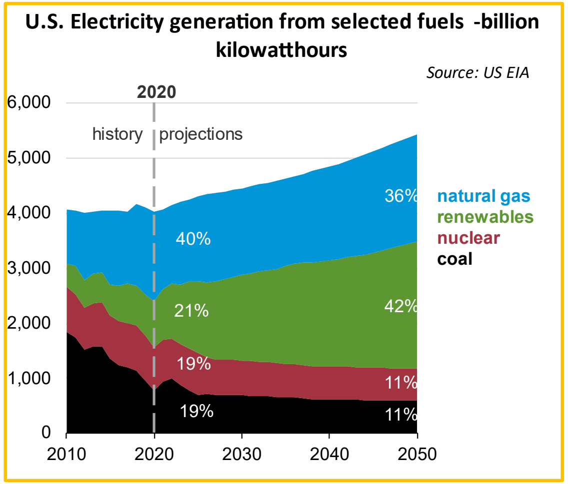
IEEE PES General Meeting 2021

Grid Resilience Super Session

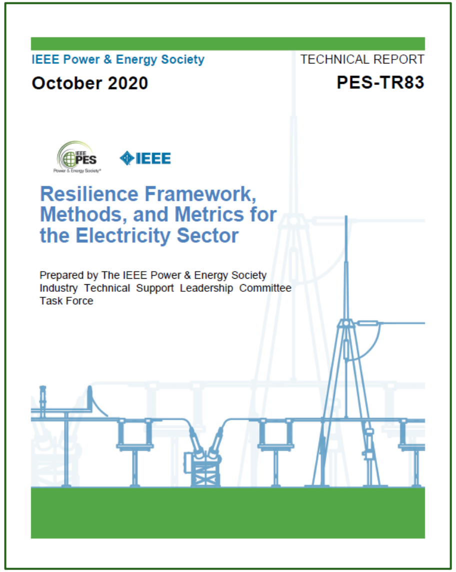


Key Success Factors for Green, Resilient, and Affordable Electrical Energy Delivery

Dr. Damir Novosel

Quanta Technology

July 27, 2021



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

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Society Targets and Solutions

Targets

- **Decarbonization**
- **Reliability and resilience**
- **Affordable electrical energy prices**

US: ~10 ¢/kWh
CA: ~15 ¢/kWh
EU: ~27 ¢/kWh

New York Clean Energy Standard
- Reduce greenhouse gas 85% by 2050
- 70% renewables by ‘30 and 100% carbon-free by ‘40
- Energy storage: 1.5GW 2025, 3GW 2030
- Doubling energy efficiency by 2025

California Senate Bill 100
- 50% renewable energy by 2026, 60% by 2030
- 100% renewable and zero-carbon resources by 2045

Germany	2020	2030	2050
Greenhouse gas reduction (1990)	40%	55%	80%
Renewable energy share	18%	30%	60%
Energy efficiency increase (2008)	20%		50%

Solutions

Energy/Fuel Transformation
- Renewable generation (solar, wind, etc.)
- Electrical Storage

