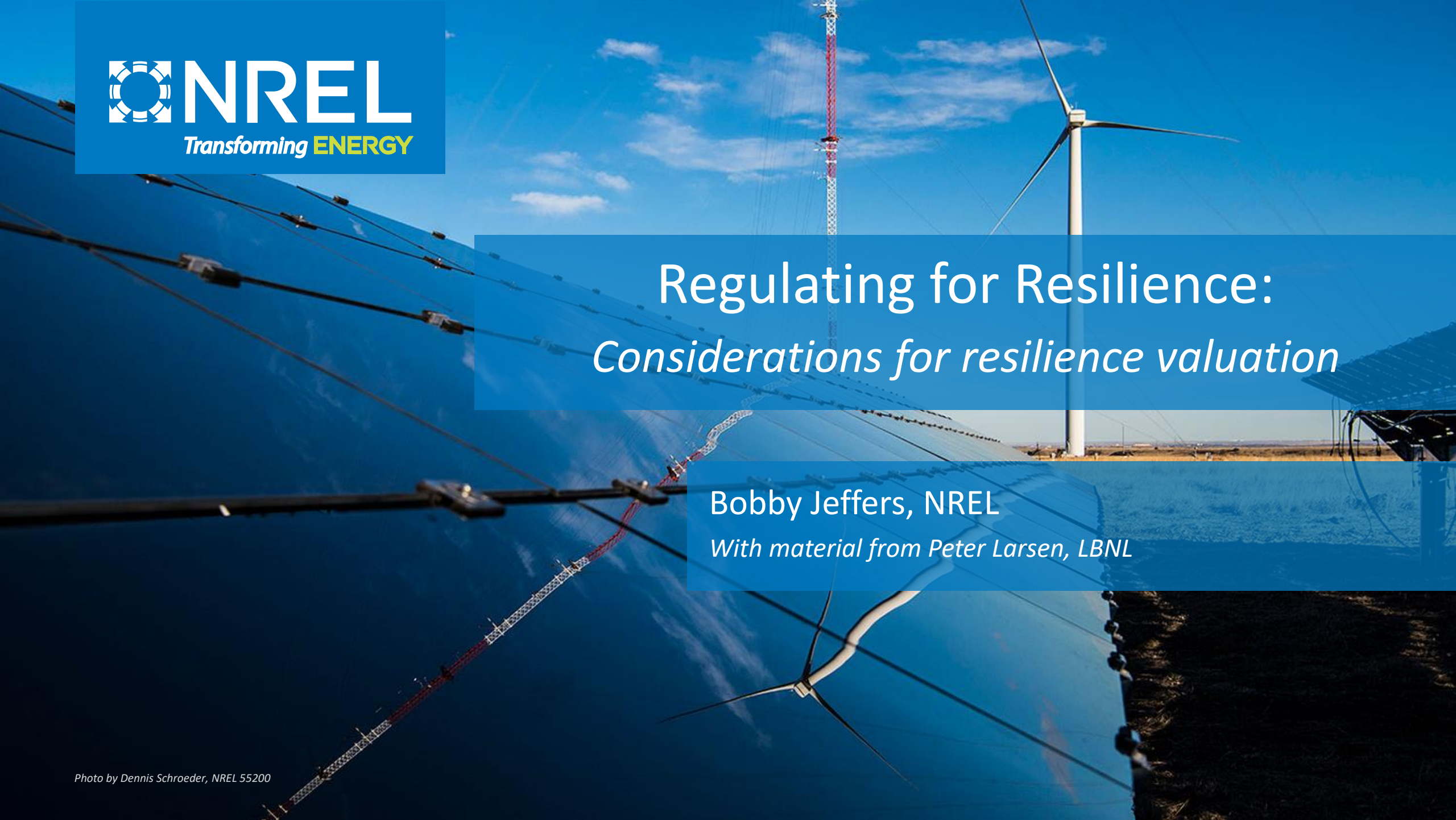


# Regulating for Resilience:

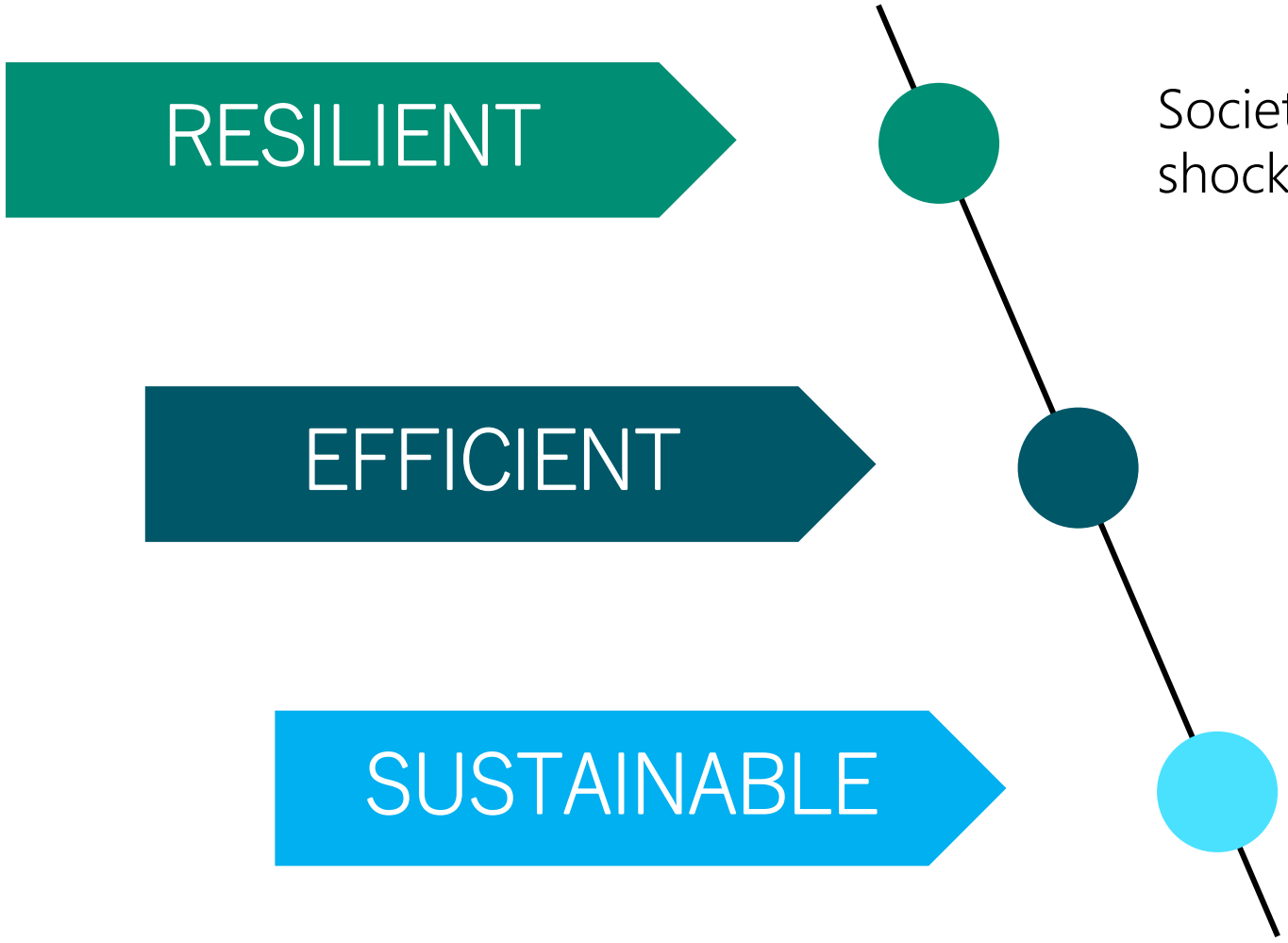
## *Considerations for resilience valuation*

Bobby Jeffers, NREL

*With material from Peter Larsen, LBNL*

*Photo by Dennis Schroeder, NREL 55200*

# Resilience is a “top-level” performance dimension




Society withstands and recovers from acute shocks, even ones never before experienced.

Society performs well day-to-day in the near-term future.

Society performs well over very long periods of time.

