Performance Incentive Mechanisms 101

NATIONAL ASSOCIATION OF REGULATORY UTILITY COMMISSIONERS

CENTER FOR PARTNERSHIPS AND INNOVATION

PERFORMANCE-BASED REGULATION STATE WORKING GROUP

MARCH 12, 2021

About the PBRSWG and NARUC

- **The Performance-Based Regulation State Working Group is facilitated by the National Association of Regulatory Utility Commissioners' Center for Partnerships and innovation (NARUC CPI).**

- **NARUC CPI thanks the US department of Energy for their ongoing support.**

Hon. Charlotte Mitchell

Joe Eto
Berkeley Lab

Reliability vs. Resilience: Features, Metrics, Actions, Decision-making and Grid Resilience Metrics

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NARUC Performance Based Ratemaking Working Group

April 16, 2021

Reliability vs. Resilience: features, metrics, actions

	Reliability	Resilience
Common features/ characteristics	Routine, expected (though, not "planned"), normally localized, shorter duration interruptions of electric service Larger events will make it into the local headlines	Infrequent, unplanned, widespread/long duration power interruptions, often with significant corollary impacts Almost always "event" based Always national headline worthy
Metrics	Well-established, annualized (SAIDI, SAIFI, MAIFI), with provisions for "major events" Rarely include non-electricity impacts	Familiar, but non-standardized, and generally event-based (number of customers affected; hours without electric service) Routinely also include non-electricity impacts (e.g., costs to firms; health and safety impacts)
Actions to improve	1. Plan and prepare; 2. Manage and endure event(s); 3. Recover and restore; and 4. Assess, learn, and update plan.	No qualitative difference But generally larger in scope/cost (see next slide)

Reliability vs. Resilience: decision-making

	Reliability	Resilience
Entities involved in decision making	Electric utility and its regulator/oversight board, primarily	Electric utility and regulator; many times, acting in response to State legislative direction or Governor's orders Routinely in conjunction with parties that have responsibilities for other critical infrastructures, including local/regional/state/federal agencies/authorities, and communities/elected officials
Factors affecting decision making	Actuarial records on frequency of exposure – widely understood risks: insurable Well-understood/tested practices/approaches Understood to be an expected cost of doing business	No actuarial basis to establish likelihood of occurrence – widely varying perceptions of risk/exposure: "un-insurable" risk Limited opportunities to test strategies in the field Large dollar amounts/extraordinary expenditures may require special approval/vote Political leadership critical

DOE Grid Modernization Lab Consortium metrics: Resilience

GMLC Resilience Metrics	Data Requirements
Cumulative customer-hours of outages	customer interruption duration (hours)
Cumulative customer energy demand not served	total kVA of load interrupted
Avg (or %) customers experiencing an outage during a specified time period	total kVA of load served
Cumulative critical customer-hours of outages	critical customer interruption duration
Critical customer energy demand not served	total kVA of load interrupted for critical customers
Avg (or %) of critical loads that experience an outage	total kVA of load severed to critical customers
Time to recovery	
Cost of recovery	
Loss of utility revenue	outage cost for utility ($)
Cost of grid damages (e.g., repair or replace lines, transformers)	total cost of equipment repair
Avoided outage cost	total kVA of interrupted load avoided
	$ / kVA
Critical services without power	number of critical services without power
	total number of critical services
Critical services without power after backup fails	total number of critical services with backup power
	duration of backup power for critical services
Loss of assets and perishables	
Business interruption costs	avg business losses per day (other than utility)
Impact on GMP or GRP	
Key production facilities w/o power	total number of key production facilities w/o power (how is this different from total kVA interrupted for critical customers?)
Key military facilities w/o power	total number of military facilities w/o power (same comment as above)

Source: Petit, F., V. Vargas, J. Kavicky. Grid Modernization: Metrics Analysis (GMLC 1.1) – Resilience. April 2020
https://gmlc.doe.gov/sites/default/files/resources/GMLC1.1_Vol3_Resilience.pdf

Thank you

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LBNL publications on reliability are available at:

https://emp.lbl.gov/research/electricity-reliability

Bobby Jeffers
Sandia National Labs

Consequence-focused Resilience Analysis

PRESENTED BY

Bobby Jeffers, PhD

April 16, 2021

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Resilience Metrics

Attribute-based:

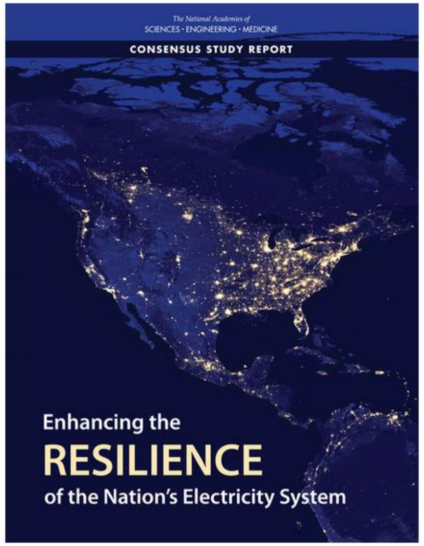
- What makes the system more/less resilient?
- Things you can count now (on a blue-sky day)
- Often grouped into categories that describe some aspect of resilience
  - Robustness, adaptivity, recoverability, etc.
- Often populated via surveys or checklists
  - Relatively simple to populate

Performance-based:

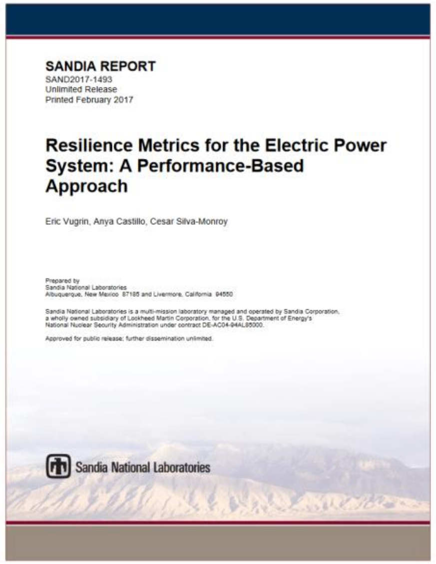
- How resilient is/was the system?
- Things you can measure only during disruption
- Often uses data from an event or a model of an event
  - Can be difficult to populate for planning
- Useful to weigh resilience against other goals
  - (e.g. within benefit cost analysis)

Either approach can be:

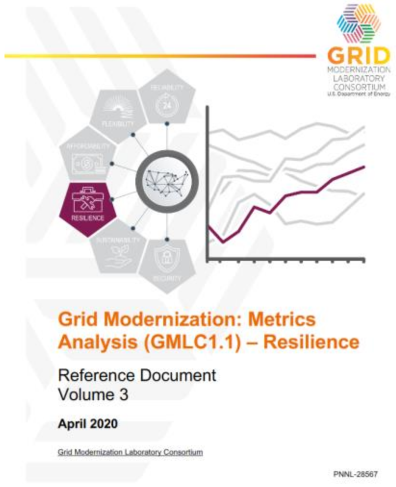
- Retrospective or forward-looking
- Power-focused or consequence-focused
- Threat-informed or threat-agnostic



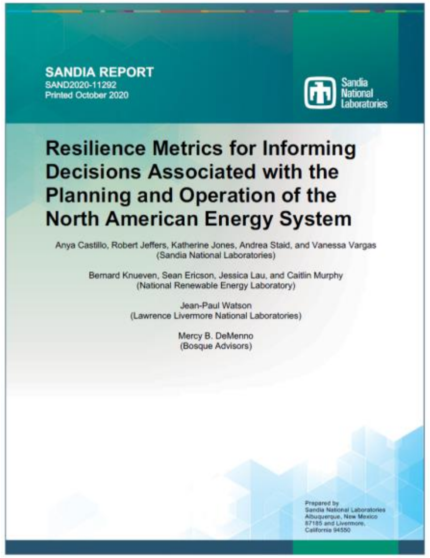
National Academies (2017), Recommendation #1 to DOE: "Improve understanding of customer and societal value associated with increased resilience and review and operationalize metrics for resilience…"



Vugrin et al. (2017) under GMLC 1.1 Foundational Metrics: First power-focused discussion of attribute-based and performance-based resilience metrics.