Energy Efficiency

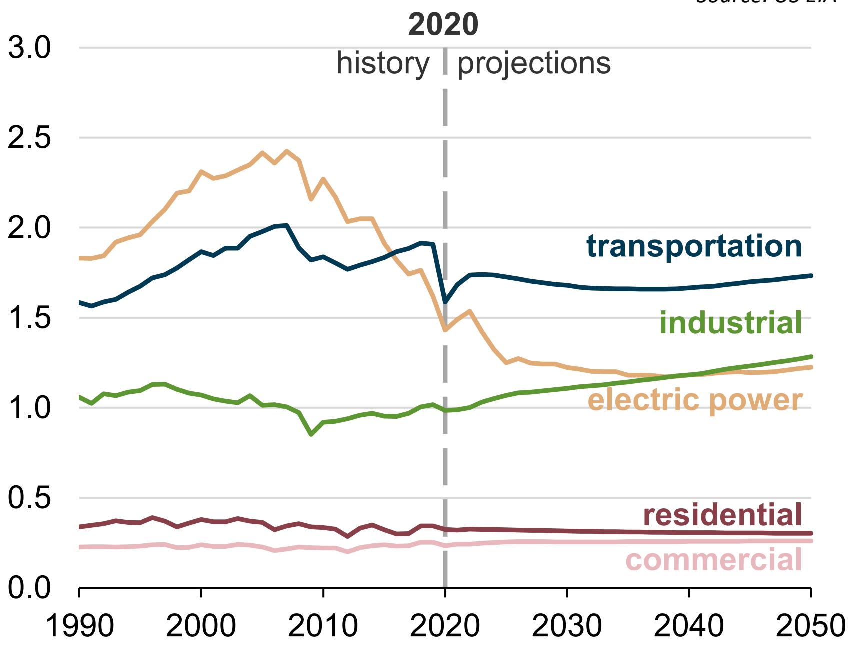
Electrification
- *Transportation:* Light-, Medium-, Heavy-Duty, Buses, Infrastructure
- *Buildings:* Residential & Commercial
- *Industrial and Agriculture*

1891: First successful electric car
1904: ~1/3 cars were electrical

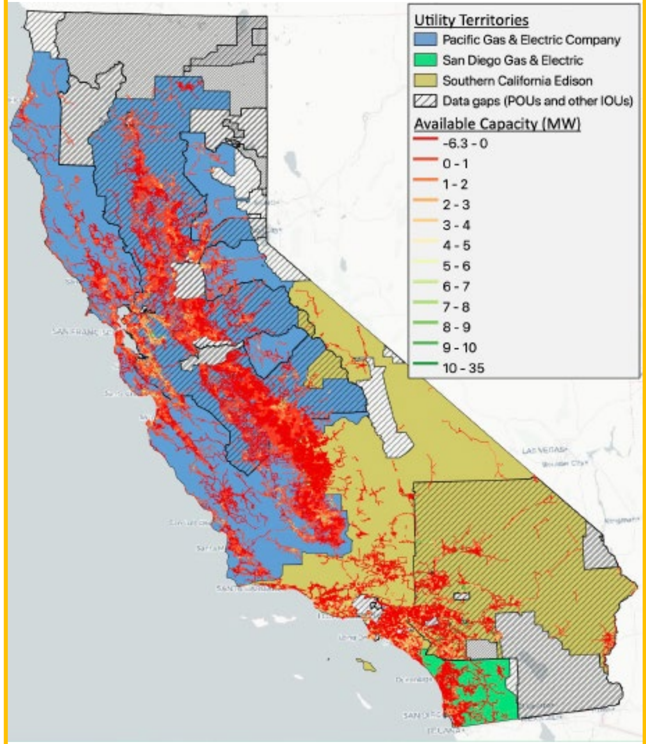
Impact of Electrical Transportation

U.S. Energy-related carbon dioxide emissions by sector in billion metric tons

Source: US EIA



EV Charging - Edge Capacity Analysis



Red lines indicate areas where the grid cannot accommodate additional load without any thermal or voltage violations. *Source*: CEC

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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 & duration
- But it is not just about providing resilience; we need to be able to measure it
- Resilience metrics enable benchmarking across industry participants and facilitate continuous improvements

Electrical power is *uniquely critical because it provides an "enabling function" across all critical infrastructures*

- ***Reliability*** is commonly acknowledged as a system performance, deterministic measure

  Metrics (e.g., SAIDI, SAIFI, LOLE, (N-1)) can gauge larger scale impacts - Do not provide the complete picture of recovery process

- ***Resilience*** is a system characteristic/ capability encompassing all events, including high-impact, low-probability events excluded from reliability calculations – (N-k) k -> large
- ***Reliability and Resilience*** often improve each other (e.g., system hardening), however, there could be opposing tradeoffs

