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Sandia National Laboratories

Resilient Energy Solutions for Community Needs

Robert Jeffers,

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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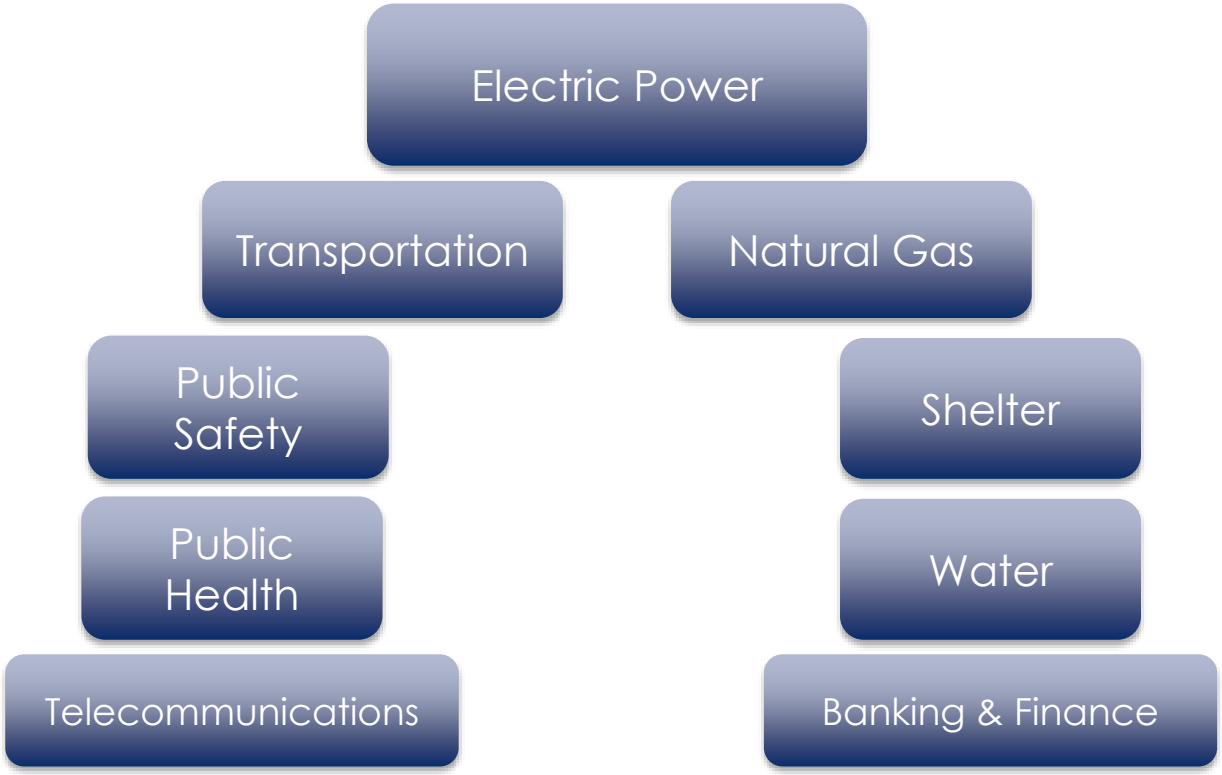
The Grid is the KEYSTONE INFRASTRUCTURE



Basic human needs are enabled by a resilient power supply during major disruptions

Resilience Science at Sandia

Presidential Policy Directive 21:
The term "resilience" means the ability to **prepare for** and **adapt** to changing conditions and **withstand** and **recover** rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents.

Disaster Resilience A National Imperative, National Academy of Sciences:
"without some numerical basis for assessing resilience, it would be impossible to monitor changes or show that community resilience has improved. At present, no consistent basis for such measurement exists…"

$$SI = \int_{t0}^{tf} [TSP(t) - SP(t)]\,dt. \qquad TRE = \int_{t0}^{tf} [RE(t)]\,dt.$$

Resilience combines performance and response

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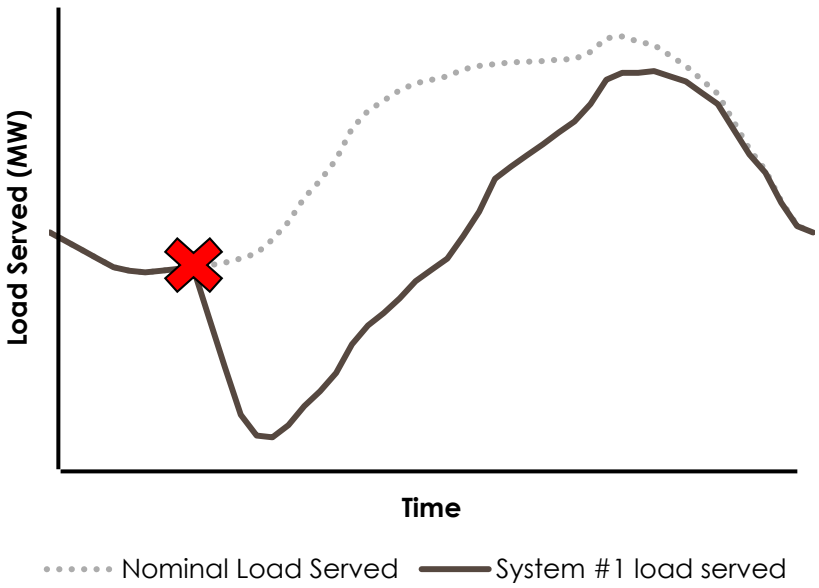
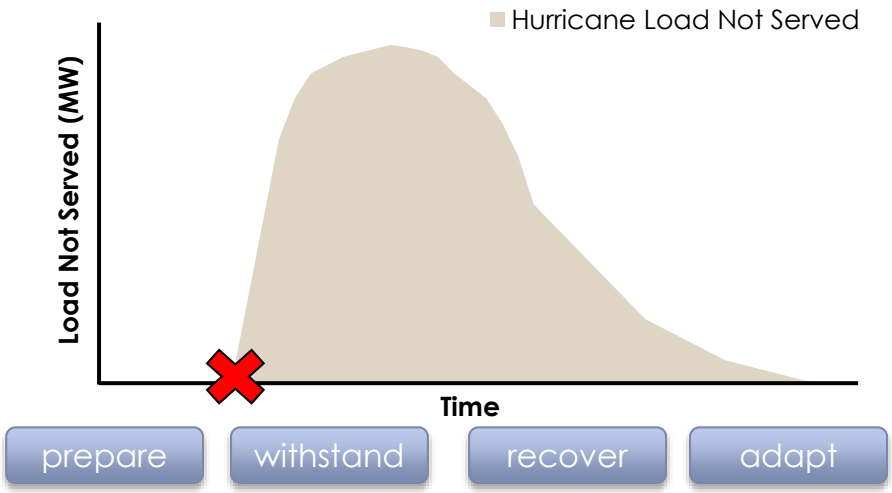
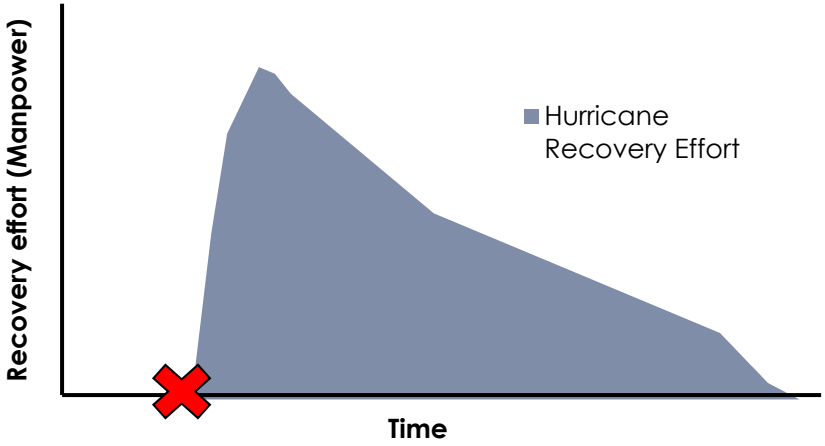
Load Served, Hurricane