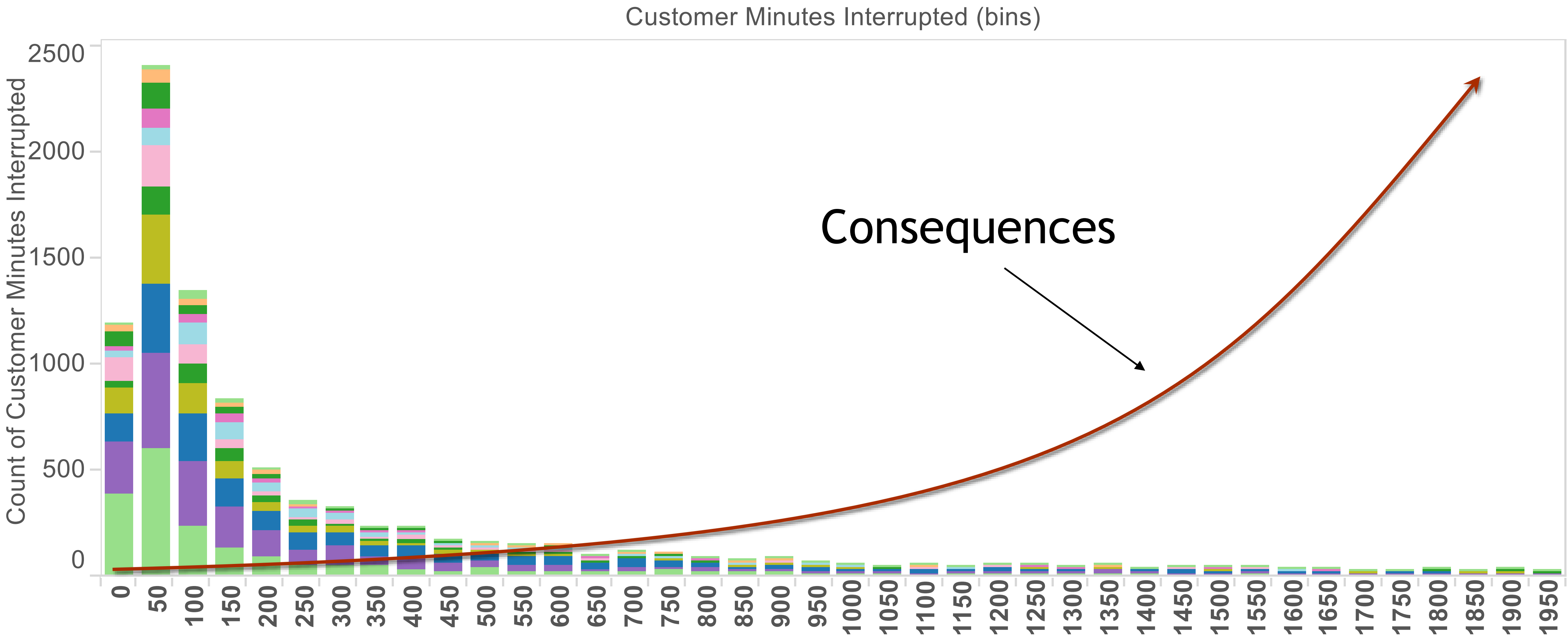


GMLC 1.1 Final Report (2020): Begins to clarify how attribute and performance-based approaches can complement.



NAERM Metrics Report (2020): Describes consequence dimensions and metric formulation

Histogram of Customer Minutes Interrupted, Selected Causes



Customer Minutes Interrupted (Filter)

0 to 2000

Real Performance-Based Resilience Metrics

The ideal:

Society

Social Burden

Time + money spent to achieve basic level of human needs

Economy

Extreme Event VoLL

Economic losses to customers due to an extended duration power outage

National Security

Mission Availability

Are power needs met sufficiently across the most important missions for national security?

The incremental:

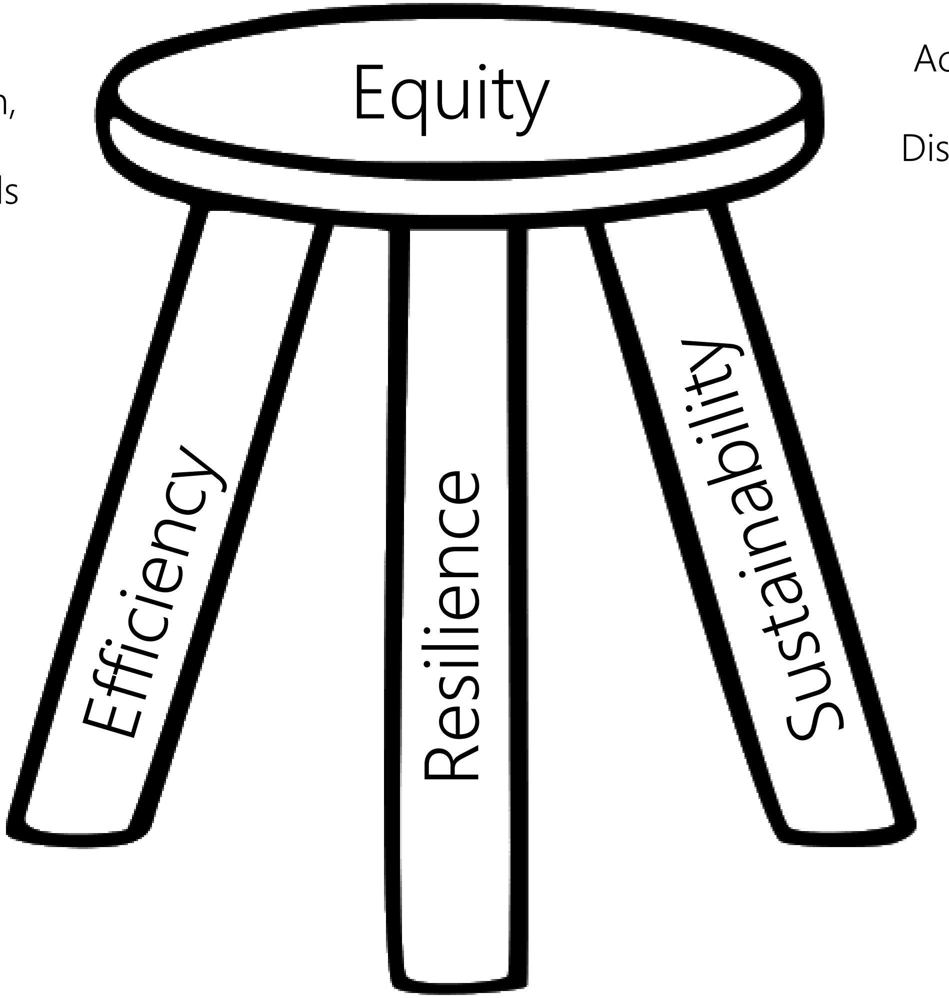
1. Report major event day SAIDI, SAIFI, CAIDI, CAIFI separately
2. Work with state and local emergency management officials to develop a tiered list of critical life-sustaining infrastructure.
    a. Map infrastructure assets to the services they provide
    b. Include "front-door" infrastructure: grocery stores, pharmacies, community centers, laundromats, etc.
    c. Include "back-door" infrastructure: communications, water, transportation, emergency ops, etc.
3. Report major event day CAIDI, CAIFI for each tier of this list
4. Option: discuss value-at-risk approach – what is the outage duration for which 95% of grocery stores experience less for major event days?
5. Baseline for the past x years (5, 10?). Discuss options for forecasting/improving the metric