  E.g., reliability practice of reclosing power lines could have negative resilience impact with ignitions during wildfire season

Electrical System Hazards




Natural Phenomena

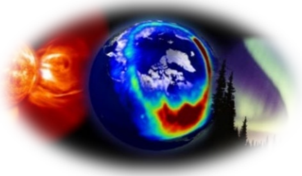
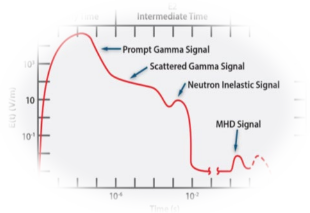
- "The New Normal" of more extreme weather events (hurricanes, torrential rain, wind-storms, wildfires, earthquakes, etc.)
- Space weather events

Man-Made

Cyber and physical security, EMP

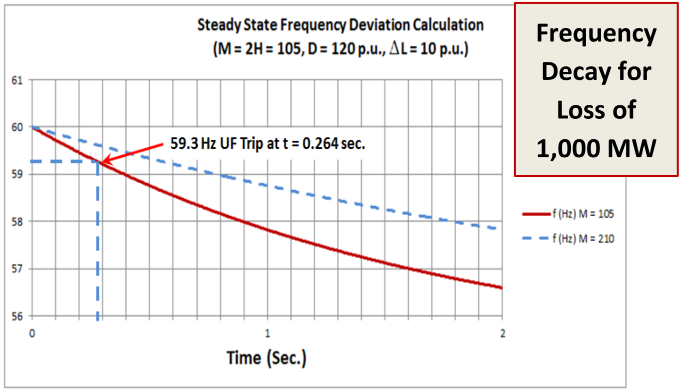
System Design, Aging, and Human Error

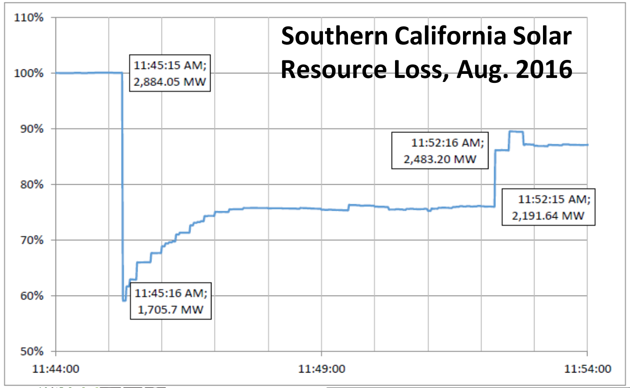
Equipment tripping, power system islanding, voltage and angular instability


Renewables Integration Challenges and Solutions

Inverter Based Resources (IBR) → Less Inertia → Things Happen Faster!
+ Low Fault Currents





Essential Reliability Services

- Quantifying the value in a technology neutral manner, mix of conventional generation + IBR to improve reliability and resilience
- IBR can provide reserve margins if recognized in the marketplace
- Monitoring & control of smart inverters to mitigate impact and enhance the DER benefits
- Increased visibility and communication - Improved Monitoring, Control, and Adaptive Protection
  - T&D planning & operations require accurate modeling
  - IEEE Std. 1547-2018 defines reliability services, e.g. frequency response, ramping and voltage support

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Achieving Desired Resilience and Reliability

