The Role of Energy Storage in a Resilient and Decarbonized Grid

PRESENTED BY

Bobby Jeffers, PhD

SAND2021-1377 PE

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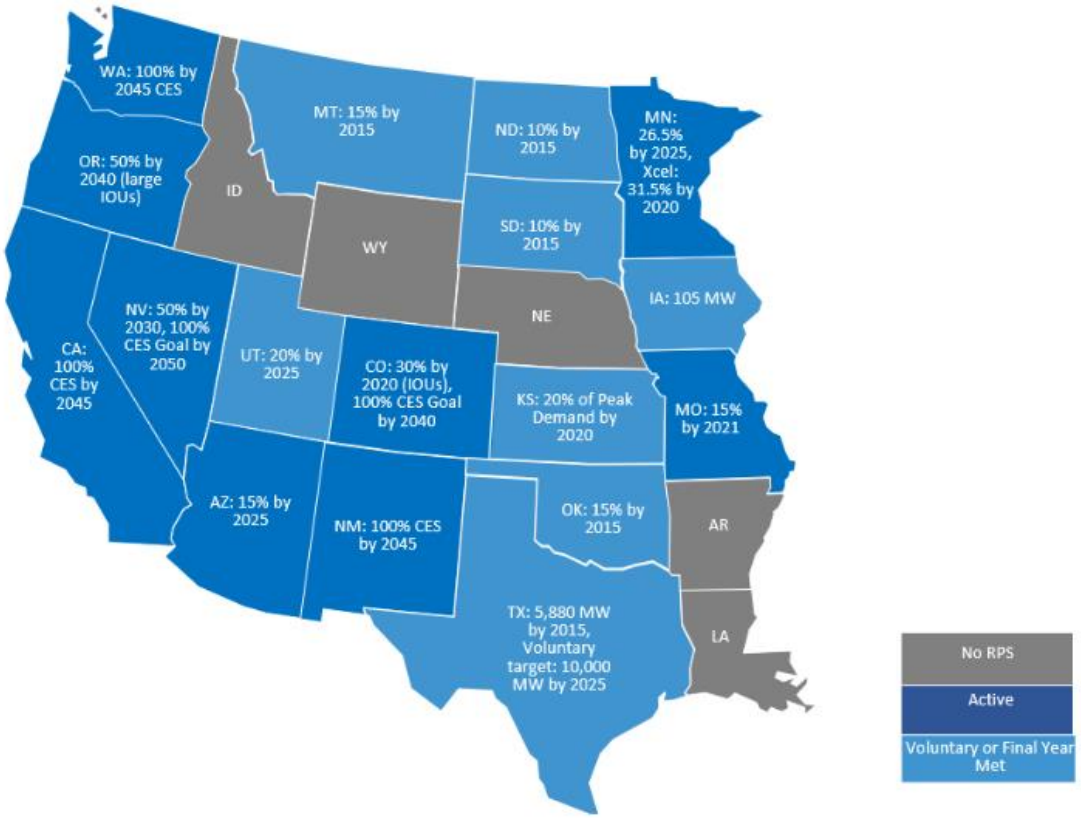
16 states have enacted ambitious decarbonization objectives.

10 of them are 100% and binding:

- California
- Hawaii
- Washington
- Nevada
- Arizona
- New Mexico
- Colorado
- New York
- Maine
- Virginia

Exhibit 43. Clean and Renewable Energy Standards in WECC and SPP States (excluding voluntary standards)



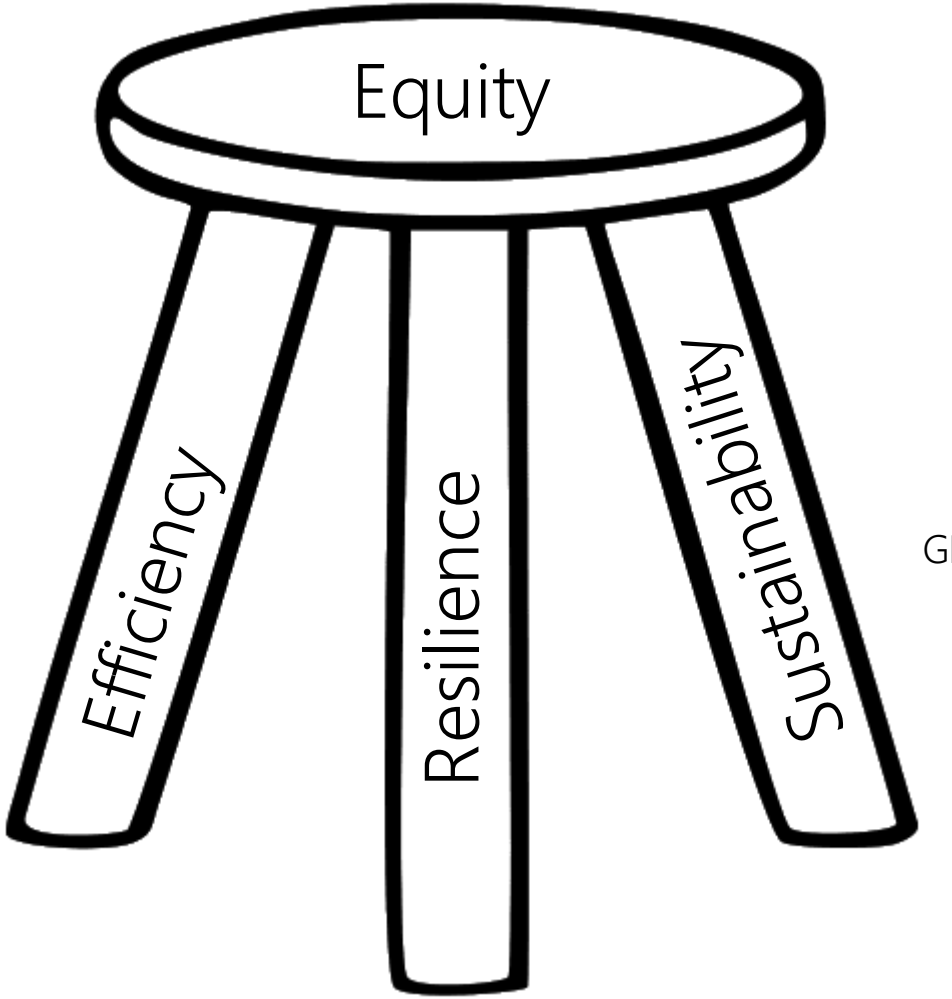
NM RETA study, 2020: https://nmreta.com/wp-content/uploads/2020/10/NM_RETA_Transmission_Study_June2020v2.pdf

Decarbonization

How do we design an energy future with zero GHG emissions?

How do we design an equitable, affordable, and resilient energy future with zero GHG emissions?