Informing equitable performance

Acute Social Burden

Energy Burden,
Chronic Social Burden,
Exposure to
environmental hazards
…

Access to clean energy
solutions,
Distributional impacts of
climate change
…



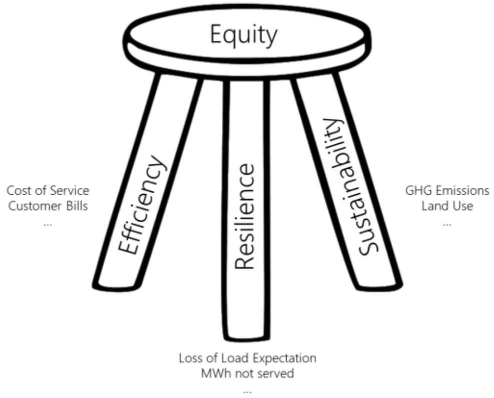
Cost of Service
Customer Bills
…

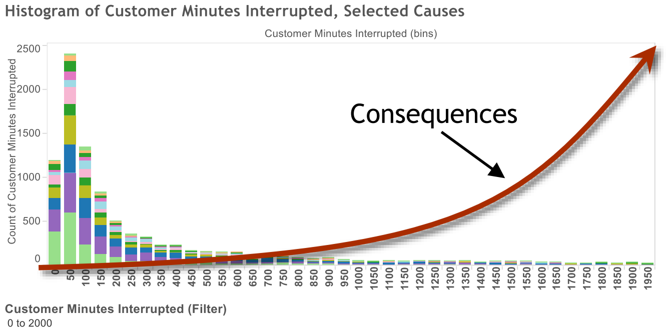
GHG Emissions,
Land Use,
Ecosystem Services
…

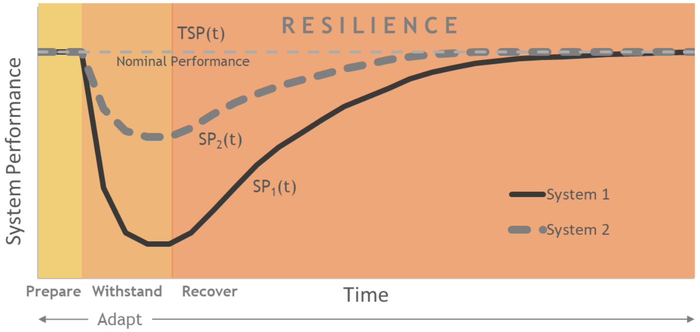
Loss of Load Expectation
MWh not served
…

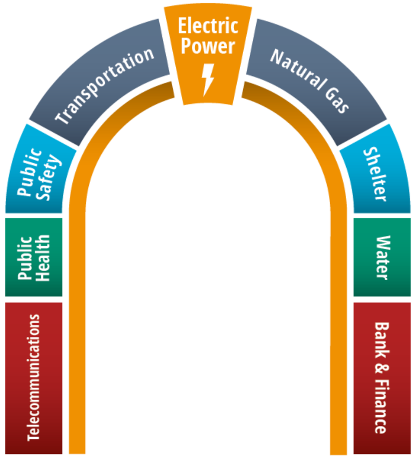
Thank You!

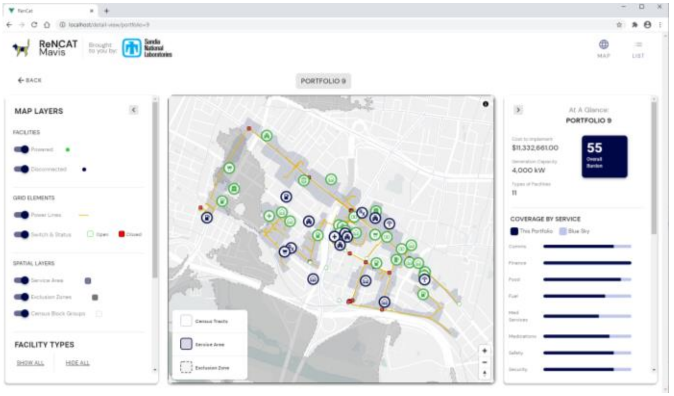
rfjeffe@sandia.gov





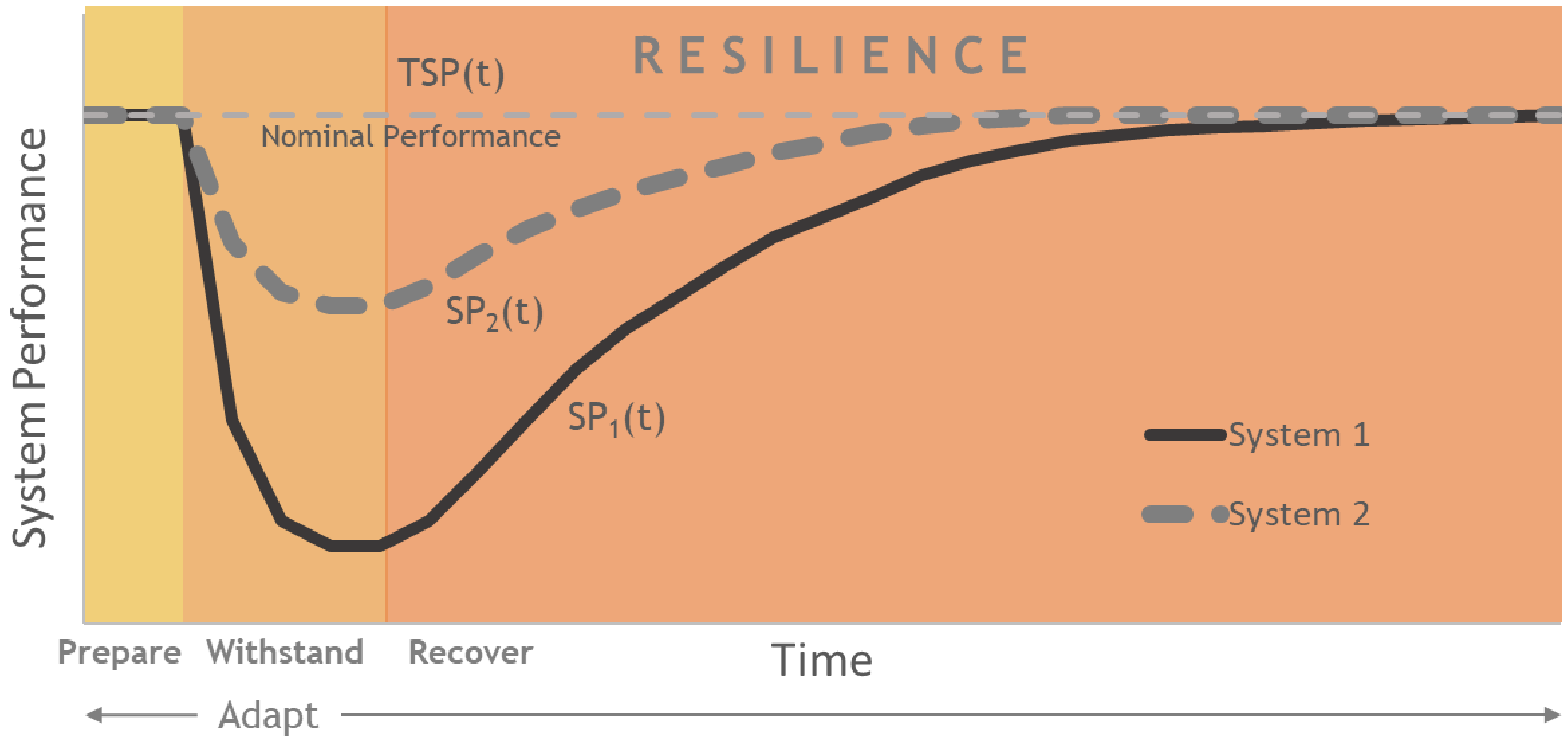






Backup slides

Measuring and forecasting resilience



Resilience metrics should:

