



Challenges & Opportunities in Sustainable Energy

***Jessica Bian**, Chair, IEEE Industry Engagement Committee (2024-25)*

President, IEEE Power & Energy Society (2022-23)

IEEE Industry Engagement Committee | IEEE

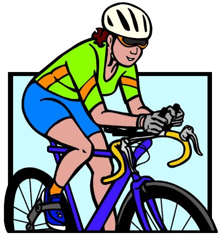
IEEE Advancing Technology

My Career "Pivot"

- Academic (teaching, research)
- Manufacturing (Invention, application)
- Electric Utility (planning, operations, becoming a leader)
- Standards Organization (consensus building)
- Regulatory Agent (collaborating with lawyers and economists for bigger social impact)
- Association (volunteer, President)
- Shaped me over the years…
- https://www.linkedin.com/in/jessica-bian-b2b44615/

What is Energy?





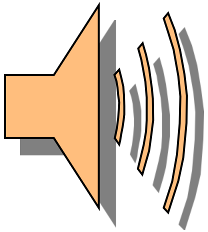



Moving and/or doing work is ***Energy***

Forms of Energy

Hea
t

Ligh
t



Soun
d

Magneti
c

Electricit
y

Chemica
l

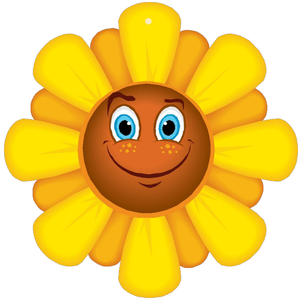
Sources of Energy

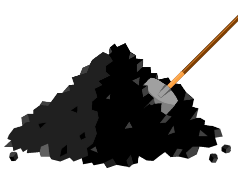
- Biggest source of energy is our Sun
- Some other sources are
  - Coal
  - Wood
  - Wind
  - Water

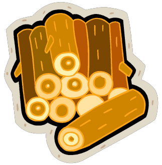
Primary Sources of Energy

  - Food
  - Electricity
  - Hydrogen

Secondary Sources of Energy

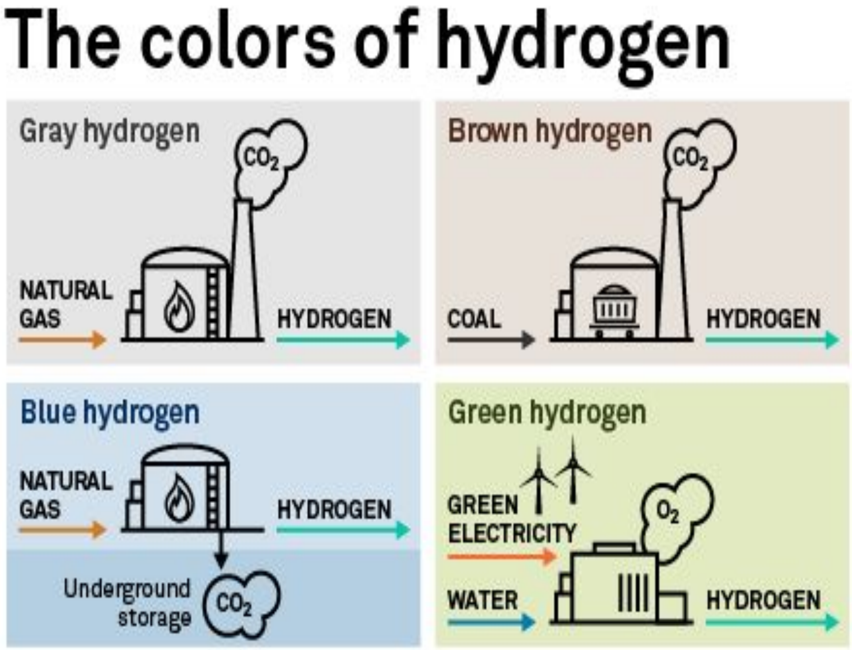






Types of Clean Energy

Moving water, solar, wind, biomass, geothermal, and ocean energy



Brown hydrogen

In this method, brown coal is 'gasified' to create a synthesis gas of carbon monoxide, carbon dioxide, hydrogen and steam from which hydrogen is extracted. However, several greenhouse gases remain, meaning brown hydrogen is not carbon-neutral.

Grey hydrogen

Currently responsible for 70% of global production, 'grey' hydrogen is produced by applying steam reformation to natural gas. Here, methane in the natural gas reacts with steam to cause a reaction by which hydrogen (and carbon dioxide) is produced.

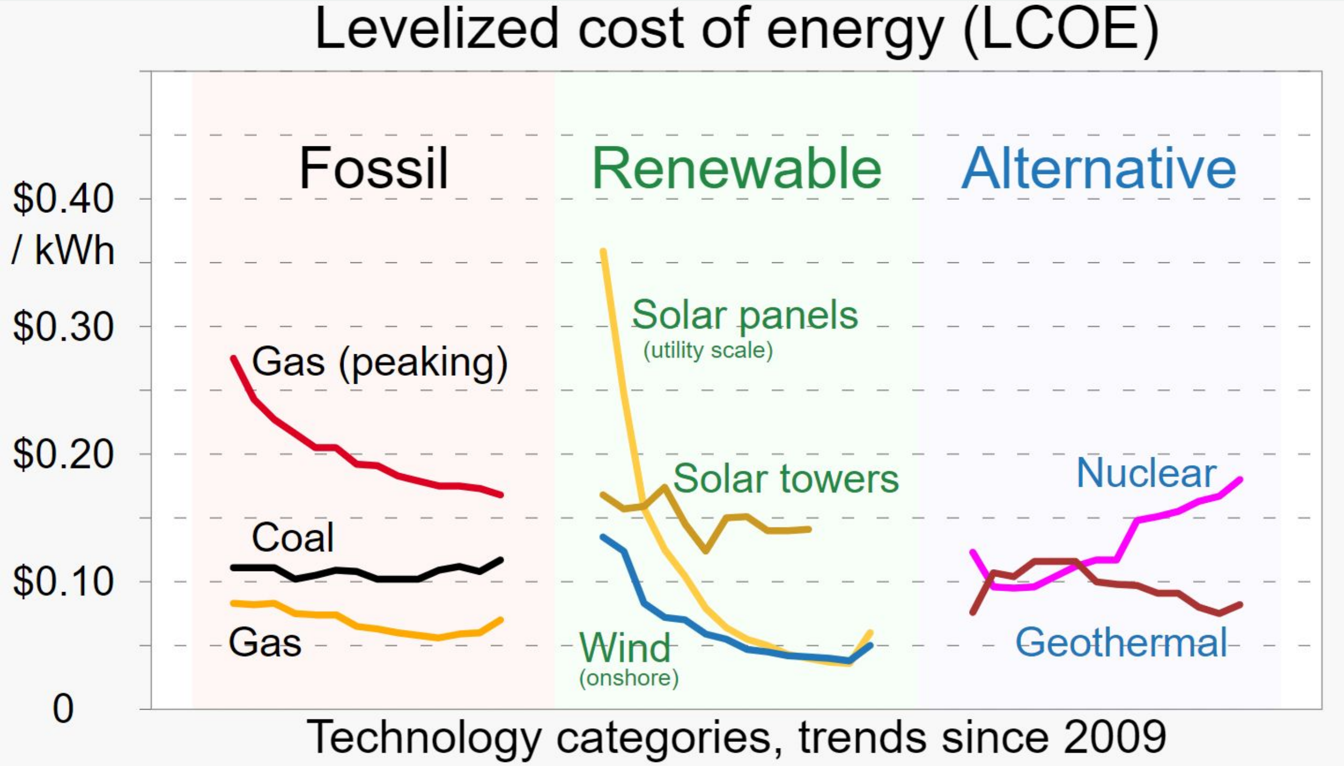
Blue hydrogen

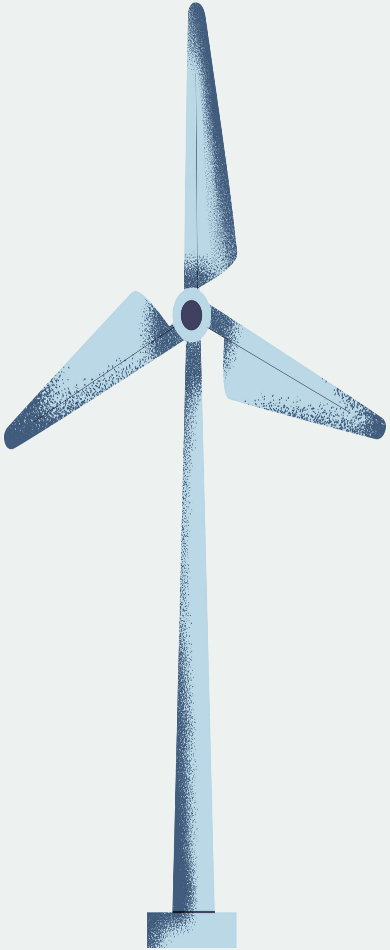
When the CO_2 from grey or brown hydrogen is captured and stored, it is known as 'blue' hydrogen. While adequate carbon capture and storage ("CCS") capacity is required for this method, and it is currently more expensive and less efficient to produce than grey hydrogen, it is considered an important step in the energy transition.

Green hydrogen

Renewable or 'green' hydrogen is produced by splitting H_2O molecules into hydrogen and oxygen, using electricity from renewable sources to pass a current through water. This method results in zero carbon emissions throughout the production process.