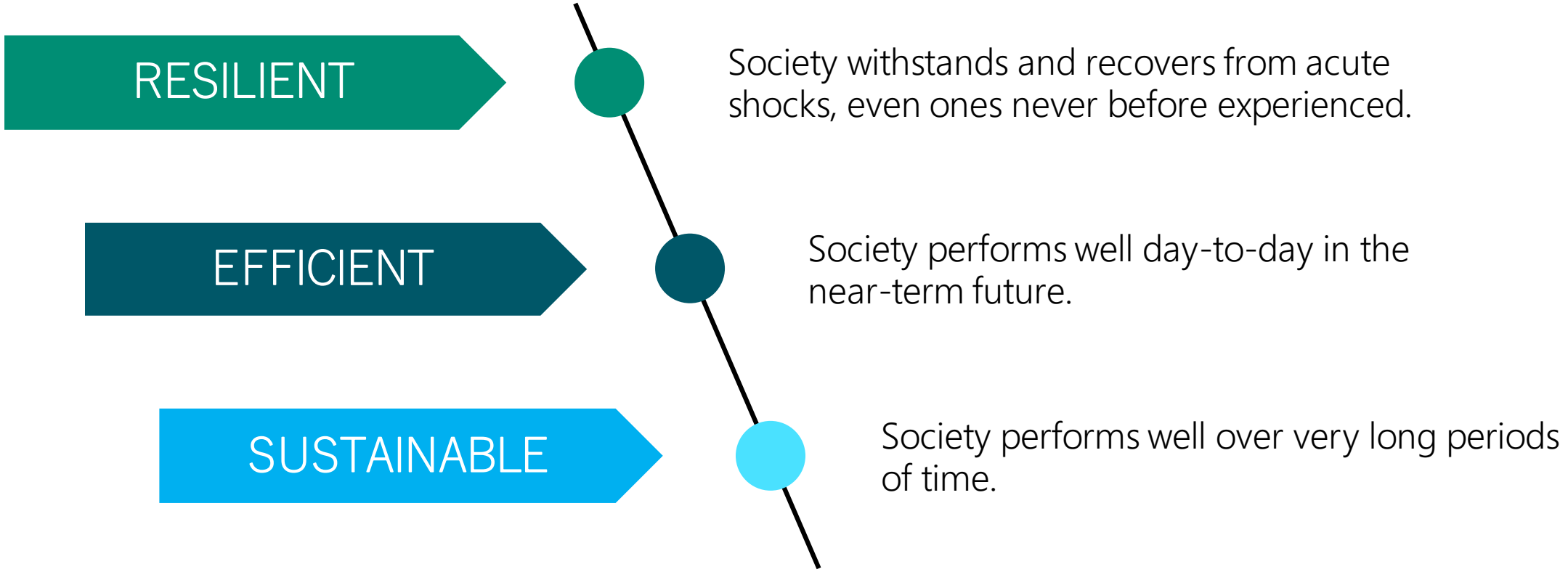
Three performance dimensions



Cost of Service
Customer Bills
…

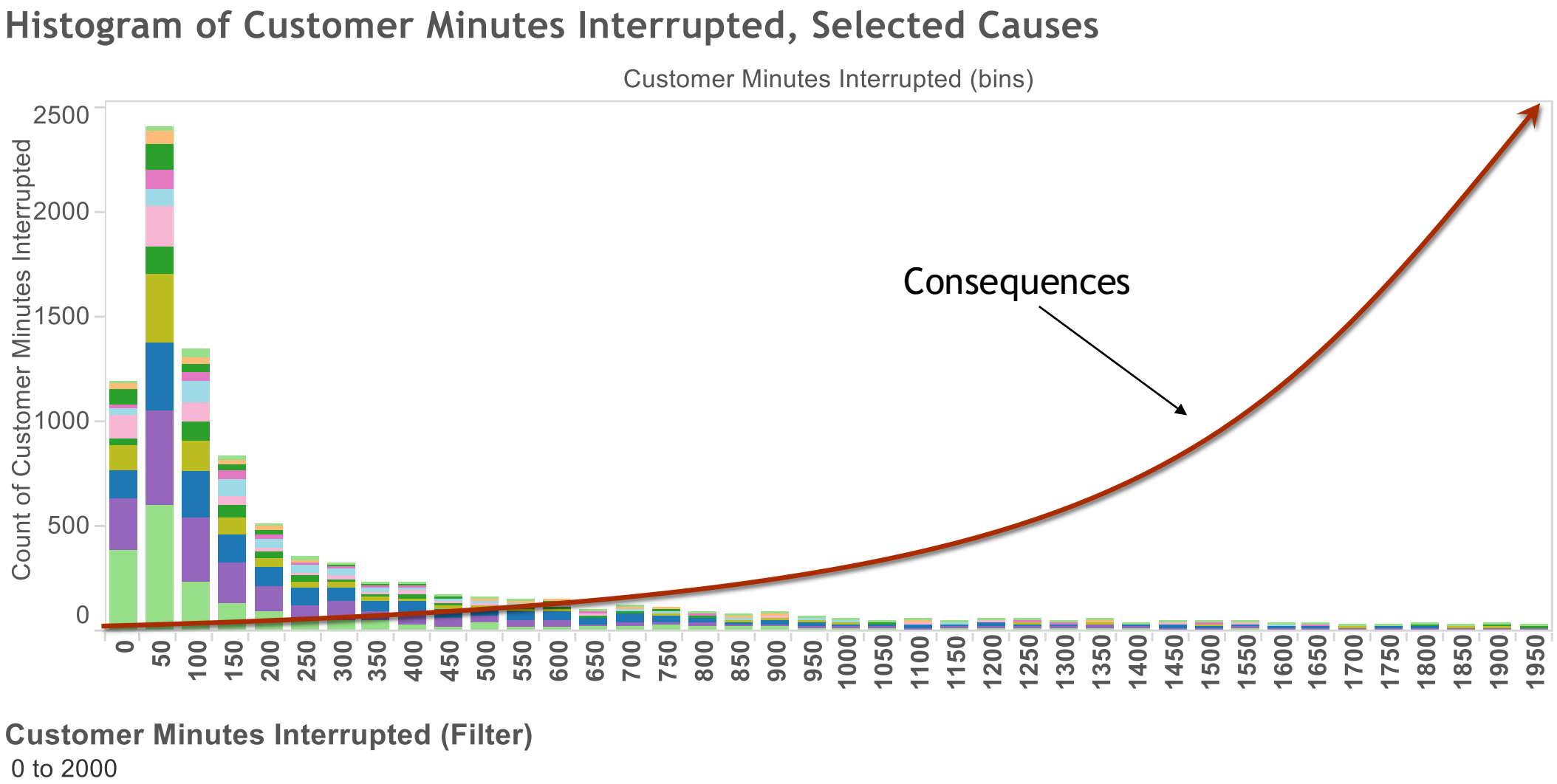
GHG Emissions
Land Use
…

Loss of Load Expectation
MWh not served
…



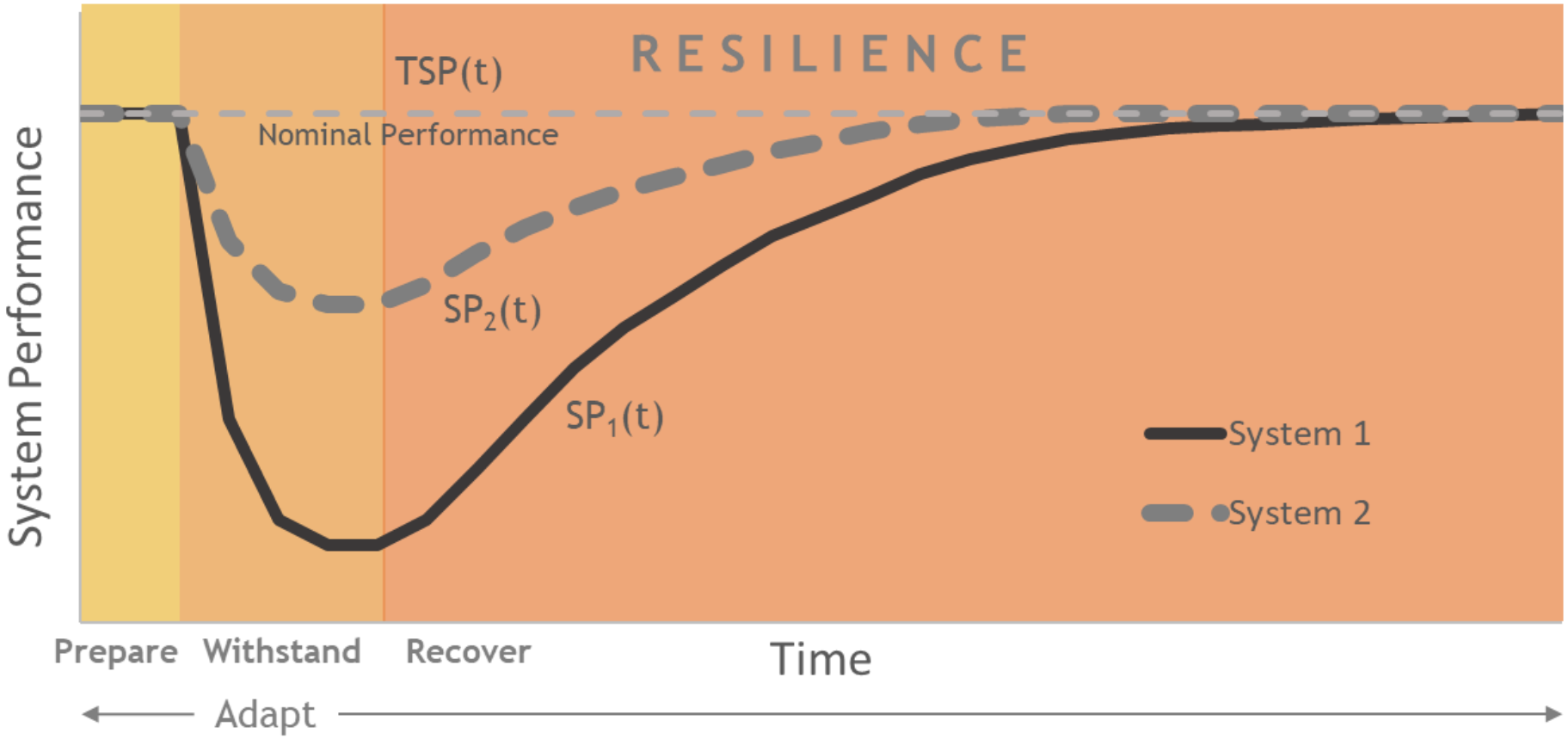
At all scales (T, D, Buildings, Vehicles), there are very real tradeoffs between performance in these dimensions.