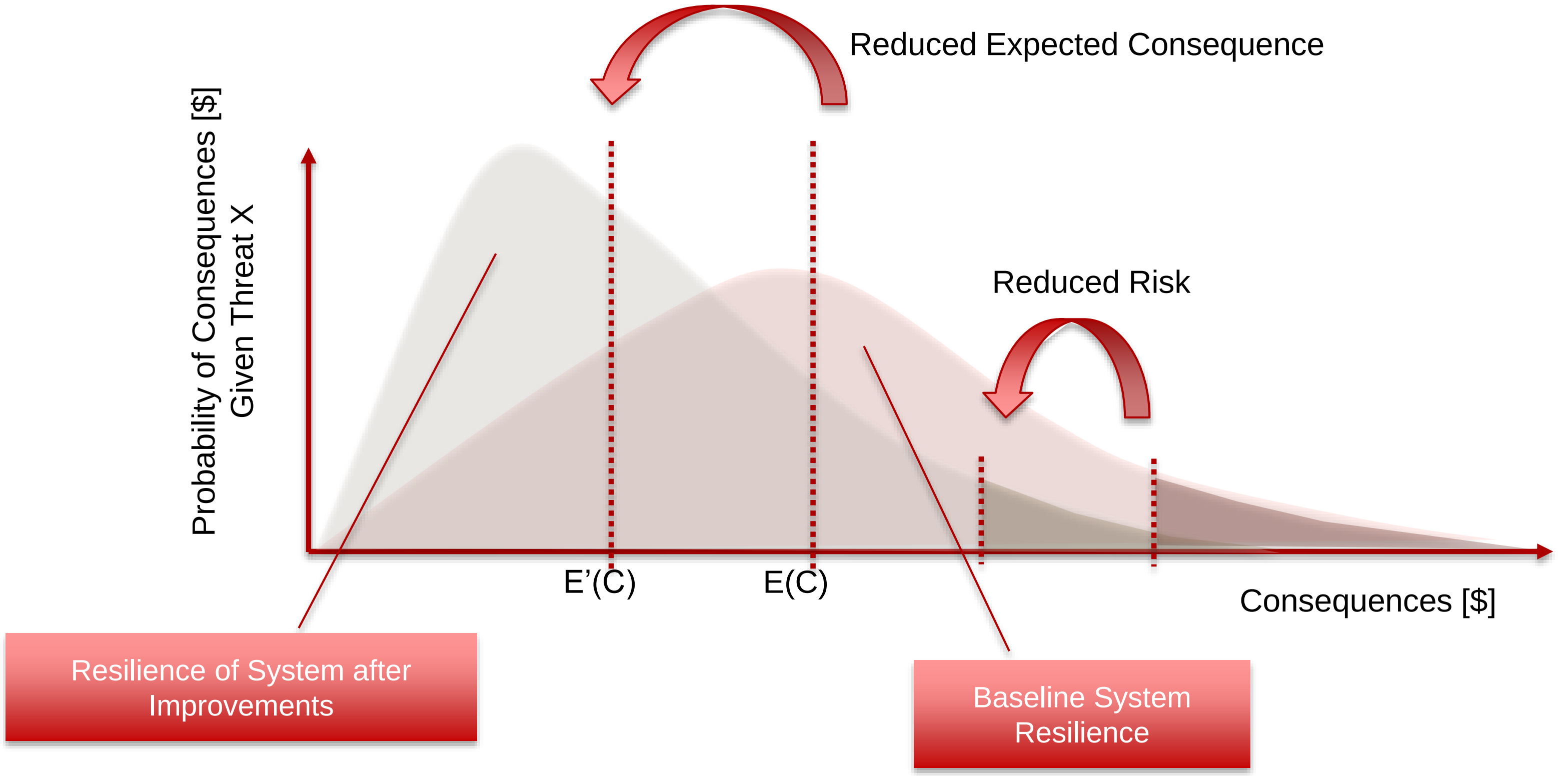
- Convey the wide variance among outages in terms of size, duration, and impact on customers
- Focus on the impact on critical sectors, capture context of the threats
- Translate system performance into consequence, where the severity of consequences can change nonlinearly over time

There are three temporal components of infrastructure and societal performance

- **RESILIENT** — Society withstands and recovers from acute shocks, even ones never before experienced.
- **EFFICIENT** — Society performs well day-to-day in the near-term future.
- **SUSTAINABLE** — Society performs well over very long periods of time.

At all spatial scales (local, regional, global), there are very real tradeoffs between performance in these dimensions.

Ideal resilience quantification



Using a probabilistic risk analysis approach:

- Model or measure the performance of the system subject to threats
  - Cover a range of events from low-probability/high-impact to high-probability/low-impact
- Generate histogram of infrastructure performance vs. frequency at all nodes
- Convert histogram of outage duration to consequence-focused metric
  - Often relies on additional modeling
- Propose investments and perform these steps again
- Optional: weigh resilience metrics against other goals such as efficiency and sustainability

Dimensions of consequence

Society

- 2015-16 GMLC: New Orleans Grid Resilience
- 2017-present GMLC: Designing Resilient Communities
- 2018-present SETO and OE: Puerto Rico Recovery

Economy

- 2015-17 GMLC: Valuation
- 2017-present GMLC: Lab Valuation Analysis Team

National Security

- 2017-18 ESTCP: Resilience-Inclusive Energy Master Planning
- 2019-present OE: Energy Assurance for Critical Infrastructure
- 2020-present GMLC: Energy Resilience for Mission Assurance

Cross-cutting:

- 2013-14 DOE Quadrennial Energy Review
- 2015-17 GMLC: Foundational Metrics
- 2019-21 OE: North American Energy Resilience Model

Social Burden: a new resilience metric

Effort
Time + money spent to achieve basic level of human needs

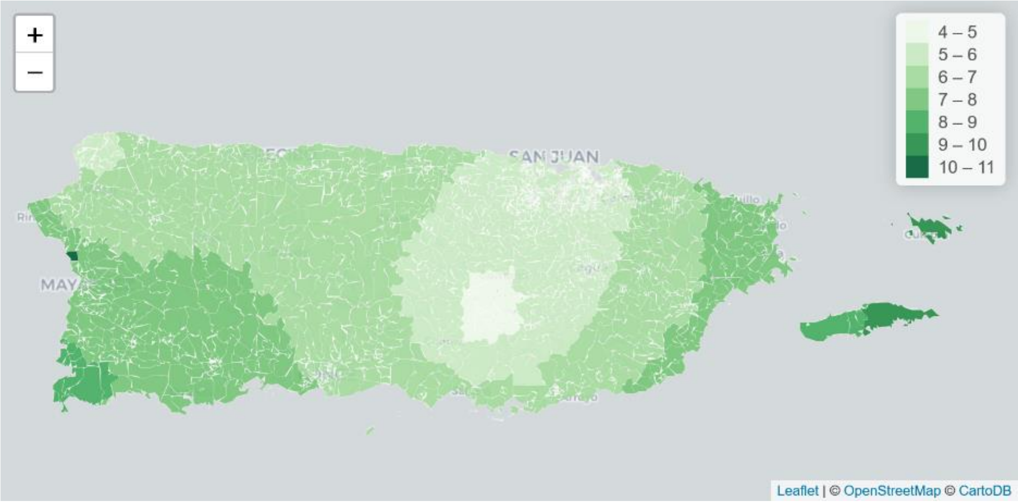
Ability
Median household income, additional predictors