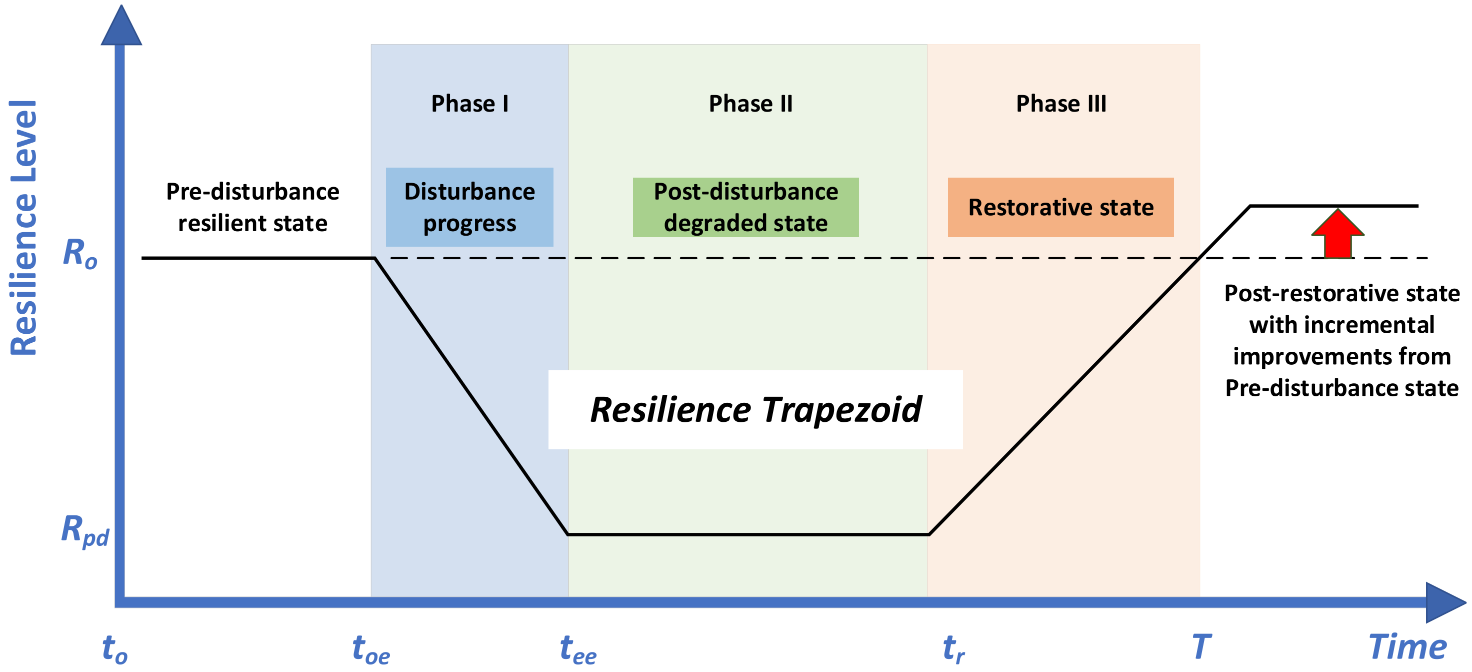
Preconditions for Outages

- Congested grid with tight operating margins.
- Human error (i.e., lack of training, operational execution).
- Substation bus or protection system design.
- Inadequate warning, protection, and control systems.
- Non-optimal planning and visibility of DER, storage, and electrification, incl. system inertia and current levels.
- Uncoordinated GTD planning and operations and lack of
  - System and component knowledge (e.g., line loading).
  - Advanced load, DER, storage, EV, and weather forecasts.
- Insufficient generation to meet the system needs or energy policy, driving untimely generation retirements.
- Regulatory uncertainty resulting in insufficient investment to improve aging infrastructure.

Resilience Targets and Process

- Fast changing environment (e.g., cyber risks, DER integration) requires adaptive response
- Priorities to invest time and funds (Hurricane vs. High-altitude Electro Magnetic Pulse risks)
- Framework and Metrics
  - Framework using base state and performance targets applying risk and probabilistic tools
  - System dependent metrics
- Investment priorities in balancing reliability and resilience
- Solutions to improve current state:
  - DER, storage, microgrids integration
  - Advanced monitoring, control, and protection
  - Tools, processes, training, etc.