Reliability is a subset of resilience



Because consequences to society increase exponentially with duration and extent of outages, a “load not served” metric is not adequate for resilience

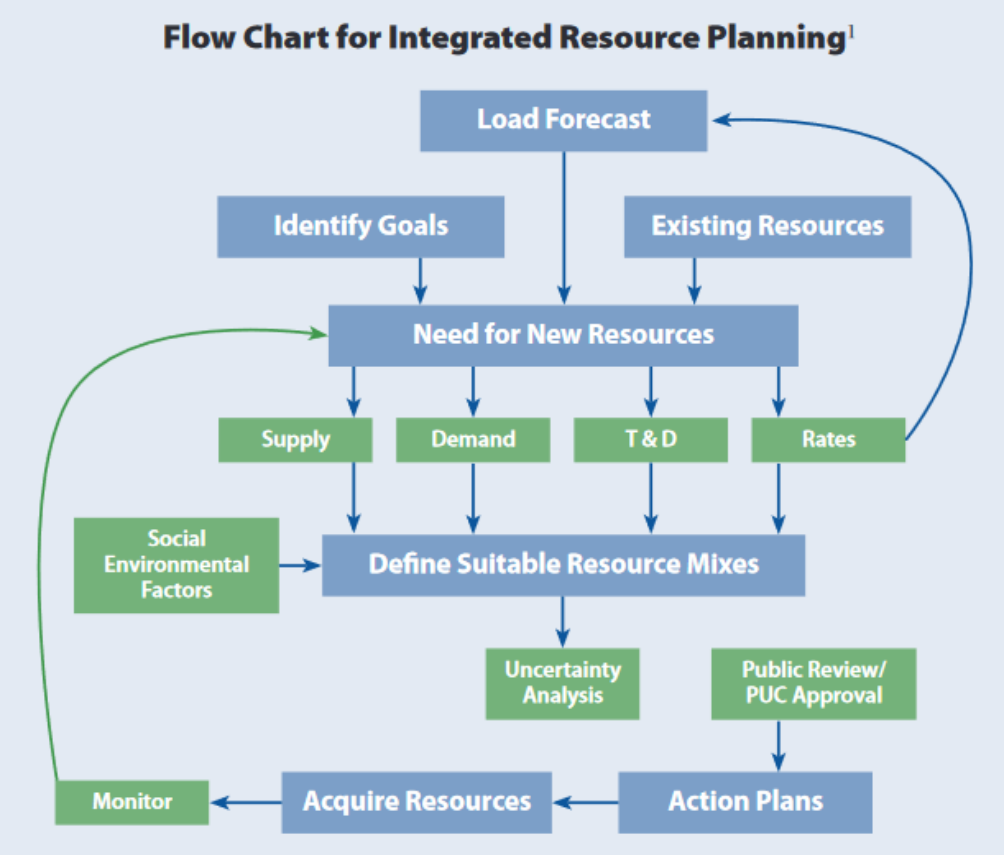
Measuring and forecasting resilience



Resilience metrics should:

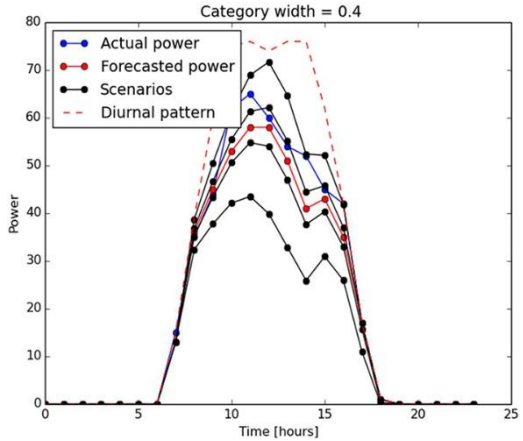
- Convey the wide variance among outages in terms of size, duration, and impact on customers
- Focus on the impact on critical sectors, capture context of the threats
- Translate system performance into consequence, where the severity of consequences can change nonlinearly over time

Integrating resilience within regulatory decision making



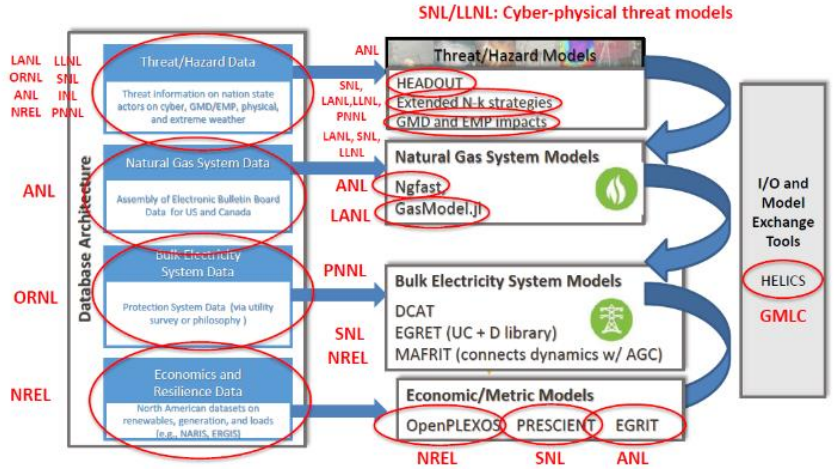
https://www.raponline.org/wp-content/uploads/2016/05/rapsynapse-wilsonbiewald-bestpracticesinirp-2013-jun-21.pdf

Stochastic Production Cost/ Capacity Expansion



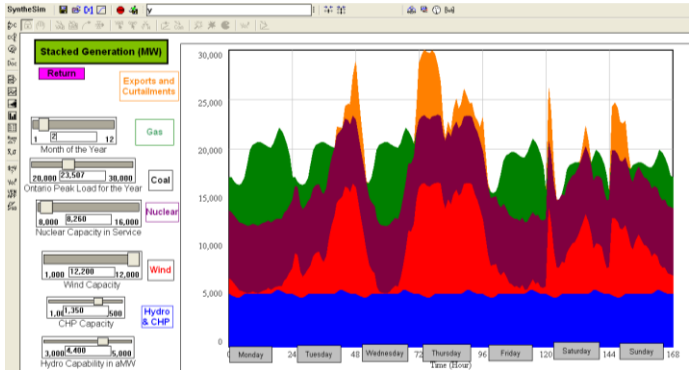
https://energy.sandia.gov/sandia-develops-stochastic-production-cost-model-simulator-for-electric-power-systems/

Grid Resilience Modeling

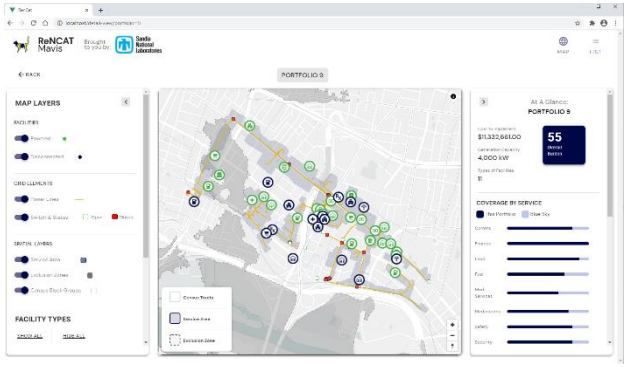


https://www.energy.gov/sites/prod/files/2019/07/f65/NAERM_Report_public_version_072219_508.pdf

Decision Support Tools



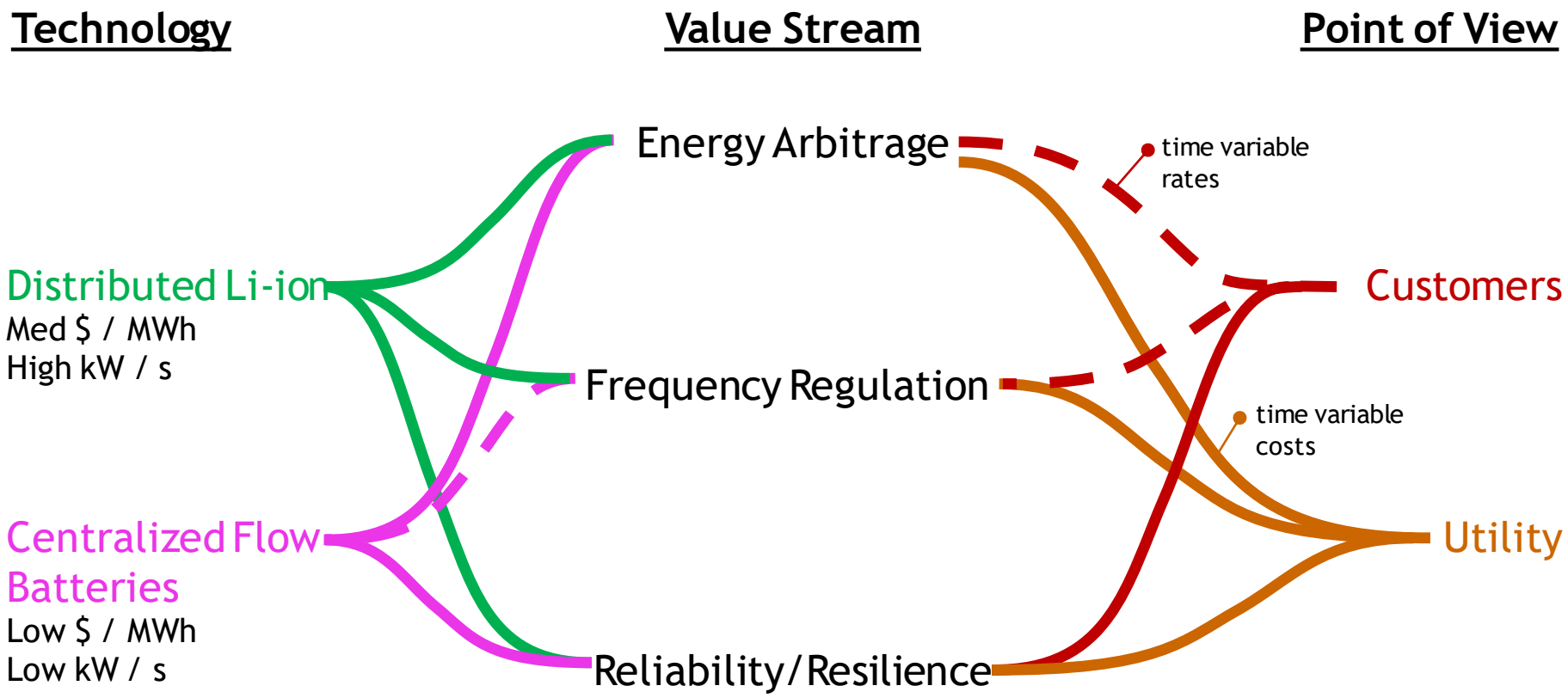
Resilience Valuation Tools



The role of energy storage

- Energy Arbitrage
- Renewable Integration
- Reliability / Resilience
- Avoided Investment
- Voltage Regulation
- Frequency Regulation
- Capacity