At all scales, there are very real tradeoffs between these performance dimensions.

# Established Resilience Definitions

**Resilience can be measured** as a system's performance subject to acute shocks.

- NOTE: chronic stresses are also often placed within the resilience goal.

**Resilience is contextual.** A system resilient to one type of hazard may not be resilient to another.

**Types of shock and stress:**

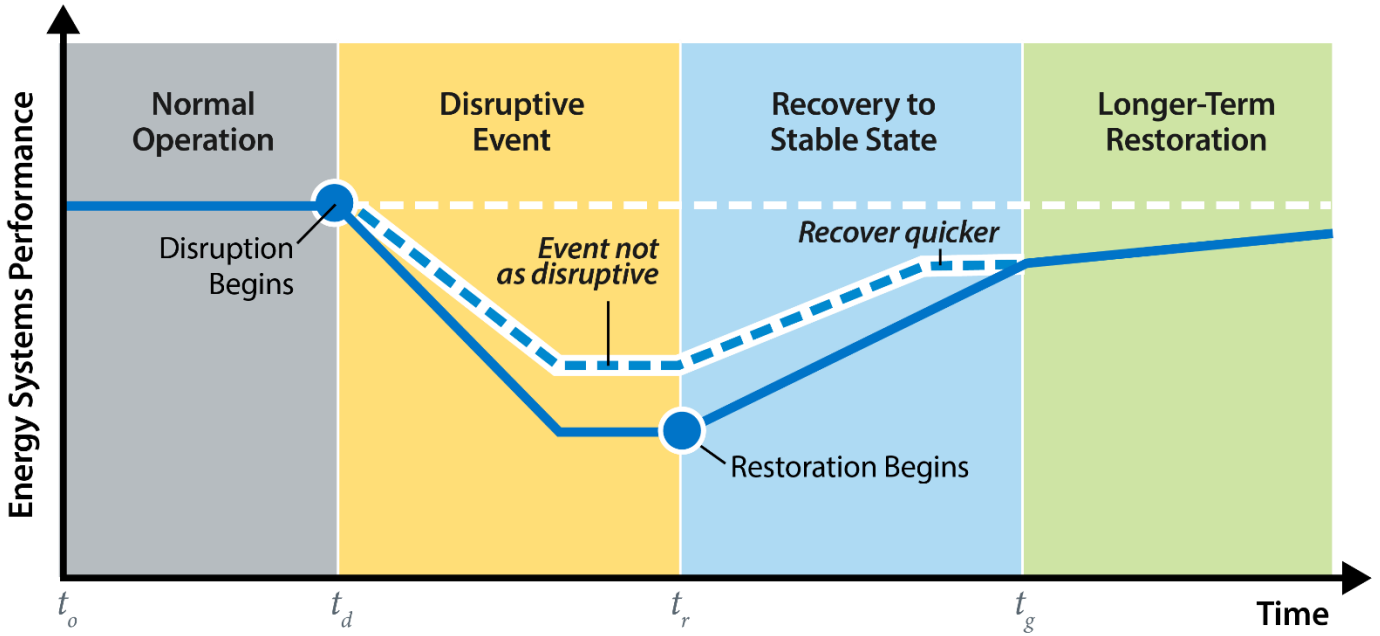
- Natural
- Human caused (either intentional or non-intentional)
- Systemic (resulting from the internal structure of the system)