Social Burden

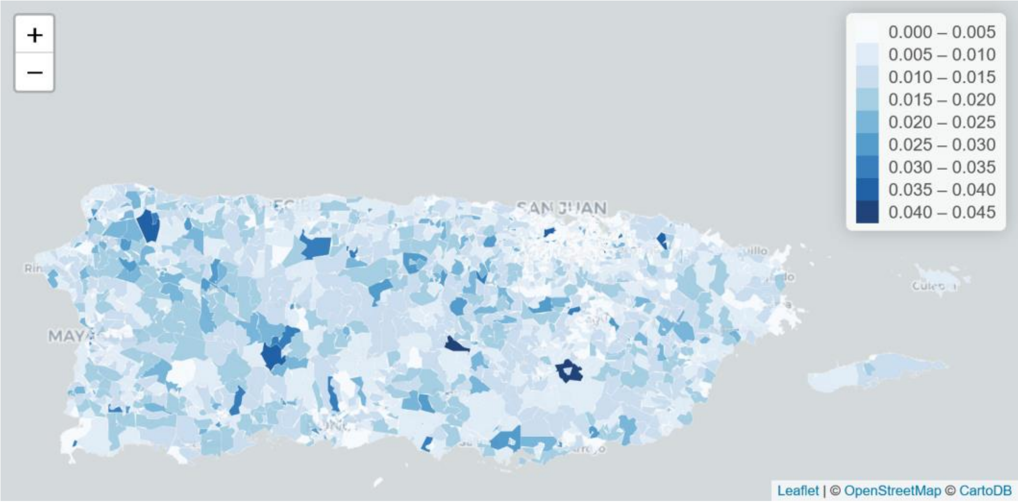
$$B_C = \sum_{inf} \sum_{pop} \frac{E_{inf,pop}}{A_{pop}}$$

Image credit: Wikimedia Commons user "Mdf"

Effort during outage: 80 (out of 159 sited) microgrids

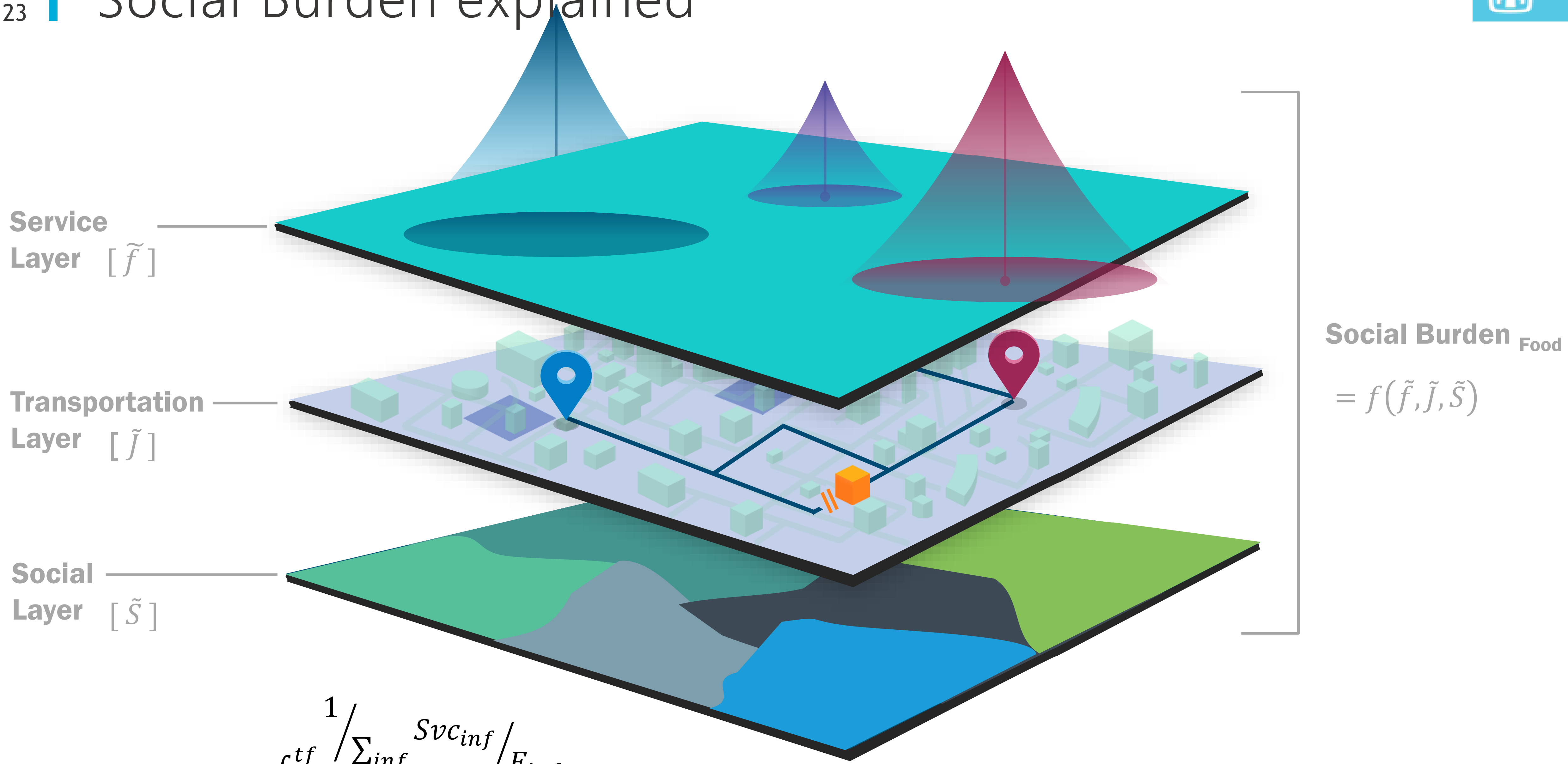


Burden during outage: 80 (out of 159 sited) microgrids



Jeffers et al. (2018) Analysis of Microgrid Locations Benefitting Community Resilience for Puerto Rico. SAND2018-11145

Social Burden explained



$$Social\ Burden_{s,f} = \int_{t0}^{tf} \frac{1 / \sum_{inf} {}^{Svc_{inf}} / E_{inf}}{Ability}$$

Units:
Hours of effort per dollar of ability

Do we know what equitable resilience looks like?

Texas 2021: In some instances, downtowns remained powered and with gas while neighborhoods went without

- Employees of downtown businesses slept in their offices
- Critical load (hospitals and shelters) on the same circuit as non-critical
  - "This (downtown Austin) is a complicated, inter-connected network that includes critical buildings like the Dell Seton Medical Center, warming centers, the COVID-19 Alternate Care Site, Capitol Complex and Austin City Hall, as well as other critical infrastructure and government buildings," the city said in a news release. "Shutting down the downtown network would also cut off electricity to these critical buildings, which may also house vital communications equipment."
- Not clear what utilities use to define critical load in this situation
  - E.g. difference between economically critical and socially critical
- If social resilience metrics were used within AMI-enabled load shed scheme, what could be different?

Posted by u/Omarkhan1234 7 days ago

820

While the rest of us freeze to death the empty office building and parking lot at Legacy West stays brightly shining undisturbed.