The "value" of energy storage depends on the value streams captured, point of view, and technology characteristics



Bhatnagar, D., Loose, V. (2012). *Evaluating Utility Procured Electric Energy Storage Resources: A Perspective for State Electric Utility Regulators*. Sandia National Laboratories, SAND2012-9422.

ES resilience value #1: stability

Energy storage (with the right inverter/control) is capable of:

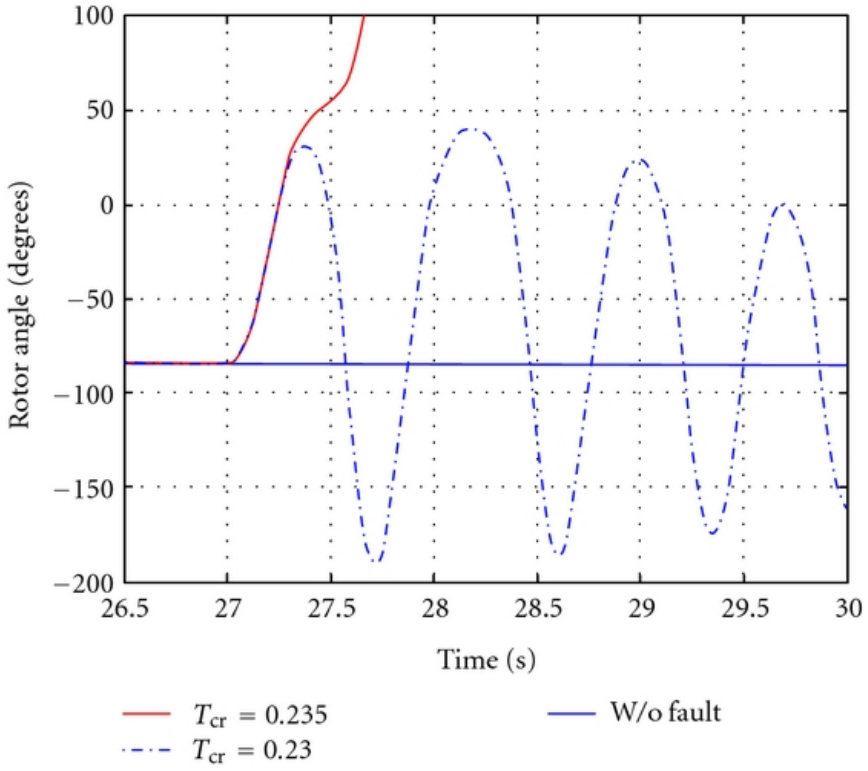
- Providing rapid **"tunable" inertia**
- Adjusting **reactive power independent of real power output**
- **Eliminating inter-area oscillation**

Energy storage can help to keep the grid from entering blackout conditions

Are we evaluating future stability of our grid under high renewable penetrations?

New tools being developed that can integrate this value into power system design and valuation:

- Sandia Egret / Prescient
- PNNL DCAT
- LANL LPNORM / RONM



Chakraborty, A. et al. (2012) Integrating STATCOM and Battery Energy Storage System for Power System Transient Stability: A Review and Application. Advances in Power Electronics, v 2012. https://www.hindawi.com/journals/ape/2012/676010/

Knueven, B., Laird, C., Watson, J-P., Bynum, M., and Castillo, A. Egret v. 0.1 (beta). Sandia National Laboratories. https://www.osti.gov/biblio/1498854 , https://github.com/grid-parity-exchange/Egret

R. Bent, G. L. Toole, and A. Berscheid. Transmission Network Expansion Planning with Complex Power Flow Models, IEEE Transactions on Power Systems, Volume 27 (2): 904-912, 2012.

NAERM:

https://www.energy.gov/sites/prod/files/2019/07/f65/NAERM_Report_public_version_072219_508.pdf

ES resilience value #2: outage ride-through

With the right (grid forming) inverter, Energy Storage can be the backbone of microgrids and mini grids

- Near-term, it's expensive to keep the entire grid energized in this way
- Where should we sight this technology to improve value?

NYU Microgrid during Superstorm Sandy

https://blogs.ei.columbia.edu/2017/04/18/microgrids-taking-steps-toward-the-21st-century-smart-grid/

Jury finds New Mexico utilities responsible for fire caused by downed power line

Cameron Strandberg from Rocky Mountain House, Alberta, Canada [CC BY 2.0 (https://creativecommons.org/licenses/by/2.0)], from Wikimedia Commons

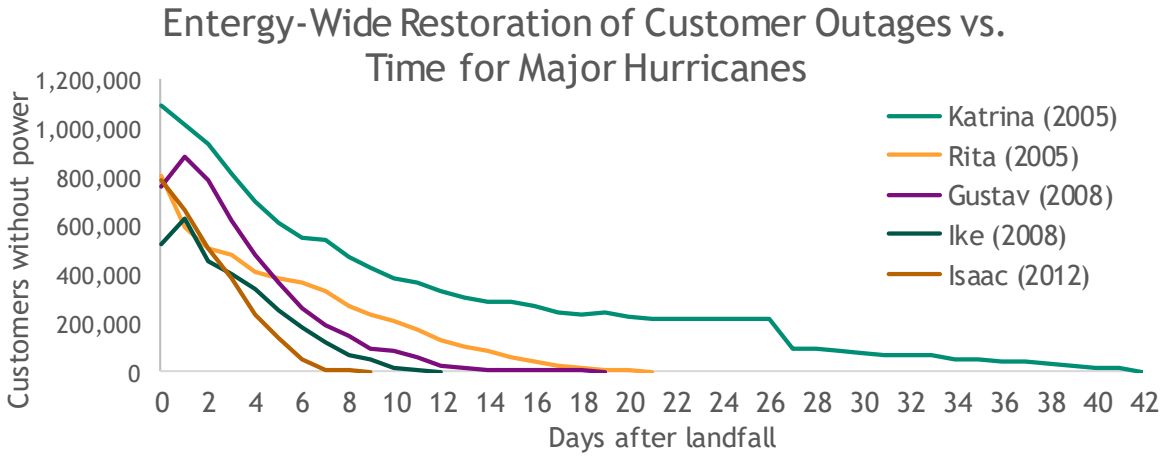
https://www.utilitydive.com/news/jury-finds-new-mexico-utilities-responsible-for-fire-caused-by-downed-power/408327/

Energy resources tested as Western states see soaring demand

Photo: Pixabay

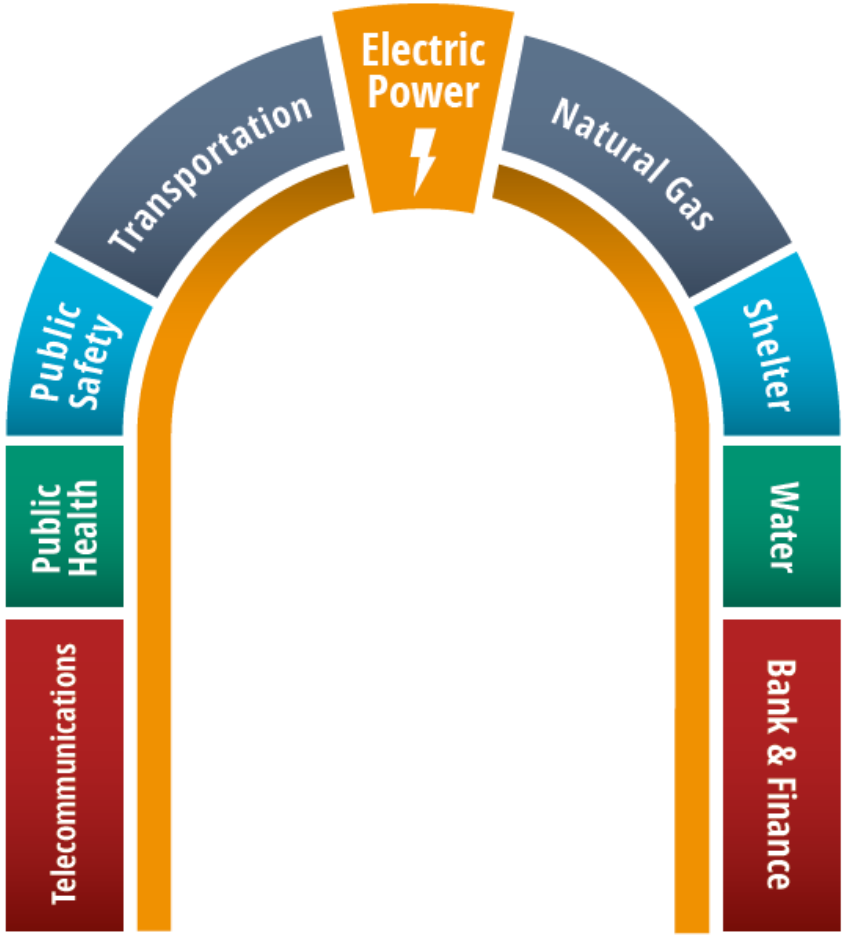
The Associated Press
Created: August 22, 2020 11:14 AM

https://www.kob.com/albuquerque-news/energy-resources-tested-as-western-states-see-soaring-demand/5835797/



