

IEEE Power & Energy Society

Grid Reliability and Its Vital Signs

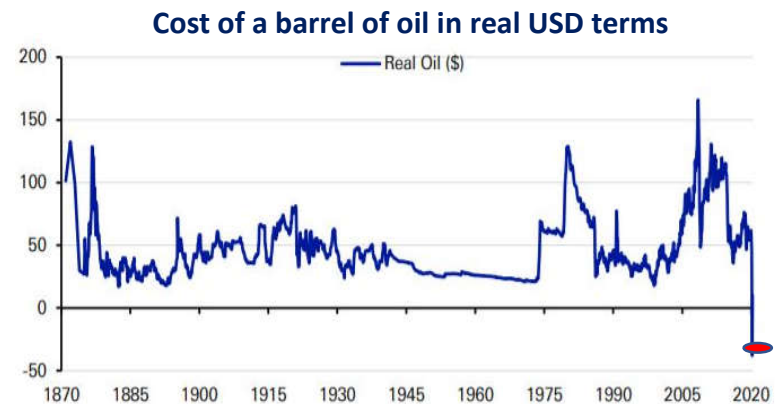
Jessica Bian, PES President-Elect
Vice President, Grid-X Partners

May 28, 2020



COVID-19 Global Health Crisis and **Uncertainty**

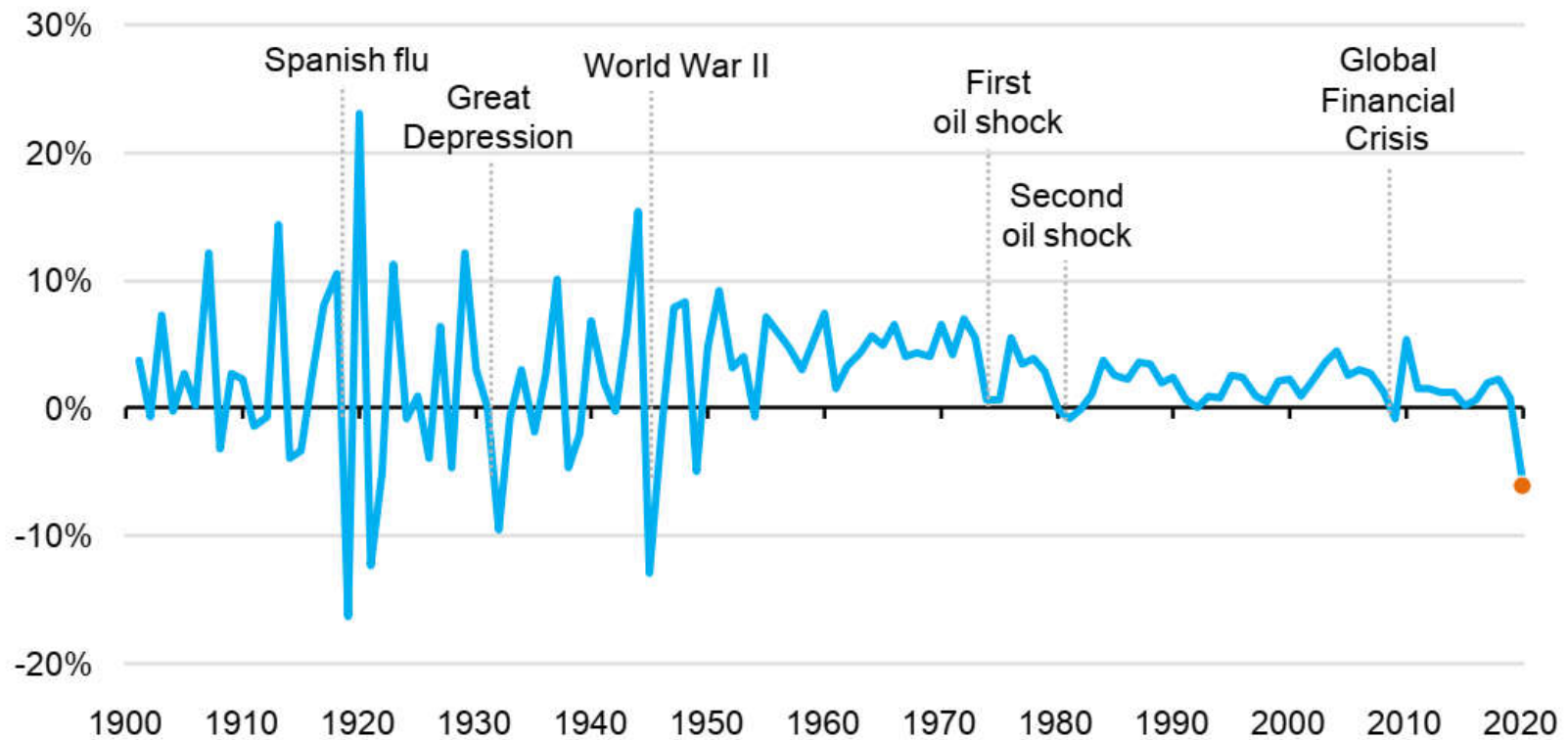
- Economic crisis - record job loss
- Egg price - soared
- Video game sales - surged
- Mental Illness – jumped
- Bicycles rides - peaked
- CO₂ emission - largest decline
- Energy use
 - Oil price dropped below \$0 first time in history
 - Renewables, the only source, posted a growth by larger installed capacity and economic dispatch