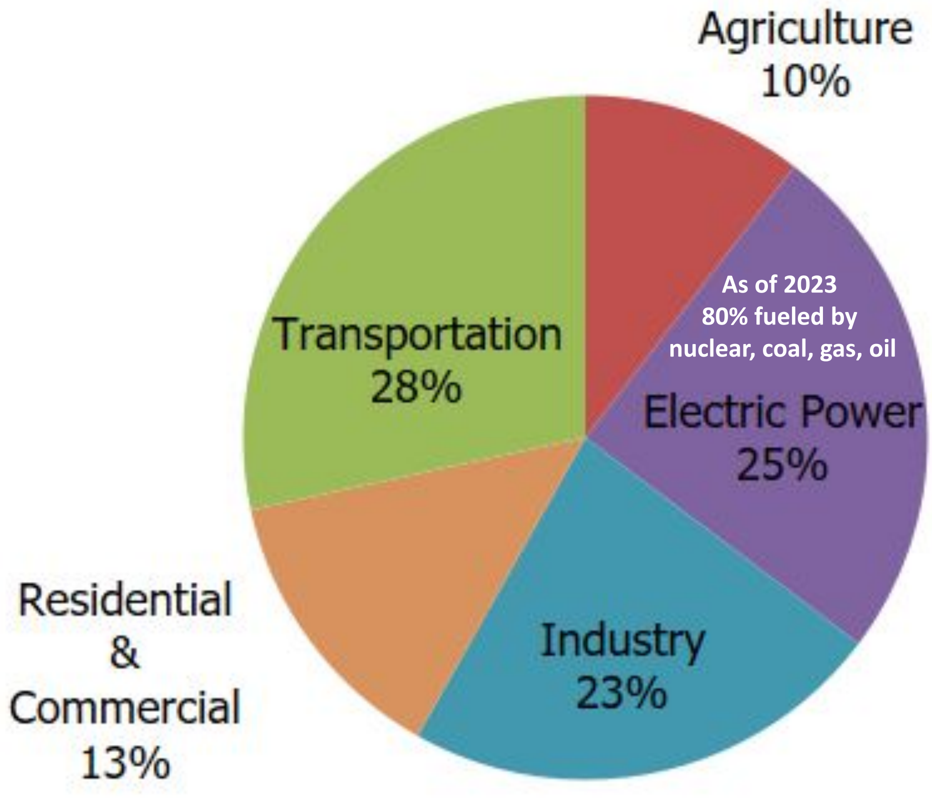
Cost of Electricity by Source





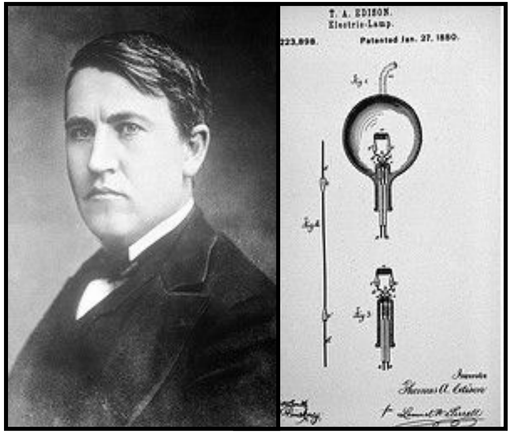
https://en.wikipedia.org/wiki/Cost_of_electricity_by_source

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2022

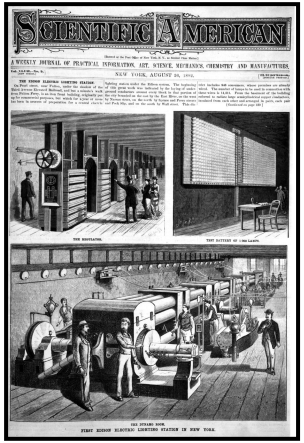


https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

Frontiers - A New Energy Industry

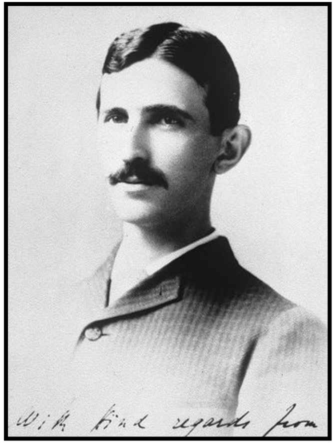


Thomas Edison and his incandescent light patent



Edison's 1st commercial plant, Pearl St., NY 1882

Samuel Insull built the reliable "power pool", reducing production costs and rates and increasing efficiency



Nikola Tesla, inventor of the induction motor and a comprehensive system for polyphase AC power

Safety

Reliability

Cost-effectiveness

- Edison opened his first electric power plant in New York in 1882
- Within a decade, electric power had spread to every corner of the globe

Why We Need Regulators in Energy Industry?

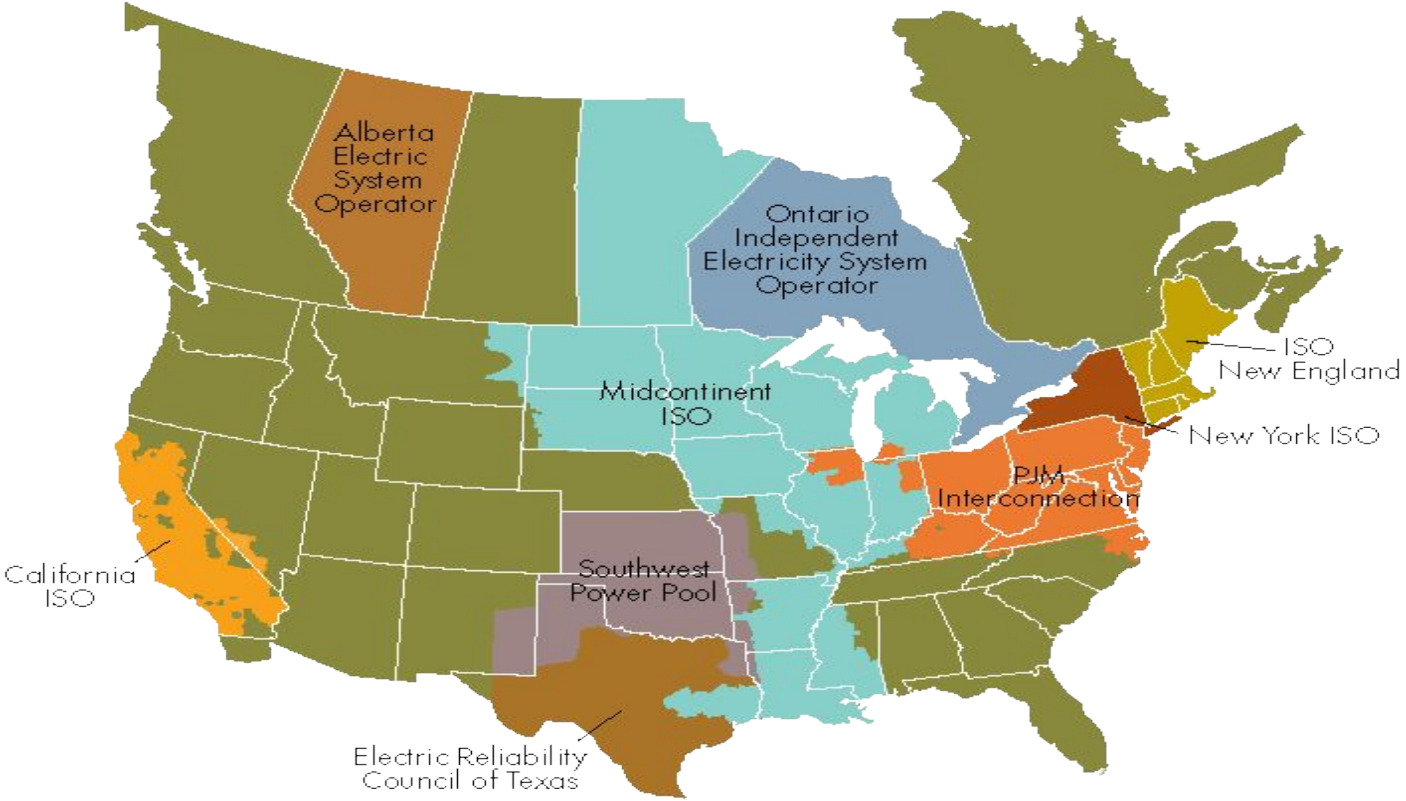
- In 1920, US Congress established the Federal Power Commission (FPC) for licensing hydroelectric projects
- In 1935, authorized FPC to regulate both hydropower and interstate electricity
- From 1940 to 1950, FPC pressured electric utilities to extend power into neglected rural areas and to lower electricity rates to increase use
- In 1977, FPC changed its name to the Federal Energy Regulatory Commission (FERC)
- Determine whether wholesale electricity prices were unjust and unreasonable and, if so, to regulate pricing and order refunds for overcharges to ratepayers
- Yes, Lawyers and Economists…
- Frontiers - Engineers and Advanced Technology