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

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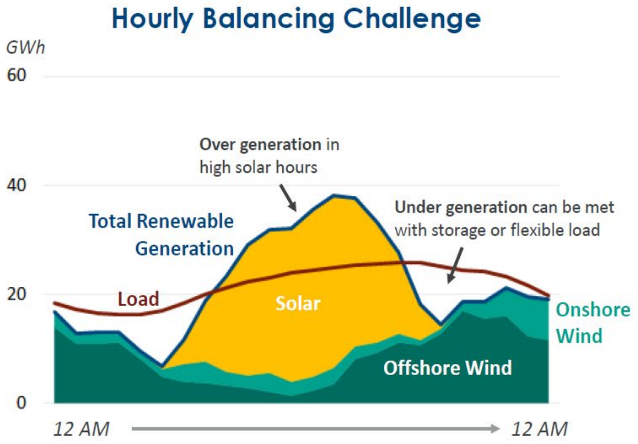
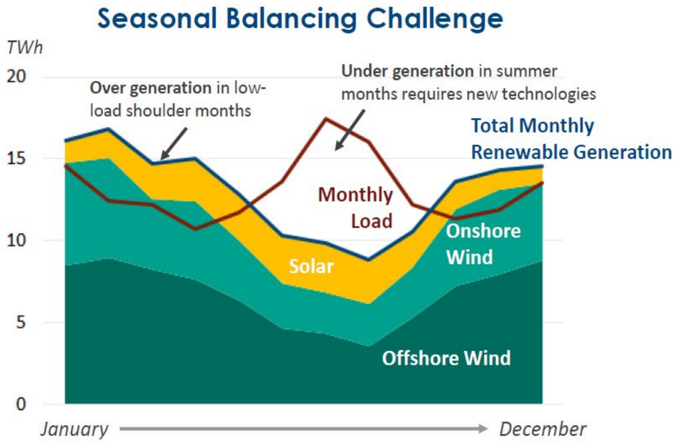
Planning with Higher Levels of Renewables - Effective Load Carrying Capability



Batteries and load flexibility can provide short-term balancing.



Seasonal balancing is the more difficult challenge, requiring new technologies such as seasonal storage or zero-emission dispatchable generation.

Courtesy of NYISO

- Effective Load Carrying Capability (ELCC) assessment - How much “perfect capacity” can be replaced by renewables?
- Perfect capacity is never out, can ramp up and down instantly, and can operate around the clock (ELCC = 100%). If it takes 30 MW of “perfect capacity” to replace a 100 MW solar plant, the solar plant ELCC = 30%.
- As the renewable capacity reaches 50% in the overall generation mix, there is a need for flexible generation with fuel certainty to support the grid resilience and reliability.

Technologies, Tools, and Methods (TT&Ms)