Source: Deutsche Bank, Global Financial Data

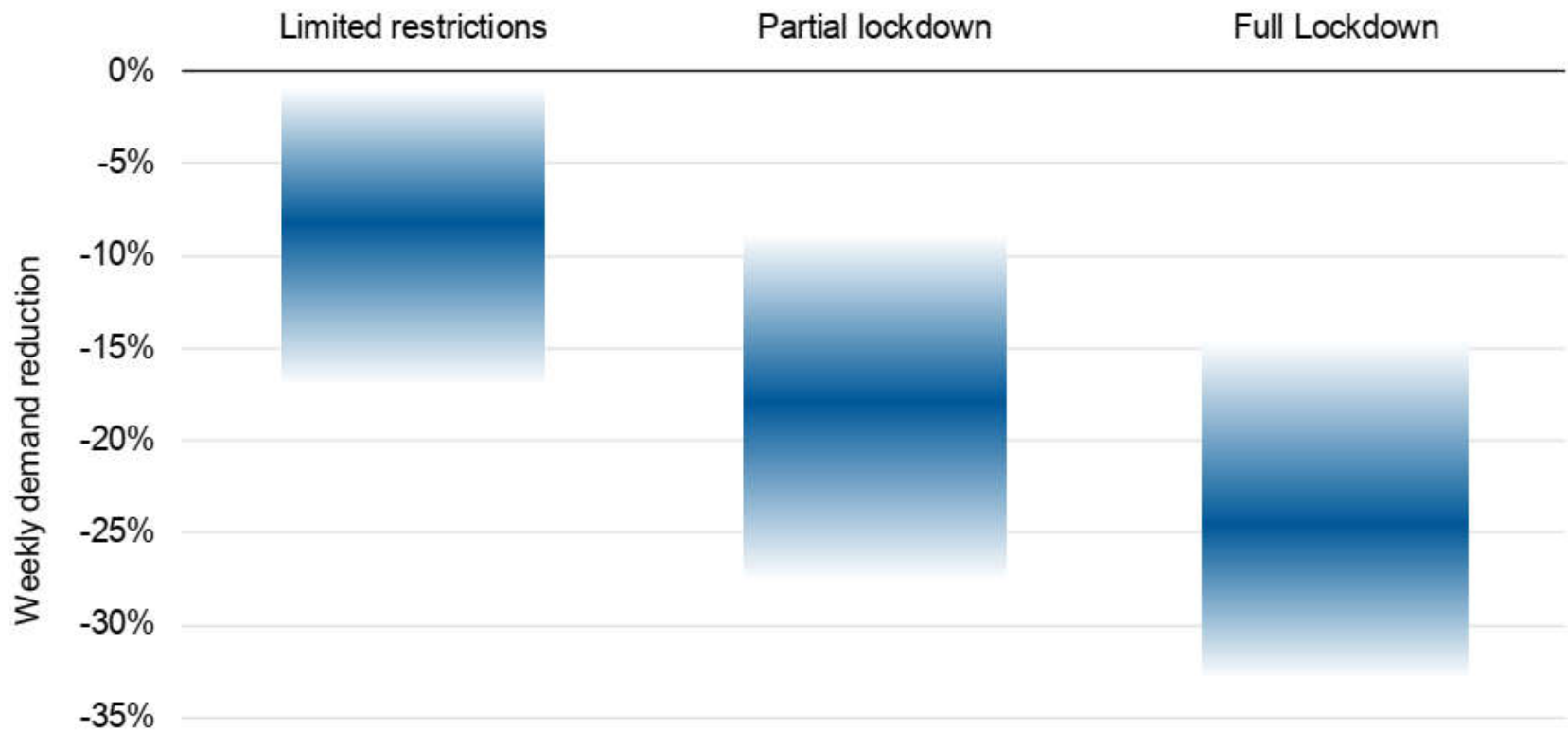
Change in Energy Demand

Rate of change in global primary energy demand, 1900-2020



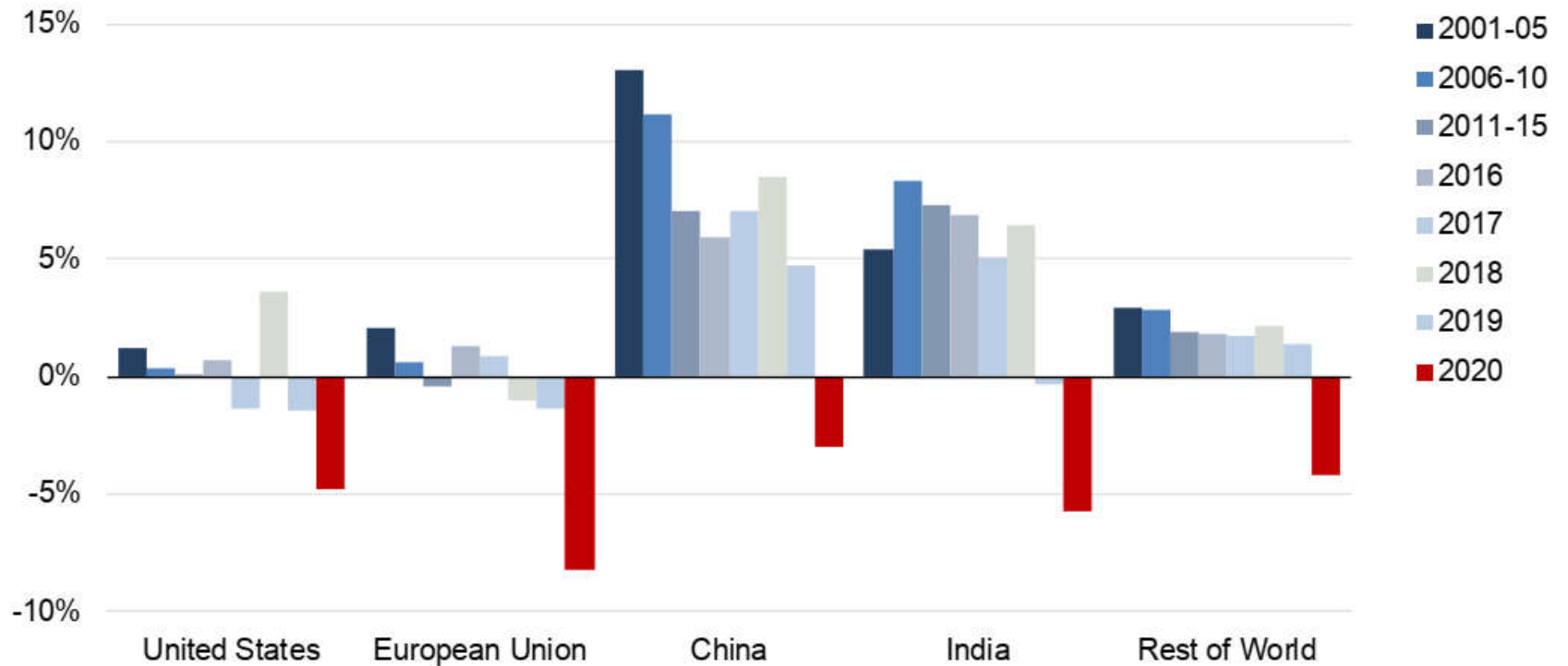
World in Lockdown

Impact of Covid 19 containment measures on weekly total energy demand



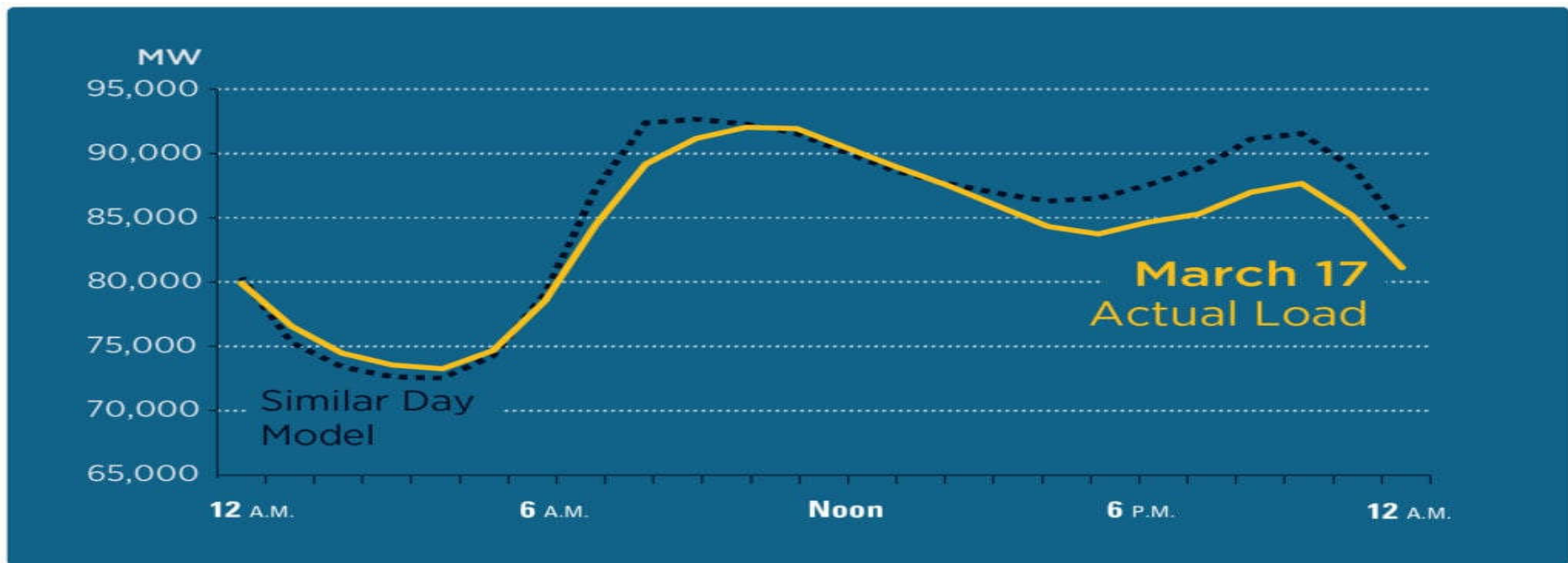
Projected Electricity Demand

Annual average growth rates of electricity demand in selected regions, 2001-20



Source: <https://www.iea.org/reports/global-energy-review-2020>

PJM Load Curve During the Pandemic



- Morning peak - arriving later, as many forego their commute
- Evening peak - lower
- Load curve - flatter, similar to a snow day

Reliable Electric Grid World-Wide

- IEEE Power & Energy Society's white paper - Sharing Knowledge on Electrical Energy Industry's First Response to COVID-19*
 - Europe, Asia, Oceania, Latin America, North America
- Planned and operated to ensure reliability
 - Hurricanes, Ice storms, heat waves, solar flare, etc.
 - Pandemics, e.g., 2009-2010 H1N1 influenza virus
- Mandatory reliability standards and compliance
- Business continuity and contingency plans always in place
- Control centers – Grid operators sequestered
- Field operations – Work prioritization and staffing changes
 - 1 person per vehicle
 - Use drone and helicopter inspections
- Customer operations and office staff - Telework
- Mitigating technical issues – Load forecast, high/low voltages, etc.

Keep the Lights on during COVID-19 Emergency



Grid operators living in RVs and trailers

Engineers converting offices into living spaces



Source: <https://abcnews.go.com/Politics/lights-covid19-emergency-power-company-workers-sequester-office/story?id=69934136>

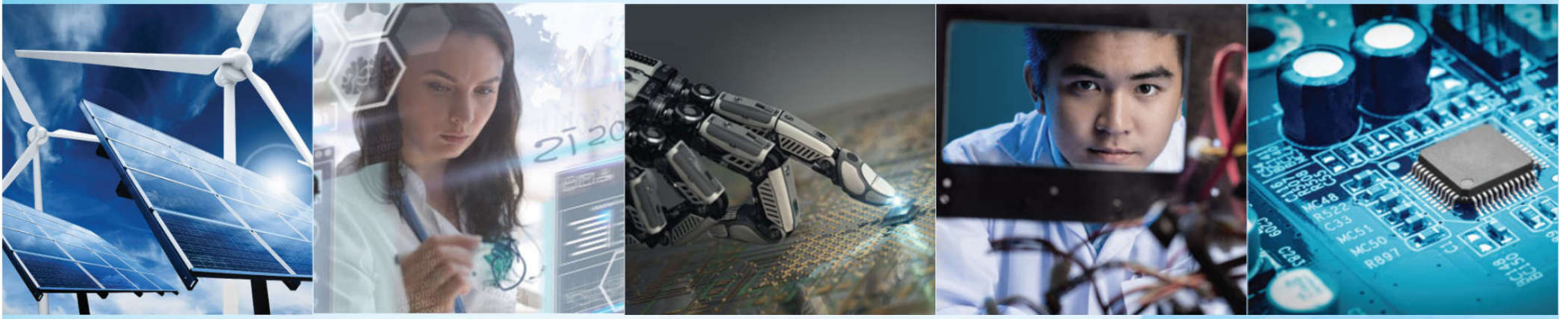
Regulatory Relief

- US grid regulators provided relief, e.g.,
 - Acceptable basis for non-compliance with obtaining and maintaining personnel certification, as required in reliability standard PER-003-2, for the period of March 1, 2020 to December 31, 2020
 - Postpone on-site audits, certifications and other on-site activities at least until September 7, 2020.
 - Defer Implementation for Seven Reliability Standards
 - 3 to 6 months

Mid-Term Impact

- In times of uncertainty, the electric grid remains the foundation for continuity and the enabler of change
 - Well-positioned for ongoing spring operations
 - Preparing for the summer period
- Risk increased
 - Prolonged periods of operator sequestration
 - Deferred equipment maintenance
 - Supply chain disruptions

Long-Term Impact - Look Across All The Factors That Drive Change



- Science and technology (e.g., more robots)
- Culture (e.g., more telework)
- Business strategy
- Politics (and geopolitics)
- Regulatory policy
- Law and the courts





Grid Reliability and Its Vital Signs

Note: The views expressed herein are the author's, and do not necessarily reflect the views of the PES or any other organizations.