Spectacular Results

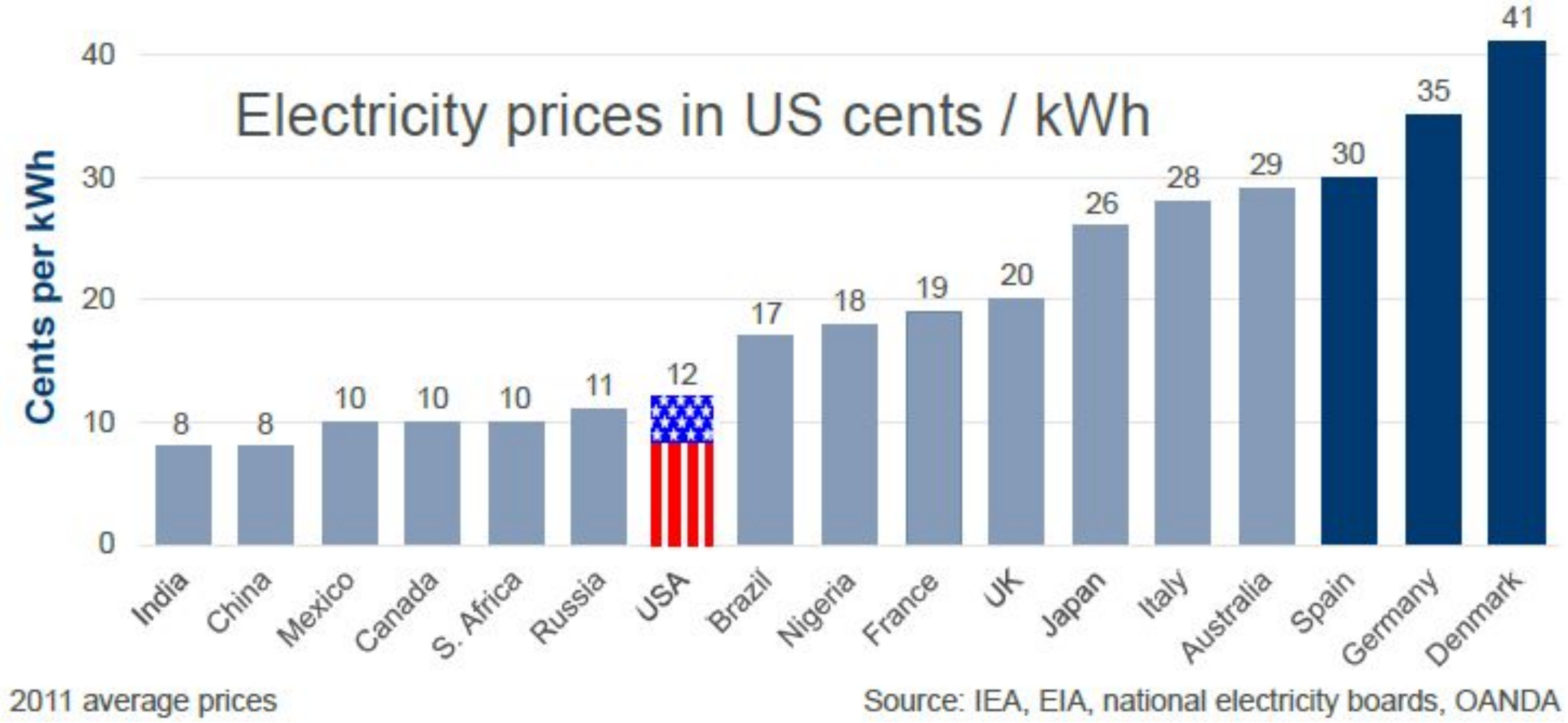
Year	Share of Homes with Service	Kwh Consumed per Home	Price Paid
1912	16%	264	9.1₵
1920	35%	339	7.5₵
1948	90%	1,563	3.0₵

Source: U.S. Department of Commerce, Historical Statistics of the United States, Colonial Times to 1970, Part 2, Series S, 108-119.

Interconnected Grids and Wholesale Electricity Markets in North America



Electricity Average Prices with Transmission and Distribution Delivery Cost



Challenges and Opportunities

Increased Billion-Dollars Weather and Climate Disasters

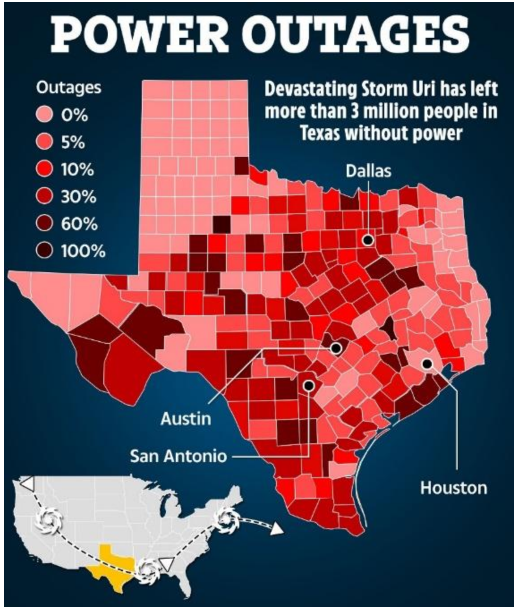
- **3 events in 1980; 22 in 2020**

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.

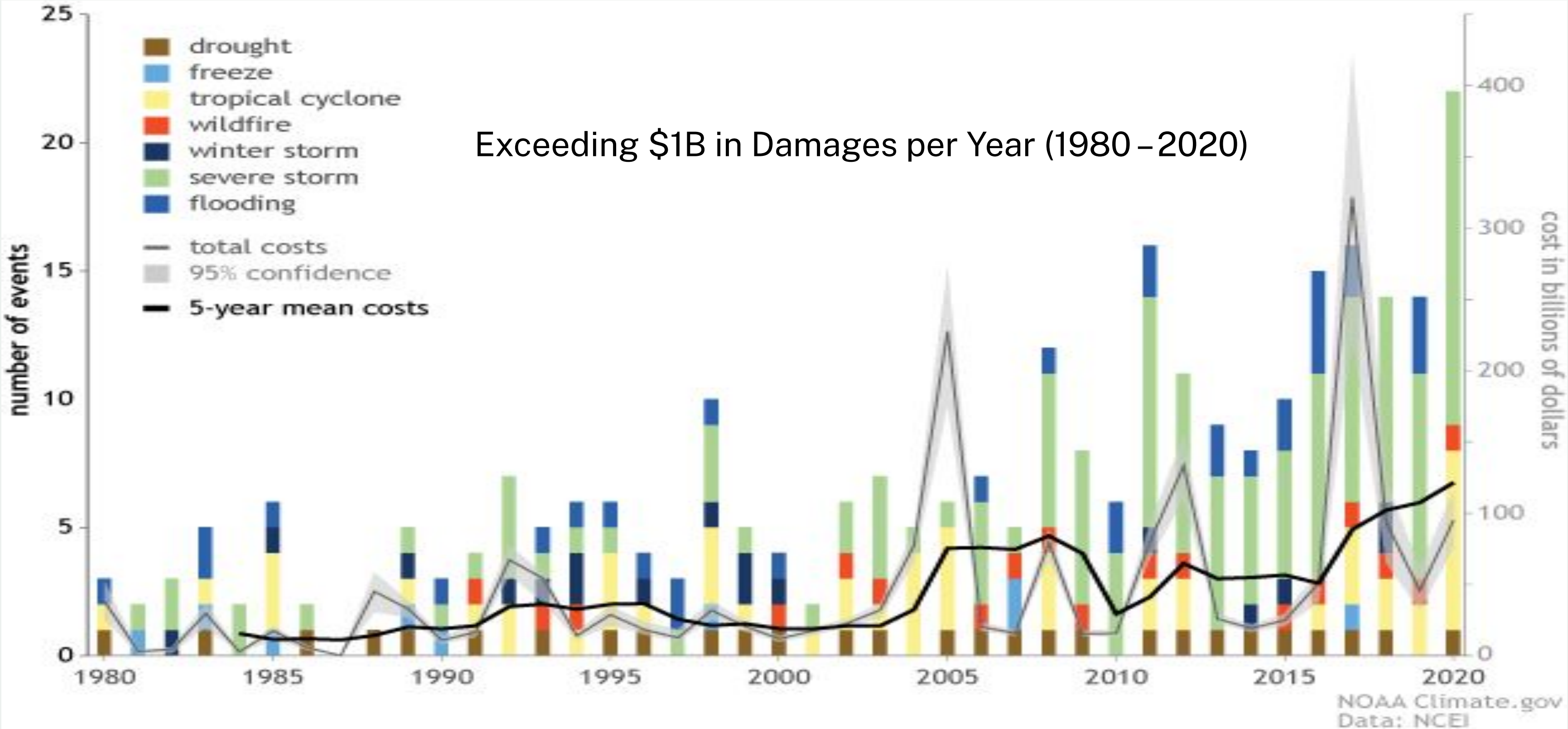
Texas Rolling Blackouts (Feb 15-17, 2021)

Frozen gas valve and high pressure pipe



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

U.S. Economic Losses Due to Natural Disasters



Solutions & Trend

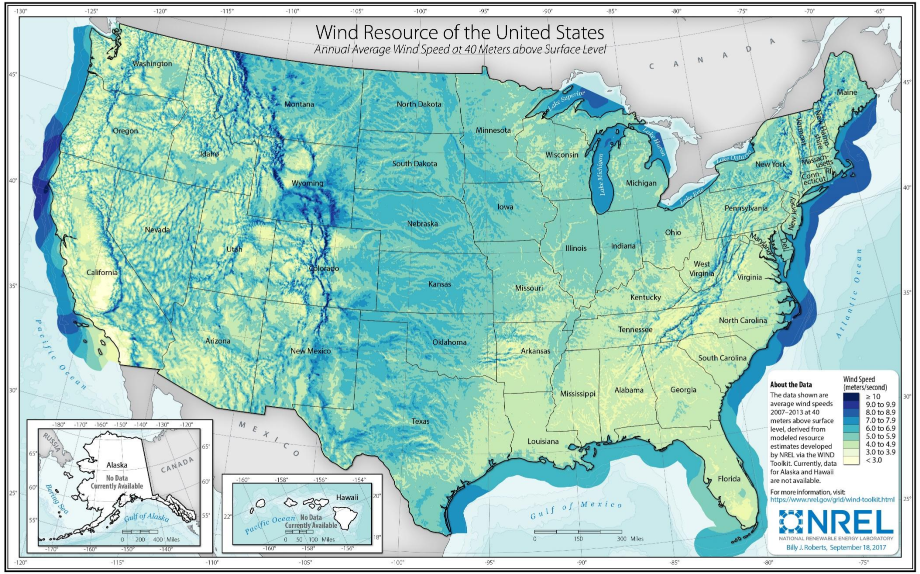
Electric Vehicles

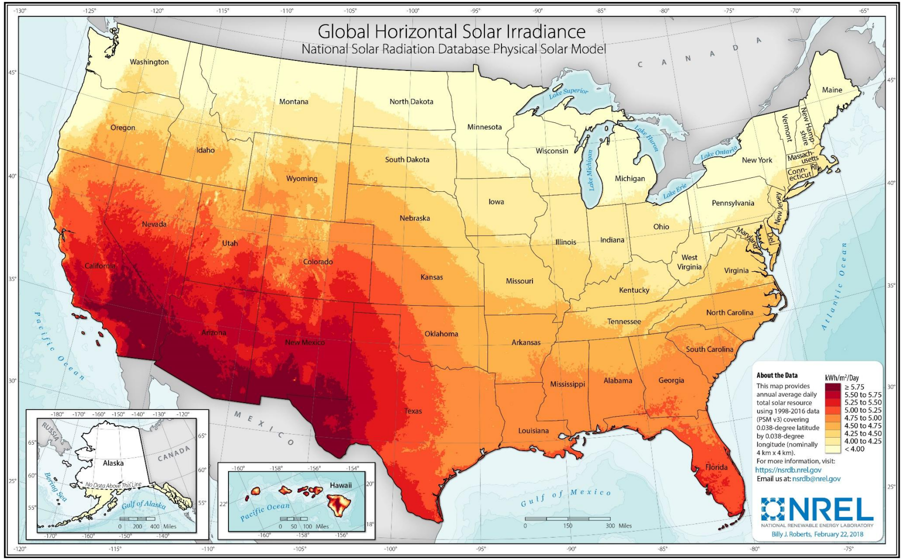
Energy storage

Microgrids (no delivery cost)

Green Energy (Green

Wind Map





Solar Map

Challenges and barriers to their implementation

01. Policy

02 Cost

.