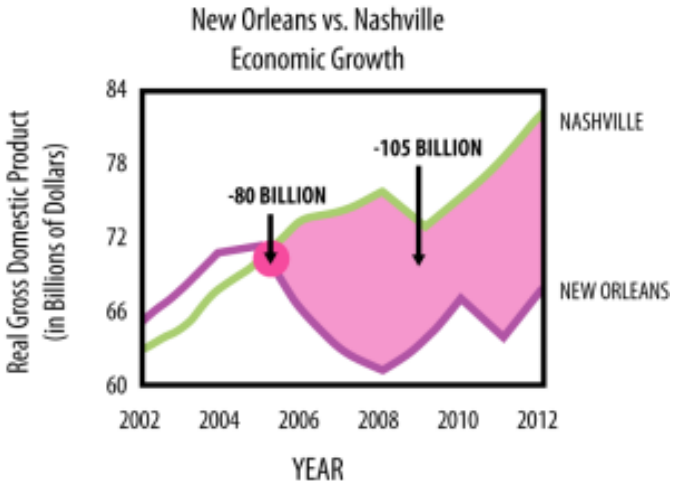
Estimating resilience value

The grid is the keystone infrastructure – central to the web of interconnected systems that support life as we know it.

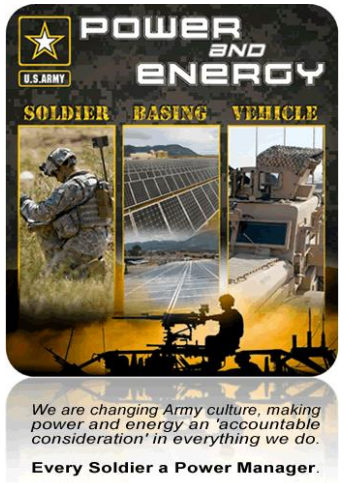


Society

Economy



National Security



Society

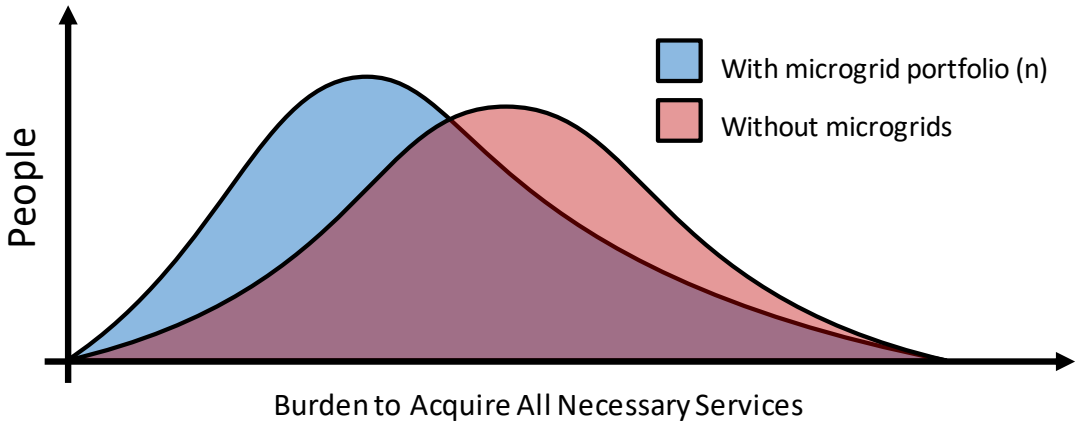
Effort
Time + money spent to achieve basic level of human needs

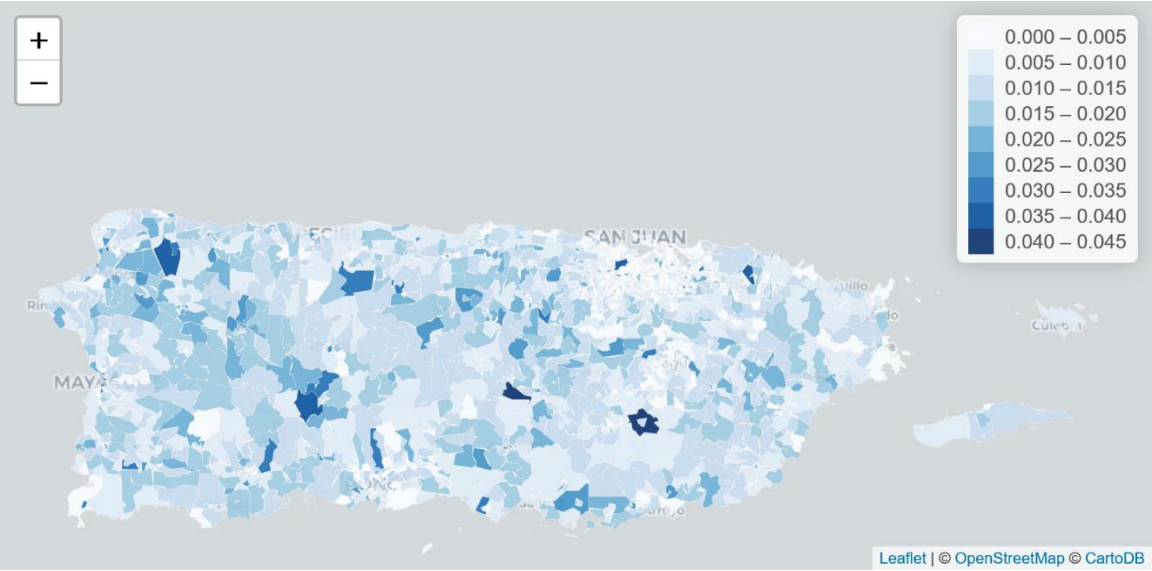
Ability
Median household income

Social Burden

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

Image credit: Wikimedia Commons user "Mdf"





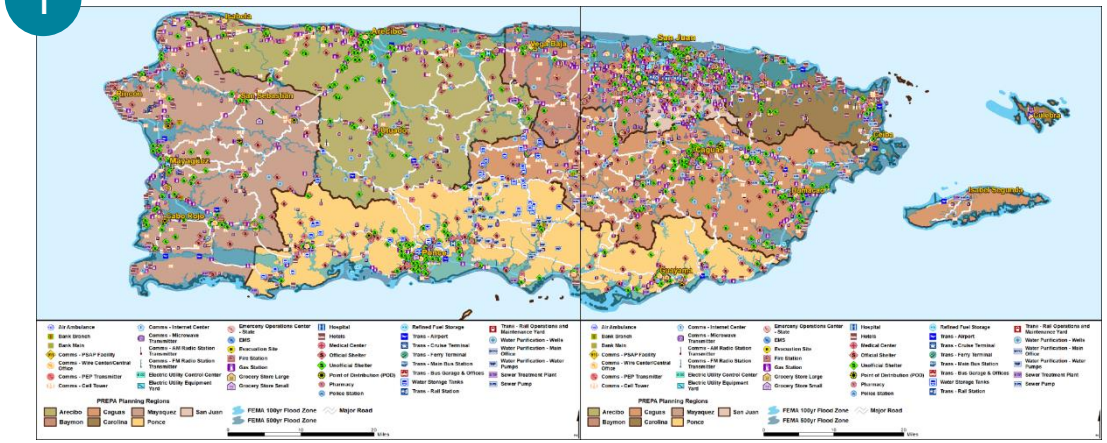
Jeffers et al. (2018) Analysis of Microgrid Locations Benefitting Community Resilience for Puerto Rico. SAND2018-11145

Burden by census block group for one random portfolio of ~50 microgrids

Society

- At the end of the **phase 1 PR recovery effort**, Sandia developed and demonstrated a process for siting and roughly sizing/costing microgrids with a focus on resilience metrics that quantify how well primary human needs are satisfied during and after disruptions.
- Phase 2 efforts resulted in the development of **ReNCAT 2.0**, which is intended to become an open-source environment for optimal distribution system investment planning