Electricity in the USA is a *Good Deal*

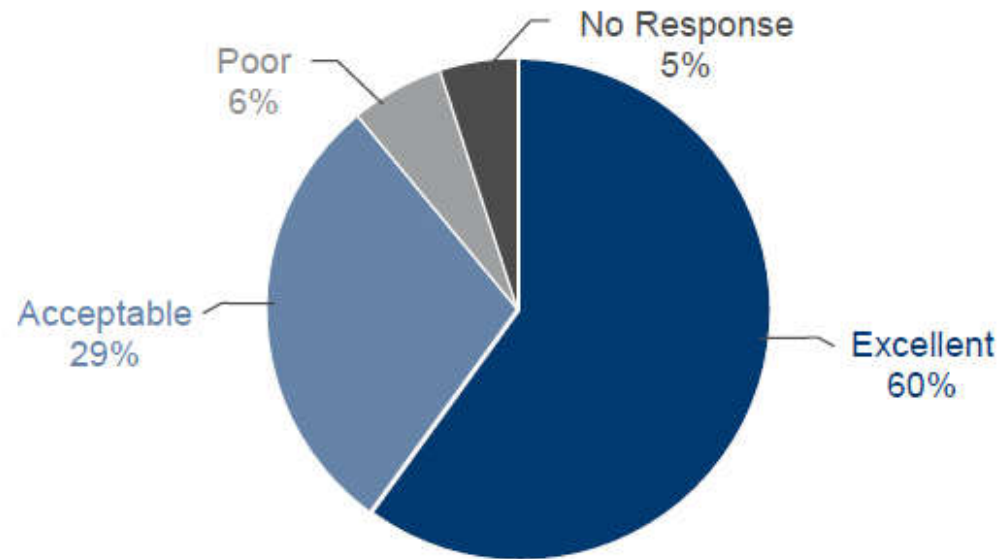


2011 average prices

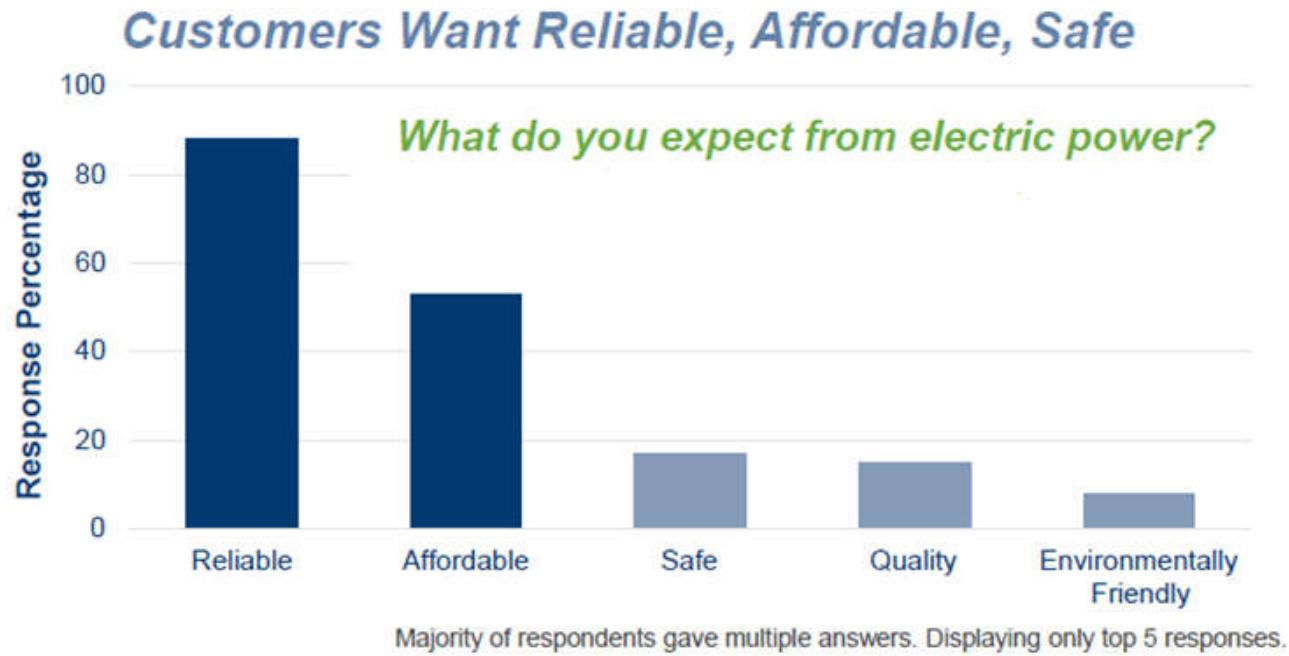
Source: IEA, EIA, national electricity boards, OANDA

Surveys - Customer Satisfaction

How well does your supplier work for you?



What More Can We Ask For?

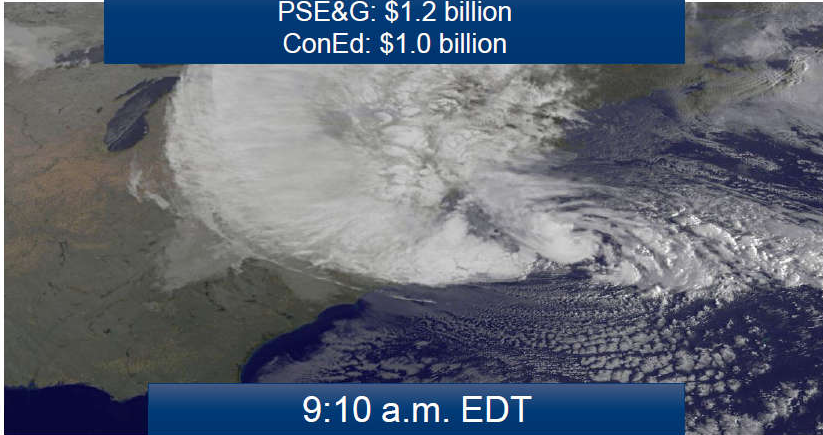


Does It Mean Grid Is Not Reliable?

Engineering Storm Hardening

PSE&G: \$1.2 billion

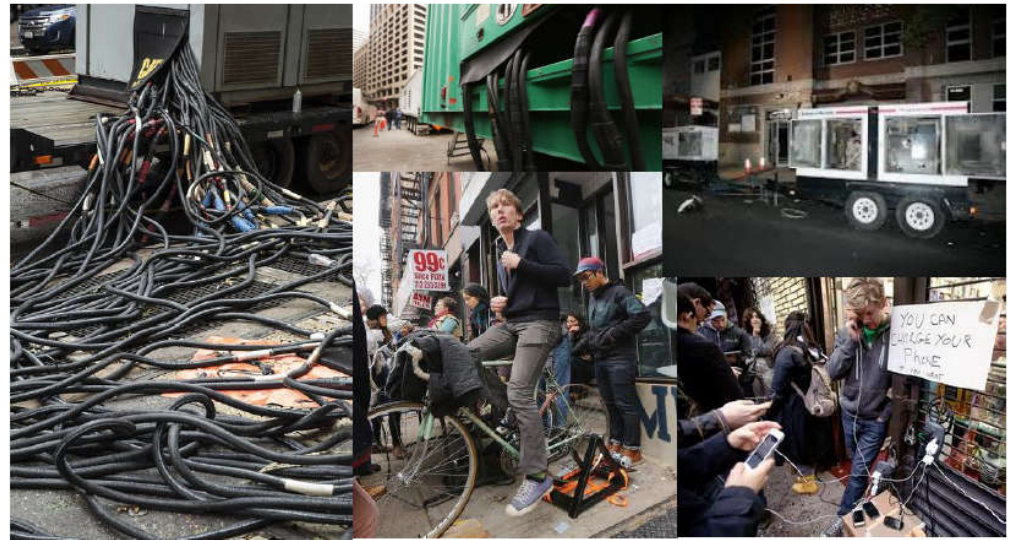
ConEd: \$1.0 billion



9:10 a.m. EDT

Superstorm Sandy – Northeast Coast, October 29, 2012

Microgrids ... New York City After Superstorm Sandy



Reliability History: Key Dates

November 9, 1965 – Northeast Blackout

1968: National Electric Reliability Council (NERC) established by the electric industry

July 13-14, 1977 – NYC Blackout

2002: NERC operating policy and planning standards became mandatory and enforceable in Ontario, Canada

August 14, 2003 Blackout

2005: U.S. Energy Policy Act of 2005 creates the Electric Reliability Organization (ERO)

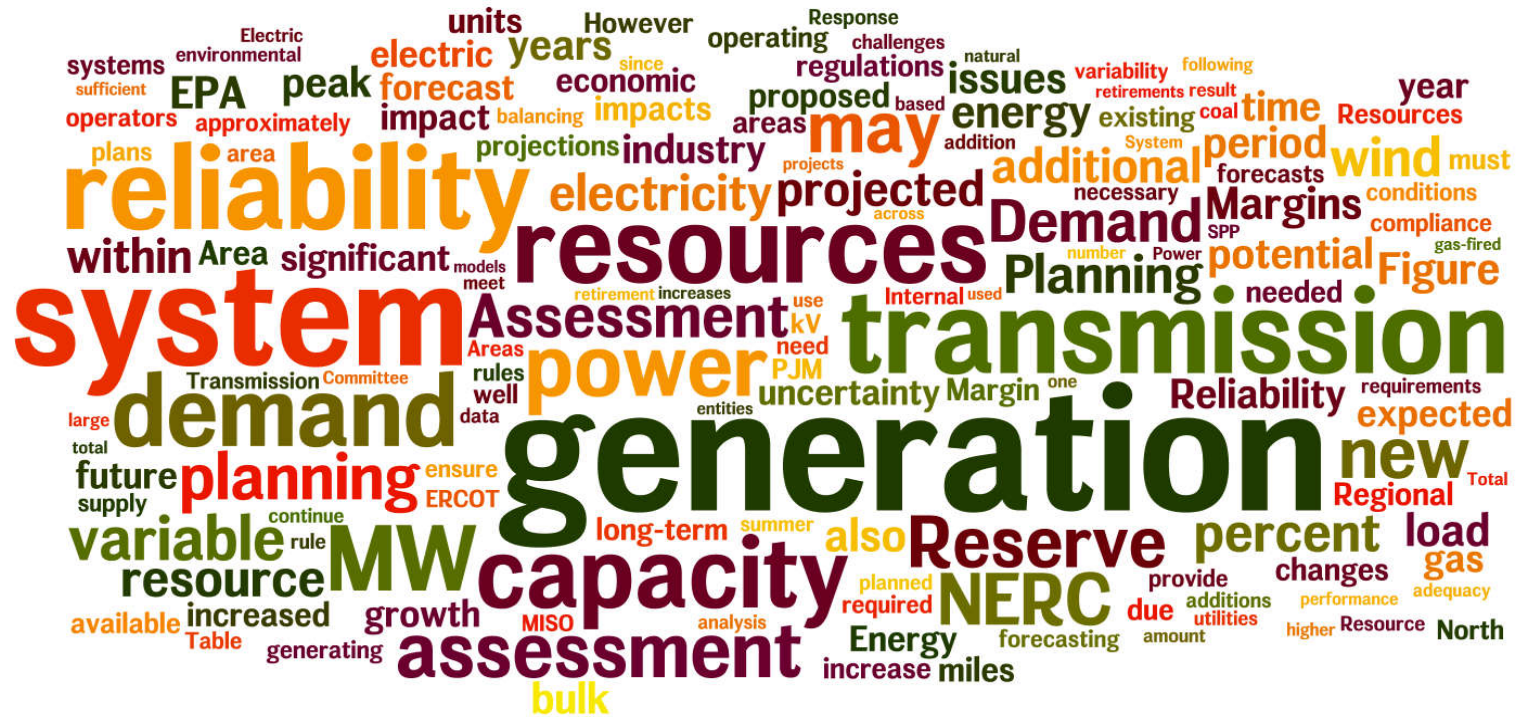
2006: FERC certified NERC as the ERO; MOUs with some Canadian Provinces

2007: North American Electric Reliability Council (NERC) became the North American Electric Reliability Corporation (NERC); FERC issued Order 693 approving 83; became mandatory and enforceable

Electric Reliability (Adequate Level of Reliability, ALR) – Legal Definition

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.

Is Reliability Improving?