**Types of systems:**

- Engineered system (e.g., power grid)
- Social system (e.g., communities)
- Geographically-defined systems (e.g., military installation)

*"The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions"*

- Presidential Policy Directive 21



# Growing focus on social equity and environmental justice


(1) Decrease **energy burden** in DACs.

(2) Decrease **environmental exposure and burdens** for DACs

(3) Increase **parity in clean energy technology** (e.g., solar, storage) **access and adoption** in DACs.

(4) Increase **access to low-cost capital** in DACs.

(5) Increase **clean energy enterprise creation** (MBE/DBE) in DACs.

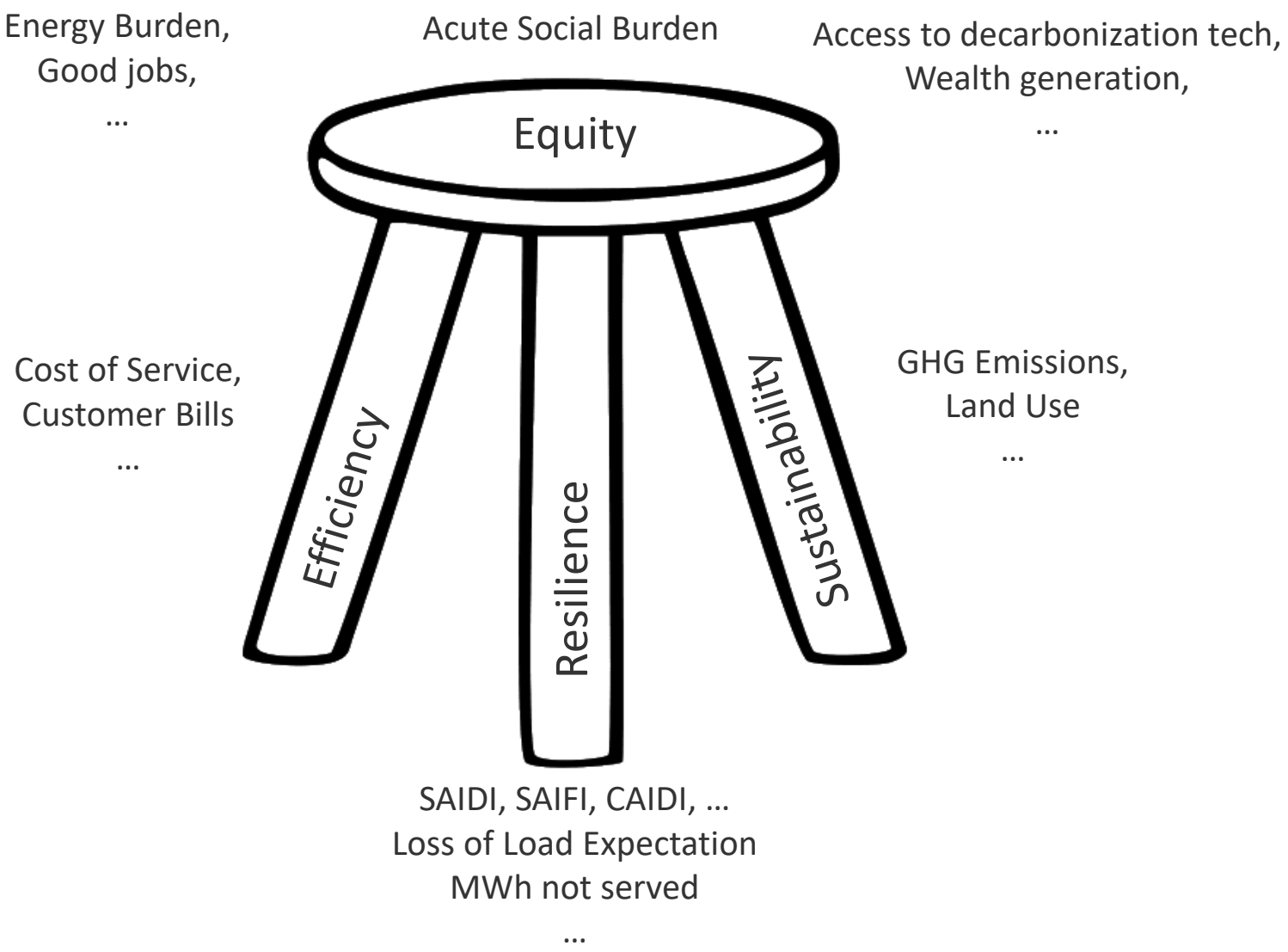
(6) Increase the **clean energy job pipeline and job training** for individuals from DACs.