1



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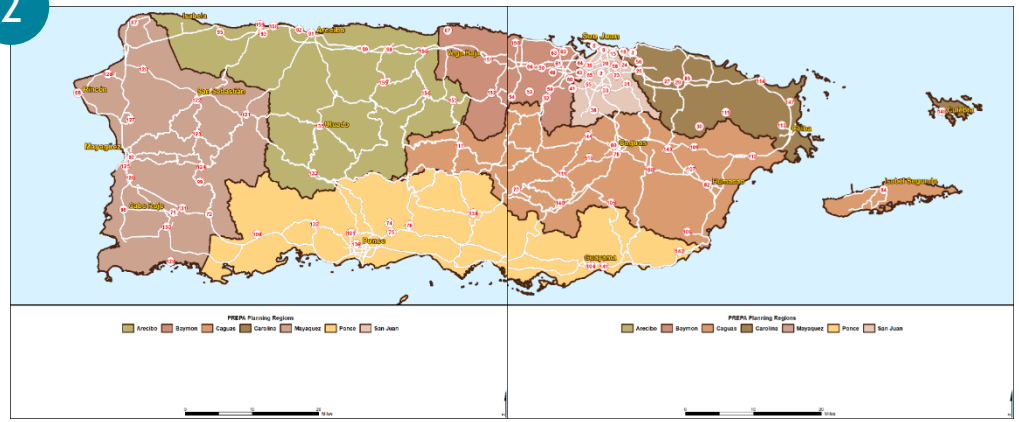

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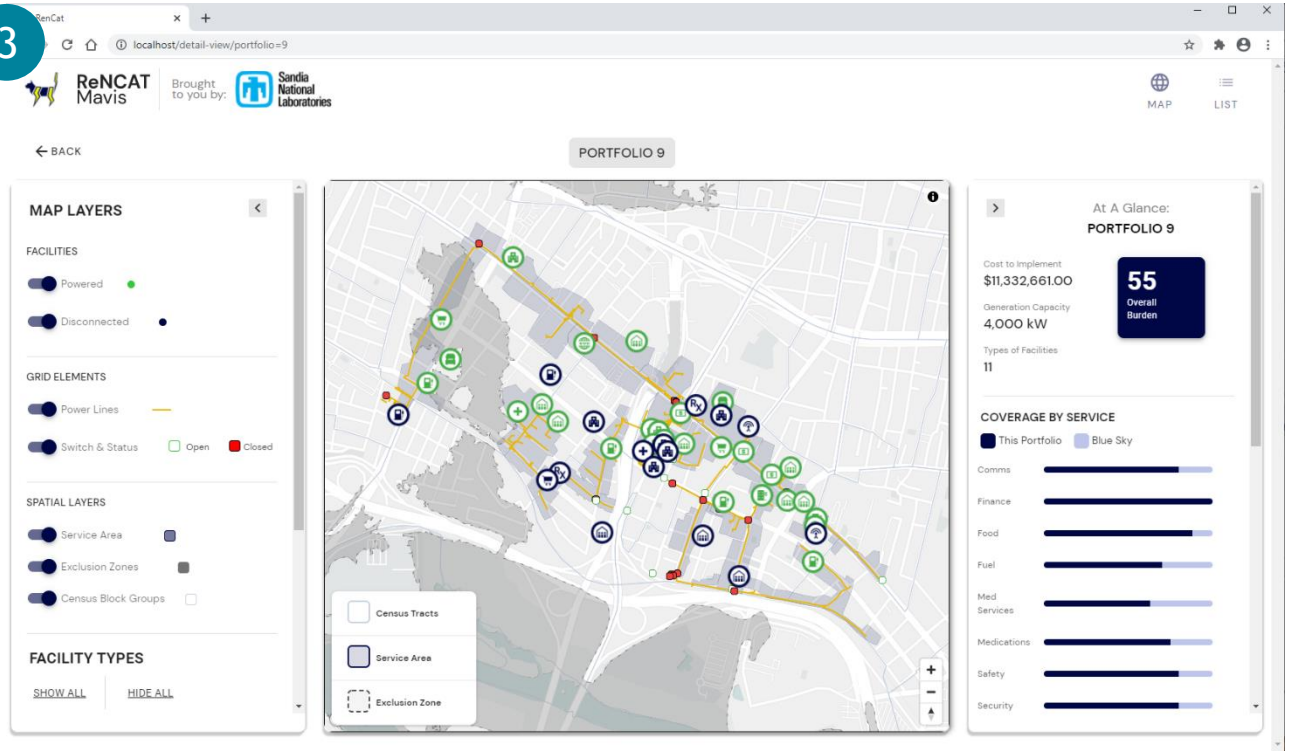


Jeffers et al. (2018) Analysis of Microgrid Locations Benefitting Community Resilience for Puerto Rico. SAND2018-11145

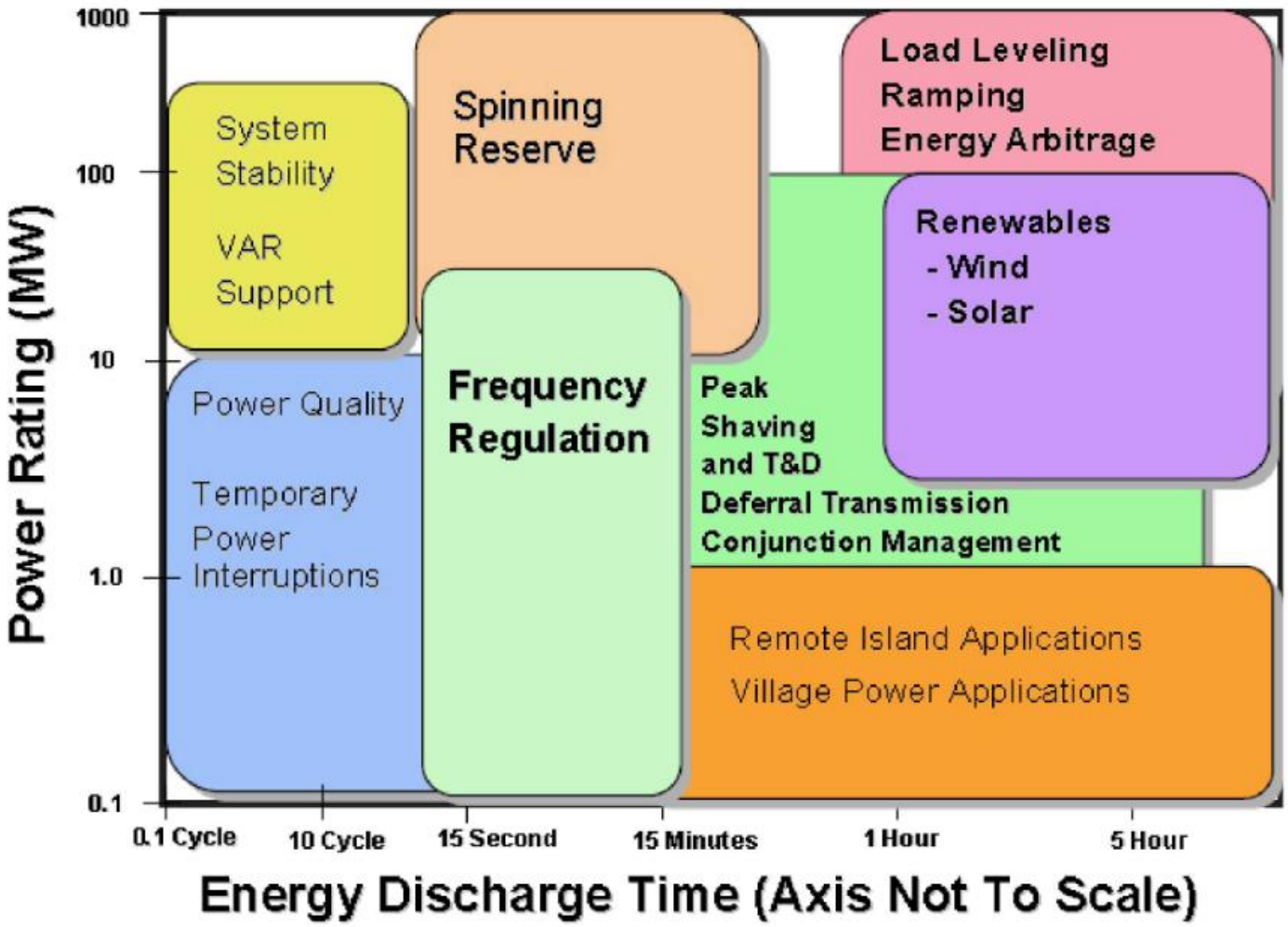
Conclusions

- Planning for aggressive decarbonization AND resilience is hard
- New techniques can support regulatory decision making, helping to determine the optimal blend of technologies both on the transmission and distribution system, in front of and behind the meter
- Energy Storage is a "value stacking" technology – resilience should be on the stack
- Because consequences increase dramatically with longer-duration and more widespread outages, we should integrate consequence-based metrics within resilience planning

Thank you!