Load Not Served, Hurricane

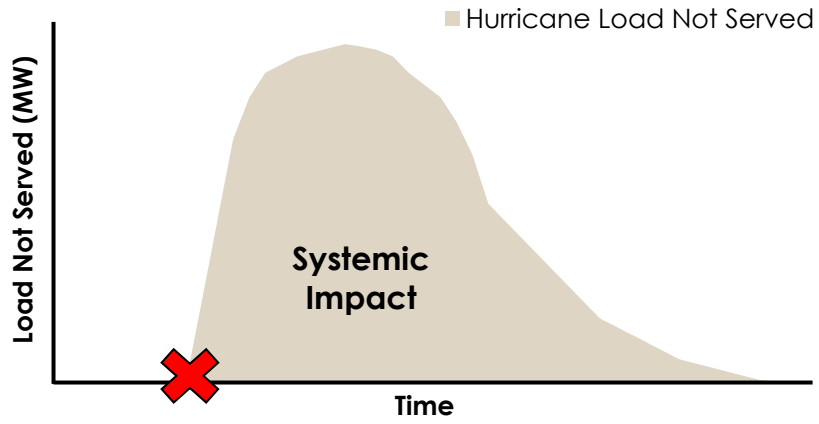


Labor, Hurricane

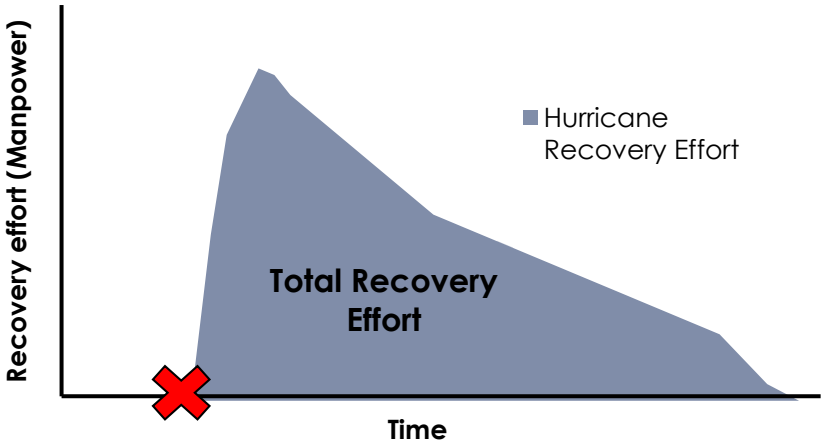


Optional: higher level metrics of consequence

Load Not Served, Hurricane



Labor, Hurricane

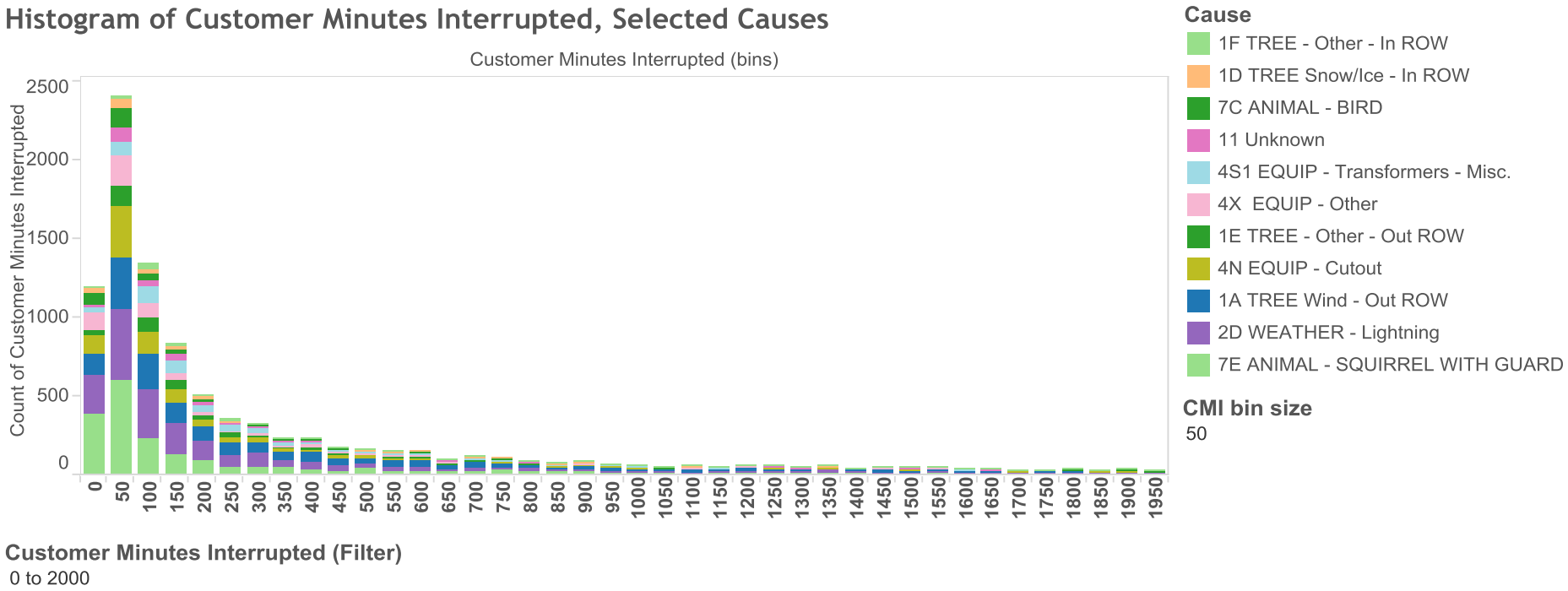


Resilience Index =
Systemic Impact +
Total Recovery Effort

Optional metrics of consequence:

- Gross Product ($$)
- Total Losses (insured vs. uninsured)
- Goods and Services Delivered
- People With Adequate Infrastructure Services

