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Adapting Existing Energy Models for Resilience Analysis

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ThB11. Economic and Technological Challenges facing Resilient Energy Infrastructure

“Defining” Resilience

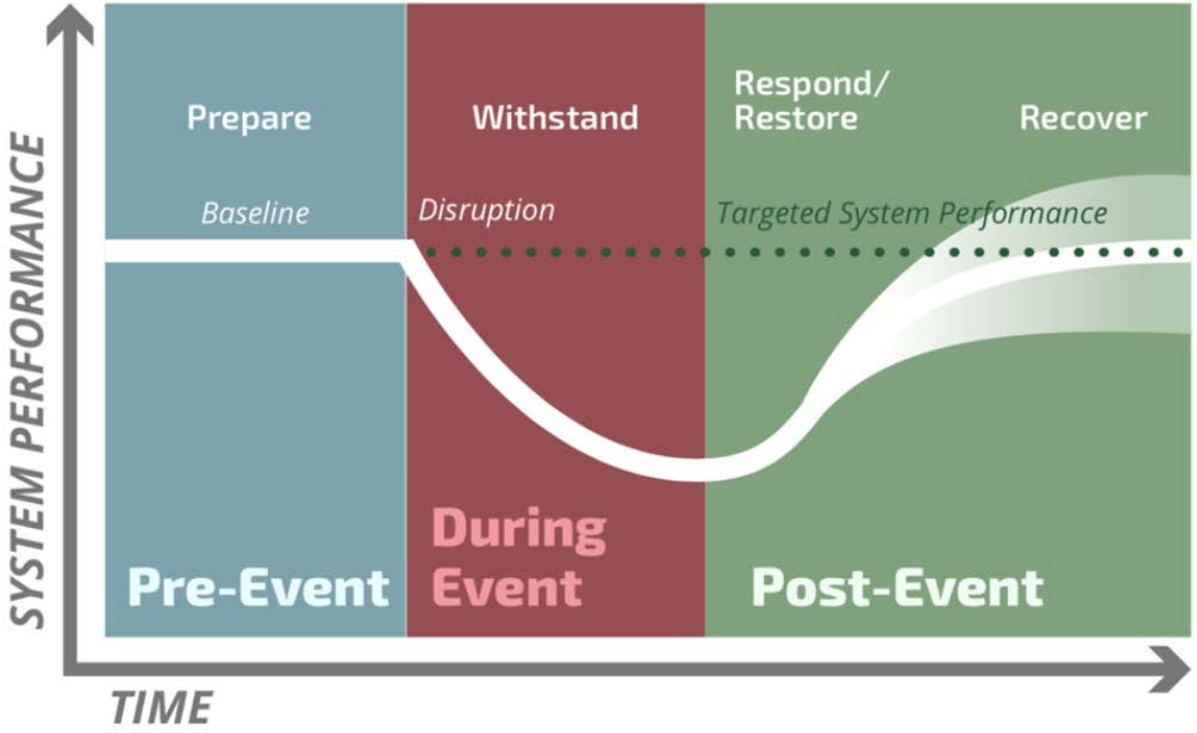


Figure 1. System Performance Curve and Timeline

Castillo et al. (2020), SAND2020-11292

“Defining” Resilience

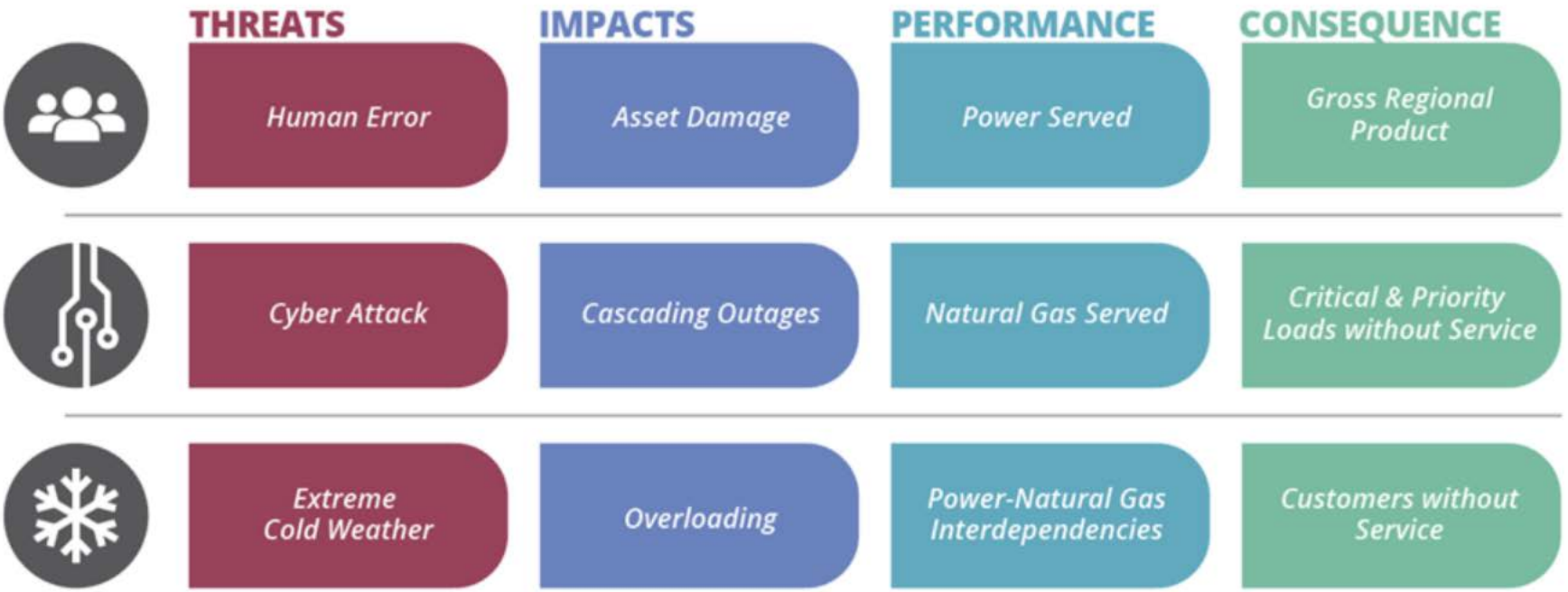


Figure 5. Notional Representation of the Translation of Threats into Consequences

Castillo et al. (2020), SAND2020-11292

Resilience Metrics (or Indicators)

Energy sector resilience can be quantified through temporally explicit performance-based metrics or indicators (e.g., comparing baseline and investment scenarios)

Table S.1. Examples of Consequence Categories for Consideration in Grid Resilience Metric Development

