
6	Power System Operator Survey Toward Global Energy Transformation Summary Report	White Paper
7	Electrification Volume 8: Issue 4: Microgrid Evolution Solutions	Magazine
8	Stability definitions and characterization of dynamic behavior in systems with high penetration of power electronic interfaced technologies	Technical Report
9	Power System Dynamic State and Parameter Estimation-Transition to Power Electronics-Dominated Clean Energy Systems	Technical Report
10	IEEE PES Resilience Framework, Methods, and Metrics for the Electricity Sector IEEE PES-TR83 Webinar - Part I (SLIDES)	Webinar

Distribution Reliability Metrics – IEEE Standard 1366

- Used by regulators and policy makers
  - SAIDI: System Average Interruption Duration Index
  - SAIFI: System Average Interruption Frequency Index
  - CAIDI: Customer Average Interruption Duration Index
  - CAIFI: Customer Average Interruption Frequency Index
  - MAIDI: Momentary Average Interruption Duration Index
  - MAIFI: Momentary Average Interruption Frequency Index
- Published in 1999, the latest revision in 2012

https://ieeexplore.ieee.org/document/6209381

Two Resilience Metrics Proposed by IEEE PES Distribution Resilience Working Group

- **Storm resilience metric**
  - Measure reduction of the number of customers without power for more than 12 hours
  - Consider the interruptions restored automatically without requiring human intervention
    - Distribution automation, advanced distribution management system, or microgrids, etc.
- **Calculation** - % of customers without power for more than 12 hours and total customer interruptions including customers automatically restored (avoided customer interruptions) through technology solutions

$$Storm\ event\ X = \frac{Sum\ of\ customers\ without\ power\ for\ more\ than\ 12\ hr}{Sustained\ Customer\ Interruptions + Avoided\ Customer\ Interruptions}$$

Note:
1. The threshold value is required for baselining.
2. Based on the threshold value, categorize each storm event as significant, large, medium, or small

https://sagroups.ieee.org/distreswg/

Two Resilience Metrics Proposed by IEEE PES Distribution Resilience Working Group (cont'd)

- Non-storm, gray sky days (GSD) resilience metric
  - Measure robustness and the ability to withstand most weather events
  - Vary by utility size
- Calculation
  - % of customer interruptions over the total customer base (e.g., 0.375% of the total number of customers)
- Consider certain weather criteria
  - ≥ average precipitation across the service territory (e.g., 1" of rain)
  - ≥ average maximum temperature across the service territory (e.g., 90°F max)
  - ≤ average minimum temperature across the service territory (e.g., 0°F min)
  - ≥ average maximum wind speed across the service territory (e.g., 25mi/h sustained wind speeds)

Priority – Technical Support to Industry, Policy Makers and Regulators

Government Agency

- Ecuadorian Ministry of Electricity
- US Department of Energy (DOE)
- US Federal Energy Regulatory Commission (FERC)
- National Association of Regulatory Utility Commissioners (NARUC)
- North American Electric Reliability Corporation (NERC)
- National Secretariat of Energy (Panama)

Technical Support to Corporations

- PES Liaisons and Quarterly Collaboration Meetings

PES Corporate Engagement Program (CEP)

- Australian Energy Market Operator (AEMO)
- Burns & McDonnell
- Bangalore Electricity Distribution Company Limited (BESCOM), India
- Calcutta Electric Supply Corporation
- Commonwealth Edison Company (ComEd)
- ISO New England
- National Grid
- Quanta Technology
- Smart Wires Inc
- State Grid Corporation of China (SGCC)
- Vermont Electric Power Company (VELCO)

https://www.ieee-pes.org/technical-activities/memorandums-of-understanding

PES Resource Center 2020 Top Downloads

Title	Type
Stability definitions and characterization of dynamic behavior in systems with high penetration of power electronic interfaced technologies	Technical Report
Sharing Knowledge on Electrical Energy Industry's First Response to COVID-19	Webinar
Energy Storage Primer	White Paper
Sharing Knowledge on Electrical Energy Industry - Response to COVID-19	Webinar Video
Microgrid Stability Definitions, Analysis, and Modeling (Video)	Webinar
Smart Distribution: DA/DMS Systems and ADMS Integration with DERs and Microgrids - Session 1	Tutorial
Plain Talk About the Electric Power System- Transmission System, Session 1: Evolution of the Electric Transmission System	Plain Talk
Microgrid Stability Definitions, Analysis, and Modeling (Slides)	Webinar Slides
Electric Signatures of Power Equipment Failures	Technical Report
Smart Distribution: DA/DMS Systems and ADMS Integration with DERs and Microgrids - Session 2	Tutorial

Latest Technical Report

“Importance of T&D Grid Modernization to Mitigate Impacts from and Adapt to Climate Change”

- Released in February 2022
- Impact and social implications of climate change on T&D
- Technical and market targets, issues, and solutions
- DER value and grid metrics
- Workforce development
- Importance of power grid resilience
- Industry vision and strategy for the energy future

https://resourcecenter.ieee-pes.org/publications/technical-reports/PES_TP_TR93_ITSLC_022822.html

Moving to a 3D Energy Landscape –

Decarbonized, Democratized, Decentralized

- Safe, Reliable and Affordable - Done
- Resilient?
- Carbon Free?
- Reconfigurable and Autonomous?
- Flexible, Friendly and Nice Looking?
- Other Cool Features?
- Complete Makeover?

I often wish that I could see 50 years ahead…

“The best way to predict the future is to invent it.”

– Alan Kay

More Power to Your Future!

Thank You!

Get Involved. Visit: ieee-pes.org

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