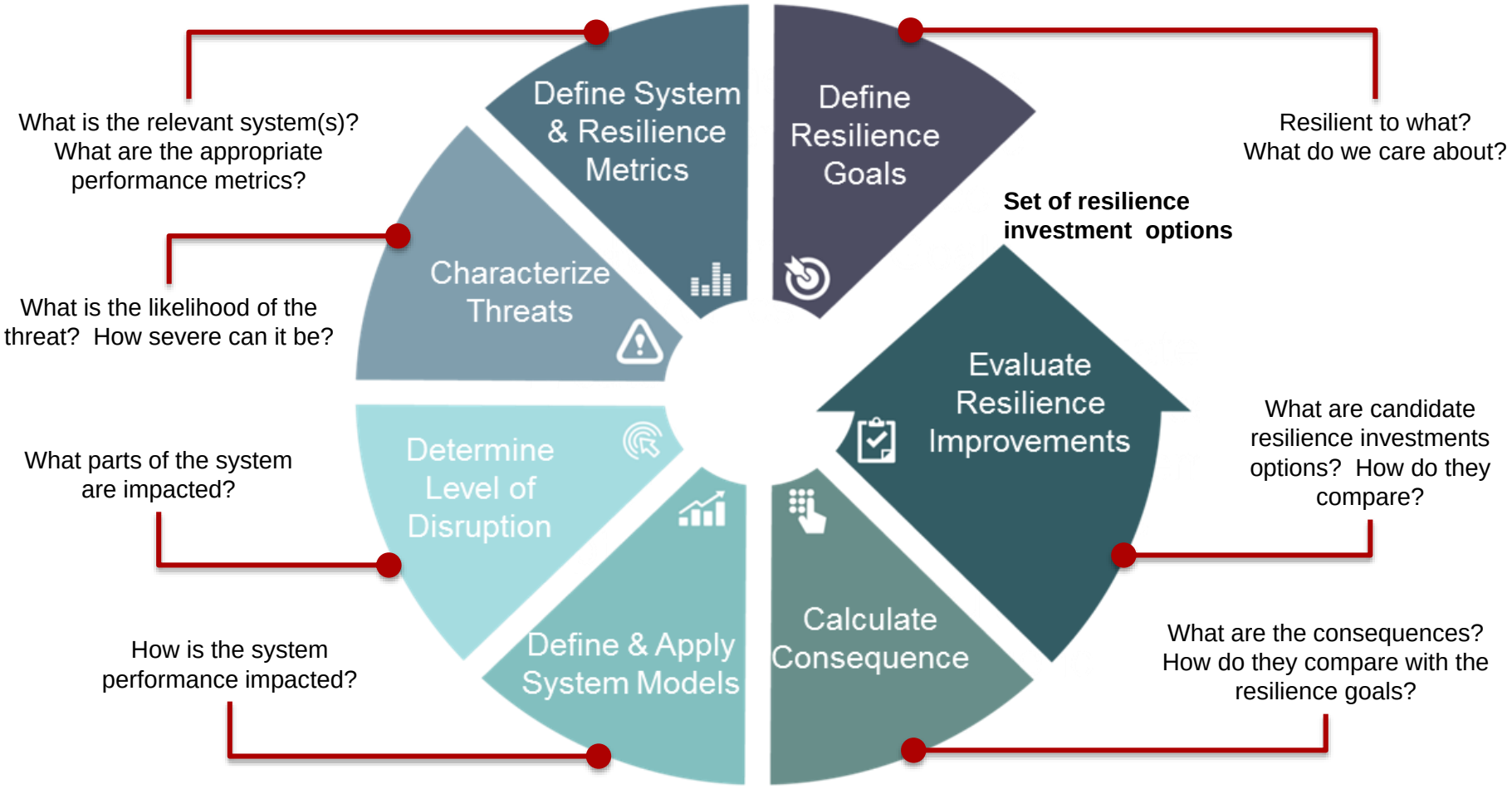
Power system planners focus on keeping the lights on



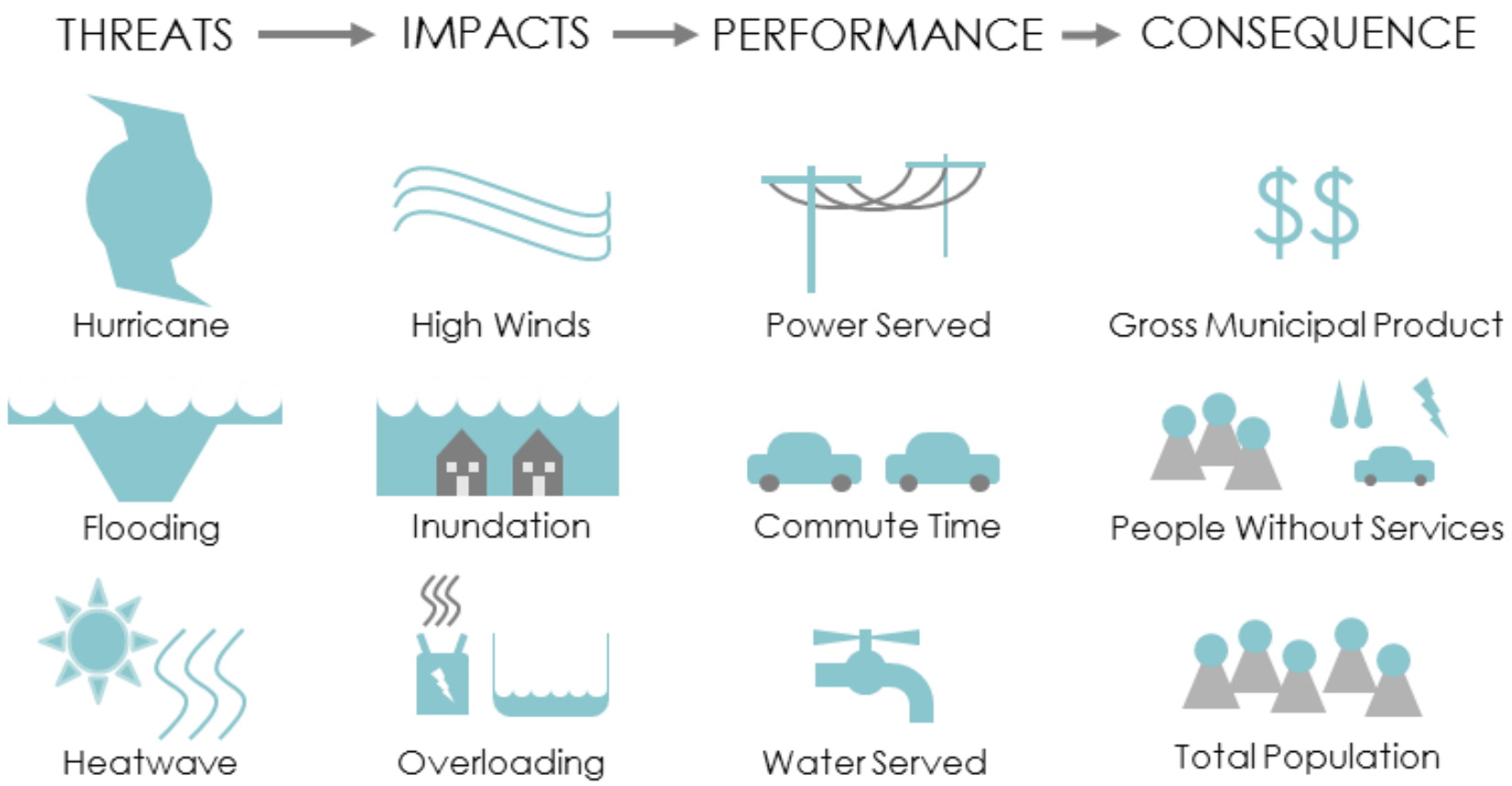
There are few regulatory mechanisms that reward power system planners for improving those measures city planners focus on

The Resilience Improvement Process

Source: SAND2014-18019—September 2014
A Resilience Framework published in the 2015 Quadrennial Energy Review (QER)