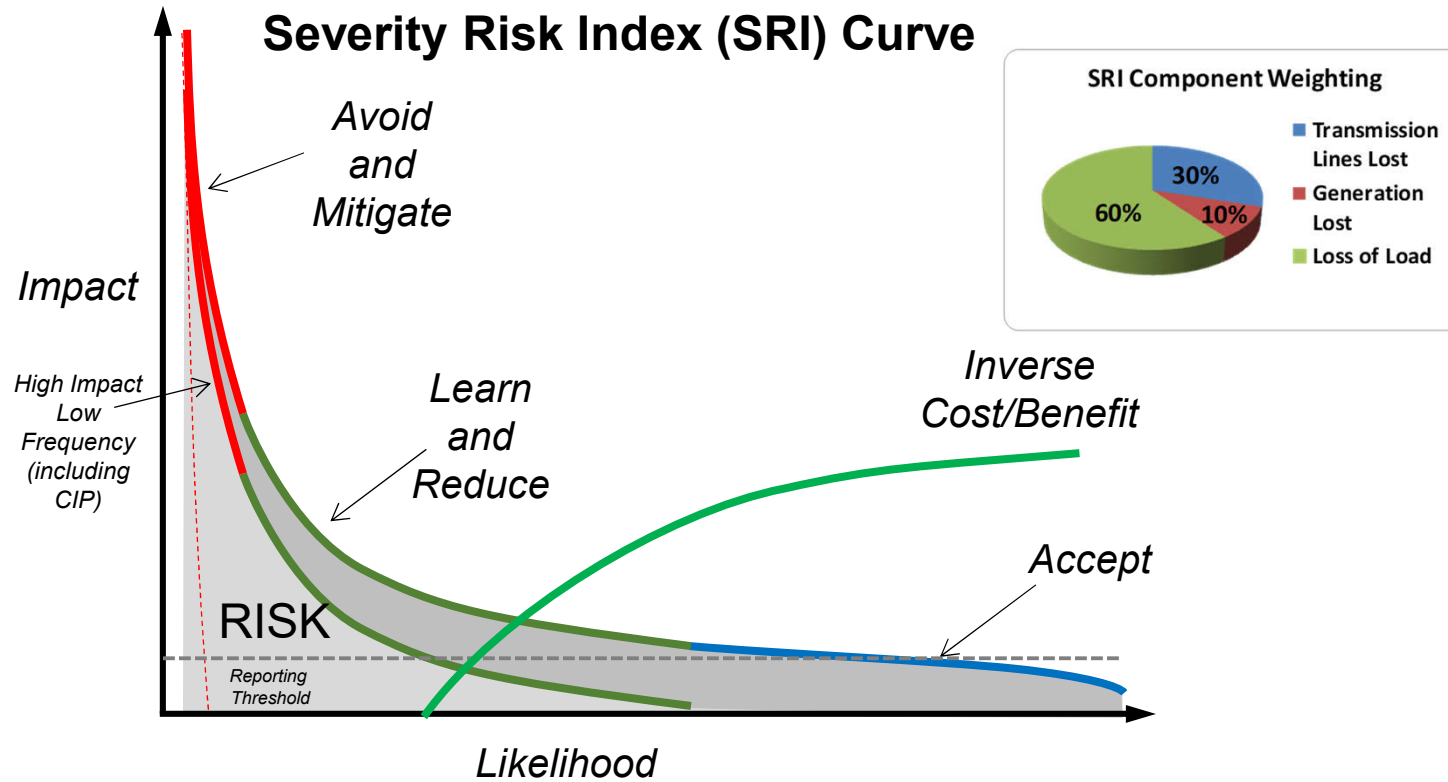


What We Worry About? – High Impact Events

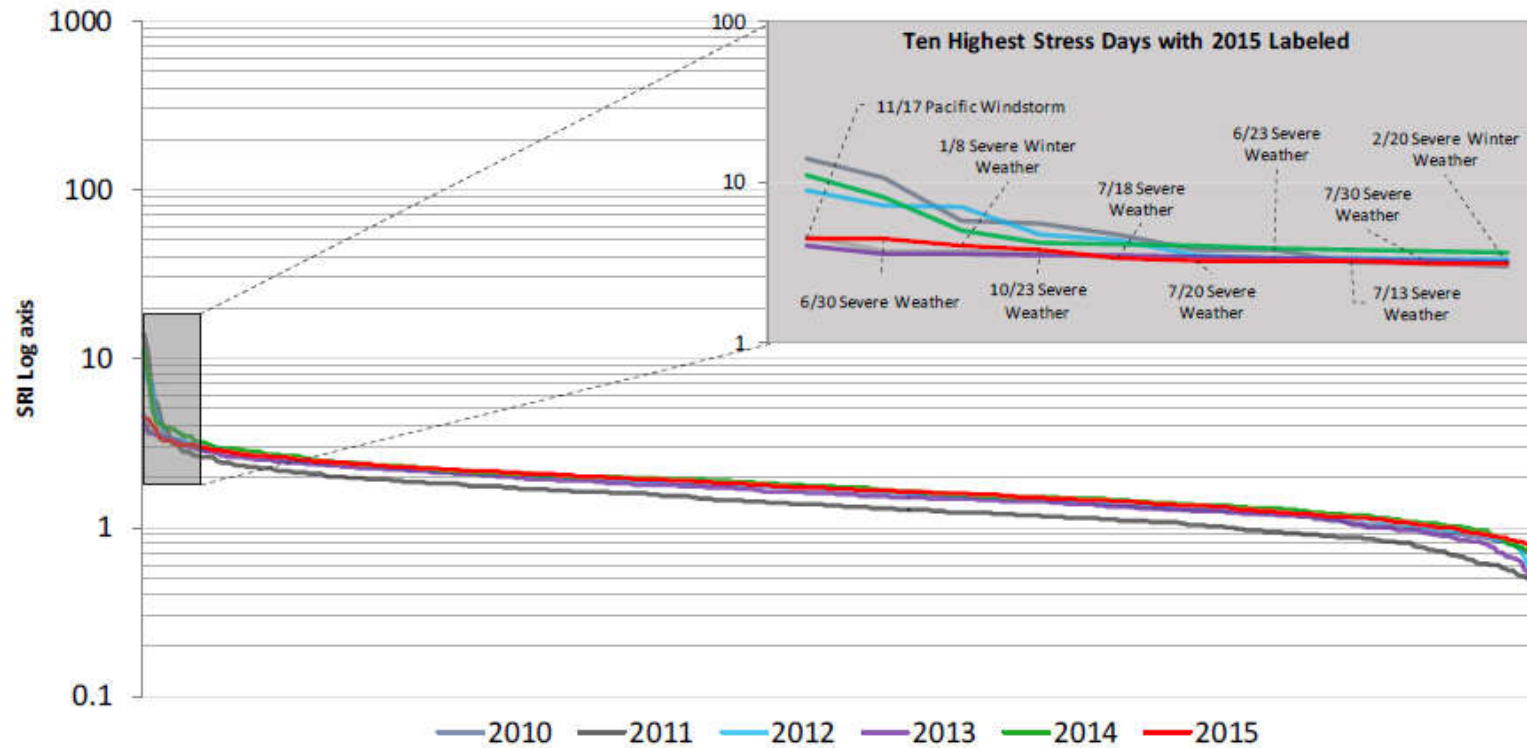
- Threats to reliability and resiliency of electric infrastructure
 - Coordinated cyber attack
 - Physical attack
 - Major hurricane
 - Potential solar weather
- Not a daily event
- No one company can deal with alone.



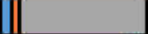









Measure Risk from Events



NERC Annual Daily Severity Risk Index (SRI) Sorted Descending



Top 10 SRI 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

*Note: SRI for Aug 14, 2003 blackout event is close to 80.

13 Industry-Defined Reliability Vital Signs

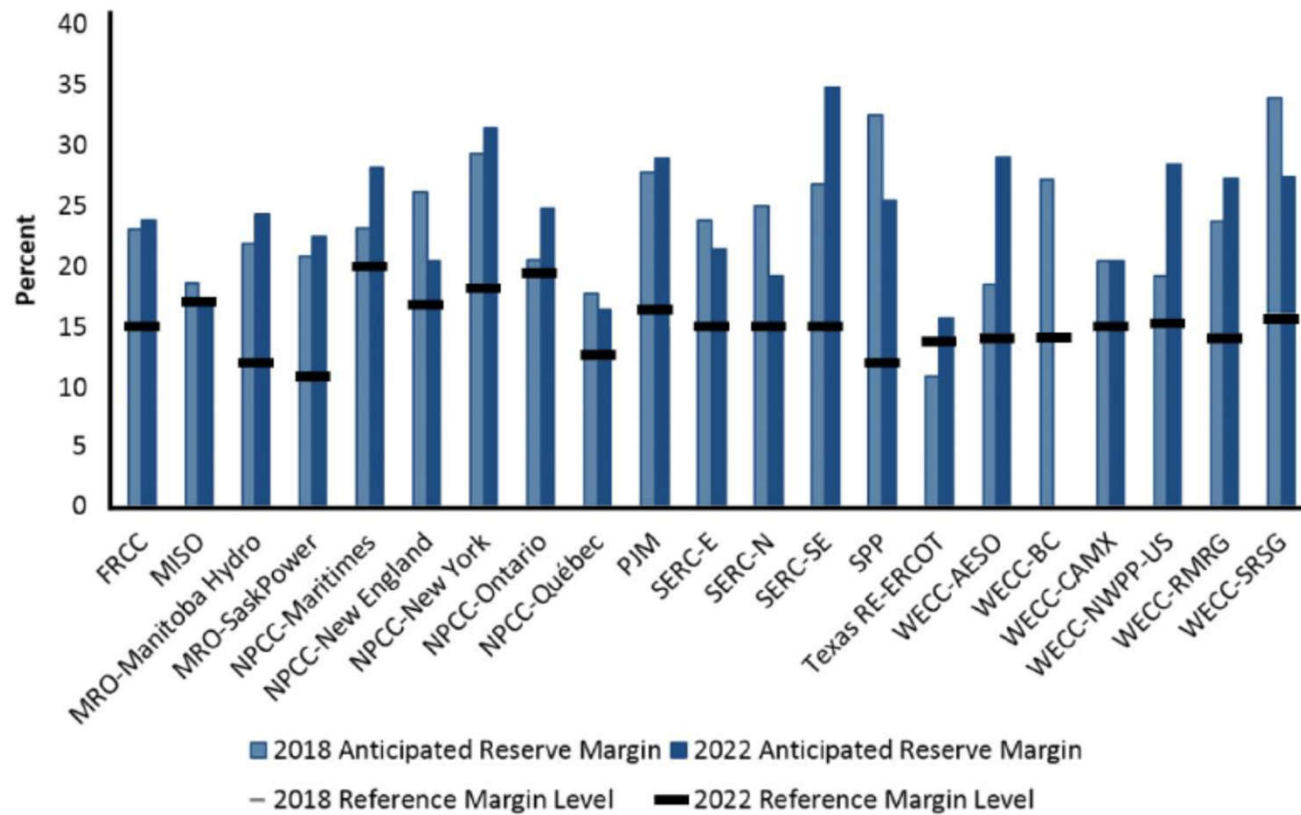
M-1	Reserve Margin
M-2	BPS Transmission Related Events Resulting in Loss of Load
M-4	Interconnection Frequency Response
M-6	Average Percent Non-Recovery Disturbance Control Standard Events
M-7	Disturbance Control Events Greater than Most Severe Single Contingency (MSSC)
M-8	Interconnection Reliability Operating Limit/System Operating Limit (IROL/SOL) Exceedances
M-9	Correct Protection System Operations
M-11	Energy Emergency Alerts
M-12	Automatic AC Transmission Outages Initiated by Failed Protection System Equipment
M-13	Automatic AC Transmission Outages Initiated by Human Error
M-14	Automatic AC Transmission Outages Initiated by Failed AC Substation Equipment
M-15	Automatic AC Circuit Outages Initiated by Failed AC Circuit Equipment
M-16	Element Availability Percentage