(7) Increase **energy resiliency** in DACs.

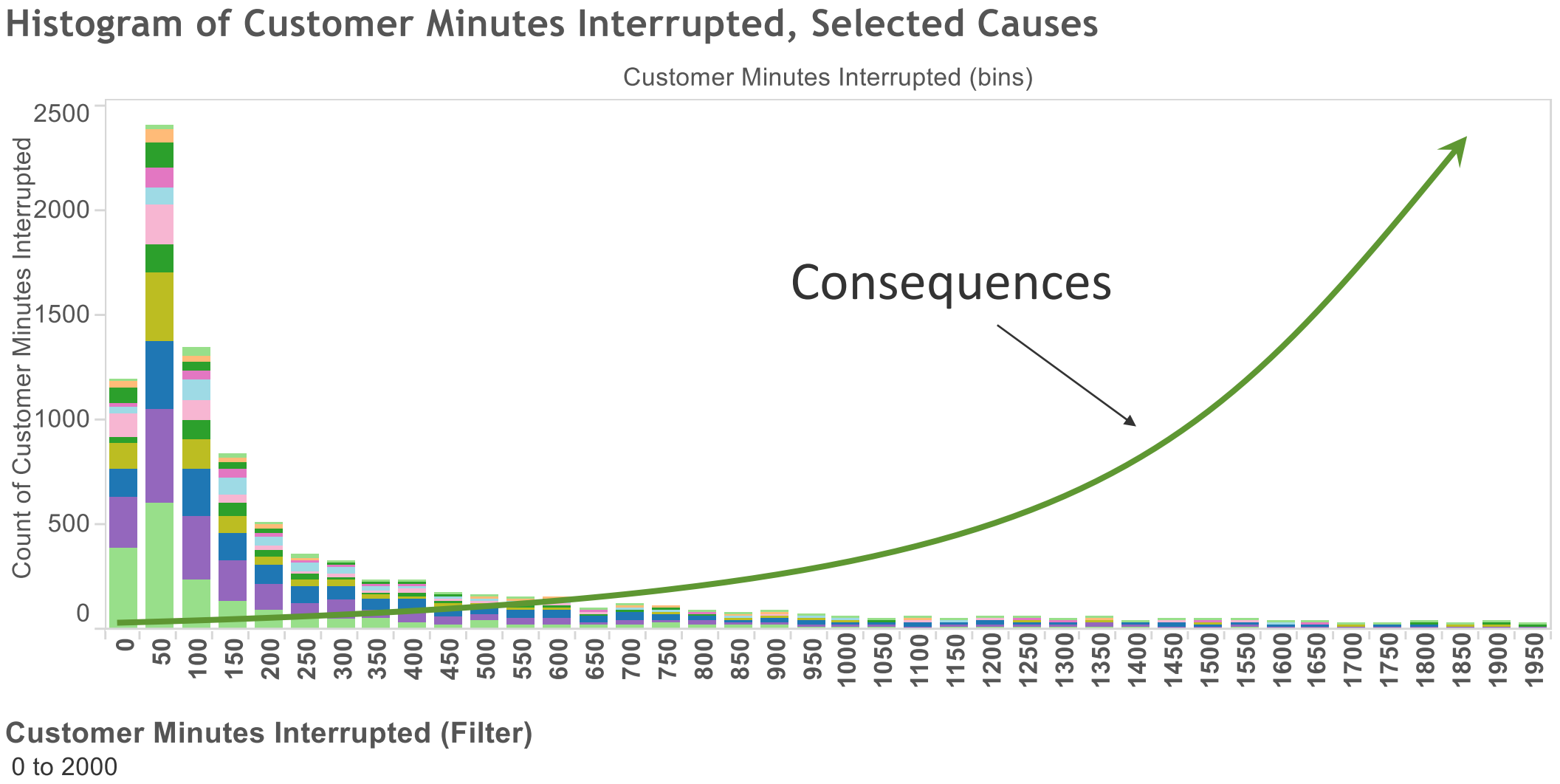
(8) Increase **energy democracy** in DACs.

https://www.energy.gov/em/justice40-initiative

# Growing focus on social equity and environmental justice



# Squashing the Resilience Externality



# Measuring resilience – performance vs. attribute

## Attribute-based:

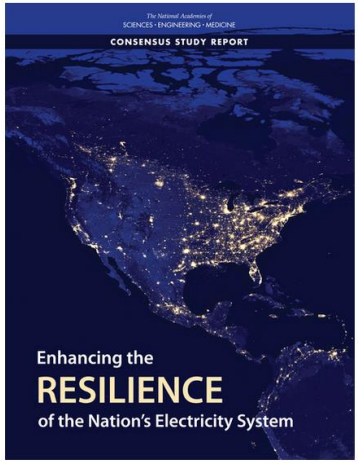
- What makes the system more/less resilient?
- Things you can count now (on a blue-sky day)
- Often grouped into categories that describe some aspect of resilience
  - Robustness, adaptivity, recoverability, etc.
- Often populated via surveys or checklists
  - Relatively simple to populate