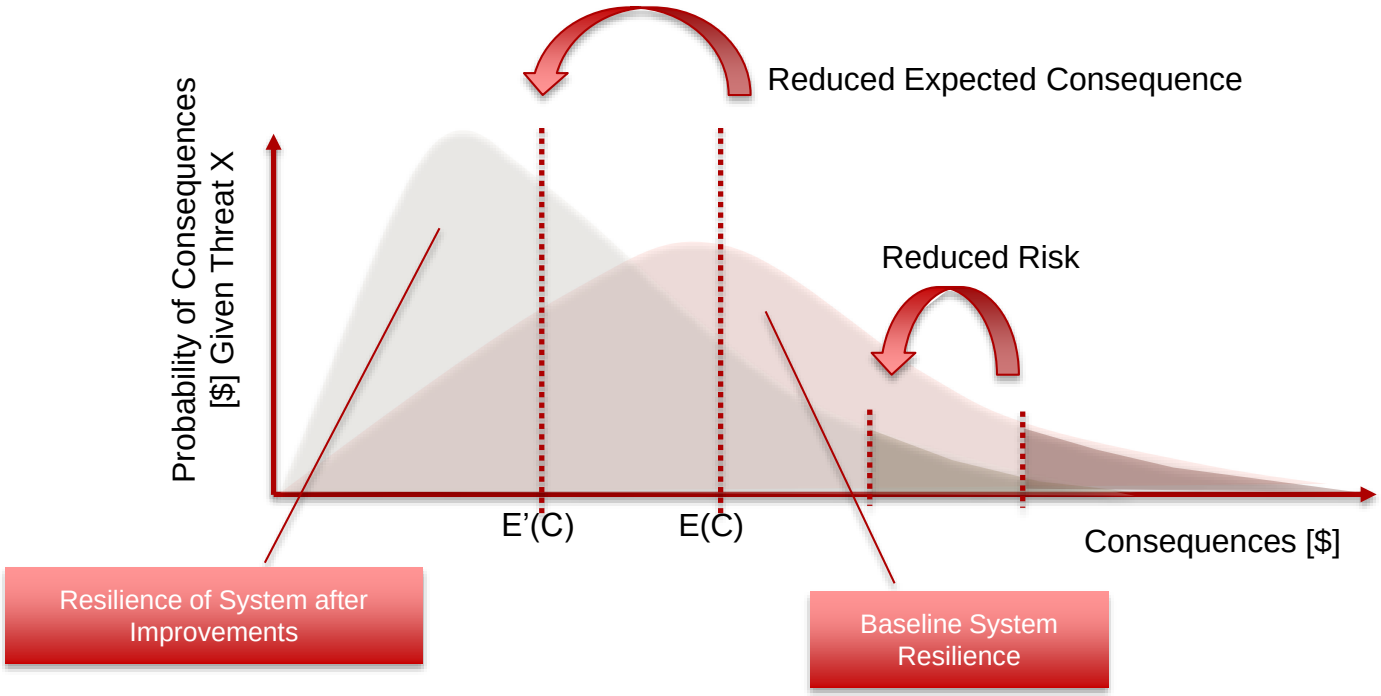


Translation between planning metrics is possible



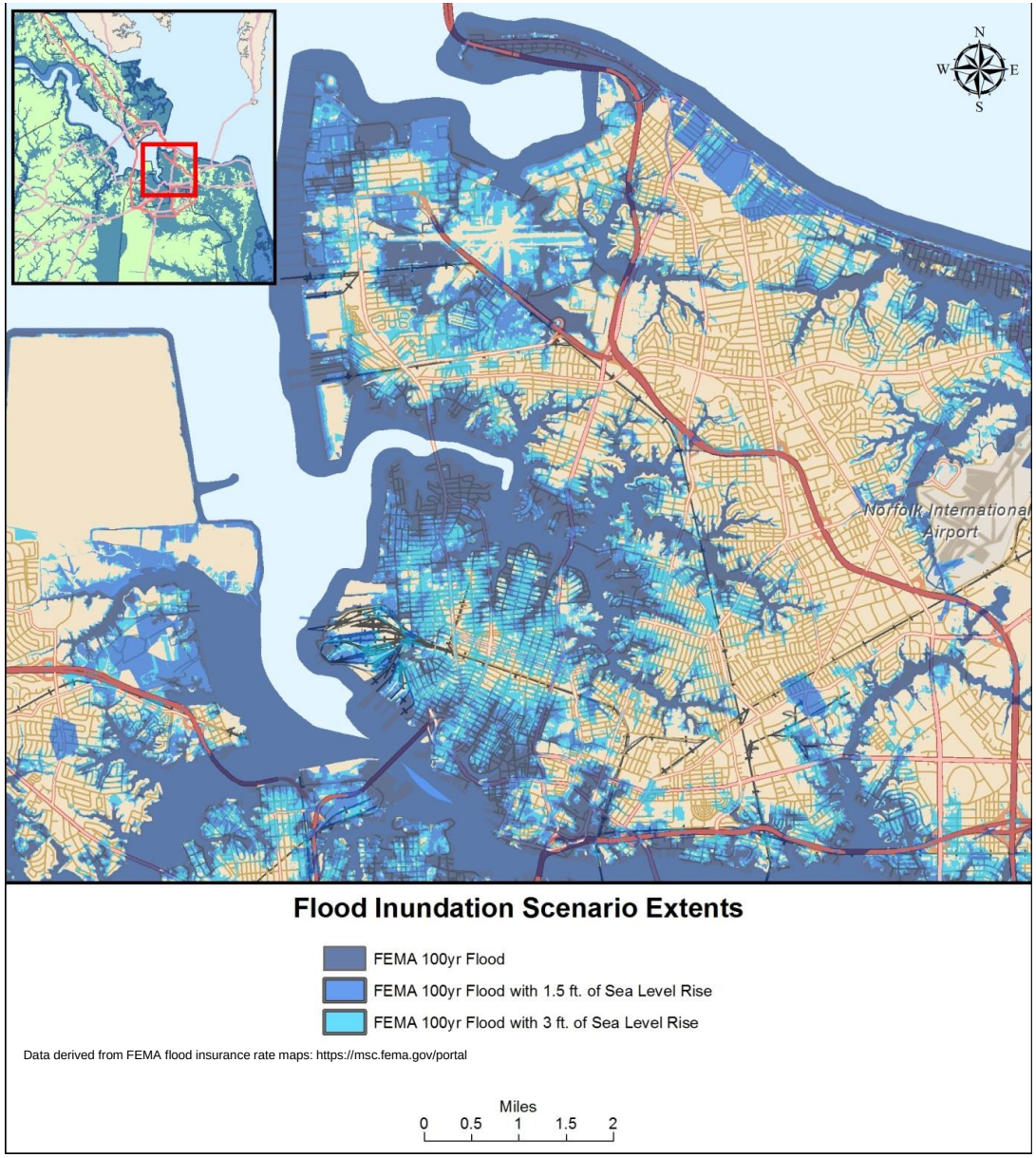
Projecting performance-driven consequence subject to a wide range of threats provides a better overall risk profile

Goals and Metrics



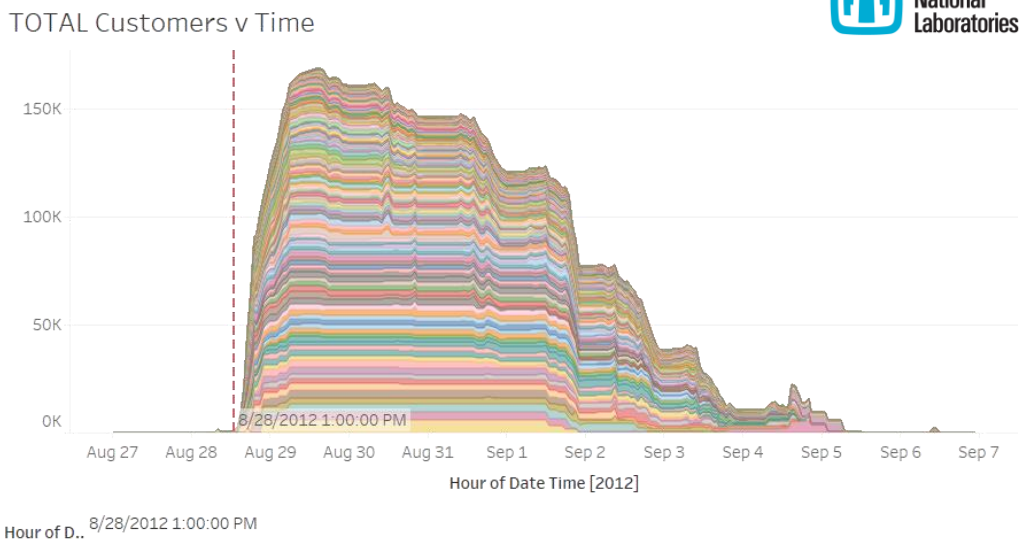
Measure Classification	Common Examples
Community Measures	Number of People Without Necessary Services
	Lives at Risk
	Net Population Change
Economic Measures	Gross Municipal Product / Net Economic Losses
	Change in Capital Wealth
	Business Interruption Costs