03 Scale

Federal Energy Regulatory Commission (FERC)

- Order 1920 - Issued May 13, 1,363 pages
  - Building for the Future Through Electric Regional Transmission Planning and Cost Allocation
- Votes - 2 to 1
- Dissent – ‘Shell Game’ ‘Serve a major policy agenda’ ‘Serve the profit-making interests of developers of politically preferred generation,

How we got to this point

Need Regulators in Energy & Power Industry!

- In 1920, US Congress established the Federal Power Commission (FPC) for licensing hydroelectric projects
- In 1935, authorized FPC to regulate both hydropower and interstate electricity
- From 1940 to 1950, FPC pressured electric utilities to extend power into neglected rural areas and to lower electricity rates to increase use
- In 1977, FPC changed its name to the Federal Energy Regulatory Commission (FERC)
- Determine whether wholesale electricity prices were unjust and unreasonable and, if so, to regulate pricing and order refunds for overcharges to ratepayers

- Yes, Lawyers and Economists...
- Frontiers - Engineers and Advanced Technology

Mission for Regulators

- Ensure Reliable, Efficient and Sustainable Energy for Customers
  - Assist consumers in obtaining reliable, efficient and sustainable energy services at a reasonable cost through appropriate means
    - Market
    - Regulatory
- Reliability – Adequate Level of Reliability?
- Affordability – Reasonable Cost?
- Transmission Services/Rates – Just, Reasonable and Non-Discriminatory

Reliability History: Key Dates

November 9, 1965 – Northeast Blackout

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

Understand What Is Happening Today – How History Helps

- Look across time
  - Decades are not detached
  - Energy policy is local and political
- Look across all the factors that drive change
  - Science and technology
  - Business strategy
  - Local Culture
  - Politics (and geopolitics)
  - Regulatory policy
  - Law and the courts

Does it mean grid is not reliable?

What is Grid Reliability?

Keep Lights On.

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.

30

Reliability and Resilience

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

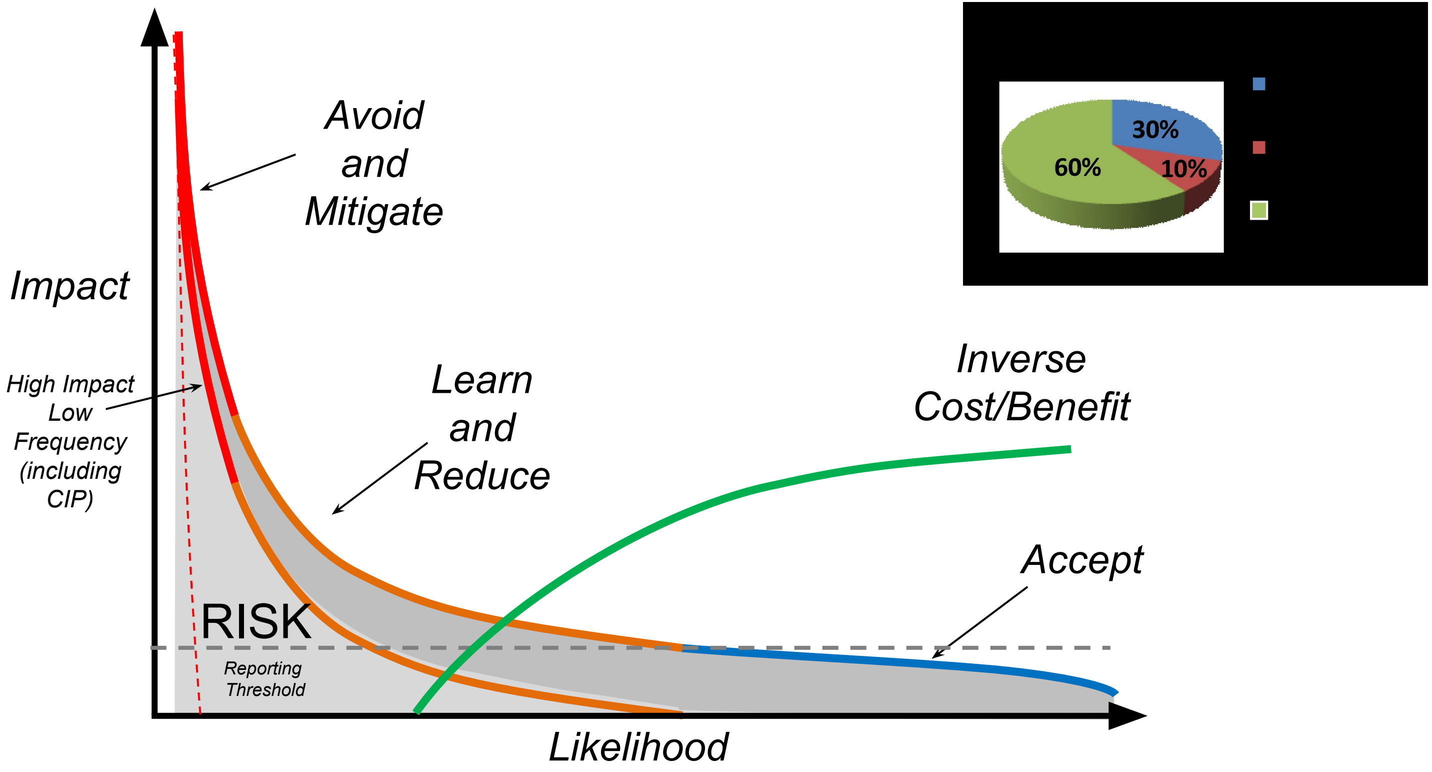
- Resilience is a system characteristic/capability encompassing all hazards and events, including high-impact low-probability events that are excluded from reliability calculations.

- 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.