Vital Signs vs Performance Objectives for Reliability Standards

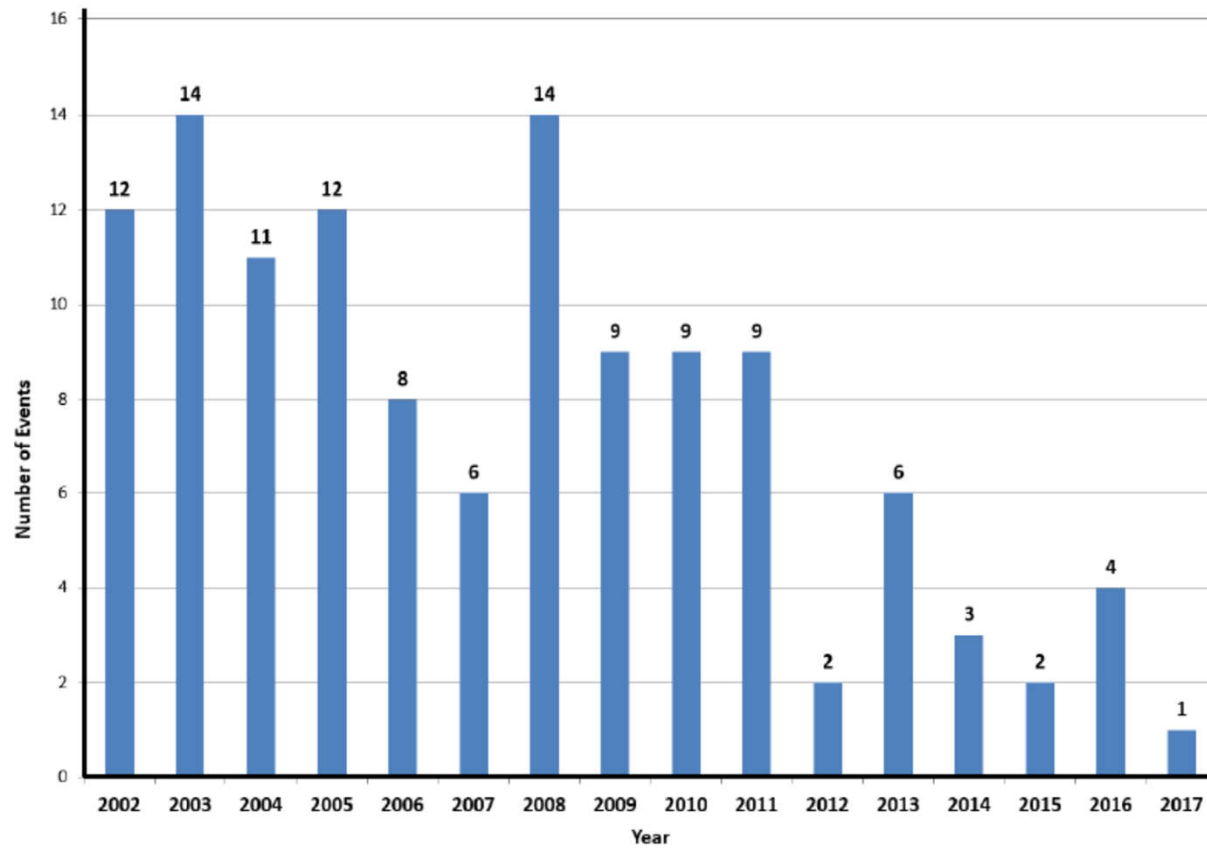
Adequate Level of Reliability (ALR) Metrics							
Reliability Performance Objectives	System Stability	System Frequency	System Voltage	Manage Contingencies	Coordinated Restoration	Transmission Adequacy	Resource Adequacy
ALR Metrics	M-2 M-4 M-9	M-4 M-6		M-2 M-6 M-7 M-8 M-11	M-2 M-11	M-2 M-8 M-12 M-13 M-14 M-15 M-16	M-1 M-11

- Purpose – Objectively provide an integrated view of reliability performance
- Serve as risk-informed input to:
 - Standards and project prioritization
 - Compliance process improvement
 - Event analysis, reliability assessment, and CIP
- Reference for trends risks to reliability
- Offer analytical insights towards actionable risk control

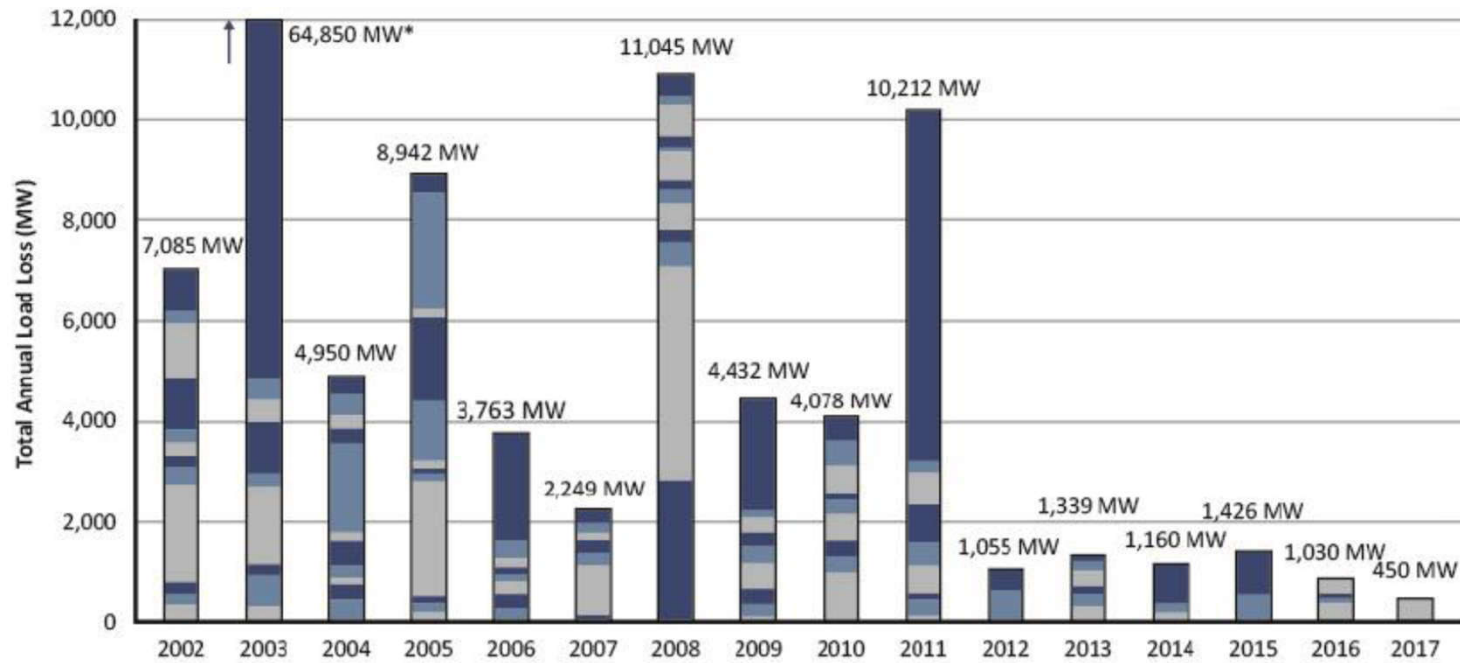
M-1 Planning Reserve Margin



M-2 BPS Transmission Related Events Resulting in Loss of Load - Number of Events



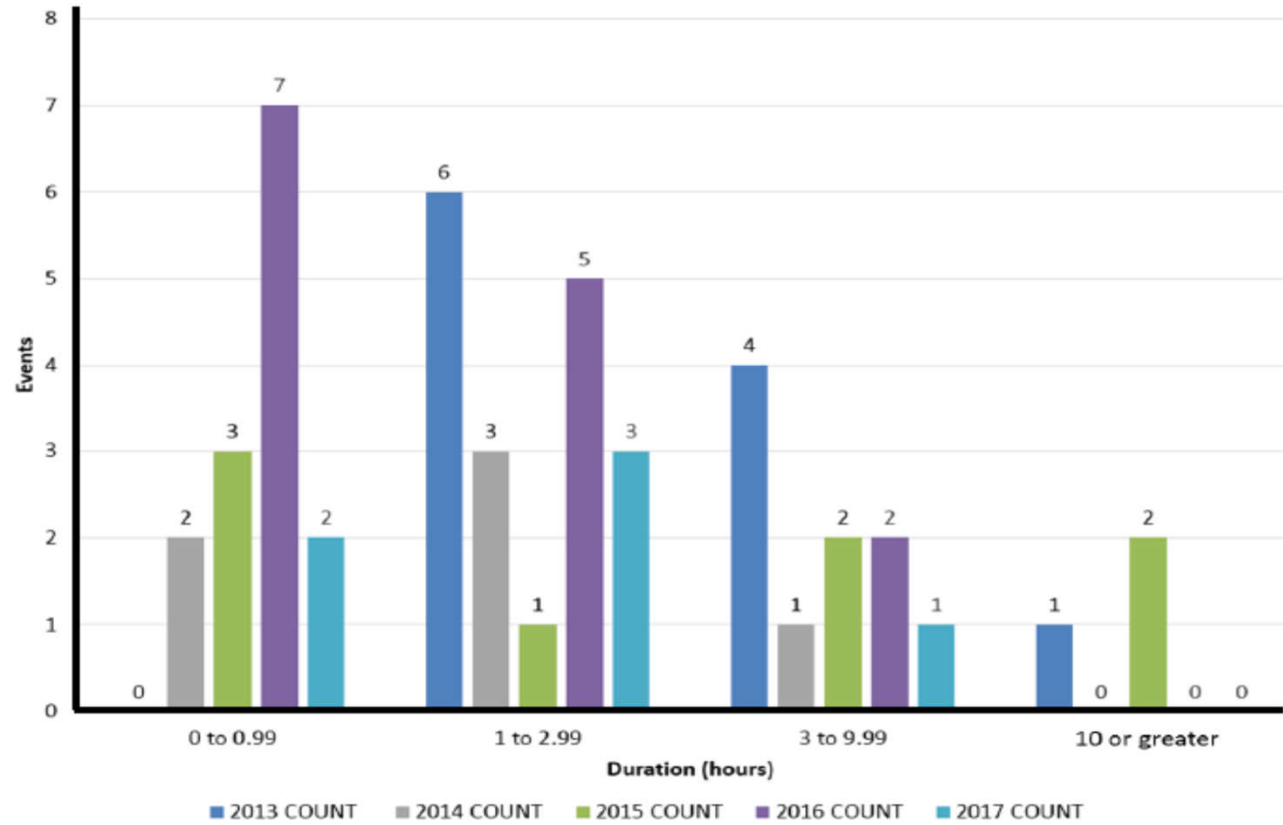
M-2 BPS Transmission Related Events Resulting in Loss of Load - Total Load Loss