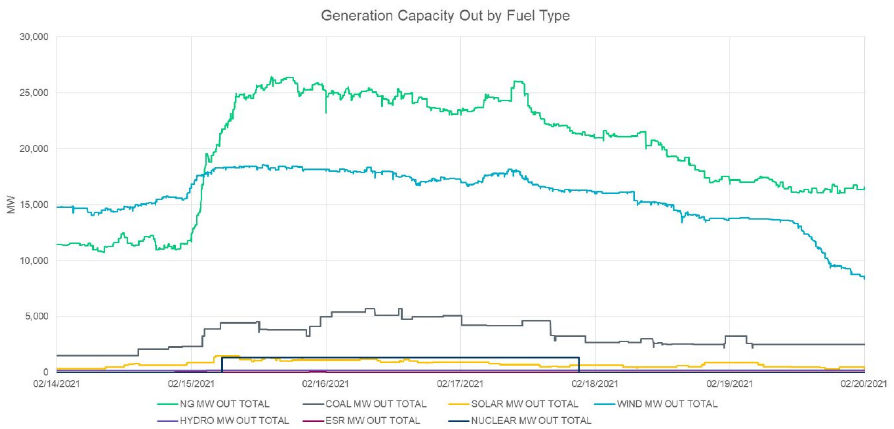
Deployed TT&Ms

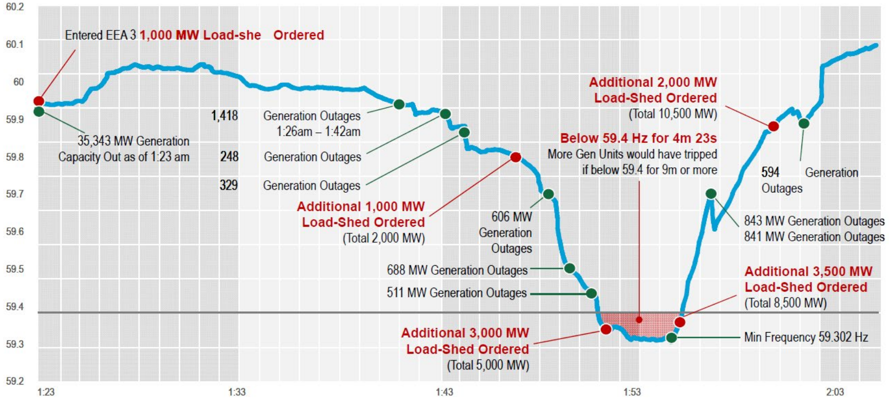
- On-line analysis tools for extreme events/cascading analysis and situational awareness (weather forecasting, dynamic security assessment, etc.)
- Sensors (e.g., Synchronized measurements, GIC monitors) and drones for situational awareness and condition assessment
- System operating procedures and design objectives
- Controls for DERs and energy storage (incl. smart inverters), energy efficiency, and demand response
- Microgrids w/smooth transition to islanding
- Modeling interdependencies between electric, gas, and communication systems

Emerging TT&Ms

- Coordinated resource and T&D planning and operations for investment prioritization
- Risk- and probability-based tools
- Real-time tools for monitoring, protection, and control of T&D systems
- Emerging communication technology (e.g., Black Sky Emergency Communication System)
- Data mining/Machine Learning and AI analytics on extreme event analysis and decision support, etc.

Texas Energy Crisis - Solutions for Resilience Improvements



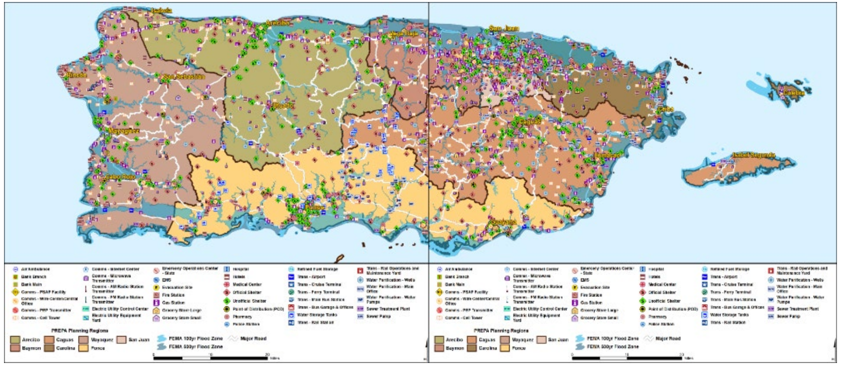


- **Generation**
  - Planning for similar severe weather events considering resource adequacy, operating reserves, and generation flexibility – Benefits of diverse generation resources
  - Winterizing gas pipelines and the whole generation fleet with measurable performances.
  - Evaluate storage as integrated resources with wind farms and align it with ERCOT's coincident peak demands.
- **Transmission**
  - Connections to other RTOs to help for extreme conditions.
  - Probabilistic-based analysis of outages with consideration of codependent extreme events.
- **Distribution and Consumer**
  - Leverage DERs, storage, microgrids and the DSM programs.
  - Better information to consumer on outage location and duration.
- **Coordinated planning for investment prioritization**
- **Address dependencies with other infrastructures**