Bobby Jeffers, rfjeffe@sandia.gov

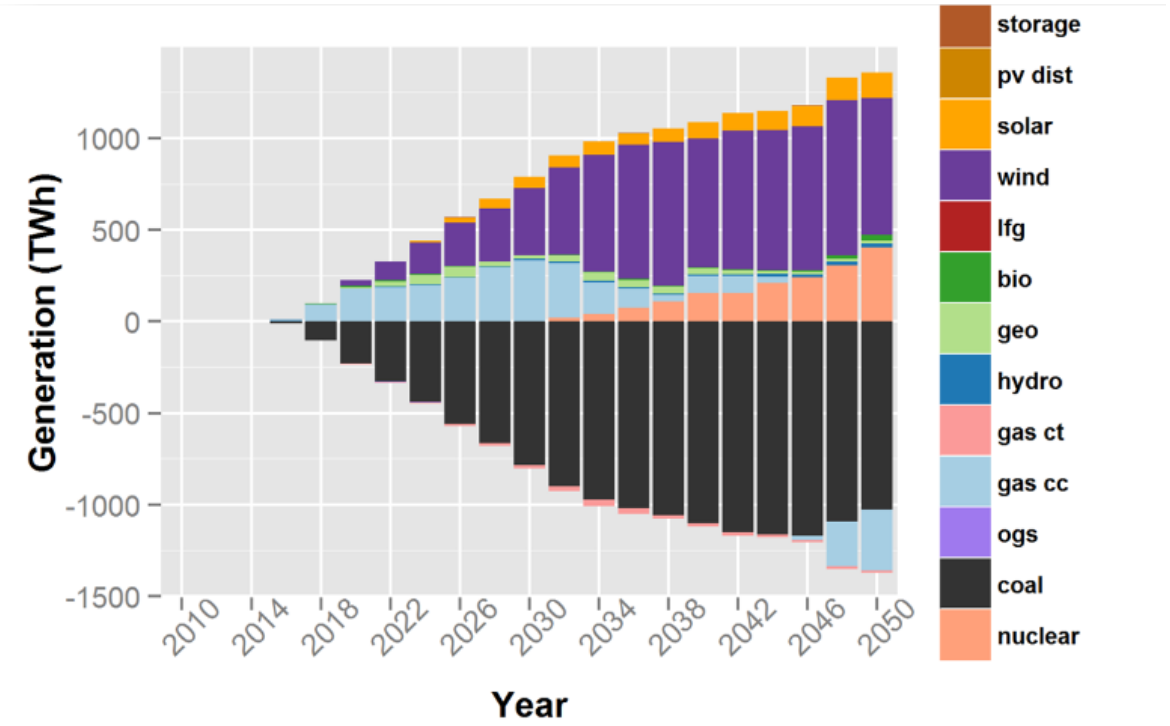
Backup


1000
100
10
1.0
0.1
Power Rating (MW)
System Stability
VAR Support
Spinning Reserve
Load Leveling
Ramping
Energy Arbitrage
Renewables
- Wind
- Solar
Power Quality
Temporary Power Interruptions
Frequency Regulation
Peak Shaving and T&D Deferral Transmission Conjunction Management
Remote Island Applications
Village Power Applications
0.1 Cycle
10 Cycle
15 Second
15 Minutes
1 Hour
5 Hour
Energy Discharge Time (Axis Not To Scale)

How do we design an equitable, affordable and resilient energy future with zero GHG emissions?

Capacity Expansion Modeling

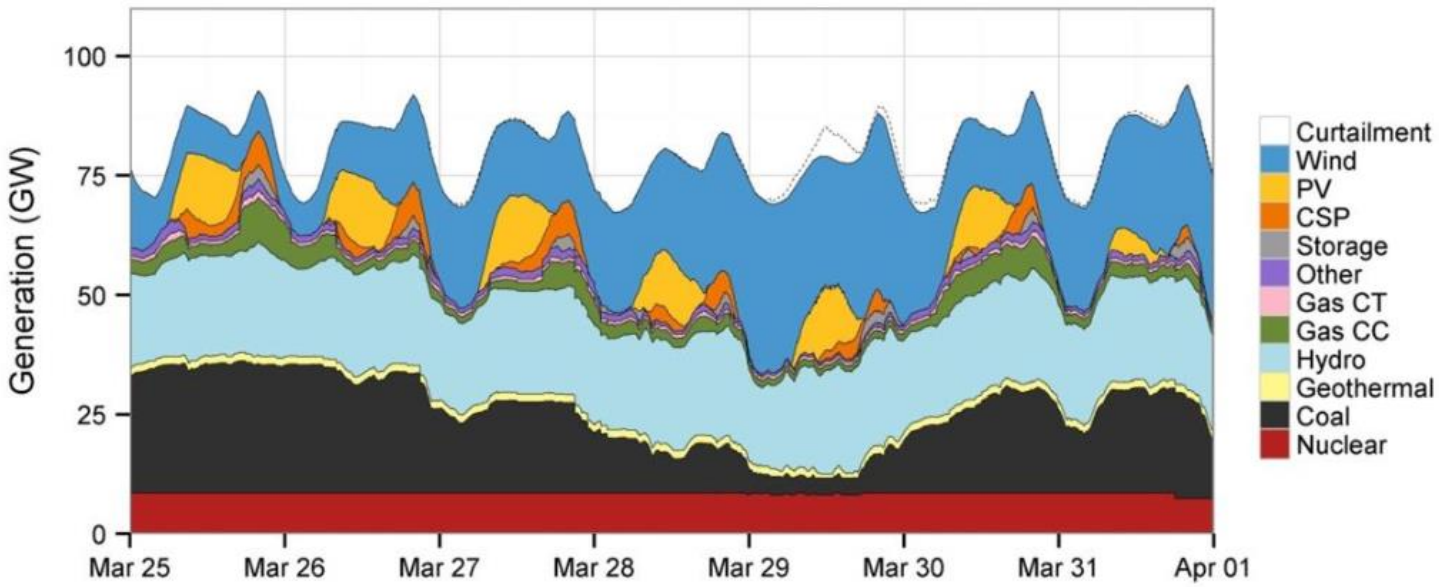
- Optimize generation and transmission capacity investment given assumptions about future electricity demand, fuel prices, technology cost/performance, and policy/regulation
- What mix of generators should we build to meet load?
- Typical output: annual generation, capacity builds/retirements, emissions, fuel consumption, overall electricity price
- What don't they do?
  - Many don't have hourly resolution
  - Transmission and power flow are stylized representation
  - Difficult to include DER explicitly
  - Don't explicitly include resilience performance
  - Don't handle path dependence (e.g. several cloudy days in a row)



How do we design an equitable, affordable and resilient energy future with zero GHG emissions?

Production Cost Modeling

- Given a set of alternative investment portfolios over time, how do we expect each to perform?
- Simulates the operation of a set of power assets over a time horizon (can be 1 to 20 years) at a more detailed resolution than capacity expansion models.
- Can include more physics-based representations of the power system at a computational cost.
- What they don't do?
  - Don't suggest investments in generation and transmission – mostly run in "evaluation" mode
  - Computationally expensive, larger regions get expensive quickly
  - Don't explicitly include resilience performance
  - Don't often include DER

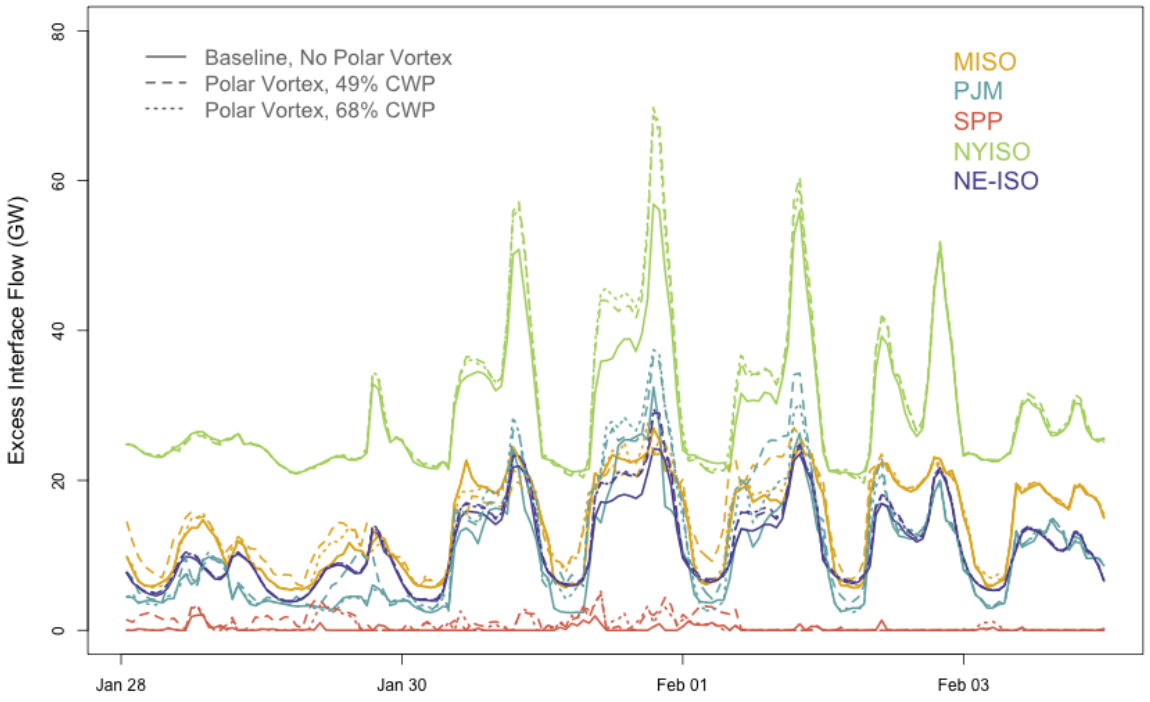


How do we design an equitable, affordable and resilient energy future with zero GHG emissions?