Photo

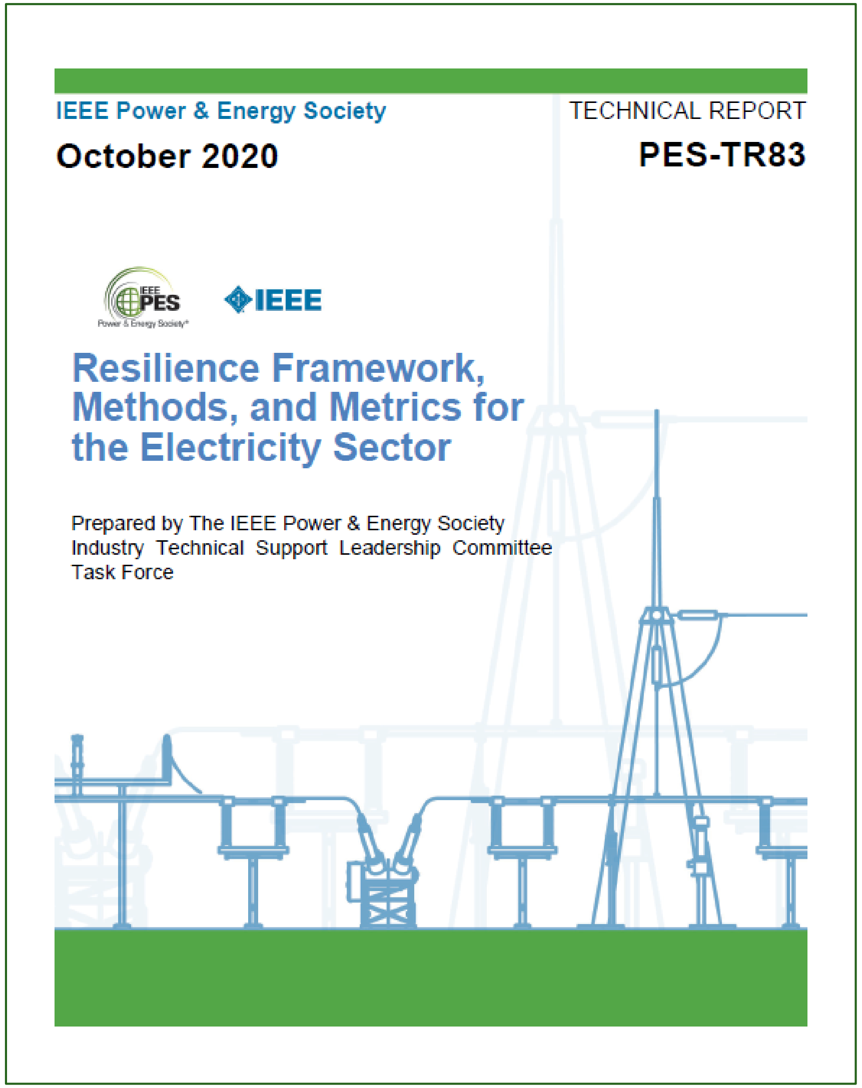
138 Comments Share Save Hide Report 95% Upvoted

Texas Blackouts Hit Minority Neighborhoods Especially Hard

As the freak winter storm raged, historically marginalized communities were among the first to face power outages, experts say.

https://www.houstonchronicle.com/news/houston-texas/houston/article/Houston-skyline-lights-energy-conserve-weather-tx-15954535.php
https://spectrumlocalnews.com/tx/san-antonio/news/2021/02/16/some-say-privilege-factoring-into-which-communities-have-worst-power-issues-

Bill Chiu
SCE, IEEE Task Force Chair


IEEE Power & Energy Society
TECHNICAL REPORT
October 2020
PES-TR83

Resilience Framework, Methods, and Metrics for the Electricity Sector

Prepared by The IEEE Power & Energy Society Industry Technical Support Leadership Committee Task Force

Resilience Framework, Methods, and Metrics for the Electricity Sector

Bill Chiu

Managing Director, SCE

Resilience Task Force Chair, IEEE PES ITSLC

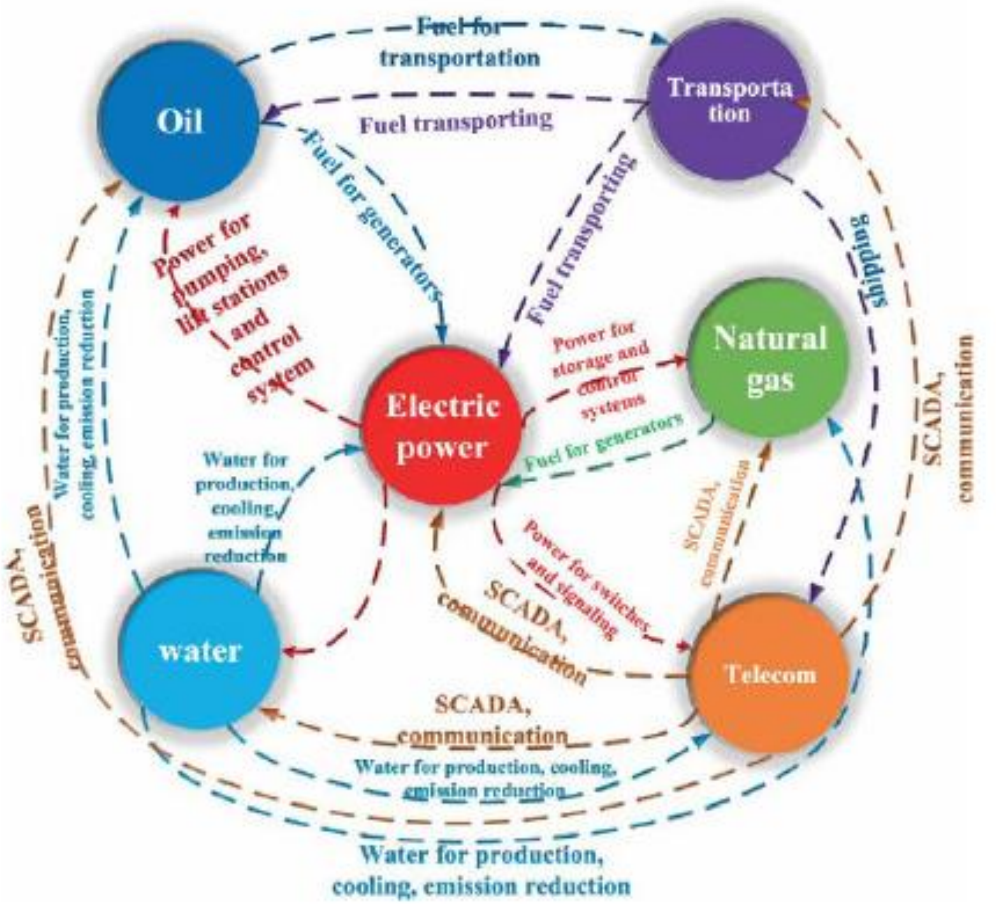
NARUC Resilience Metrics Webinar

Performance Based Regulating State Working Group & Black Sky Subcommittee

April 16, 2021

The Importance of Power Grid Resilience

- As threats are evolving, there is more emphasis on the resilience of the electric grid
- ***Protect against and recover from any event that would significantly impact the grid***
  Prepare => Withstand => Reduce magnitude and duration
- But it's not just about providing resilience; we need to be able to measure it
- Resilience metrics enable benchmarking across industry participants and facilitate continuous improvements



Energy Sector, including power grids, is *uniquely critical because it provides an "enabling function" across all critical infrastructures*

Electrical System Hazards

Natural Phenomena

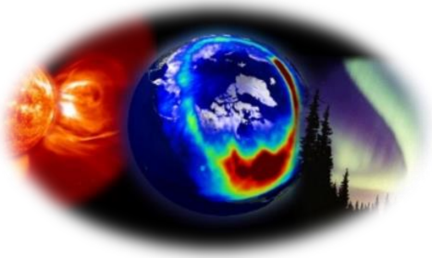
- “The New Normal” of more extreme weather events (hurricanes, torrential rain, wind-storms, wildfires, earthquakes, etc.)
- Space weather events