Threats and Impacts

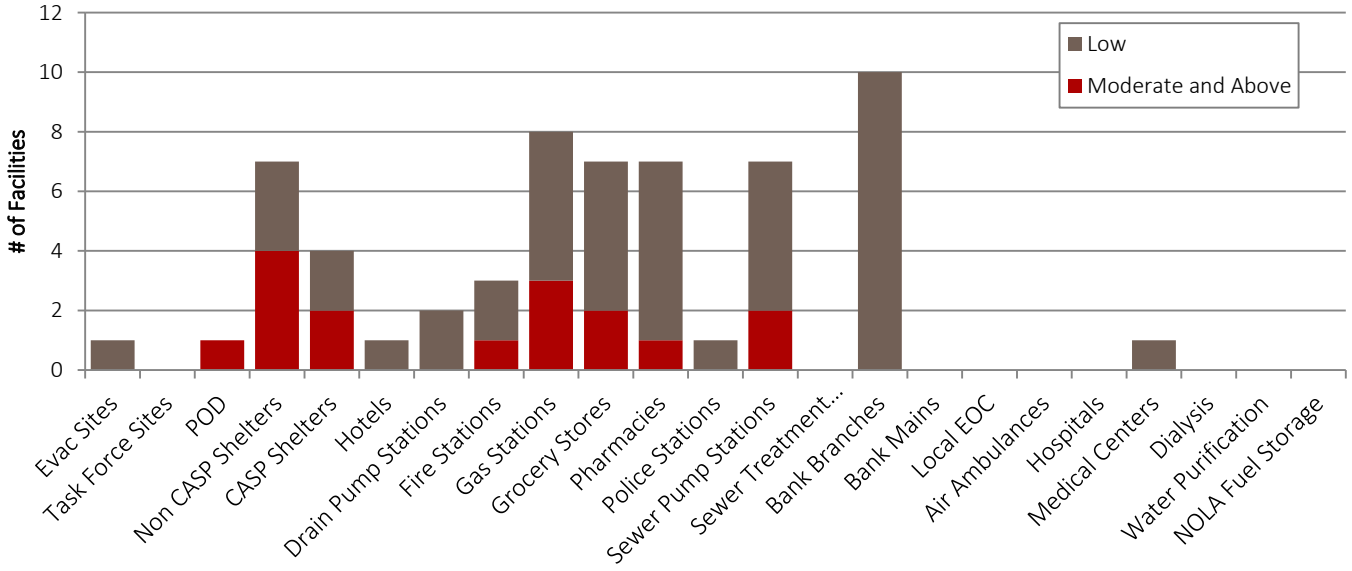


Baseline Performance

Simulate and analyze performance of an interdependent system of critical infrastructure



Quadrant 2 – Count of buildings above and below inundation risk cutoff



Conversion to ***economic*** metrics of consequence

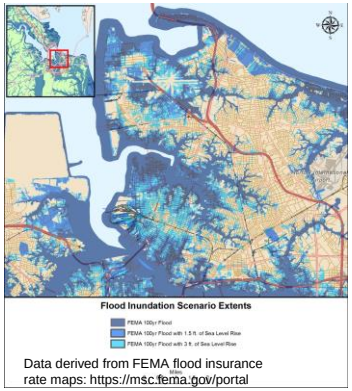
Flood extent

Flood duration / dynamics

Outage extent

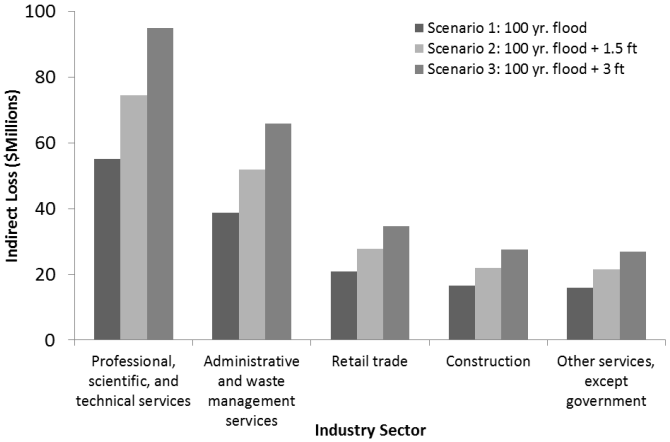
Outage duration / dynamics

Other Critical Infrastructure Services

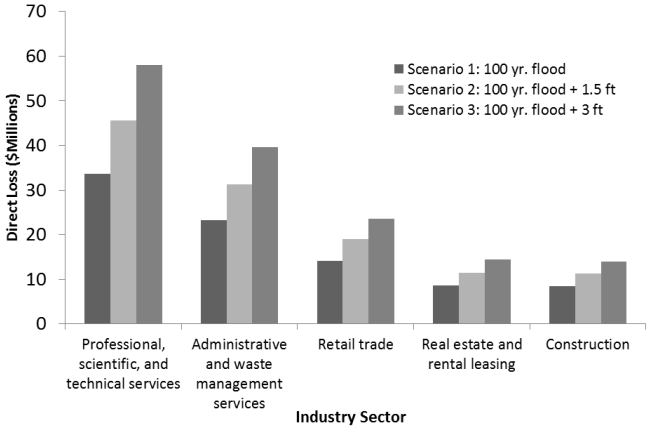


Input-output modeling: REAcct REMI Others

Direct Impacts

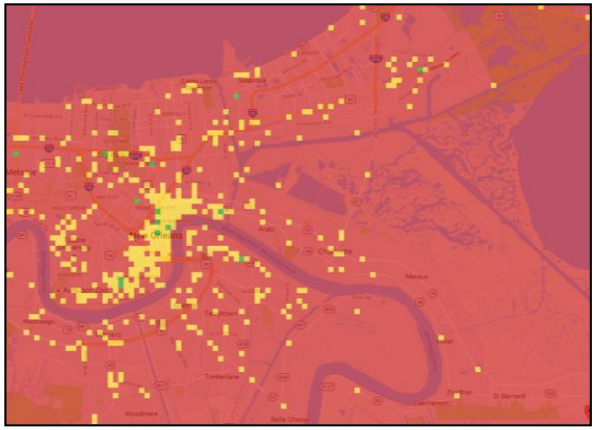


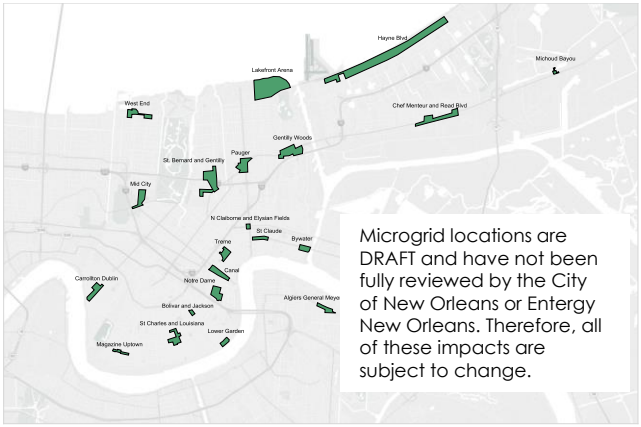
Indirect Impacts



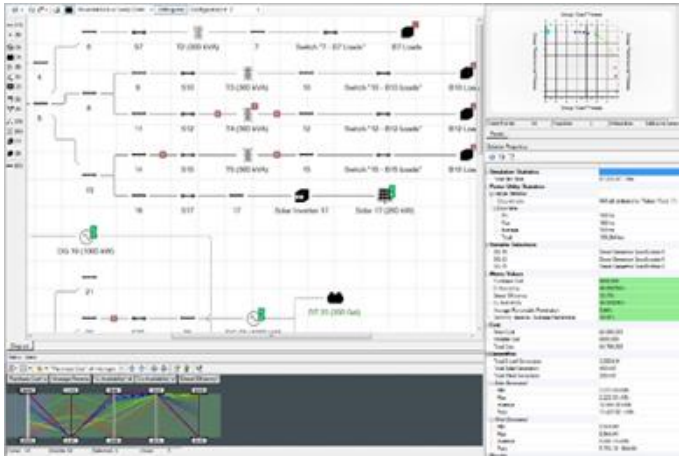
Design resilience solutions with metrics in mind