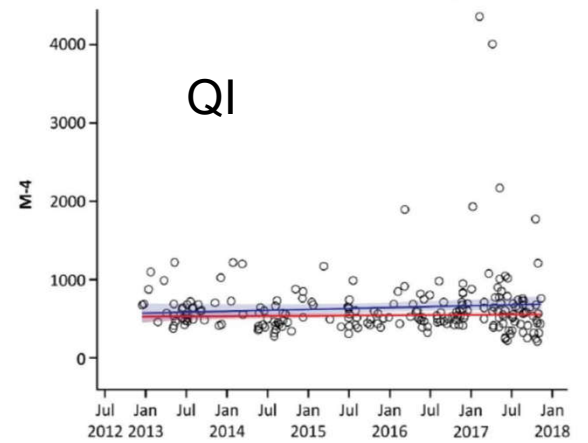
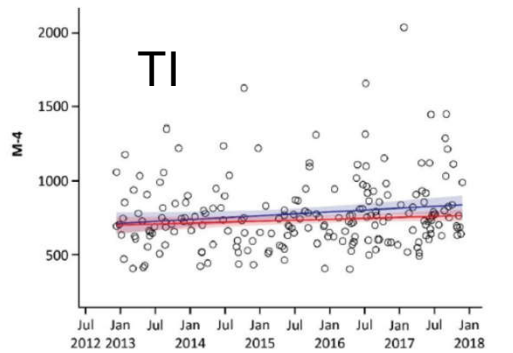
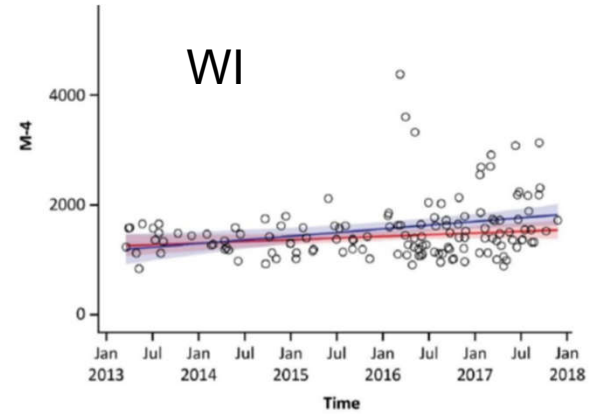
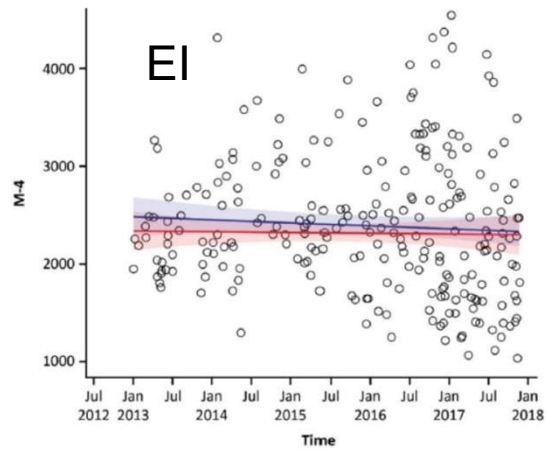
Each band of color represents a different event.

*Vertical axis scale has been reduced due to large value of 2003 NE blackout event.

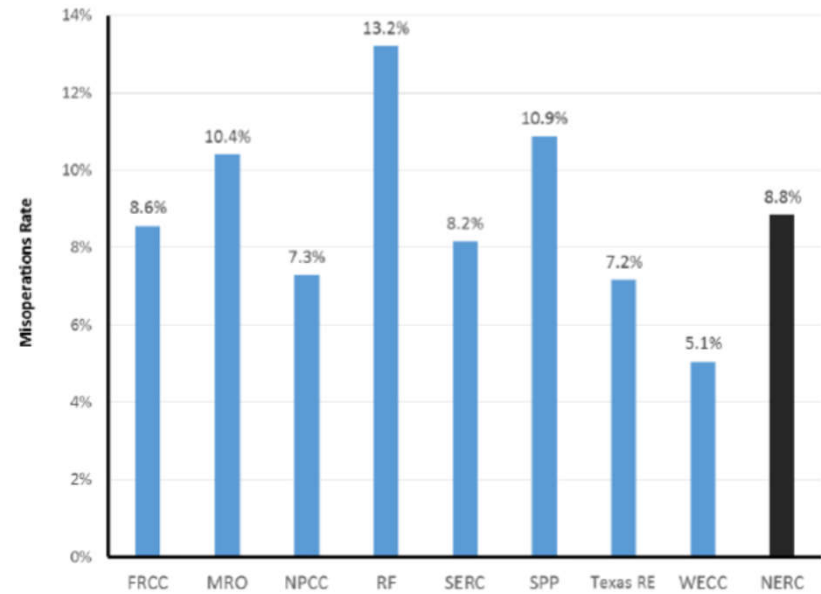
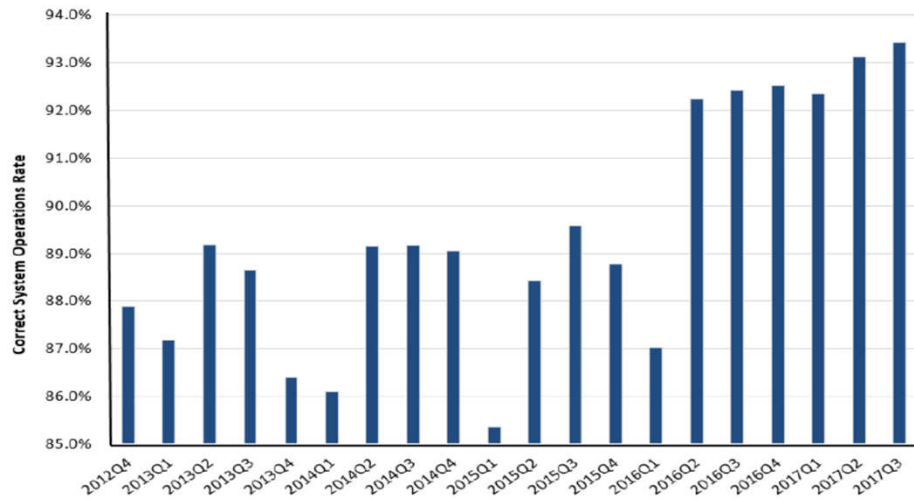
M-2 BPS Transmission Related Events Resulting in Loss of Load - Event Duration



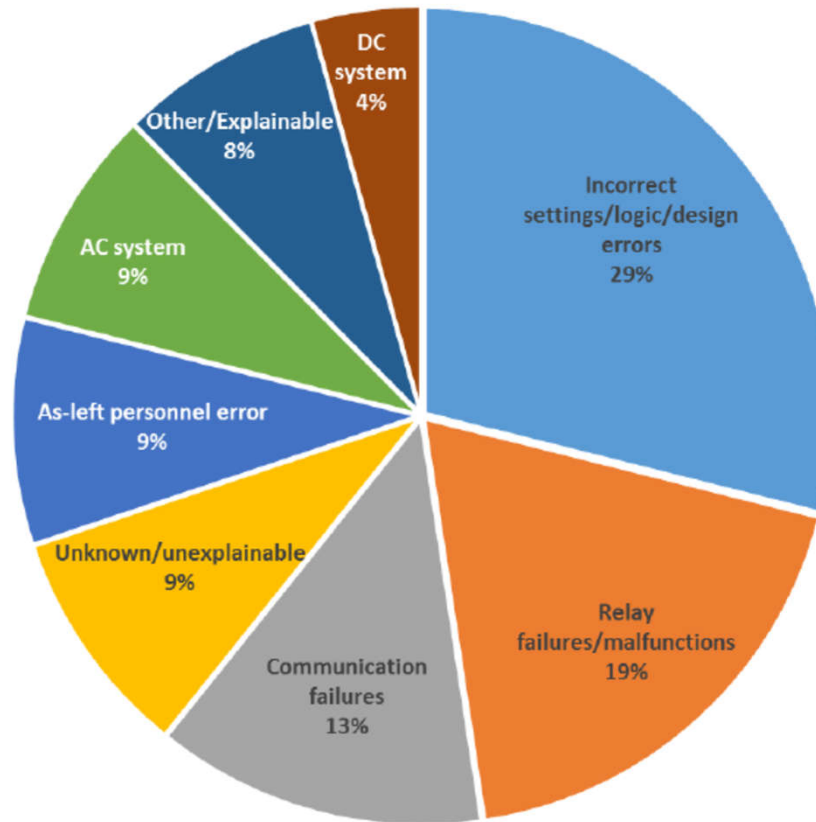
M-4 Interconnection Frequency Response (Eastern, Western, Texas and Quebec Interconnections)