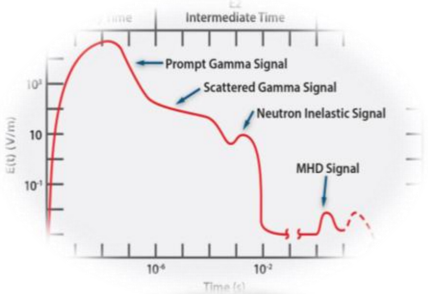
Man-Made

Cyber and physical security, EMP

System Design, Aging, and Human Error

Equipment tripping, power system islanding, voltage and angular instability





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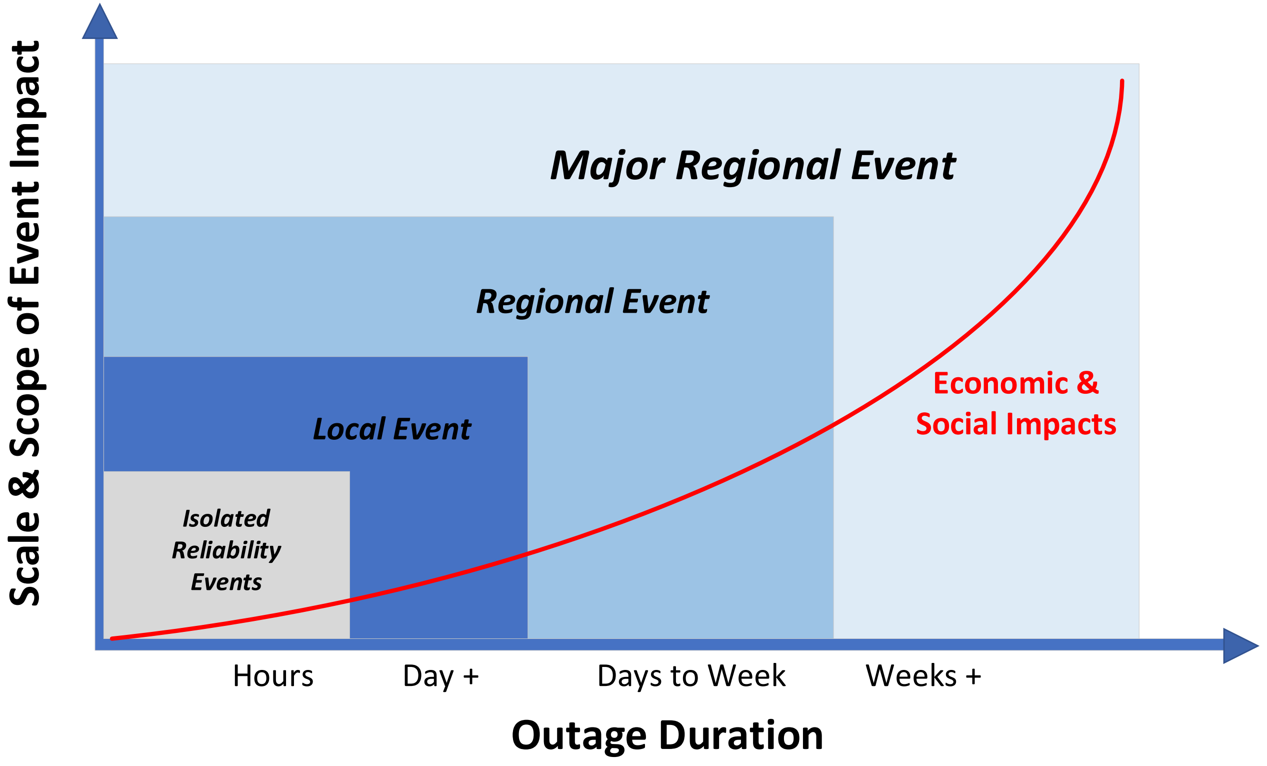
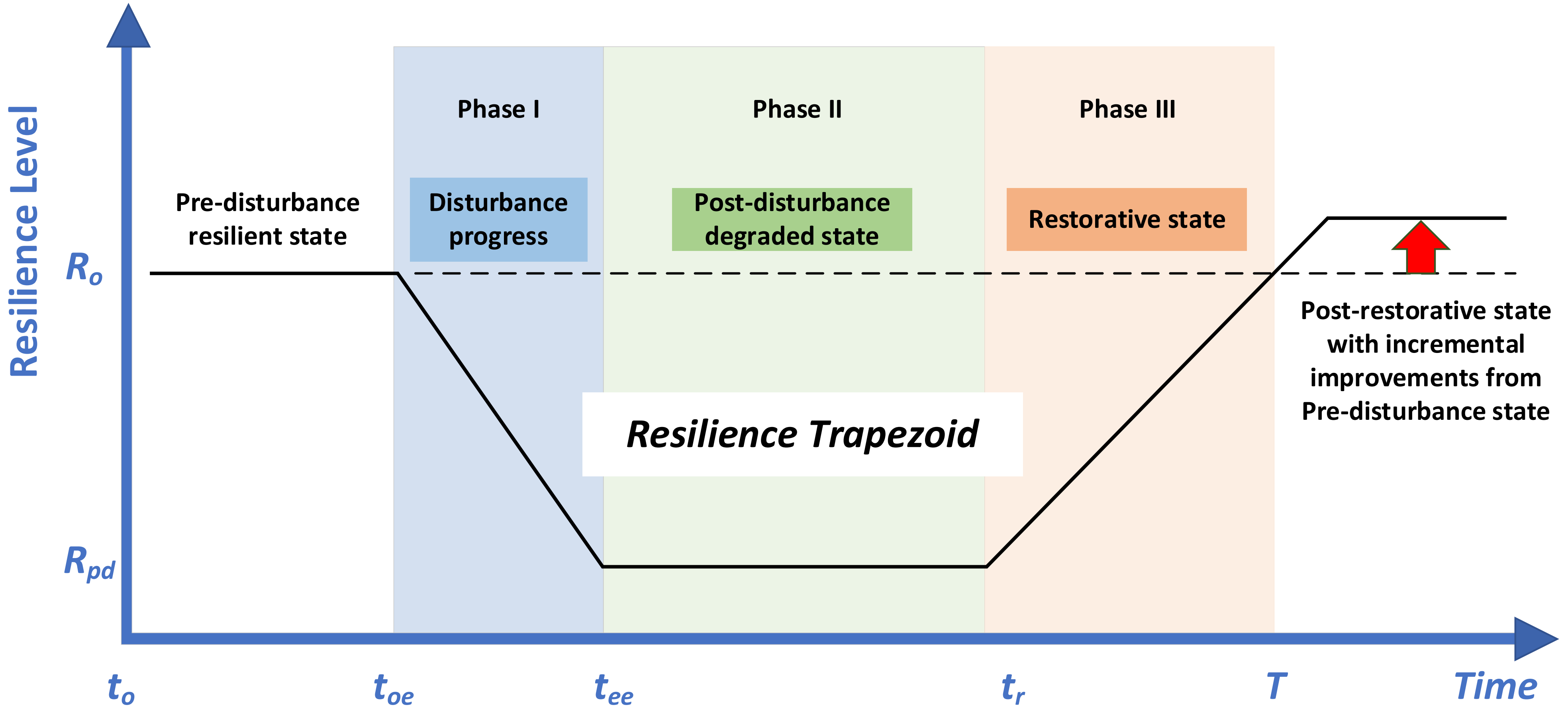
Interplay Between Reliability and Resilience

- ***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
  - While reliability metrics (SAIDI, SAIFI, etc.) can still be used to gauge larger scale impacts, they do not provide the complete picture of process of recovery
- ***Reliability and Resilience*** often improve each other (e.g., system hardening), however, there could be opposing tradeoffs
  - Traditional reliability practice of reclosing power lines could have negative resilience impact with ignitions from foreign debris during wildfire season)



Resilience Considerations & Timeline



Time Sequence	Events hits the network	End of event	Restoration is initiated	End of rstoration
Type of Actions	Preventive	Responsive	Emergency Coordination	Restorative	Adaptive/ Corrective

Resilience Definitions

Dictionary definition of resilience is “The capacity to recover from difficulties: toughness.”

- **FERC**: “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 event.” Examples of high-impact, low frequency (HILF)disruptive events are fuel supply interruptions, extreme weather events, and HEMP attack/GMD.
- **DOE**: “The ability of a power system and its components to withstand and adapt to disruptions and rapidly recover from them.”
- **NATF**: “The ability of the system and its components (i.e., both the equipment and human components) to minimize damage and improve recovery from non-routine disruptions, including high impact, low frequency events, in a reasonable amount of time.”

As the frequency of weather-related or security events has increased, those cannot be treated as low-probability events

Resilience

The ability to protect against and recover from any event that would significantly impact the grid.