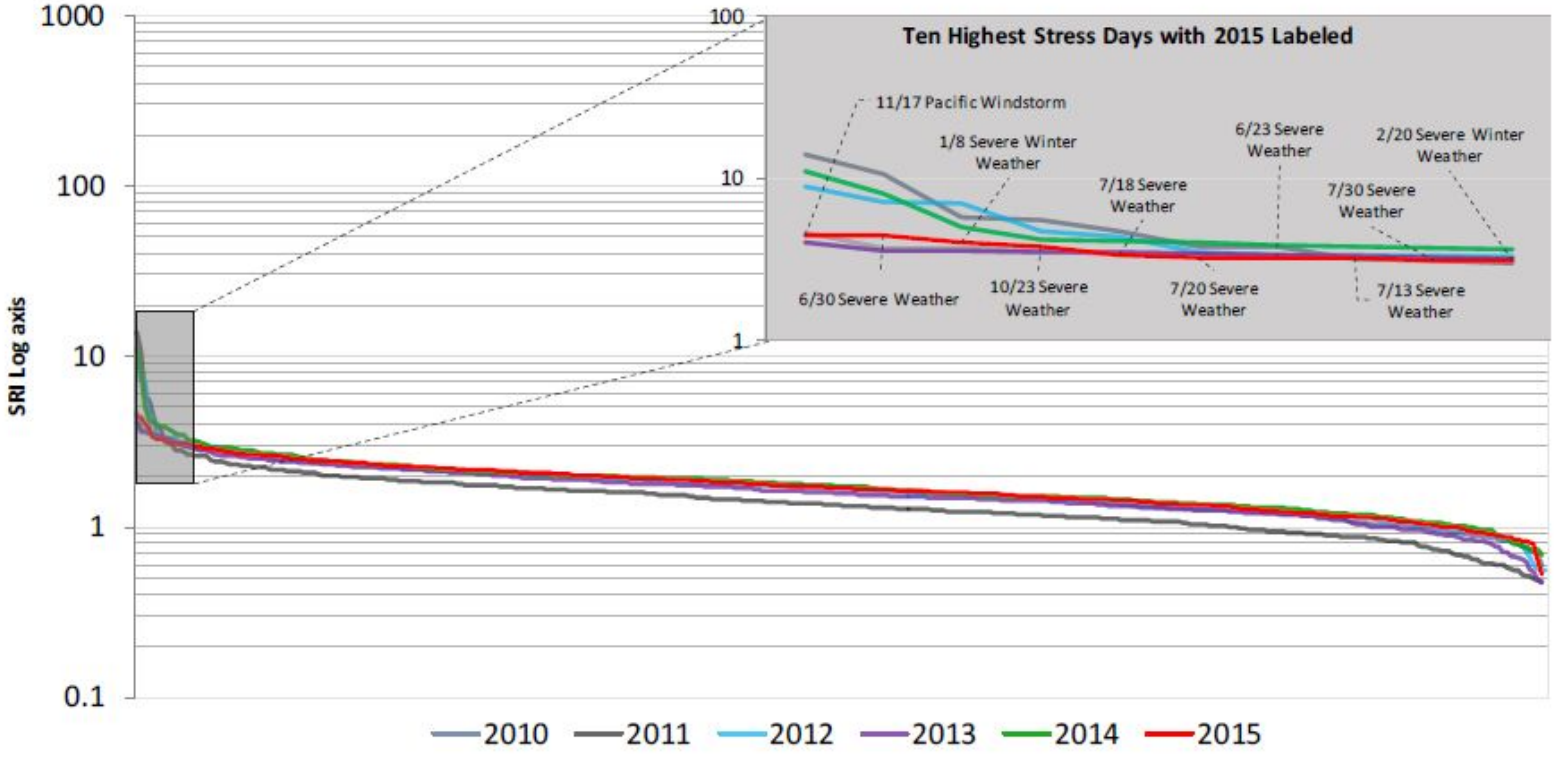
Measure Risk from Events

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

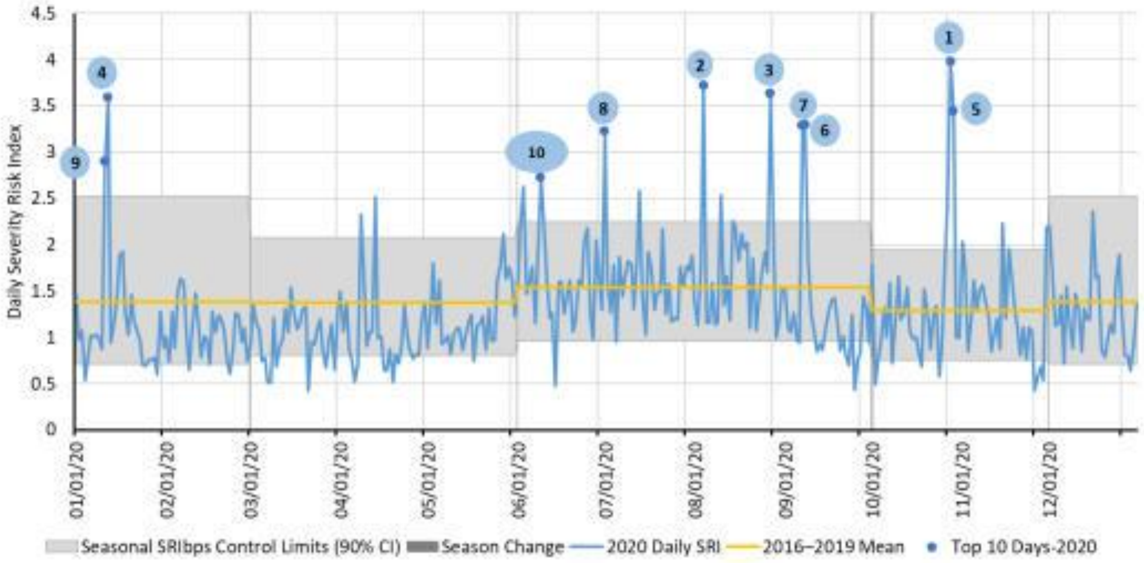
Top 10 Severity Risk Index Days (2008-2015)

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)

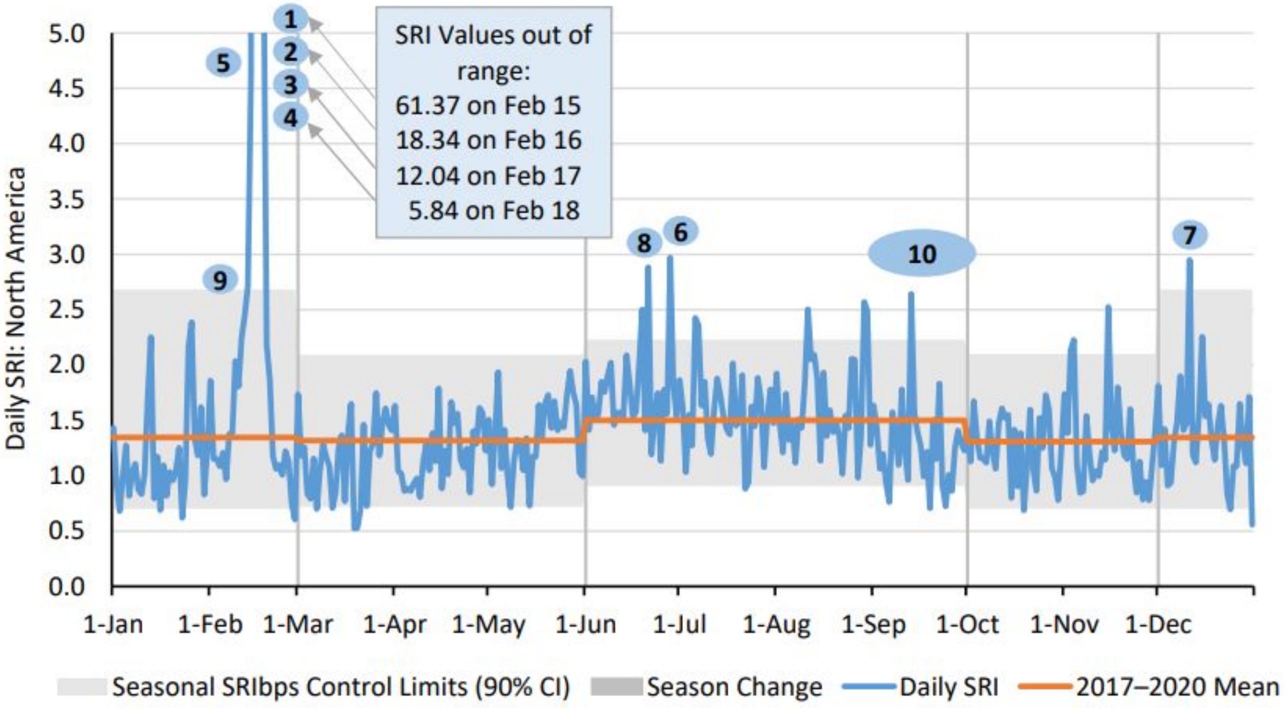
Rank	Date	SRI and Weighted Components				Event Type (*Weather Influenced)	Regional Entity
		SRI	Weighted Generation	Weighted Transmission	Weighted Load Loss		
1	September 14, 2018	4.33	1.34	0.46	2.53	Hurricane Florence*	SERC
2	March 2, 2018	4.22	0.90	0.41	2.90	Winter Storm Riley*	NPCC
3	January 2, 2018	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

Top 10 Severity Risk Index Days (2021)



Rank	Date	SRI and Weighted Components 2021				Event Type	Regional Entities
		SRI	Weighted Generation	Weighted Transmission	Weighted Load Loss		
1	February 15	61.37	5.54	0.81	55.02	Cold weather event	MRO, RF, SERC, TRE
2	February 16	18.34	5.02	0.55	12.78	Cold weather event	MRO, RF, SERC, TRE
3	February 17	12.04	2.49	0.28	9.26	Cold weather event	MRO, RF, SERC, TRE
4	February 18	5.84	2.21	0.32	3.30	Cold weather event	MRO, RF, SERC, TRE
5	February 14	4.61	1.91	0.88	1.83	Cold weather event	MRO, RF, SERC, TRE
6	June 28	2.97	1.78	0.29	0.90	Heat Dome and major thunderstorms	WECC
7	December 11	2.95	1.03	0.73	1.19	December windstorm and tornadoes	NPCC, RF, SERC
8	June 21	2.88	1.47	0.34	1.08	Major thunderstorms	RF, SERC
9	February 13	2.71	1.71	0.44	0.57	Cold weather event	MRO, RF, SERC, TRE
10	September 13	2.64	1.19	0.42	1.03	Hurricane Nicholas and special protection system misoperation dropping generation	TRE, WECC

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 (IROL) Exceedances
M-9	Correct Protection System Operations
M-11	Energy Emergency Alerts

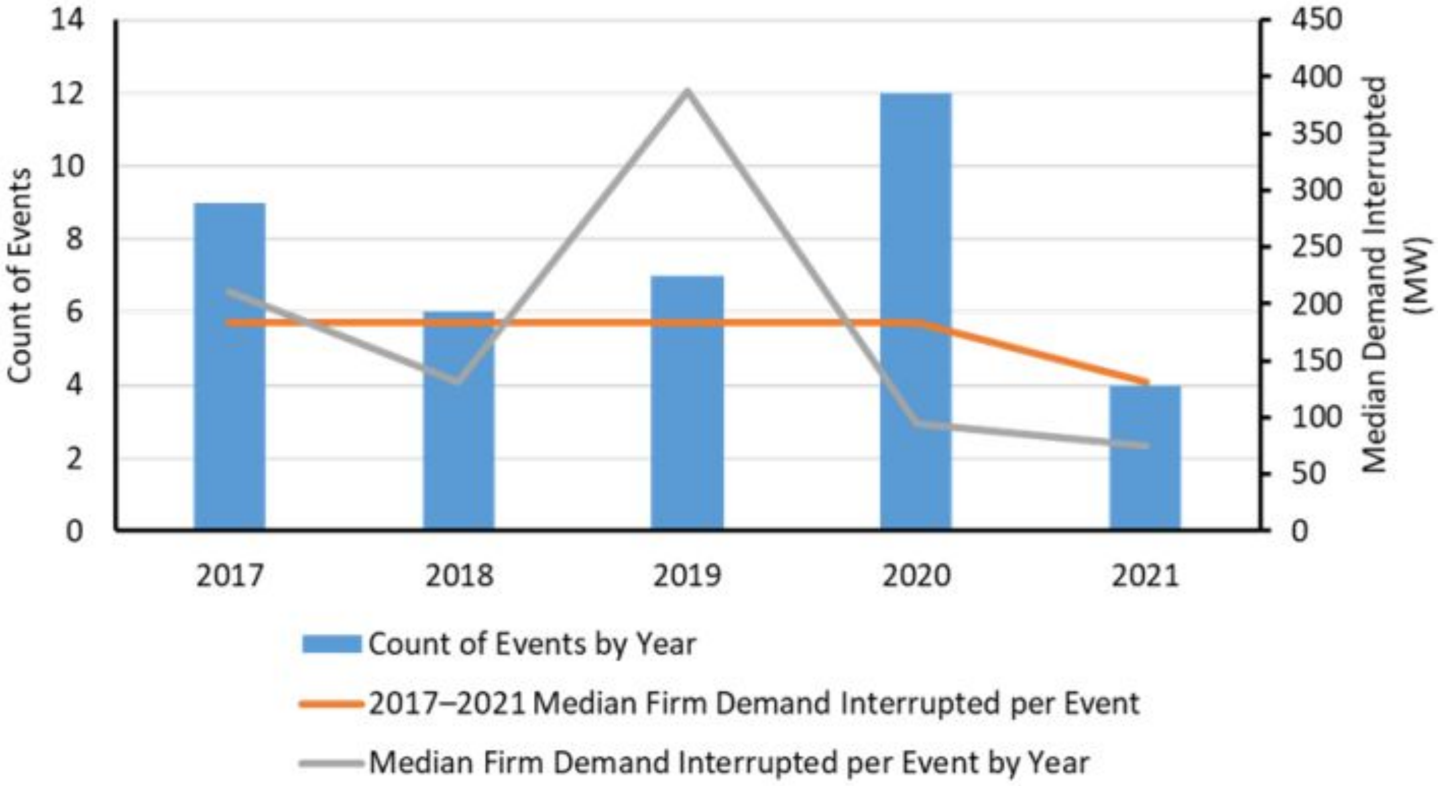
Vital Signs - Performance Metrics (cont’d)