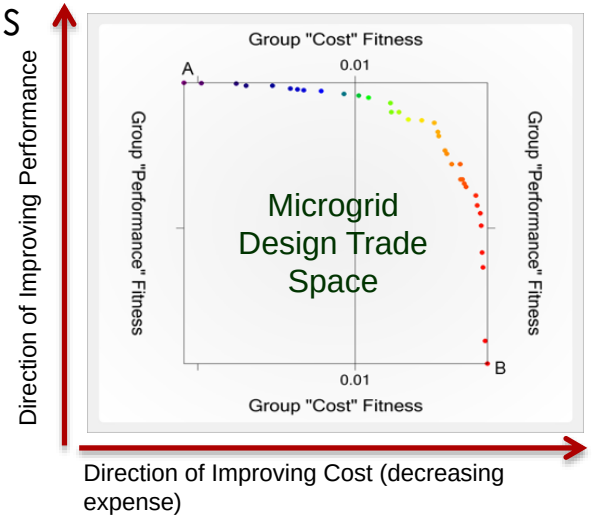
ReNCAT: Optimize selection of buildings for increased energy resilience based on consequence-focused resilience metrics





MDT: Microgrid Design Toolkit – optimizes technology selection and sizing for individual microgrids based on multiple metrics





Enabling NATIONAL Resilience

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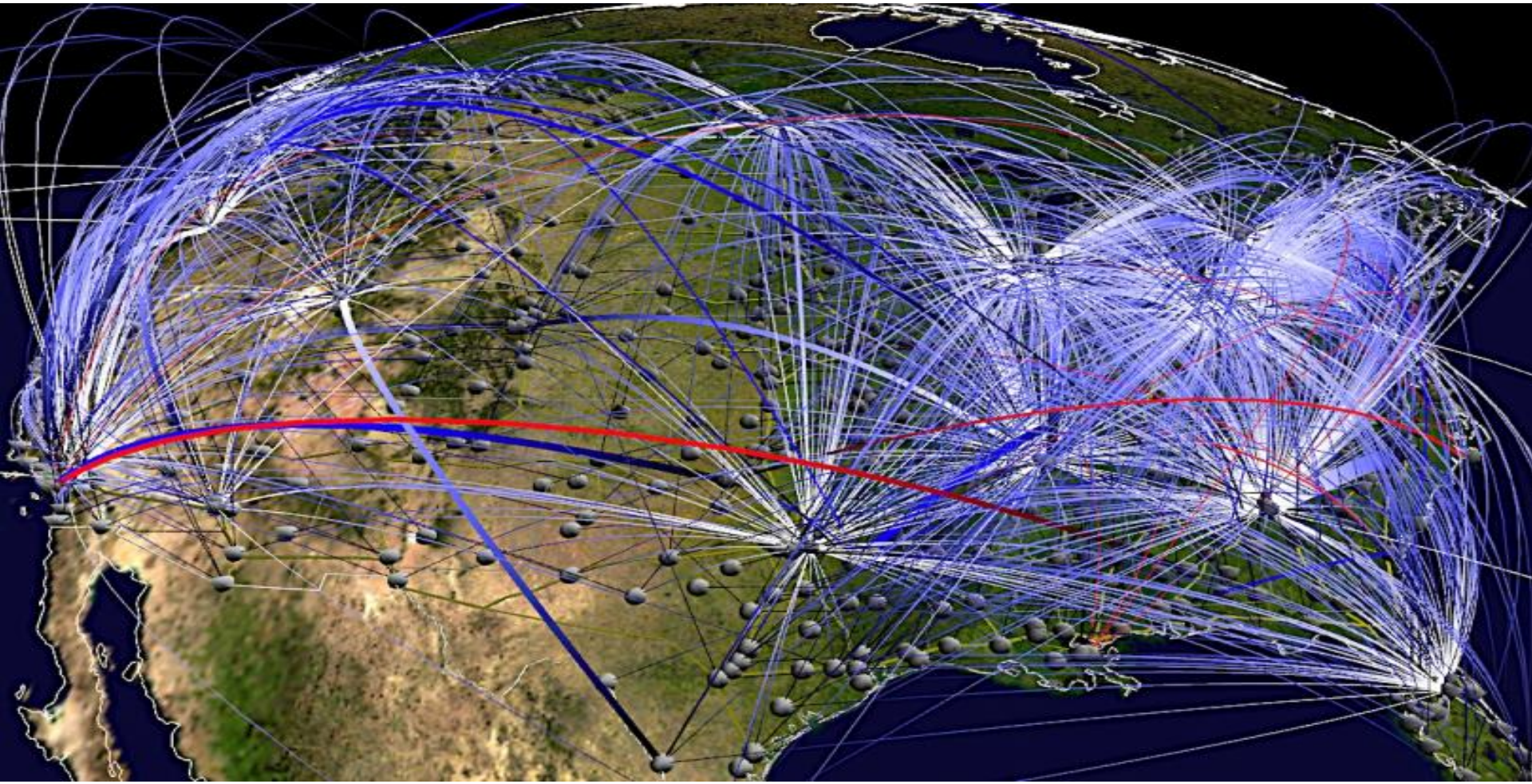

"Giving cities access to world-class analytical talent like Sandia is exactly what is needed to build resilient cities."