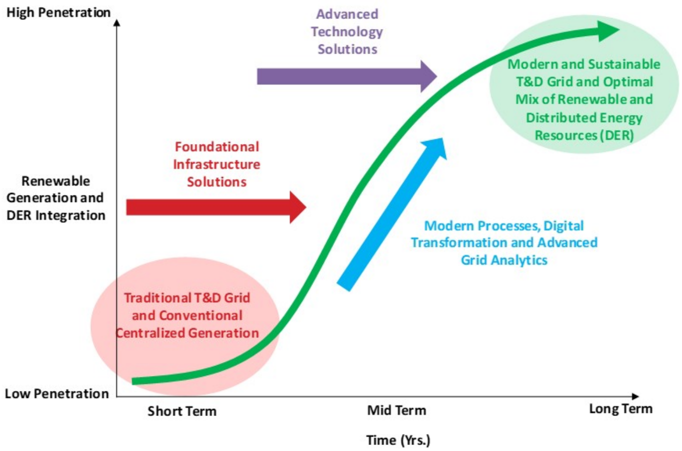
Case Study – Puerto Rico

- Hurricane Maria devastated the island creating a need for significant infrastructure investment
- Policy objectives to shift to more renewable generation and distributed energy resources to support RPS and improve grid resilience
- New planning paradigm is required to achieve improved reliability and safety, increased resilience, reduced prices, and lowered carbon emissions

Microgrid Locations Benefitting Community Resilience



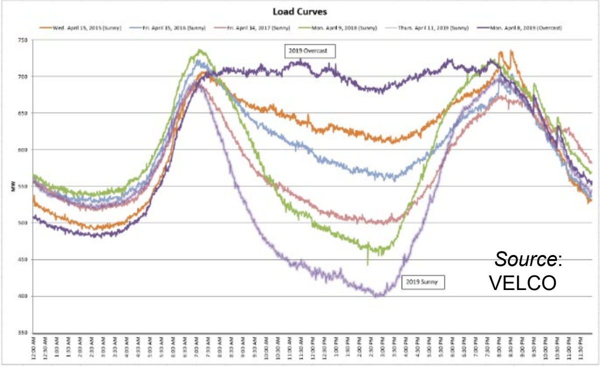
Source: Sandia National Labs

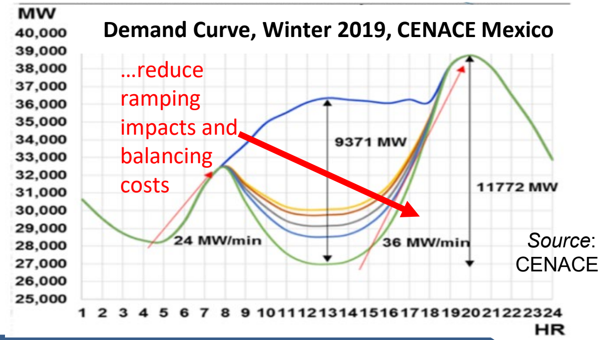


Coordination across GT&D planning and operations to guide investment prioritization is **necessary** to meet policy objectives and customer needs

Conclusions

- **Resilience**: The ability to protect against and recover from **any event** that would **significantly impact** the grid.
- **Resilience Metrics:** “One-size fits all” may not be practical.
- **Resilience Framework and Process** addressing all hazard events:
  1. Identify relevant parameters and base-case performance
  2. Apply priority weighting in risk modeling tools
  3. The probabilistic, risk framework for investment decision
- Need for **Coordinated GTD Planning and Operations and Investment Prioritization**.
- **Integrated load, DERs, and electrification forecasts** and the load following capacity to be addressed in planning and operations.
- Importance of **Diverse Generation Mix** to address uncertainties.





A resilient, modern electric grid is the foundational building block for our clean energy future, requiring renewables, energy storage, and electrification