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

Annual Checkup - State of Reliability Report

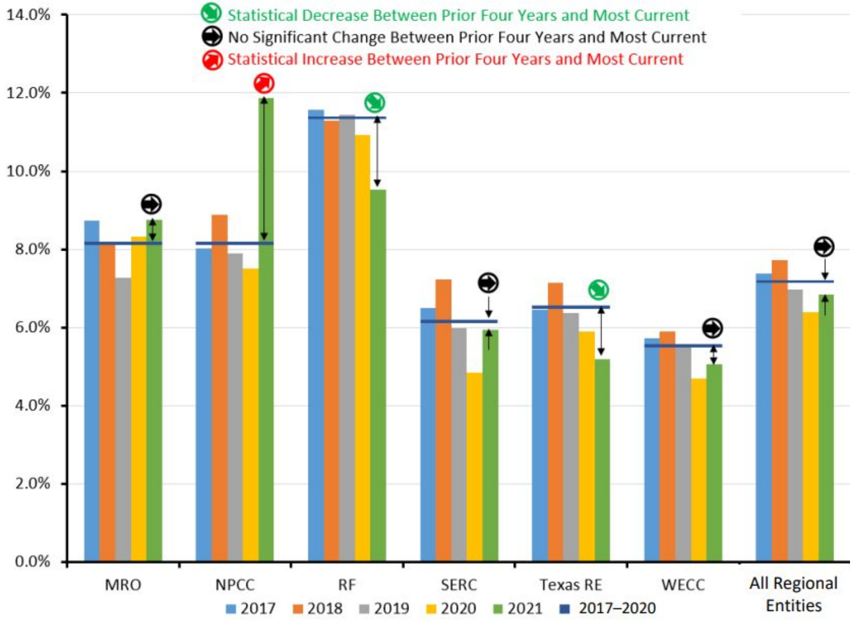
- Purpose – Objectively provide an integrated view of reliability performance
- Serve as risk-informed input to:
  - Standards and project prioritization
  - Compliance process improvement
  - Event analysis, reliability assessment, and CIP
- Reference for risk trends to reliability
- Offer analytical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

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

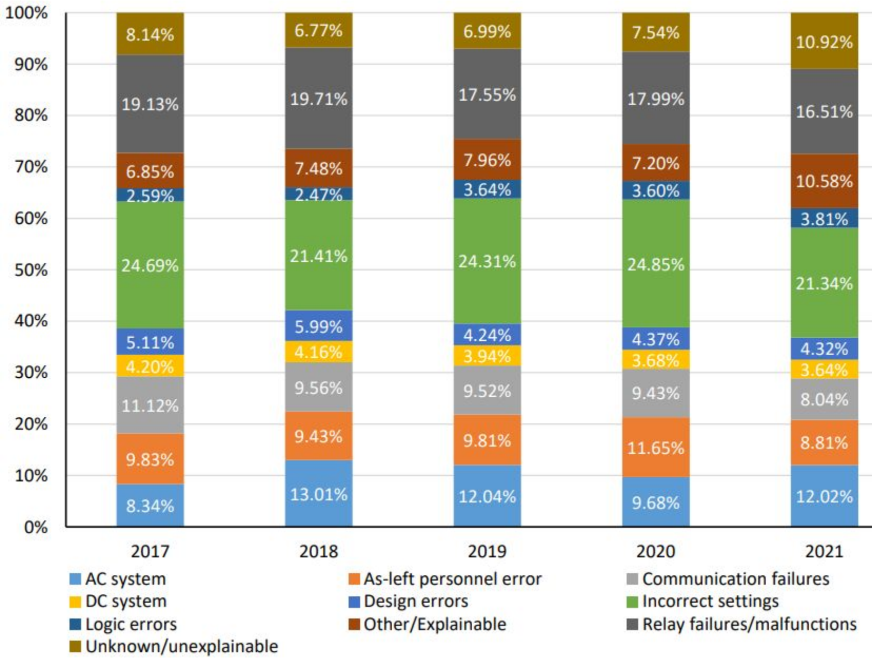


Transmission-Related Events Resulting in Loss of Firm Load Excluding Weather-Related Events

M-9 Protection System Misoperation Rate



Area	Protection System Operations					Misoperations				
	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021
All Regional Entities	20,971	19,905	19,305	18,279	17,239	1,550	1,539	1,345	1,167	1,180
MRO	3,678	3,740	3,734	3,054	2,617	321	306	272	254	229
NPCC	2,031	2,117	1,661	1,760	1,365	163	188	131	132	162
RF	2,264	2,275	2,149	1,875	1,658	262	257	246	205	158
SERC	5,411	4,873	4,753	5,267	4,616	352	352	284	255	274
Texas RE	2,385	2,279	2,639	2,000	2,599	154	163	168	118	135
WECC	5,202	4,621	4,369	4,323	4,384	298	273	244	203	222



Leading Causes of Misoperations

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

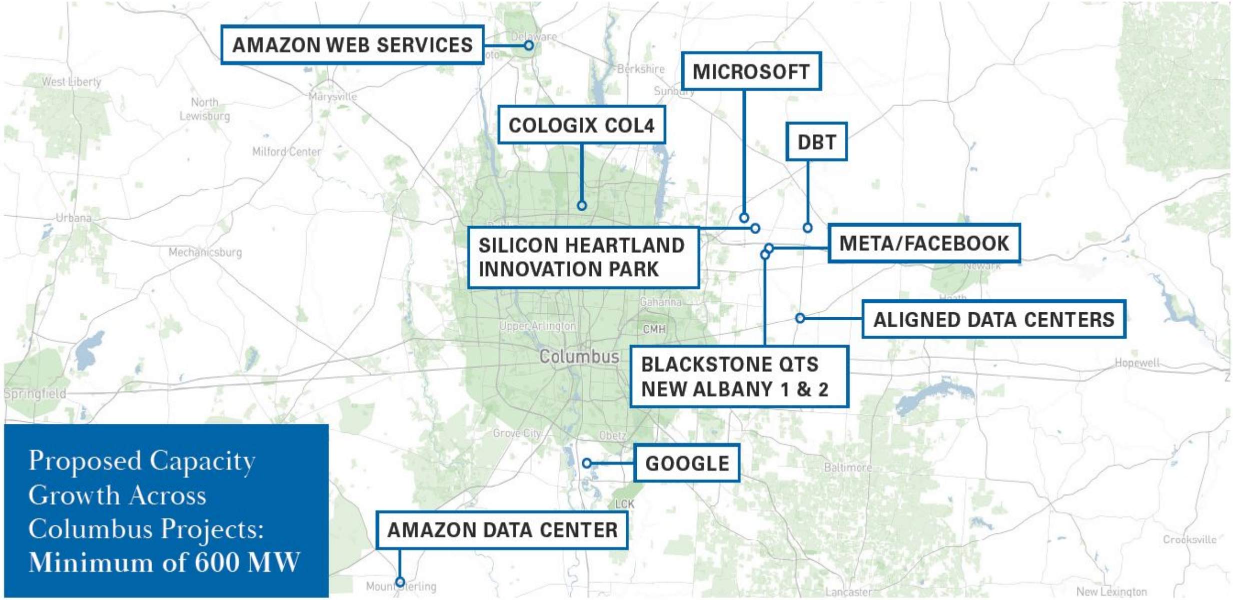
https://sagroups.ieee.org/distreswg/

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)

AI and Data Centers Booming since 2022

The following are some of the key proposed, planned, and under-construction data center developments in the Columbus metro that were announced within the last 18 months as of November 1, 2023.



Three Mile Island nuclear plant will reopen to power Microsoft data centers

SEPTEMBER 20, 2024 · 1:40 PM ET

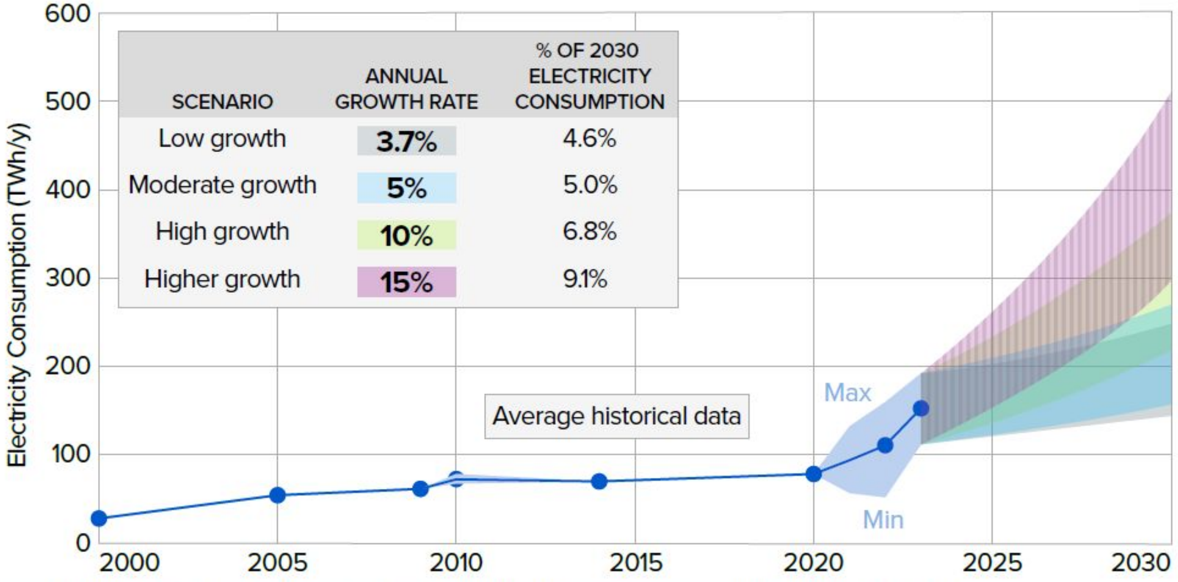
By C Mandler

The Three Mile Island nuclear plant is seen in March 2011 in Middletown, Pa.