"Resilience" Modeling

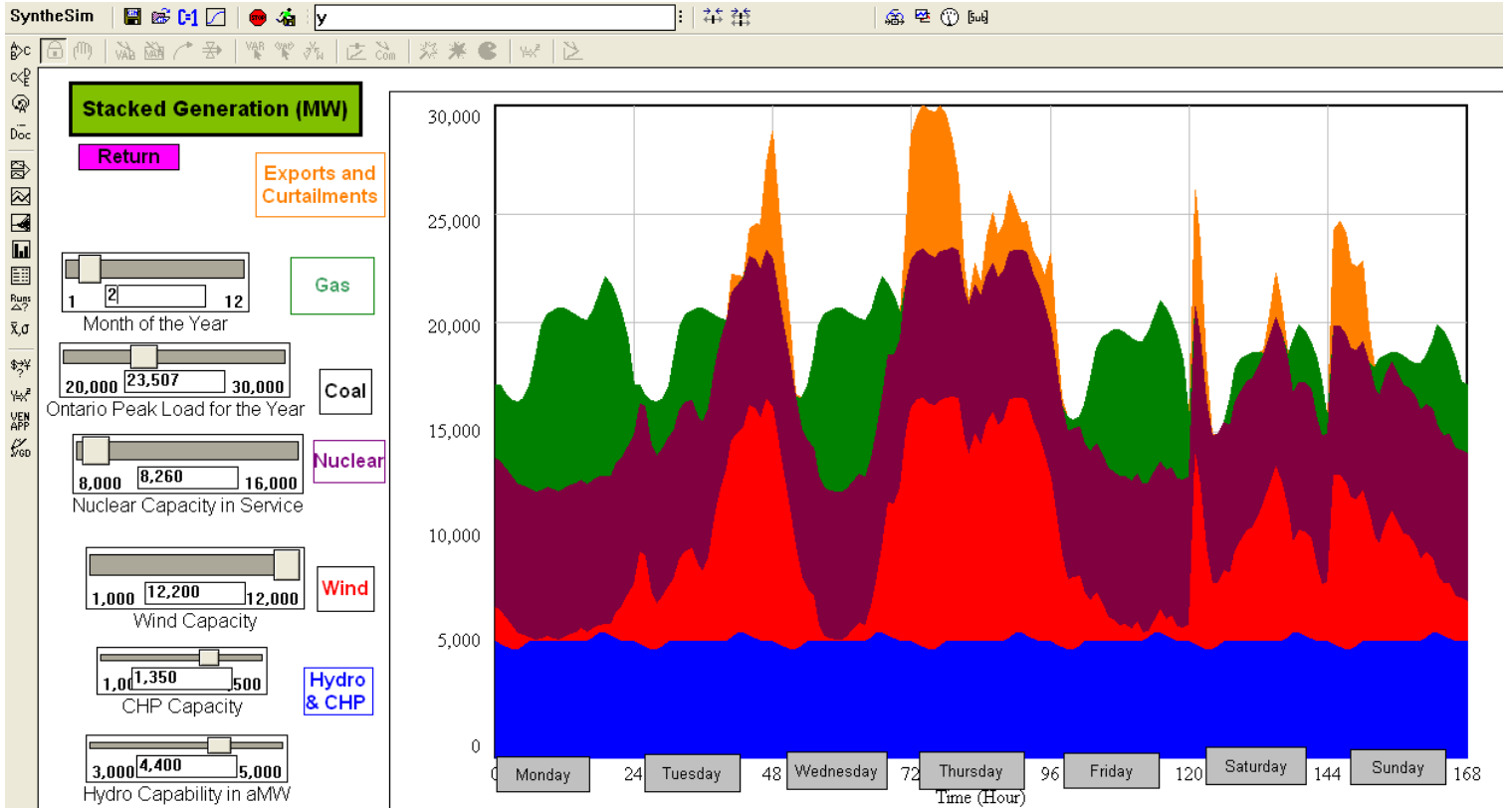
- Relatively new modeling tools designed to simulate "black-sky" performance given a particular grid configuration
- Simulates the operation of power system assets during severe multi-contingency events.
- Outputs <MWh not served> and other performance metrics at substation resolution for a region and a particular hazard instance.
- What they don't do?
  - Some don't cover the full range of uncertainty in future threats
  - Most don't suggest or optimize new investments to improve the resilience metrics
  - Not well plugged in to consequence estimation tools (e.g. social and economic consequences of the outages)
  - Still an evolving area of modeling – e.g. protection system representation needs work

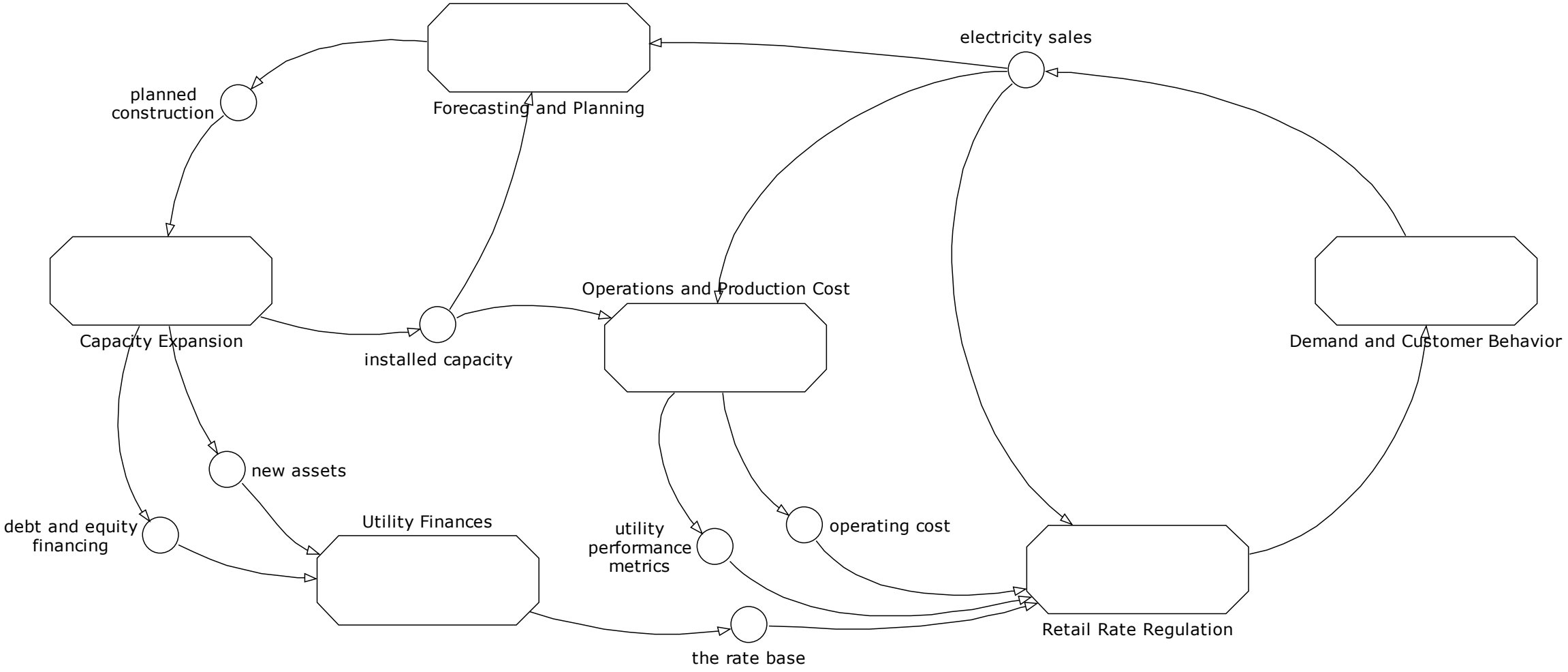
NAERM



Decision Support Simulation

- Designed to capture as many of the phenomena that matter as possible
- Often greatly enhances structural complexity at the cost of reduced categorical complexity
- Usually less precise, sometimes less accurate than "high performance" models




electricity sales
planned construction
Forecasting and Planning
Capacity Expansion
installed capacity
Operations and Production Cost
Demand and Customer Behavior
new assets
debt and equity financing
Utility Finances
utility performance metrics
operating cost
Retail Rate Regulation
the rate base