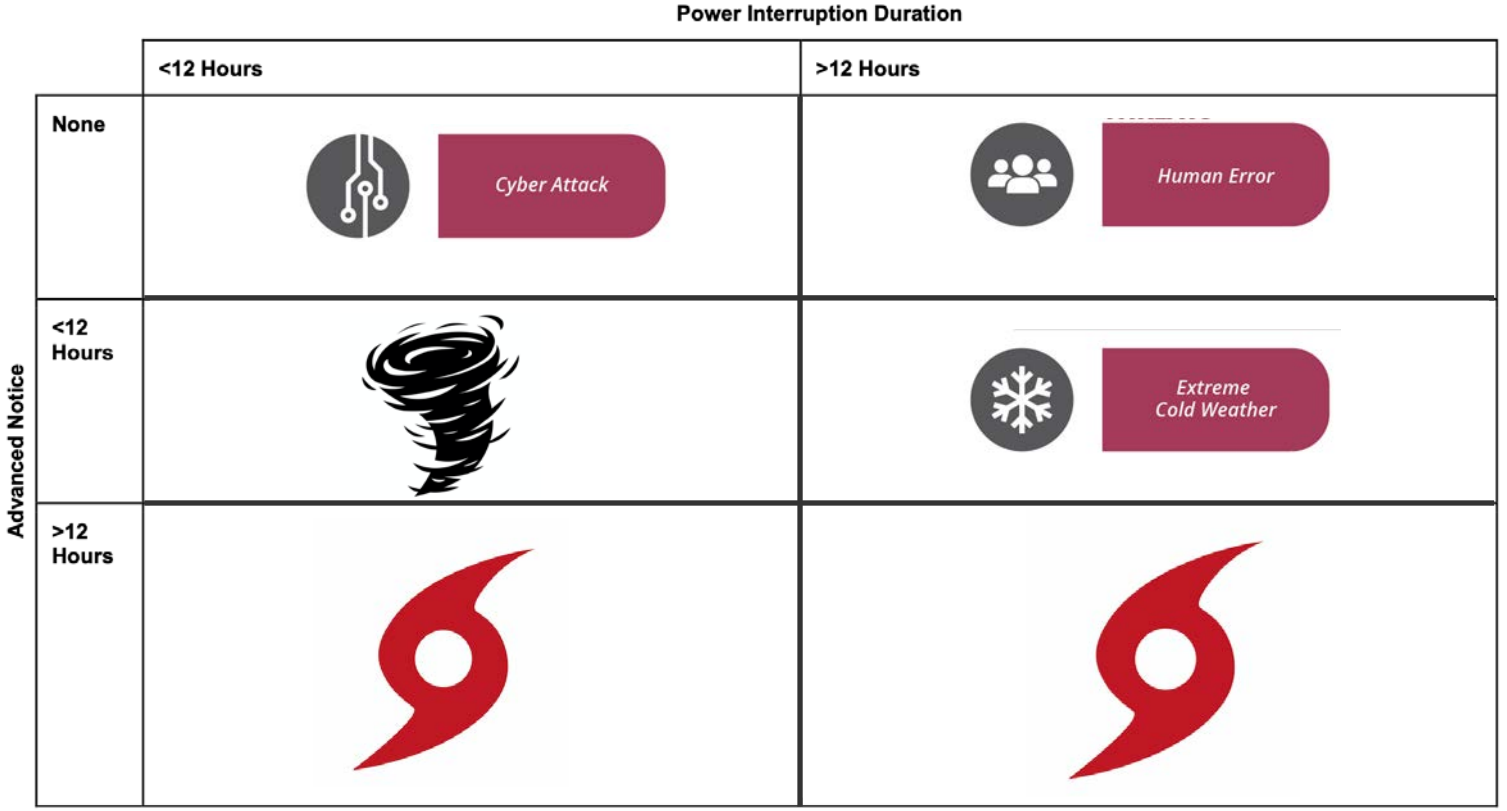
Consequence Category	Resilience Metric
Direct	
Electrical Service	Cumulative customer-hours of outages
	Cumulative customer energy demand not served
	Average number (or percentage) of customers experiencing an outage during a specified time period
Critical Electrical Service	Cumulative critical customer-hours of outages
	Critical customer energy demand not served
	Average number (or percentage) of critical loads that experience an outage
Restoration	Time to recovery
	Cost of recovery
Monetary	Loss of utility revenue
	Cost of grid damages (e.g., repair or replace lines, transformers)
	Cost of recovery
	Avoided outage cost
Indirect	
Community Function	Critical services without power (e.g., hospitals, fire stations, police stations)
	Critical services without power for more than N hours (e.g., $N >$ hours of backup fuel requirement)
Monetary	Loss of assets and perishables
	Business interruption costs
	Impact on Gross Municipal Product or Gross Regional Product
Other Critical Assets	Key production facilities without power
	Key military facilities without power

https://gmlc.doe.gov/sites/default/files/resources/GMLC1.1_Vol3_Resilience.pdf