Jeff Fusco/Getty Images

Trend and Reinvention in Energy Sector

Data Centers
Cyber Threats
DER
EV
Storage
Microgrids
Green Hydrogen



Potential US Data Center Growth

Digital Transformation in Sustainable Energy
- More efficient, resilient and sustainable

- Smart Grids - Integrate clean energy at edge
- Predictive Maintenance – Digital Twins
- Electrification of Mobility
- Demand Response
- Data Analytics
- Grid Management
- ...

Moving to a 3D Energy Landscape –

Decarbonized, Democratized, Decentralized

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

Q&A

IEEE Industry Engagement Committee | IEEE

Break

IEEE Industry Engagement Committee | IEEE

State of IEEE Industry Engagement

Personalization at Scale - Advance Student/YP Careers

IEEE Industry Engagement Committee | IEEE

IEEE Today at a Glance

Global Reach

460,000+
Members
60% of whom are from outside the US

39
Technical Societies
and **eight** Technical Councils

190+
Countries
across **10** geographic regions

Technical Breadth

2,000+
Annual Conferences

in 96 countries while contributing over 3.6 million total conference papers to IEEE *Xplore* since 1936

6,000,000+
Technical Documents

via IEEE *Xplore*® digital library, with more than **15 million** downloads each month

200+
Top-Cited Periodicals

IEEE journals, conference proceedings, and select content dating back to 1872

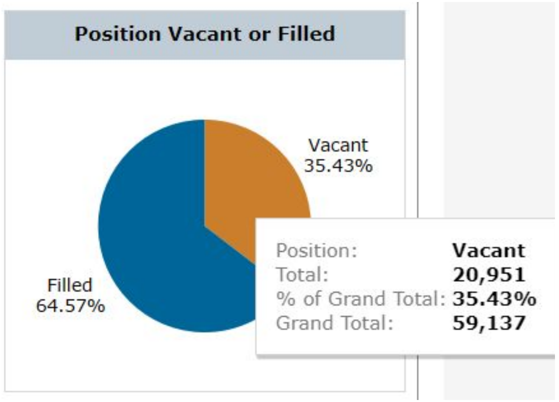
1,100+
Active Standards

and **1000+** more in development

More than 20,000 VACANT Volunteer Leadership Positions

Affinity Groups	Student Branches	Student Affinity Groups	Student Branch Chapters
766	3,725	1,083	4,589

- Total number of SBs and SBCs: 8,314 (=3,725+4,589)
- Vacant SB Counselors: 800+, >20%
- Vacant SBC Advisors: 1,000+, >20%
- Vacant SB Student Leaders: 5,200+
- Vacant SBC Student Leaders: 5,000+
- Vacant Affinity Group Leaders: 3,000+ for WIE, YP, …
    - Vacant YP Affinity Group positions: 300+, >38%

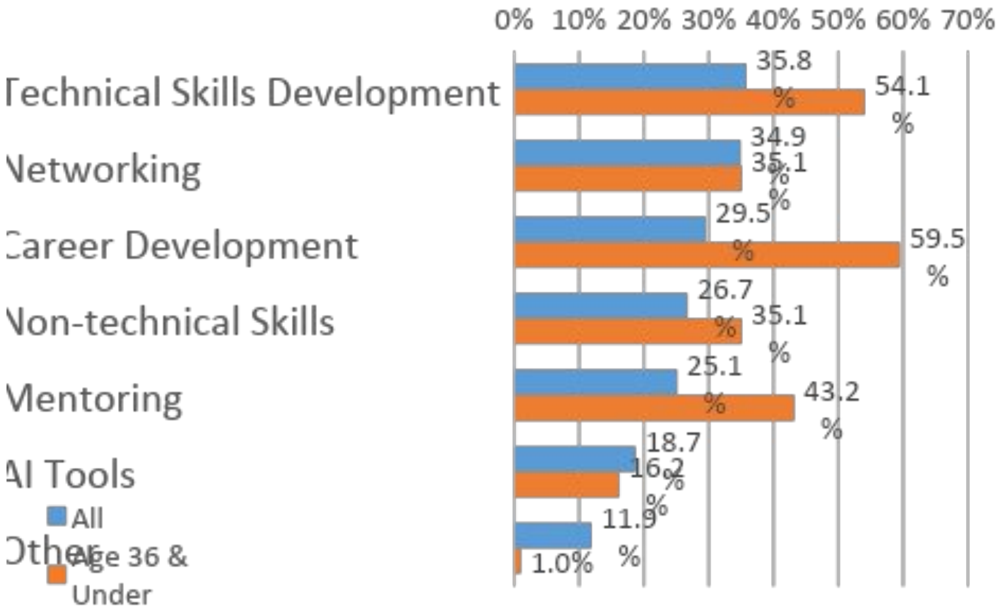


Source: IEEE OU Analytics, July 2024

IEEE Career Guidance Counselor (ICGC)

TOP PRIORITY - Increase Student Retention and YP Transition in Industry

IEEE Industry Needs Survey 2023
YPs #1 Need: Career Development



AI-powered IEEE Career Guidance Counselor (in conjunction with Young Professionals Committee)

Personalization at Scale

- Examine resumes and body of work
- Match to internships/jobs
- Match to mentors
- Identify matching skills and capabilities
- Generate personalized ILN-based learning plan

* I see great careers!

Meet Student, YP, WIE Talent Needs

- Student Branches
- Student Branch Chapters
- HKN Chapters

Counselors/Advisors

IEEE YP Committee
IEEE WIE Committee

- Section/Region YP/WIE Affinity Groups/ Committees
- Society/Council YP/WIE Affinity Groups/ Committees

- Section/Region Member Engagement Committees
- Society/Council Member Engagement Committees

IEEE Member Engagement Committee

‘Recent Graduates’
(June 13 and August 15)

- IEEE Paid-Internship
- IEEE Job Fairs
- IEEE Mentorship

Digital Solutions for Tailored Member Experiences

Personalization at Scale

- Ability to tailor experiences and interactions for a large number of members
    - Machine learning, AI, and real-time data analytics
- Deliver unique, relevant content to each member
    - Without manual intervention, making each person feel seen and valued

Win-Win

- Members
  - Paid-internship programs
  - Job fairs
  - Mentors
- IEEE
  - Fill vacant YP/WIE/LM Affinity Group leadership positions

Another Digital Solution - Industry Content Platform (ICP)

IEEE Industry Engagement Committee | IEEE

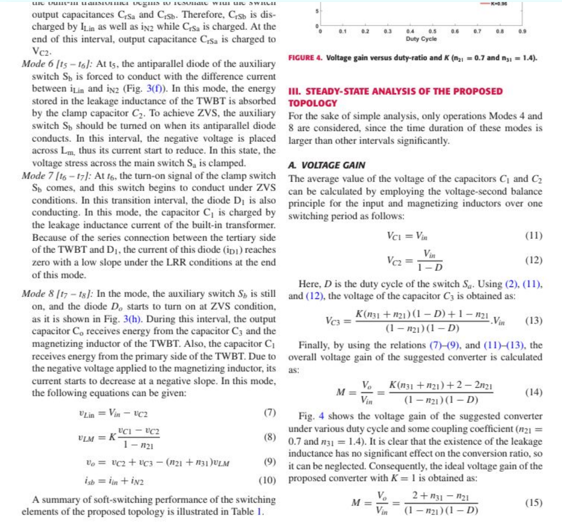
AI Transformed Publications

Industry Content Platform (ICP)

- Gathers industry-focused content from a variety of sources, with an emphasis on industry-focused articles created with new AI tool that transforms academic articles
- Early feedback from both authors and potential end users is very positive.

A New Soft-Switched High Step-Up Trans-Inverse DC/DC Converter Based on Built-In Transformer

Sara Hasanpour, Yam P. Siwakoti, and Frede Blaaabjerg



output capacitances C_{rSa} and C_{rSb}. Therefore, C_{rSb} is discharged by I_{Lin} as well as i_{N2} while C_{rSa} is charged. At the end of this interval, output capacitance C_{rSa} is charged to V_{C2}.

Mode 6 [$t_5 - t_6$]: At t_5, the antiparallel diode of the auxiliary switch S_b is forced to conduct with the difference current between i_{Lin} and i_{N2} (Fig. 3(f)). In this mode, the energy stored in the leakage inductance of the TWBT is absorbed by the clamp capacitor C_2. To achieve ZVS, the auxiliary switch S_b should be turned on when its antiparallel diode conducts. In this interval, the negative voltage is placed across L_m, thus its current start to reduce. In this state, the voltage stress across the main switch S_a is clamped.

Mode 7 [$t_6 - t_7$]: At t_6, the turn-on signal of the clamp switch S_b comes, and this switch begins to conduct under ZVS conditions. In this transition interval, the diode D_1 is also conducting. In this mode, the capacitor C_1 is charged by the leakage inductance current of the built-in transformer. Because of the series connection between the tertiary side of the TWBT and D_1, the current of this diode (i_{D1}) reaches zero with a low slope under the LRR conditions at the end of this mode.

Mode 8 [$t_7 - t_8$]: In the mode, the auxiliary switch S_b is still on, and the diode D_o starts to turn on at ZVS condition, as it is shown in Fig. 3(h). During this interval, the output capacitor C_o receives energy from the capacitor C_3 and the magnetizing inductor of the TWBT. Also, the capacitor C_1 receives energy from the primary side of the TWBT. Due to the negative voltage applied to the magnetizing inductor, its current starts to decrease at a negative slope. In this mode, the following equations can be given:

$$v_{Lin} = V_{in} - v_{C2} \tag{7}$$

$$v_{LM} = K\frac{v_{C1} - v_{C2}}{1 - n_{21}} \tag{8}$$

$$v_o = v_{C2} + v_{C3} - (n_{21} + n_{31})v_{LM} \tag{9}$$

$$i_{sb} = i_{in} + i_{N2} \tag{10}$$

A summary of soft-switching performance of the switching elements of the proposed topology is illustrated in Table 1.