-Christine Morris, Chief Resilience Officer, Norfolk, VA

Backup Slides follow

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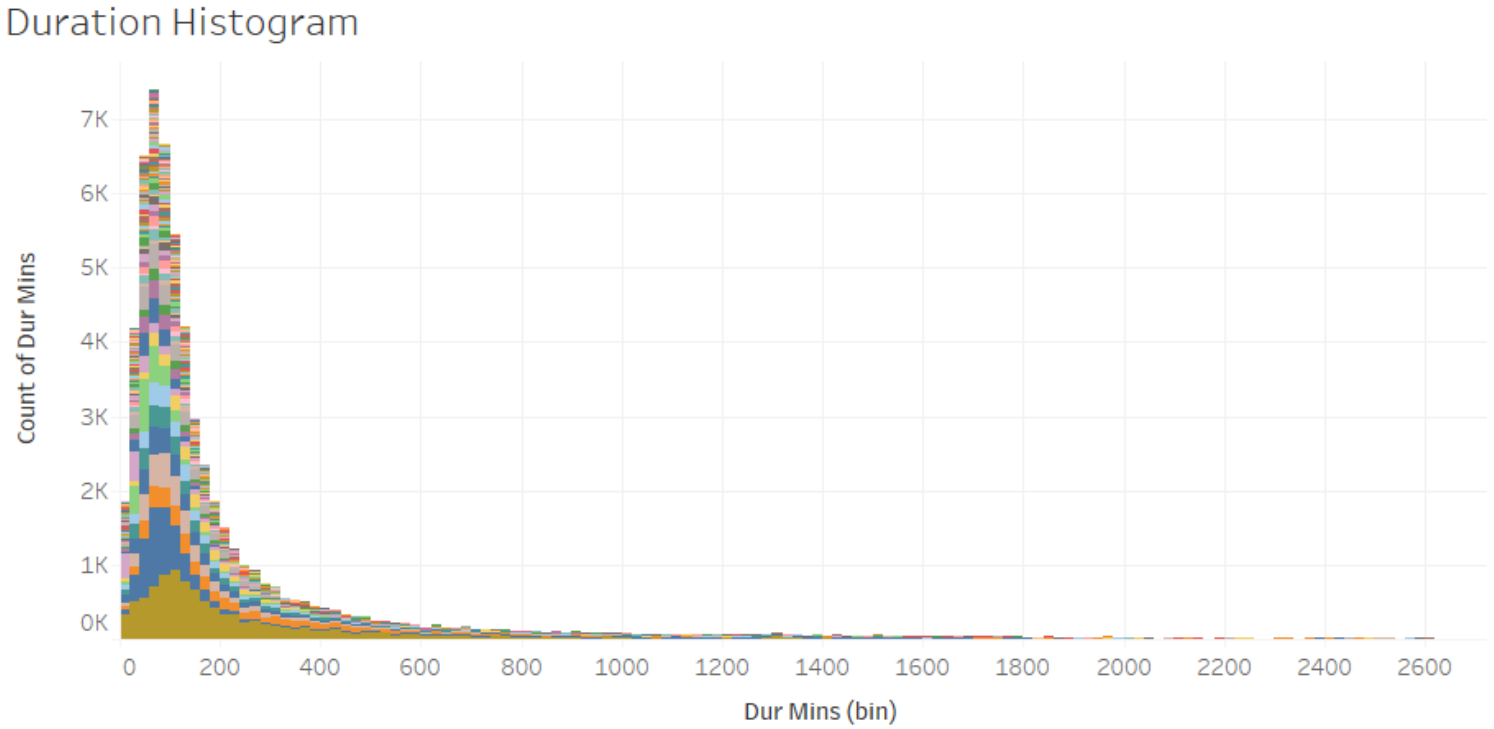
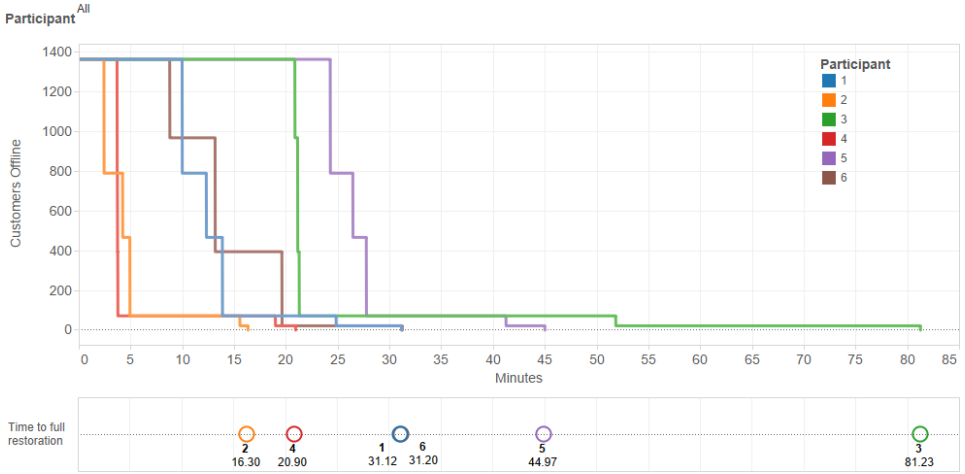
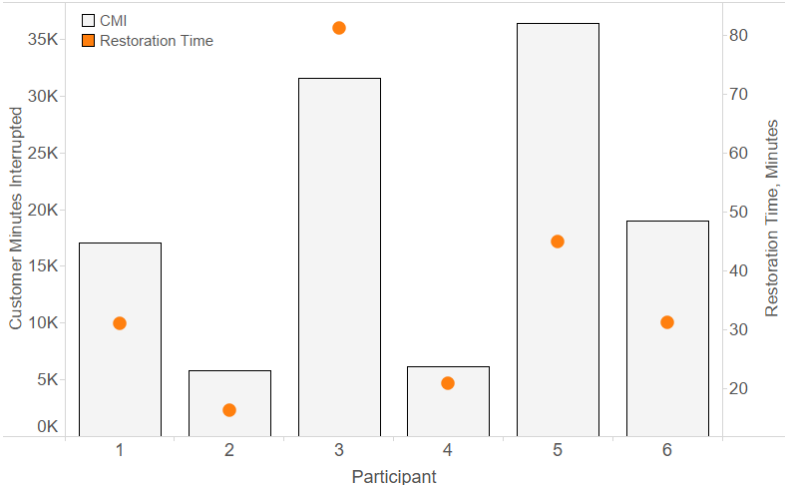
rfjeffe@sandia.gov

We know more than we simulate







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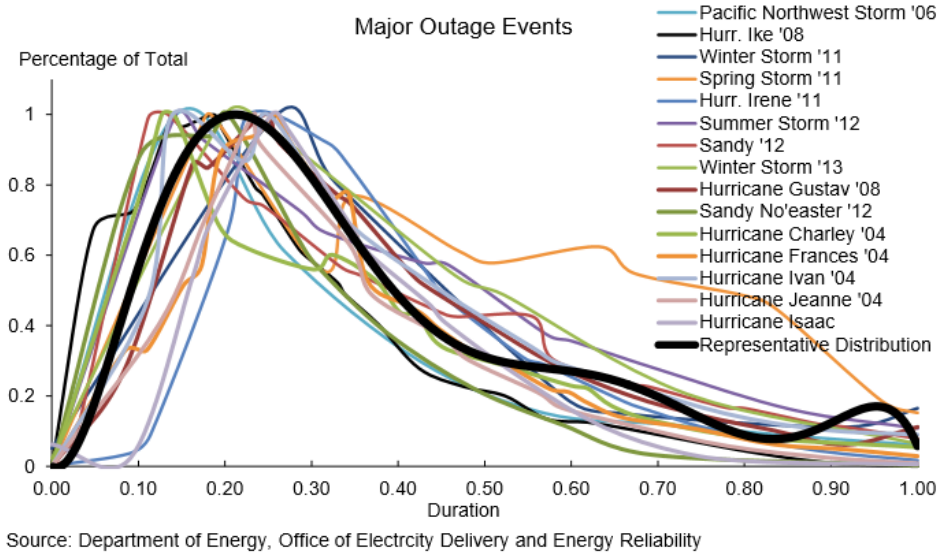
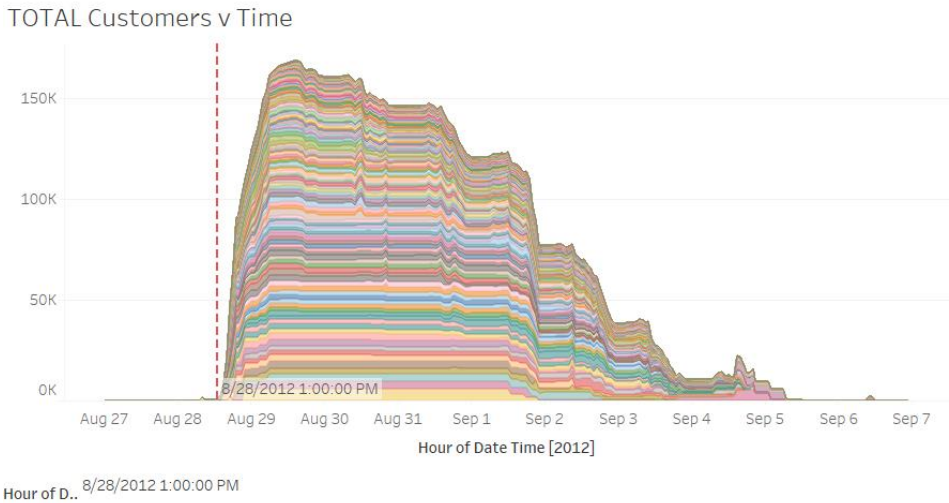
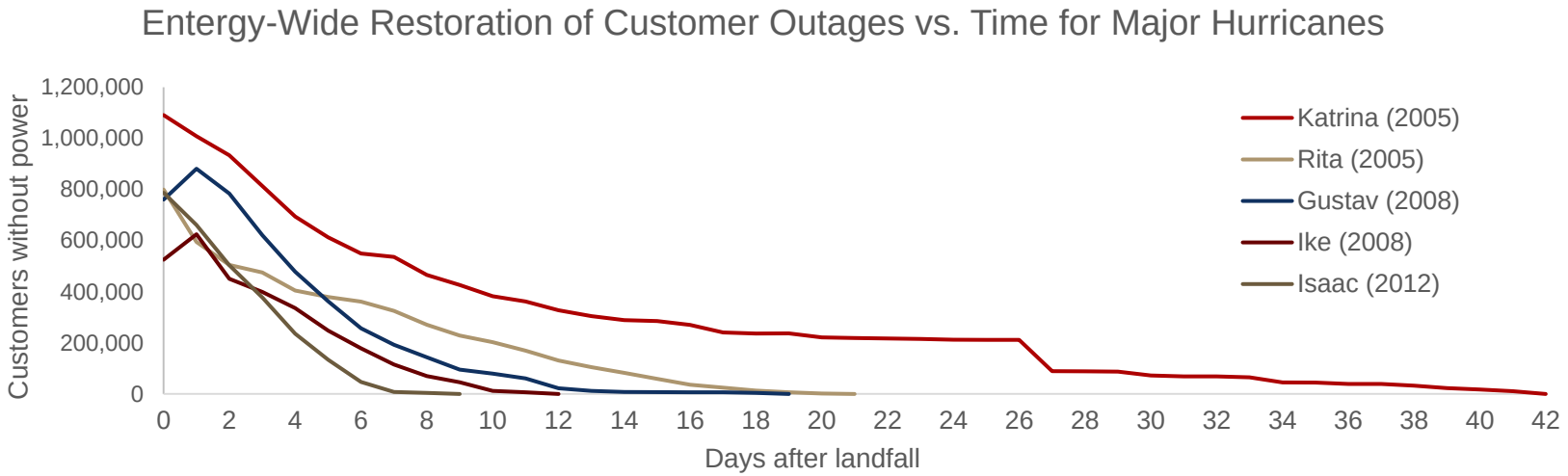