This Study

- Challenge: Doing resilience analysis “right” requires substantial computational resources and data that are often not available; so what else can you do?
- Interim Solution: modify existing modeling tools to enable imperfect (yet impactful) resilience analyses
  - Define power interruption scenarios
  - Identify key metrics, based on existing model architecture
  - Perform preliminary scenario analysis to demonstrate the ability to inform decisions

Power Interruption Scenarios



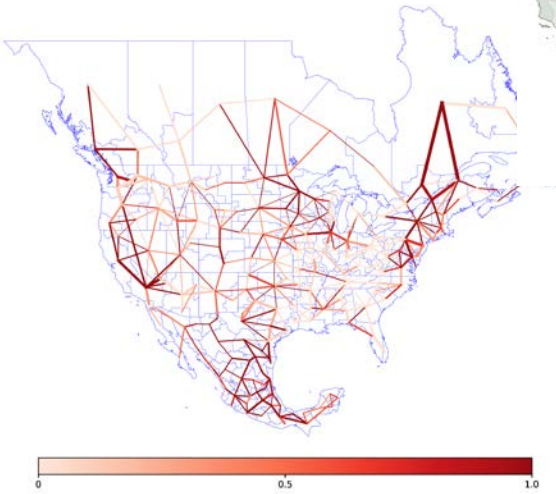
https://www.nrel.gov/docs/fy20osti/74241.pdf

Approach

Adapt a wide array of energy sector modeling tools to enable imperfect (yet impactful) resilience analysis, sampling a variety of:

- Energy subsectors
- Geographic scales
- Modeling methods
- Resilience metrics

ResStock



REopt
Renewable Energy Integration and Optimization

https://www.nrel.gov/docs/fy20osti/74241.pdf

Results: PRAS

Model Description: Probabilistic simulation of simplified power system operations and load shortfalls

Model Update: Development of a sequential simulation mode for tracking storage device state-of-charge