M-9 Correct Protection System Operations - Quarterly and Five Year Average Rate



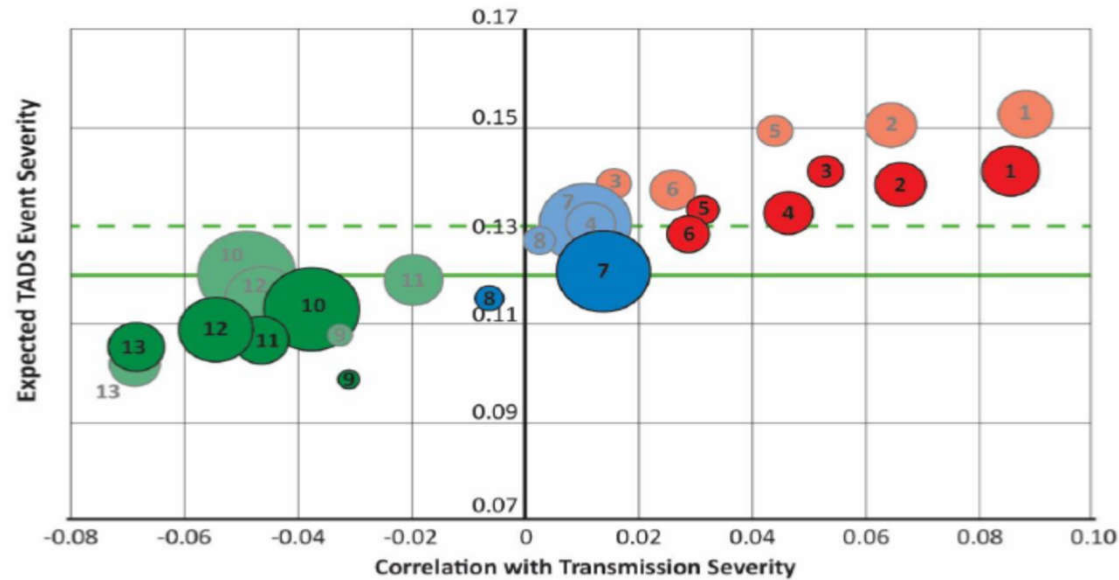
M-9 Correct Protection System Operations - by Cause Codes



M-11 Energy Emergency Alerts - Number and Level of EEAs in 2017

Region	EEA1	EEA2	EEA3	Total
FRCC	1	1	0	2
MRO	7	3	0	10
NPCC	2	0	0	2
RF	0	0	0	0
SERC	5	2	0	7
SPP	0	0	0	0
WECC	6	5	6	17
Texas RE	0	0	0	0
Grand Total	21	11	6	38

Risk Profile of Automatic Transmission Outages - by Initiating Cause Codes

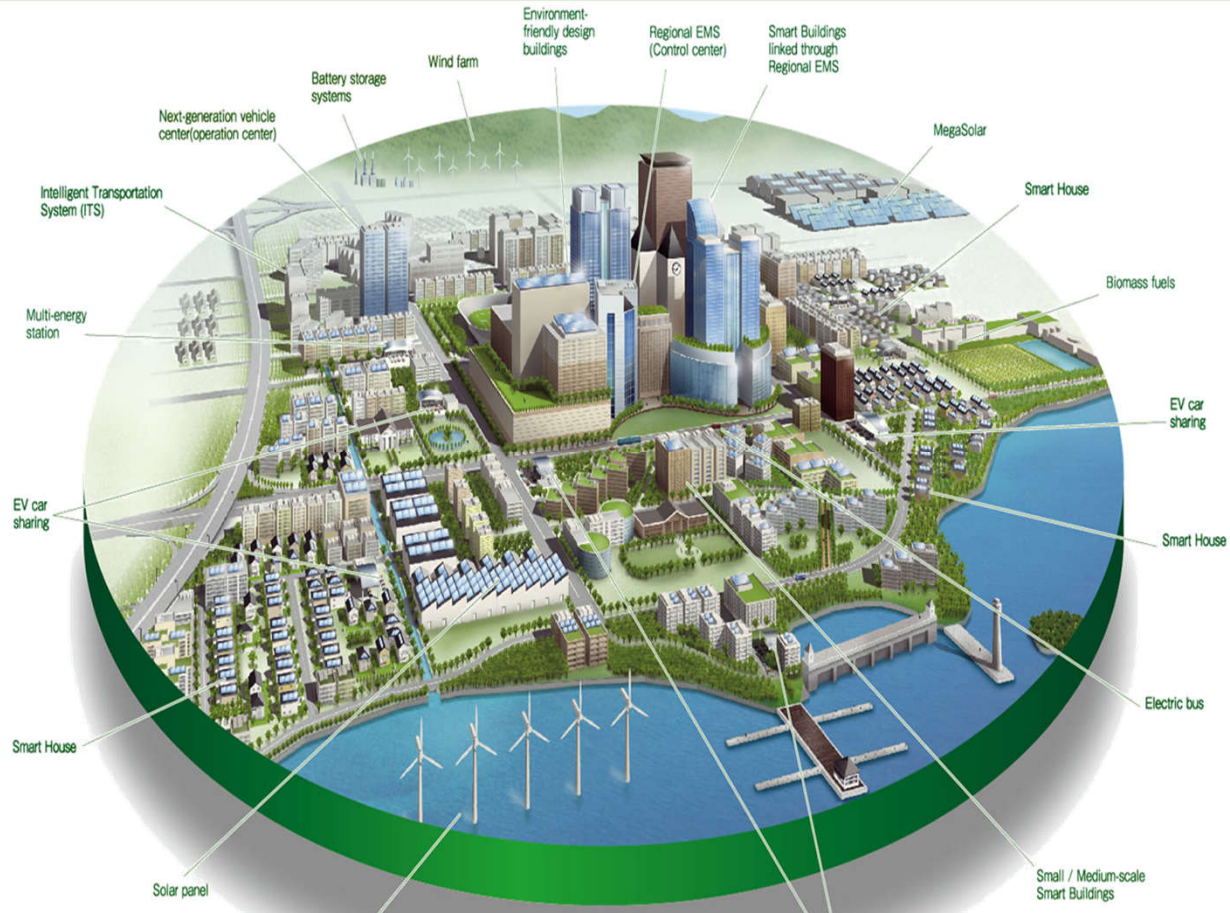


- | | | | | |
|--------------------------------|---|------------------------------|----|---|
| Misoperation | 1 | Lightning | 7 | ■ Significant Positive Correlation |
| Failed AC Substation Equipment | 2 | Other | 8 | |
| Fire | 3 | Combined Smaller ICC Groups | 9 | ■ No Significant Correlation |
| Contamination | 4 | Unknown | 10 | |
| Power System Condition | 5 | Failed AC Circuit Equipment | 11 | ● Analysis Summary of 2012–2016 (faded) |
| Human Error | 6 | Weather, Excluding Lightning | 12 | |
| | | Foreign Interference | 13 | |
- Average Transmission Outage Severity 2013–2017
- - - Average Transmission Outage Severity 2012–2016

Who Reaps the Benefits?

- Customers or Us.
- But wait...
 - Is reliability improving?
 - Is electricity rate reasonable?
 - Is the way we use energy sustainable?

Future Grid



Leading Trends

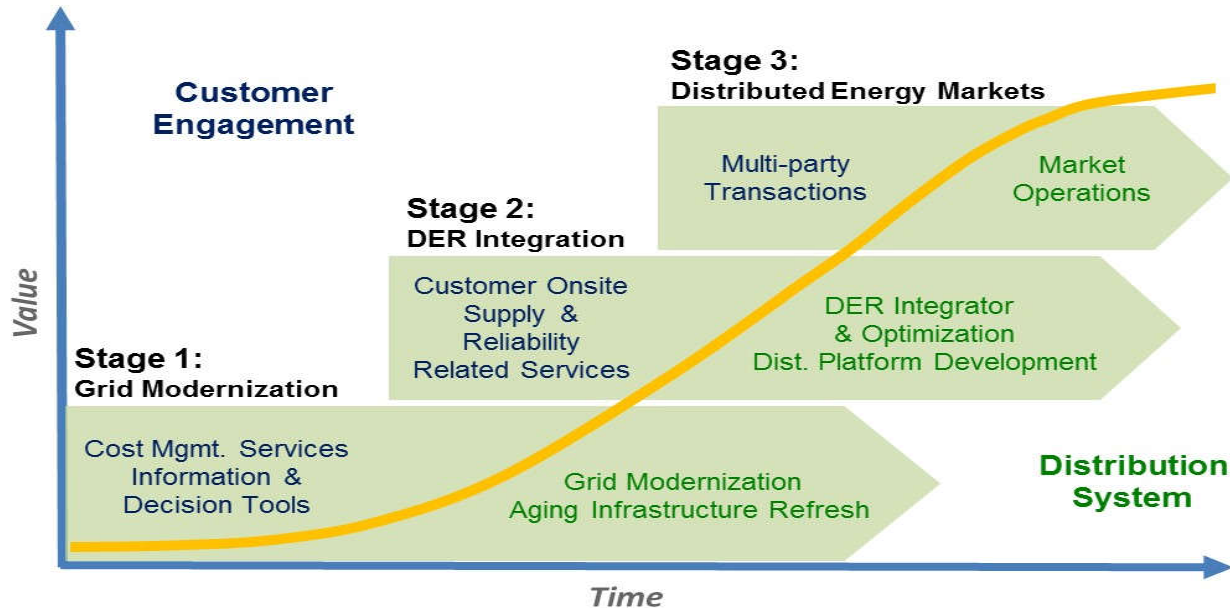
- Demand for electricity and G, T&D will increase.
 - Population growth, electric vehicles, renewables, etc.
- Fuel transformation has been occurring.
- More resilient, safe, reliable, and efficient Grid
 - Advancements in technology and processes
 - Need for clear and balanced regulatory policies
- Electricity value will be seen beyond commodity
 - Increased choices, digital age reliability, comfort value
 - Societal and economic goals to meet sustainability and support of growing economy



Key for New Grid is in educated workforce, developing & applying standards, and sharing global best practices

Electric Retail Evolution

Utility functions – Evolve over time as customer adoption of Distributed Energy Resource (DER) grows and **the opportunity** is created in this transition.



Source: Paul De Martini



ARE WE READY?