## Performance-based:

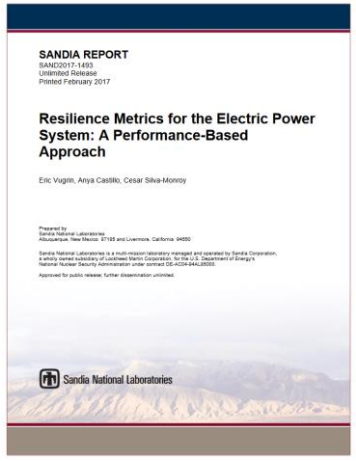
- How resilient is/was the system?
- Things you can measure only during disruption
- Often uses data from an event or a model of an event
  - Can be difficult to populate for planning
- Useful to weigh resilience against other goals
  - (e.g. within benefit cost analysis)

## Either approach can be:

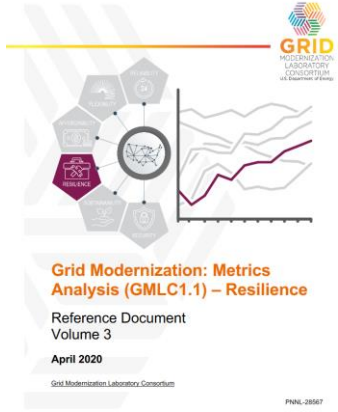
- Retrospective or forward-looking
- Infrastructure-focused or consequence-focused
- Threat-informed or threat-agnostic



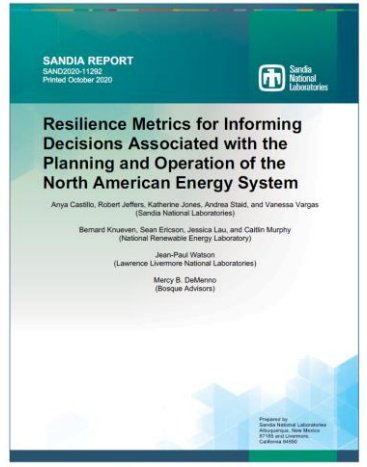

**National Academies (2017), Recommendation #1 to DOE:** "Improve understanding of customer and societal value associated with increased resilience and review and operationalize metrics for resilience…"




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

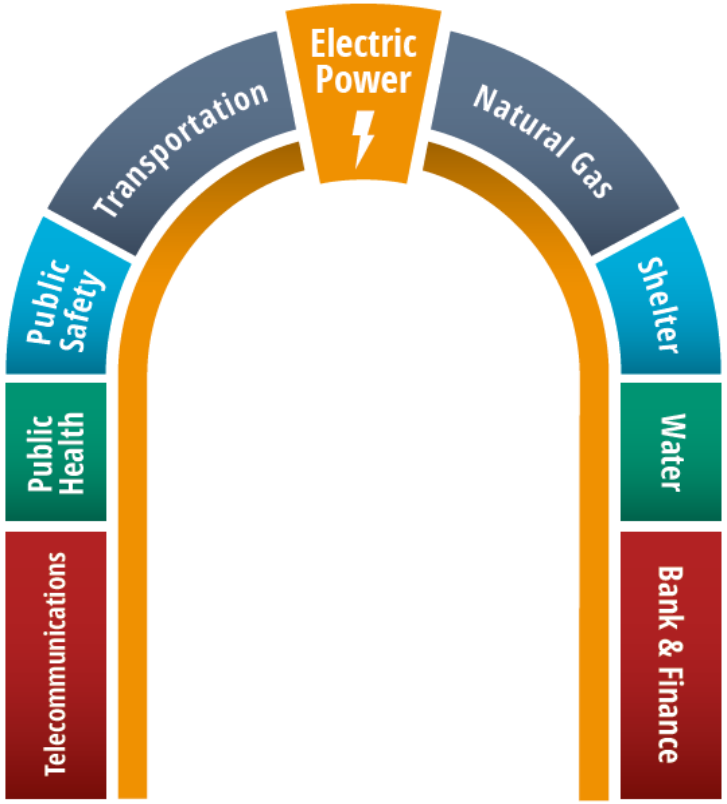



**GMLC 1.1 Final Report (2020):** Begins to clarify how attribute and performance-based approaches can complement.




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

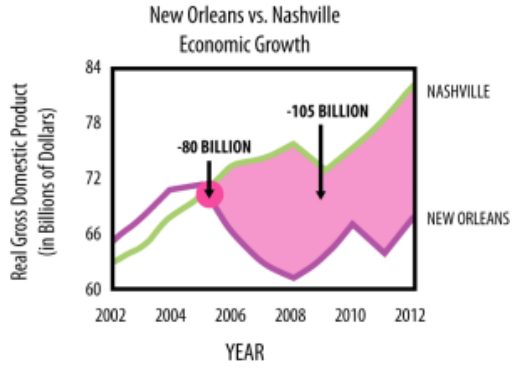
# A focus on consequence can expose externalities

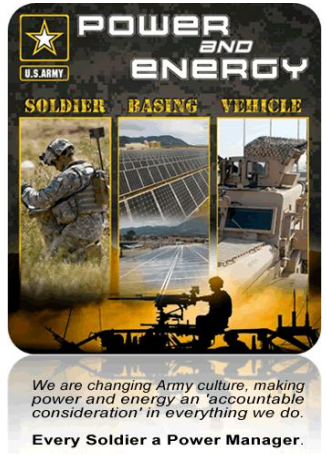



Society

Economy

National Security


Within resilience, there are three major dimensions of consequence. These better define the externality and **lead to different internalization pathways**.