Power Interruption Scenario: Long-duration fuel supply disruption with no notice

Resilience Metric: Expected unserved energy (EUE)

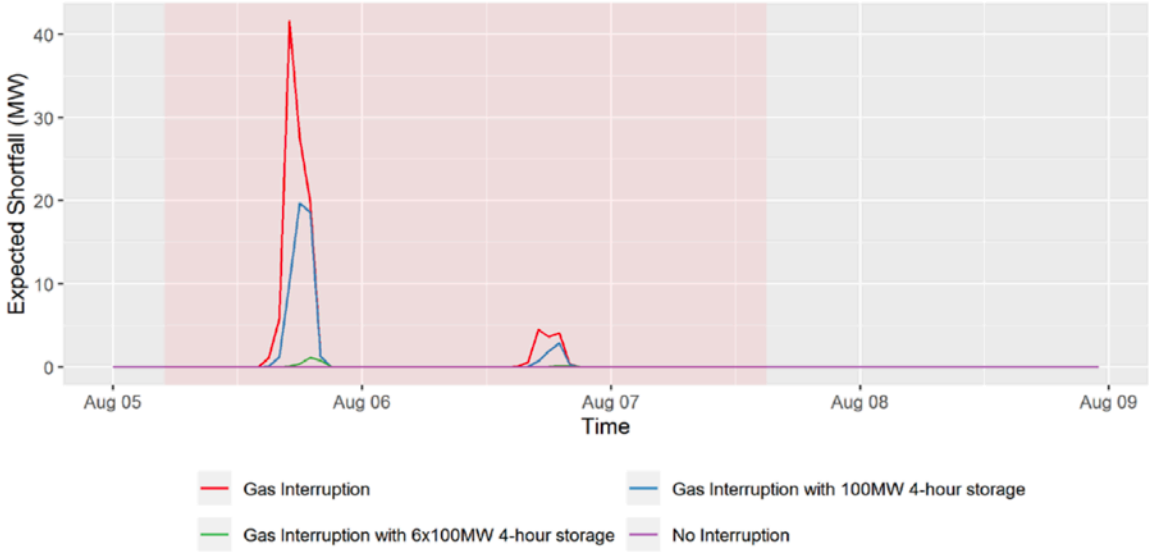


Figure 3. Expected unserved energy across natural gas disruption scenarios with varying levels of energy storage capacity, as modeled in PRAS

The four lines demonstrate the expected shortfall (in megawatts) that could occur under scenarios with varying assumptions about natural gas supply interruption and installations of four-hour battery storage systems. Obtaining the total lost load (in megawatt-hours) requires multiplying the expected magnitude and duration of the shortfall.

https://www.nrel.gov/docs/fy20osti/74241.pdf

Results: SIIP::Power

Model Description: Least-cost optimization of day-ahead and real-time bulk power system scheduling problems

Model Update: Development of a methodology for co-optimizing the dispatch of generation with the avoided power interruption cost

Power Interruption Scenario: Long-duration power disruption with no notice

Resilience Metric: Location- and duration-dependent value of lost load (VoLL)