FIGURE 4. Voltage gain versus duty-ratio and K ($n_{21} = 0.7$ and $n_{31} = 1.4$).

III. STEADY-STATE ANALYSIS OF THE PROPOSED TOPOLOGY

For the sake of simple analysis, only operations Modes 4 and 8 are considered, since the time duration of these modes is larger than other intervals significantly.

A. VOLTAGE GAIN

The average value of the voltage of the capacitors C_1 and C_2 can be calculated by employing the voltage-second balance principle for the input and magnetizing inductors over one switching period as follows:

$$V_{C1} = V_{in} \tag{11}$$

$$V_{C2} = \frac{V_{in}}{1 - D} \tag{12}$$

Here, D is the duty cycle of the switch S_a. Using (2), (11), and (12), the voltage of the capacitor C_3 is obtained as:

$$V_{C3} = \frac{K(n_{31} + n_{21})(1 - D) + 1 - n_{21}}{(1 - n_{21})(1 - D)}.V_{in} \tag{13}$$

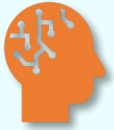
Finally, by using the relations (7)–(9), and (11)–(13), the overall voltage gain of the suggested converter is calculated as:

$$M = \frac{V_o}{V_{in}} = \frac{K(n_{31} + n_{21}) + 2 - 2n_{21}}{(1 - n_{21})(1 - D)} \tag{14}$$

Fig. 4 shows the voltage gain of the suggested converter under various duty cycle and some coupling coefficient ($n_{21} = 0.7$ and $n_{31} = 1.4$). It is clear that the existence of the leakage inductance has no significant effect on the conversion ratio, so it can be neglected. Consequently, the ideal voltage gain of the proposed converter with $K = 1$ is obtained as:

$$M = \frac{V_o}{V_{in}} = \frac{2 + n_{31} - n_{21}}{(1 - n_{21})(1 - D)} \tag{15}$$

ICP



Industry-Oriented Generated Version

Authored by ICP AI and to be reviewed by original author(s)

A New Soft-Switched High Step-Up Trans-Inverse DC/DC Converter Based on Built-In Transformer

Achieving Ultra-High Voltage Gain with Fewer Components and Improved Efficiency for Renewable Energy Applications

This article is an industry-oriented adaptation based on the original academic article "A New Soft-Switched High Step-Up Trans-Inverse DC/DC Converter Based on Built-In Transformer" by Sara Hasanpour, Yam P. Siwakoti, and Frede Blaabjerg, published in IEEE Open Journal of Power Electronics (Volume: 4), pages 381 – 394. This adapted article was created by the IEEE Industry Content Platform and reviewed by the original authors.

KEY TAKEAWAYS

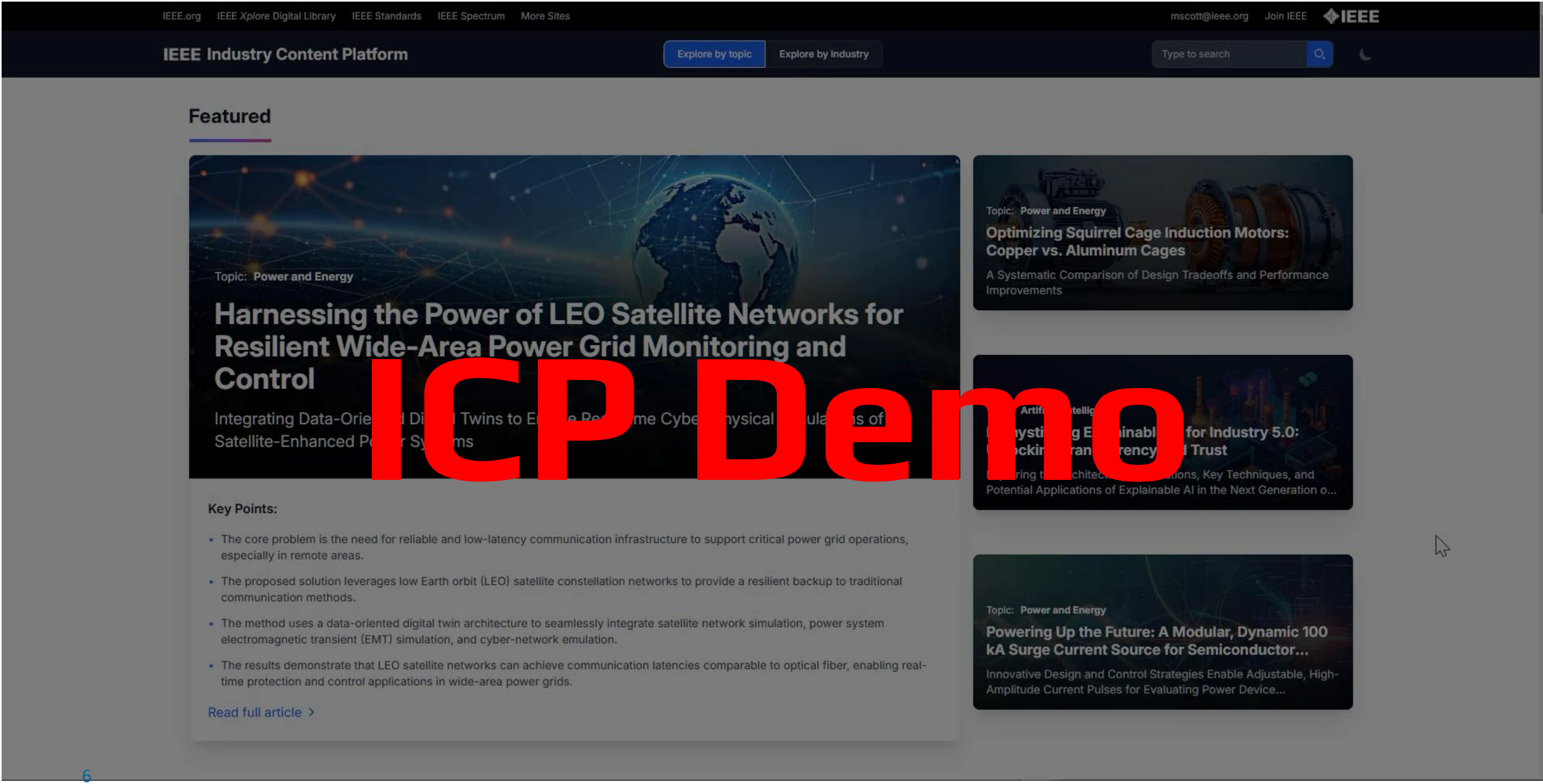
- The core problem is the need for high-voltage gain DC-DC converters with continuous input current for renewable energy source (RES) applications.
- The solution is a new non-isolated DC-DC converter topology that utilizes a three-winding built-in transformer (TWBT) and a voltage multiplier circuit to achieve ultra-high voltage gain.
- The key method is leveraging the "trans-inverse" property of the TWBT to increase voltage gain while using fewer turns, improving efficiency.
- This converter design has potential applications in various high-voltage industries like robotics, data centers, and motor drives.

AI outputs could add value across the IEEE subscription product portfolio >>

Xplore

DiscoveryPoint

ICP



IEEE.org
IEEE Xplore Digital Library
IEEE Standards
IEEE Spectrum
More Sites
mscott@ieee.org
Join IEEE
IEEE
IEEE Industry Content Platform
Explore by topic
Explore by industry
Type to search
Featured
Topic: Power and Energy
Harnessing the Power of LEO Satellite Networks for Resilient Wide-Area Power Grid Monitoring and Control
Key Points:
The core problem is the need for reliable and low-latency communication infrastructure to support critical power grid operations, especially in remote areas.
The proposed solution leverages low Earth orbit (LEO) satellite constellation networks to provide a resilient backup to traditional communication methods.
The method uses a data-oriented digital twin architecture to seamlessly integrate satellite network simulation, power system electromagnetic transient (EMT) simulation, and cyber-network emulation.
The results demonstrate that LEO satellite networks can achieve communication latencies comparable to optical fiber, enabling real-time protection and control applications in wide-area power grids.
Read full article
Topic: Power and Energy
Optimizing Squirrel Cage Induction Motors: Copper vs. Aluminum Cages
A Systematic Comparison of Design Tradeoffs and Performance Improvements
for Industry 5.0:
Trust
Potential Applications of Explainable AI in the Next Generation o...
Topic: Power and Energy
Powering Up the Future: A Modular, Dynamic 100 kA Surge Current Source for Semiconductor...
Innovative Design and Control Strategies Enable Adjustable, High-Amplitude Current Pulses for Evaluating Power Device...
ICP Demo

Ongoing Initiatives

- Lower Unknown Employer Type data from 20% to 5%
- Nominate 90% of eligible members for Senior members
- Implement per objectives and milestones
  - IEEE Career Guidance Counselor
  - Industry Content Platform
  - IEEE *Premier Program*
  - *Corporate Recognition Program*
  - Industry Impact Factor
  - Distinguished Member Recognition
  - Student elevation/transition activities

Newsletter and Other Resources for Industry and Government

IEEE for Industry (Corporations, Government, Individuals)

Follow IEEE Industry Engagement on:

Facebook | LinkedIn | Instagram | X

IEEE provides valuable resources and tools for professional engineers across multiple industries and technologies. Whether you are seeking career advancement, looking to start your own company, or need research and trend insights into emerging technologies, IEEE can help those who work in the engineering sciences, research, and technology areas.

- About
- Industry Newsletter
- Join upcoming webinar
- Watch IEEE One Voice
- View the IEEE Industry Engagement Committee

IEEE 140 YEARS 1884 - 2024

IEEE 30 YEARS MEMBERSHIP MILESTONE

IEEE®

Advancing Technology for Humanity

IEEE Industry Engagement Committee | IEEE