Source: Department of Energy, Office of Electrcity Delivery and Energy Reliability





Mapping Key Infrastructures to Resilience

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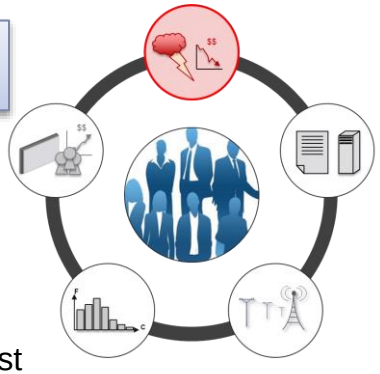
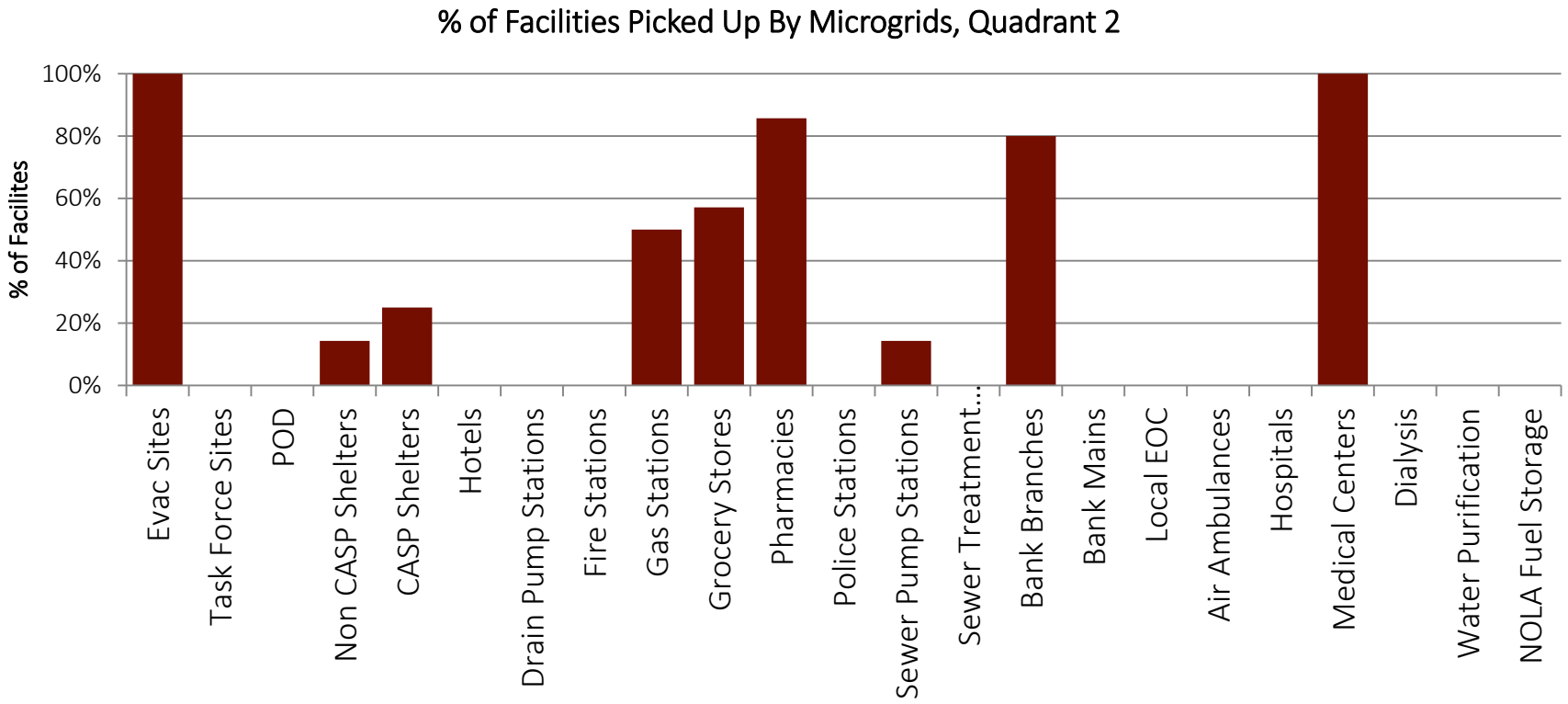
"Lifeline" Infrastructure Services			
Electric Power	Entergy, SWBNO	Food	Commercial, PODs
Drinking water	SWBNO, PODs	Emergency Response	Police, Fire, 911
Dewatering	SWBNO	Communications	Voice, data, broadcast
Sewerage	SWBNO	Finances	Banks, ATMs
Medical Services	Hospitals, Pharmacies	Transportation	Fuels, Road clearing
Shelter	City shelters, Schools		



Community Resilience:

- Ability to prepare for, adapt to, and recover rapidly from changing, non-normal events
- Metrics can include people without access to lifeline services, for how long, and at what consequence
- Consider upstream and downstream supply-chain impacts

Prioritize and select resilience nodes based on clustering and requirements of each region



Some infrastructure sectors will benefit more from non-microgrid solutions, such as localized backup generation or improvement of the existing distribution system.

Ensure city-wide coverage of centralized infrastructure services is adequate