Resilience Metrics - Summary

- Complexity of defining resilience highlights the need for a more simplistic approach
- The value of metrics lies in their ability to be benchmarked and compared across industry participants and to facilitate continuous improvements
- There is no “one-size-fits-all” solution for resilience metrics and investments as they are dependent on various factors — regional, functional, regulatory, and business
- The proposed approach is:
  - Identify relevant parameters and base-case performance metrics
  - Apply these parameters with priority weighting and addressing risks by factoring in probabilities and consequences
  - Use the appropriate framework to facilitate the prioritization process and investment decisions

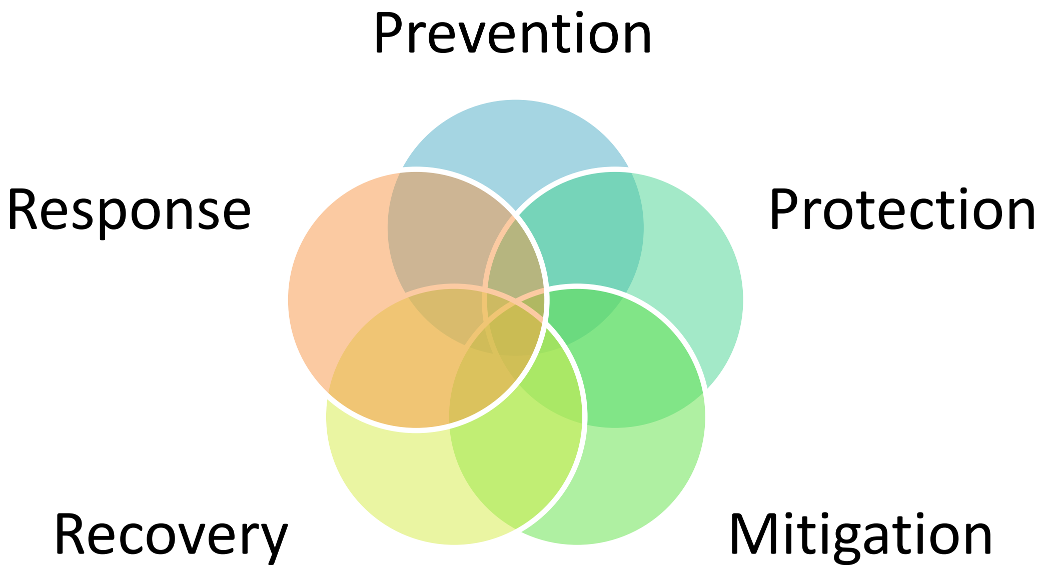
Don’t let Perfection be the Enemy of the Good

Start now and apply what is available & learn and adjust along the way

All-Hazards Framework to Resilience

All-hazard framework with five main focus areas: **Prevention, Protection, Mitigation, Response, and Recovery**

- Predict and understand the threats
- Evaluate credible scenarios before and during the event
- Decide and take preventive actions
- Track the system conditions during the event and provide adequate response to mitigate the damage
- Guide and coordinate the system through the recovery



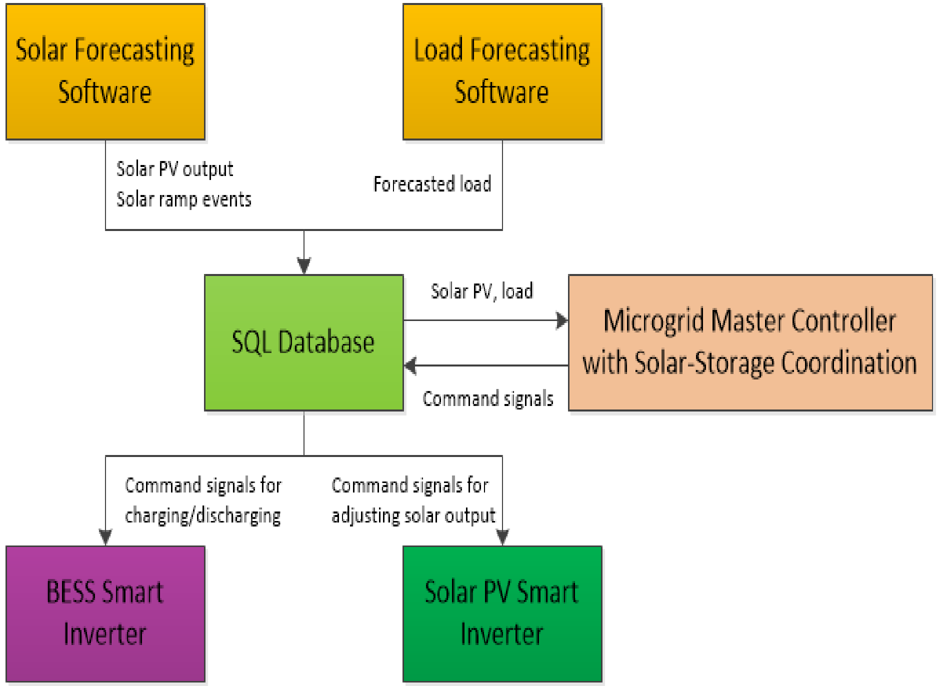
Collaboration with key stakeholders in maturing resilience competencies across all five areas of the All-Hazards approach

Emerging Technology, Tools, and Methods (TT&Ms)

- Controls for DERs and energy storage (smart inverters), energy efficiency, and demand response for smooth transition to islanding, e.g., Microgrids
- Sensors (e.g., outage-reporting smart meters, synchronized measurements, geomagnetic induced current monitoring), communications, and drones for situational awareness and condition assessment
- Real-time analysis and control and data analytics tools for extreme events, e.g., weather forecasting, dynamic security assessment, stability management, restoration-and-recovery plan
- Improved power system modeling, incl. interdependencies among electric, gas, and communication systems
- Coordinated resource and T&D planning and investment prioritization tools and processes
- Risk- and probability-based cost-benefit tools to value resilience investments from the consumer perspective
- Etc.

Examples of Progress in Resilience Across the Industry

- **ComEd's - Bronzeville Community Microgrid**
  DERs and battery storage, to increase resilience for approximately thousand residences, businesses, and public institutions.
- **Florida Utilities - System Hardening**
  Aggressive hardening programs results: overhead facilities had substantially lower and underground facilities minimal failure rates.
- **Con Edison - Climate Change Vulnerability Study**
  The "withstand" approach to prepare for both gradual (chronic) and extreme climate risks through resilience actions throughout the lifecycle of assets.
- **SDG&E - Flexible Adaptation Pathways**
  Analysis based on flexible pathways valuating infrastructure impact given different sea-level rise projections.
- **Entergy - Building a Resilient Energy Gulf Coast Plan**
  Cost-benefit analysis evaluates near-term resilience efforts that will lead to cost savings in the longer term as the frequency and severity of storms increase.
- **SCE – Comprehensive Wildfire Mitigation Plan**
  System hardening against potential sources of ignitions associated with overhead powerlines, advancing weather modeling, and deploying sensory technologies to detect incipient system anomalies.



Microgrids to mitigate climate change

Other Common Resilience Practices in the Utility Industry

- **Distribution line construction standards update**
  (e.g. structures loading criteria, Insulated conductors, Fiberglass crossarms)
- **Customer segmentation through distribution automation:** FLISR
- **Redundant protection systems**
- **Flood protection measures/Substation firewalls**
- **Emergency restoration structures**

Conclusions/Key Takeaways

The electric grid resilience is the foundational building block for our clean energy future, requiring renewables, energy storage, and electrification

- Strong mutual dependencies of the electric sector with other critical infrastructure sectors: oil, natural gas, telecom, transportation, & water supplies
- Interplay between reliability and resilience – resilience deals more with the capability to respond & recover
- One-size fits all resilience metric is not practical; dependency on the type of events with regional and stakeholder influence
- Collaboration between policy makers, regulatory oversight, grid operators, and local communities are critically important to determine the value of resilience and investment thesis
- Transparency in the planning scenarios and assumptions will help to promote consistency between the critical infrastructure sectors
- Risk-based probabilistic and stochastic analysis is more appropriate than the traditional scenario/deterministic planning approach, but in any case, planning will require integration across the G, T, and D domains.

Apply the all-hazards framework toward assessing and developing programs with five key focus areas: Prevention, Protection, Mitigation, Response, and Recovery

Q&A Discussion