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1,960+ Annual Conferences



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49 Technical Societies



Social Impact

Public Policy Engagement

Global Humanitarian Efforts

Education & Certification

Ethics in Technology



Power & Energy Society (PES) - Global Engagement Through Local Chapters

Over 40,000 members in 150 countries

REGION 1-7

128 chapters | 68 student chapters | 19,835 members

REGION 8

48 chapters | 78 student chapters | 5,803 members

REGION 9

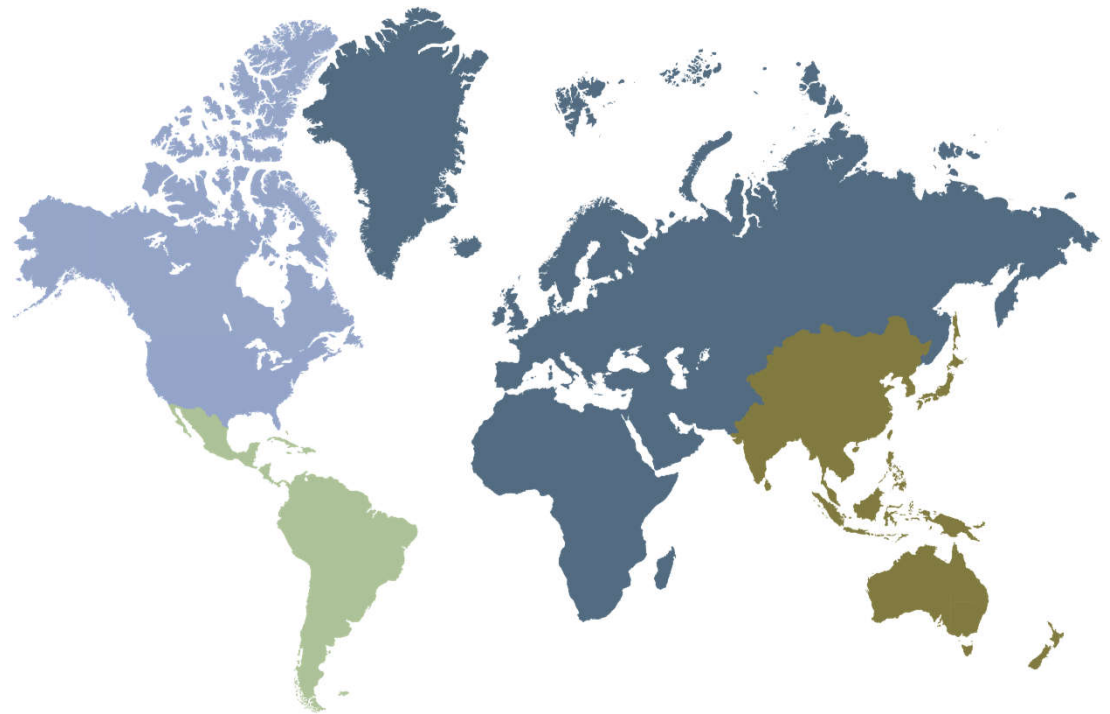
36 chapters | 114 student chapters | 3,119 members

REGION 10

46 chapters | 179 student chapters | 11,185 members

258 Chapters and 439 Student Chapters:

PES Chapters are a great way to plug in to the society in most parts of the world and get involved.

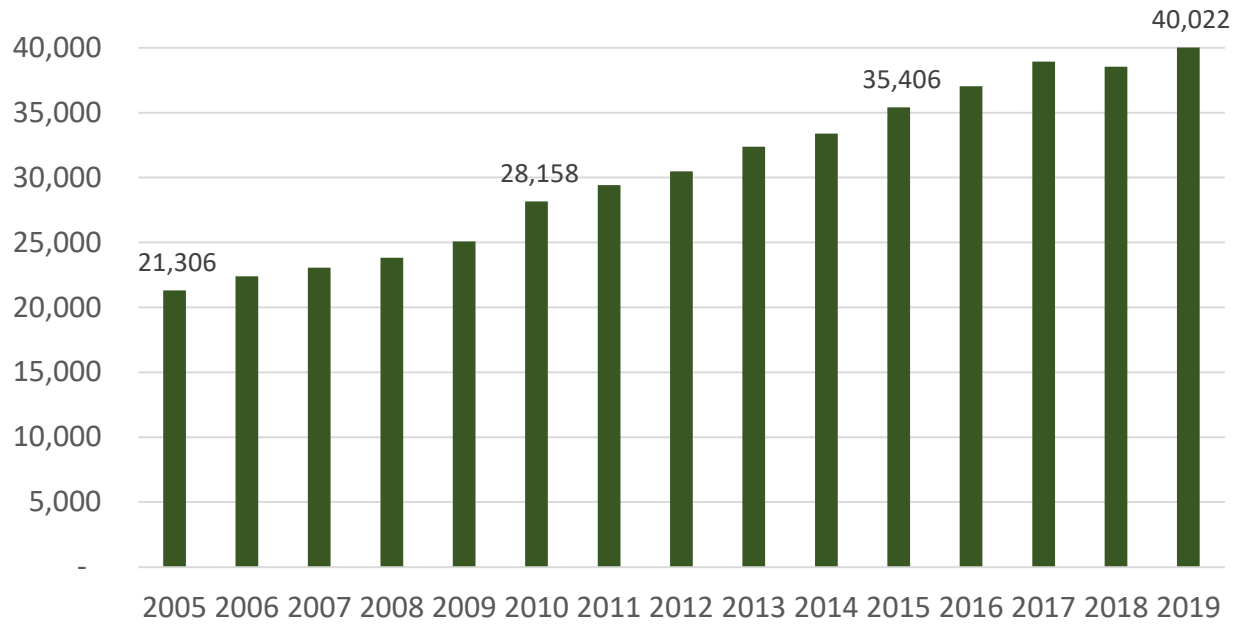


>50% of members are outside USA



Continuous Membership Growth

Celebrating Over 40,000 PES Members Worldwide!



PES Technical Community

- Analytic Methods for Power Systems
- Electric Machinery
- Energy Development and Power Generation
- Energy Storage and Stationary Battery
- Insulated Conductors
- Nuclear Power Engineering
- Power System Communications and Cybersecurity
- Power System Dynamic Performance
- Power System Instrumentation and Measurements
- Power System Operations, Planning and Economics
- Power System Relaying and Control
- Smart Buildings, Loads and Customer Systems
- Substations Committee
- Surge Protective Devices
- Switchgear
- Transformers
- Transmission and Distribution

Coordinating Committees:

- Intelligent Grid & Emerging Technologies
- Marine Systems
- Wind and Solar Power

Get Involved. Visit: www.ieee-pes.org/technical-activities

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resourcecenter.ieee.pes.org



Technical Committees: Downloads

TC: Analytic Methods for Power Systems (AMPS)	Downloads			
	2017	2019	2020	Total
Products				
PES_CVS_GM19_0806_308_8_10		38	2	40
GM 2019 - Big Data Analytics for Power System Economy Reliability and Security		38	2	40
PES_CVS_GM19_0807_308		27	6	33
2019 IEEE General Meeting 8/7 Panel Presentation: Cybersecurity and Resiliency for the Power Grid Leveraging Data-Driven Mo		27	6	33
PES_CVS_GM19_0807_222		24	7	31
2019 IEEE General Meeting 8/7 Panel Presentation: Cyber-Physical Situational Awareness for the Power Grid - Opportunities and		24	7	31
PES_CVS_GM19_0807_313b		22	3	25
2019 IEEE General Meeting 8/7 Panel Presentation: Optimization Methods for Unbalanced Power Distribution Systems		22	3	25
PES_CVS_GM19_0805_308		21	3	24
GM 2019 - Frontiers of Big Data Analytics in the Operations and Maintenance of Power Distribution Systems		21	3	24
PES_CVS_GM19_0806_308_10_12		22	1	23
GM 2019 - Thinking Outside the "Black Box" - Analytical Foundations of Power System Research		22	1	23
PES_CVS_GM19_0806_308_1_3		17	4	21
GM 2019 - Transient Modeling and Analysis of Distribution Systems		17	4	21
PES_CVS_GM19_0807_313c		12	6	18
2019 IEEE General Meeting 8/7 Panel Presentation: Concept of "Smart Cities" in the Southeastern Region of the US		12	6	18
PES_CVS_GM19_0805_GB		15	3	18
GM 2019 - Analytic Methods for Power Systems Distribution System Analysis Committee Poster Session		15	3	18
PES_CVS_GM19_0807_307		13	3	16
2019 IEEE General Meeting 8/7 Panel Presentation: Industrial Applications of Composite System Reliability Assessment Challeng		13	3	16
PES_CVS_GM19_0807_309b		11	2	13
2019 IEEE General Meeting 8/7 Panel Presentation: Reliability of Cyber-Physical Power System Test Systems and Standard Enha		11	2	13
PES_CVS_GM19_0808_223		12	1	13
2019 IEEE General Meeting Panel Presentation: Advances in Power System Studies for Geomagnetic Disturbance Vulnerability As		12	1	13
PESLL1138		1	1	2

PES MEMBER ACCESS

Most materials in the PES Resource Center are free to society members – an important member benefit.

NON-PES MEMBER ACCESS

Discounted prices, for IEEE members, are listed for each product. Non-members also have access to all the products on the IEEE PES Resource Center.



Engaging during the COVID-19 Pandemic (<https://www.ieee-pes.org/covid-19-resources>)

Upcoming Events

Sort By ▼

WEBINARS

Thu. 30 Apr. 2020

LIVE Webinar: Toward Extreme Fast Charging: Challenges and Opportunities in Directly Connecting to MV Line

WEBINARS

Fri. 1 May, 2020

LIVE Online Tutorial Transactive Energy Systems: Overview, Theory, Tool, Application, and Trend, Session 2

TECHNICAL COMMITTEES

Sun. 3 May, 2020 - Wed. 6 May, 2020

CANCELLED 2020 IEEE PES Insulated Conductors Committee Meeting (ICC)

TECHNICAL COMMITTEES

Mon. 4 May, 2020 - Fri. 8 May, 2020

CANCELLED 2020 IEEE PES Switchgear Committee Spring Meeting

[View full calendar](#)

COVID-19 Resources

IEEE PES thanks its members for their support during these challenging times. IEEE provides many tools to support our membership through virtual conferences and meetings, online collaboration tools, publishing impactful cutting-edge research, virtual educational resources, and more

- [See COVID-19 IEEE Member Resources](#)
- [View Statement from IEEE](#)

Free Tutorials & Plain Talk for PES Members

- The IEEE Power & Energy Society realizes that many are directly engaged or affected in the fight against COVID-19 and its effects on global health and safety, research, infrastructure, communications, and more. As a service to our members we're making the selected PES Tutorials and Plain Talks free to PES Members. [More information](#)

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IEEE realizes that economic circumstances may impact some members' ability to pay the full amount of IEEE membership dues. For this reason, the following special circumstance categories have been established. Special circumstance discounts are not available to Student members or to members in developing nations who take the electronic membership option. Only one category may be claimed in any year.

- Minimum income
- Retired
- Unemployed
- Permanently disabled
- Developing nations

IEEE Humanitarian Activities Committee & SIGHT Projects – Response to COVID-19

- The IEEE Humanitarian Activities Committee has adapted its requirements to better enable IEEE volunteers to contribute to the COVID-19 Pandemic. For that reason, HAC and SIGHT (Special Interest Group on Humanitarian Technology) Projects will join forces to prioritize proposals that have a strong potential for immediate impact in the fight against COVID-19. For more information and details on how to submit a proposal (deadline 15 May), see the [IEEE HAC & SIGHT Projects 2020 Special Call for Proposals related to COVID-19](#).

Get Involved - Collaboration!



Be A Part of This Transformation!

Thank You!

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