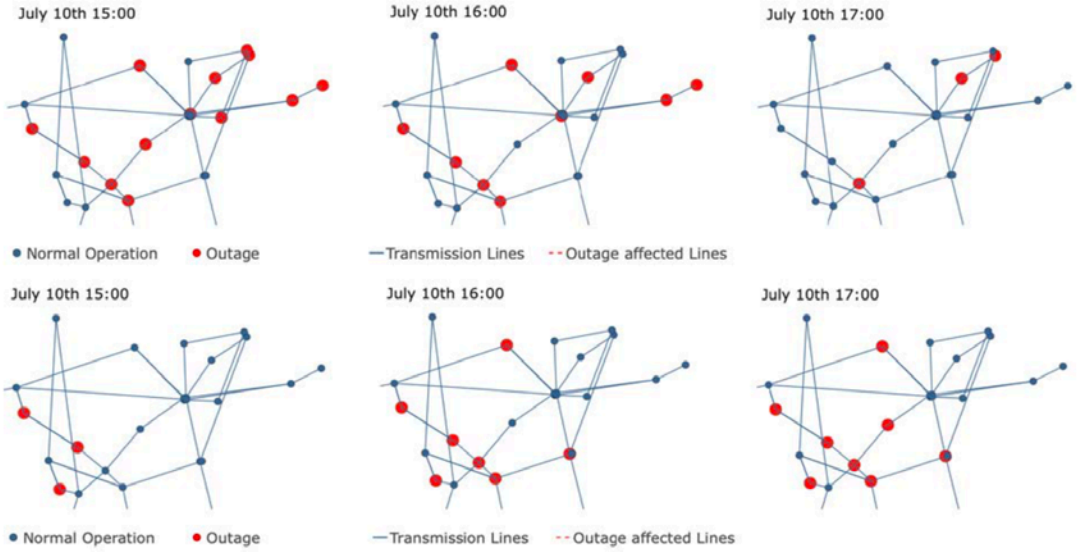


Figure 4. Under degraded conditions, considering a duration-dependent value of lost load resulted in a modified system dispatch, which reduced outage duration at each bus and overall system costs, as modeled in the production cost model framework in SIIP::Power.

Results shown here represent system dispatch in Region 1 of the RTS-GMLC under a power interruption scenario that resulted in a 15% loss in available generation capacity for 12 hours. The top row shows the dispatch pattern that resulted from consideration of a duration-dependent VoLL, whereas the bottom row considers only a static VoLL.

https://www.nrel.gov/docs/fy20osti/74241.pdf

Results: ResStock

Model Description: Physics-based simulation of the energy use and thermal performance of the U.S. residential building stock

Model Update: Development of methods for (1) representing a power outage and (2) measuring thermal resilience

Power Interruption Scenario: Long- and short-duration extreme weather with “no notice”

Resilience Metric: time to unsafe indoor conditions

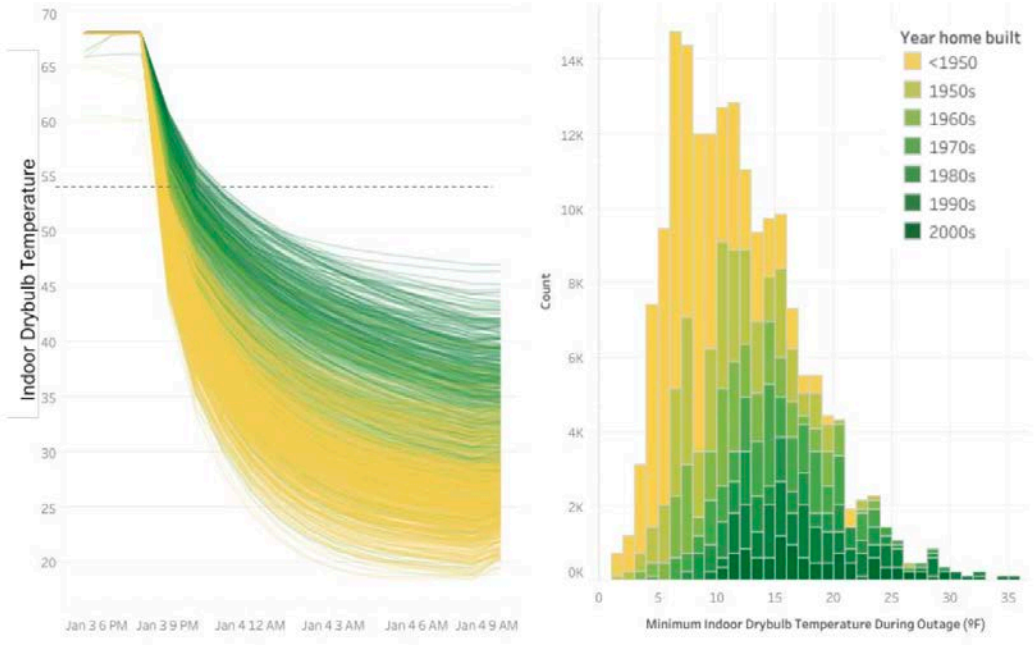


Figure 1. Internal temperature trajectories (left) and distribution of minimum indoor temperatures (right) for buildings in Buffalo, New York, during a power interruption resulting from a hypothetical 12-hour ice storm, as modeled in ResStock

Newer homes, presented in green, typically maintained a livable internal temperature for longer during the hypothetical ice storm, and they maintained higher temperatures overall over the course of the outage.

https://www.nrel.gov/docs/fy20osti/74241.pdf

Conclusions

- Challenge: Doing resilience analysis “right” requires substantial computational resources and data that are often not available
- Interim solution: be creative!
- Long-term solution: develop models that can directly quantify the resilience of energy infrastructure
  - Durability/survivability of equipment against threats
  - Financial risks associated with investments
  - Bulk power system recovery/restoration

Thank you!

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Study URL: https://www.nrel.gov/docs/fy20osti/74241.pdf

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