# Intro to Social Burden – a performance-based, equity-informing resilience metric (and more!)

The **social burden metric** calculates how hard society is working to achieve their basic human needs as defined by:

- Based on the capabilities framework, Sen and Nussbaum, later applied to energy by Day et al. (2016)
- Newly published math and theory: Clark et al. (2023) https://www.tandfonline.com/doi/full/10.1080/23789689.2022.2157116

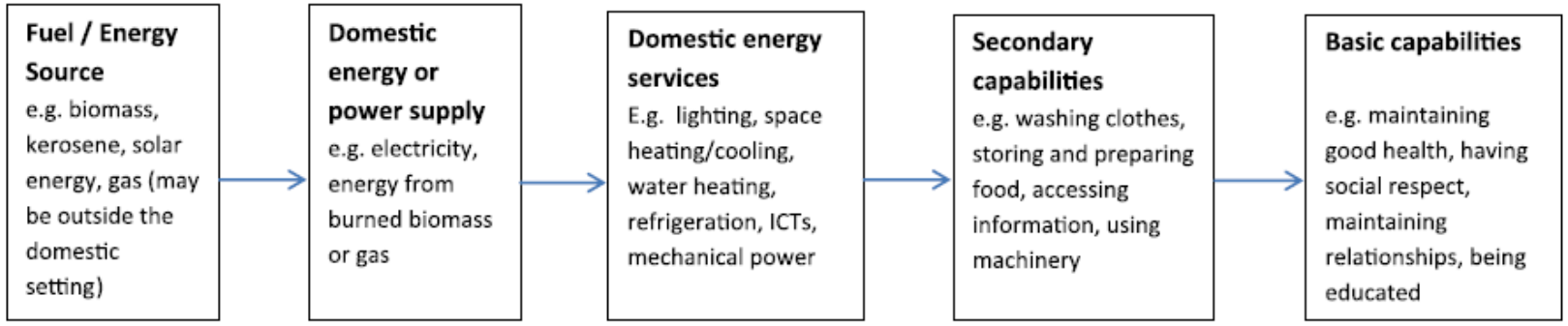
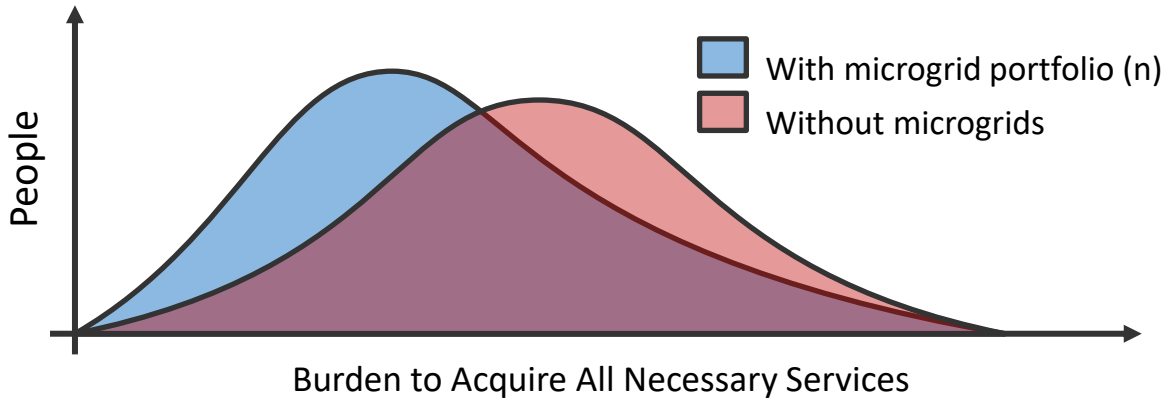



Fig. 1. Conceptualising the relationship between energy, services and outcomes.


Nussbaum, Capabilities as fundamental entitlements: Sen and social justice. 2003; Sen, Human Rights and Capabilities. 2005;
Day, R., Walker, G., Simocck, N. Conceptualising energy use and energy poverty using a capabilities framework. Energy Policy. 2016.

# Social Burden within a spatial probabilistic risk framework




**Effort**

Time + money spent to achieve basic level of human needs

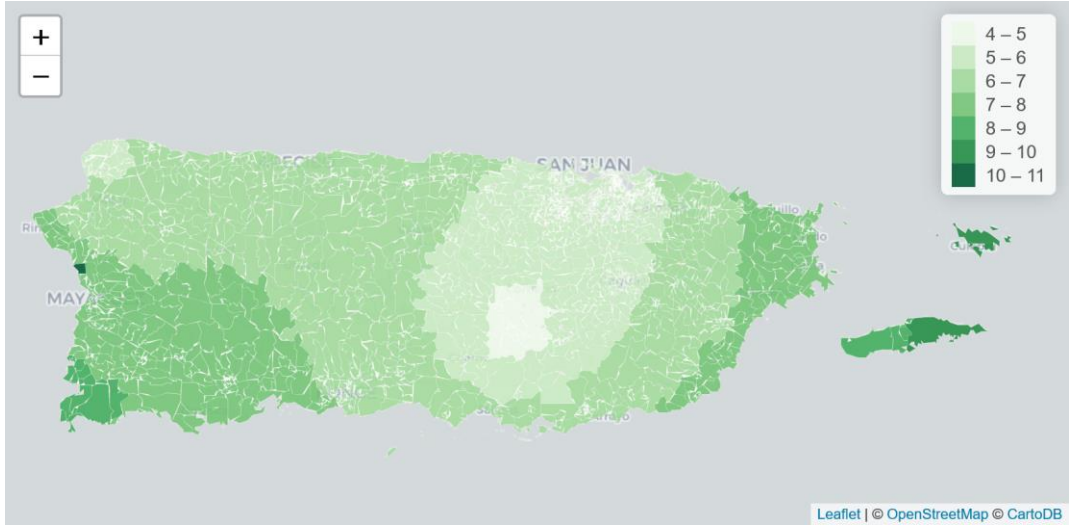
**Ability**

Median household income
Additional predictors

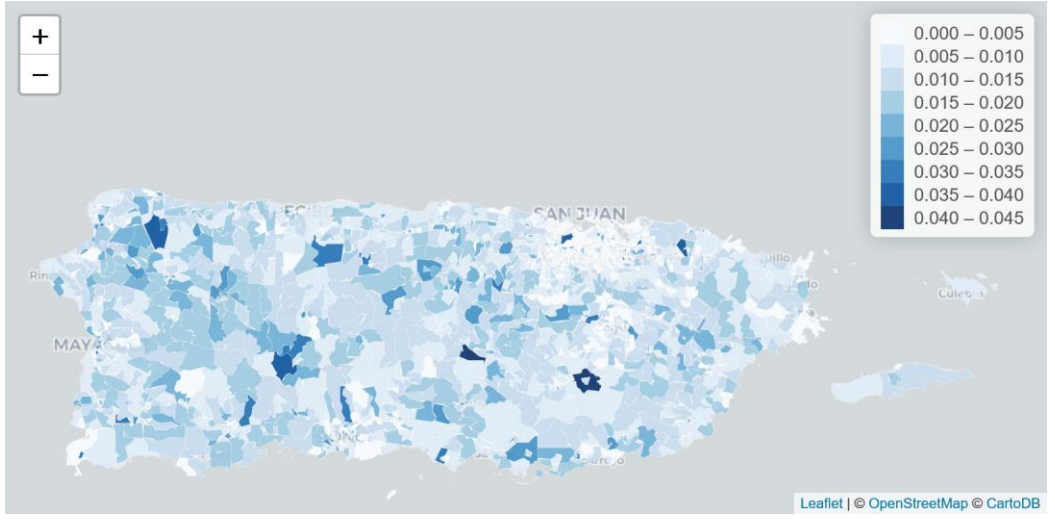
**Burden**

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

**Effort for a portfolio of 80 microgrids**

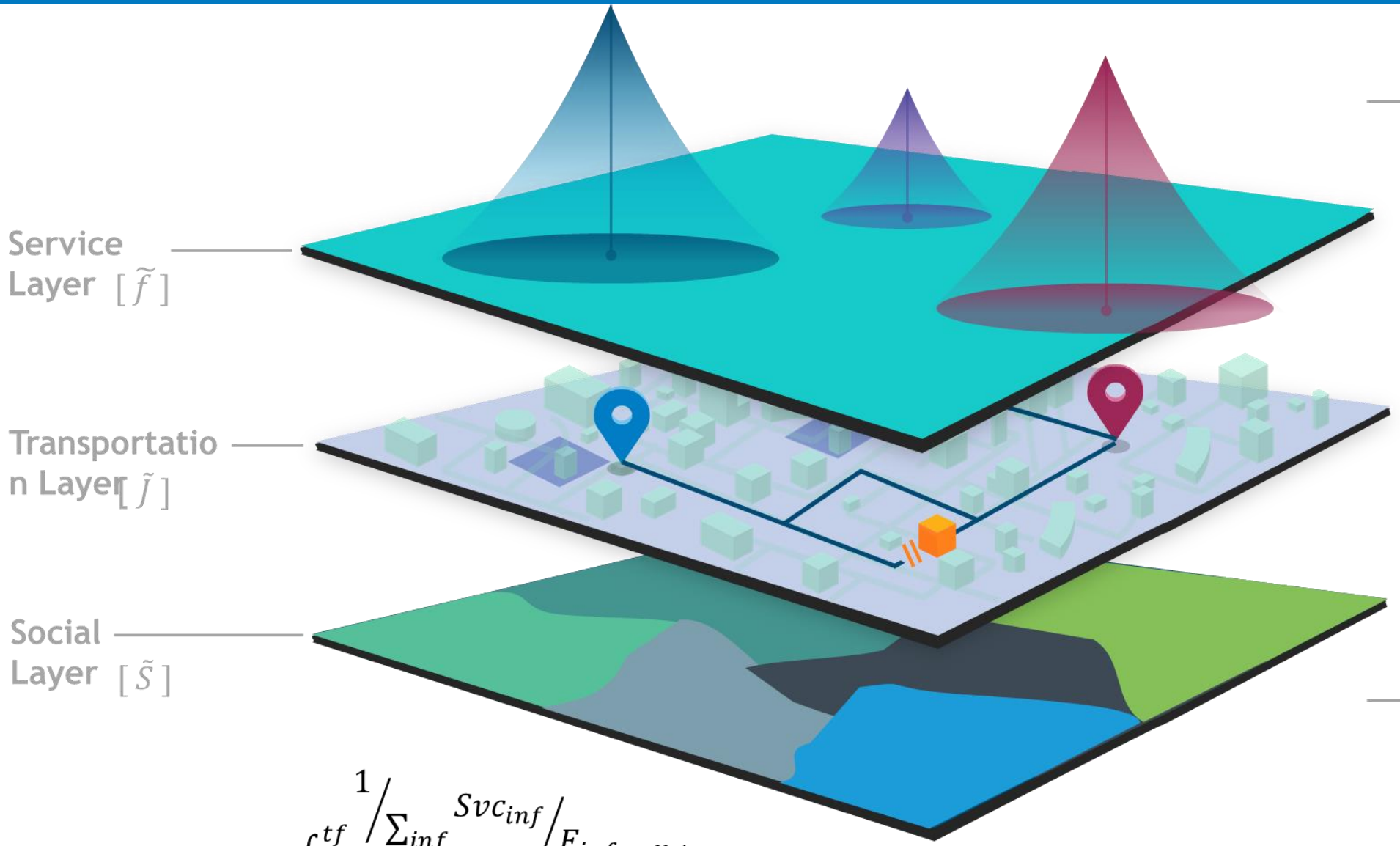



**Social Burden for the same portfolio**




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

# Social Burden deep dive



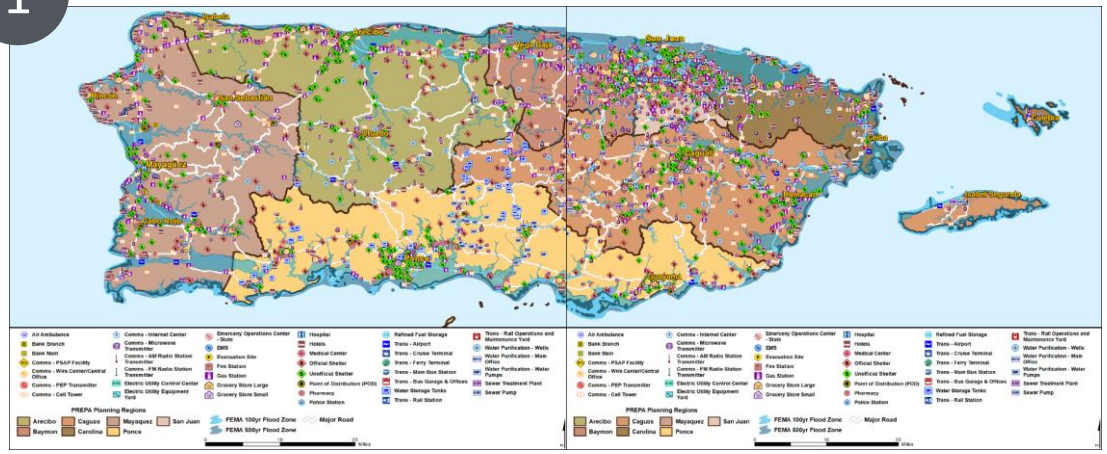

$$Social\ Burden_{S,f} = \int_{t0}^{tf} \frac{{}^{1}/_{\sum_{inf} {}^{Svc_{inf}}/_{E_{inf}}}}{Ability}$$

Units:
Hours of effort per dollar of ability

# Case study: Microgrid Siting for Puerto Rico

- 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 **social burden**, which quantifies how well primary human needs are satisfied during and after disruptions.

1



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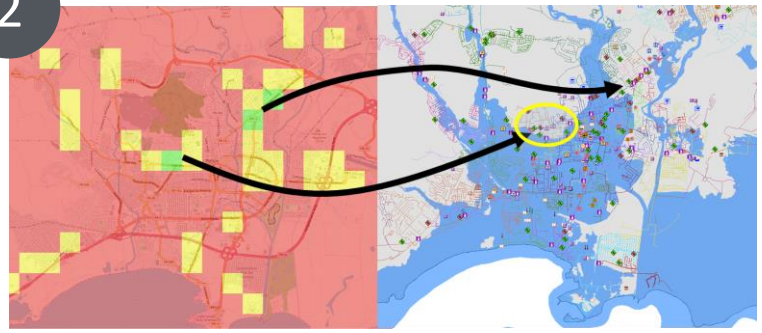

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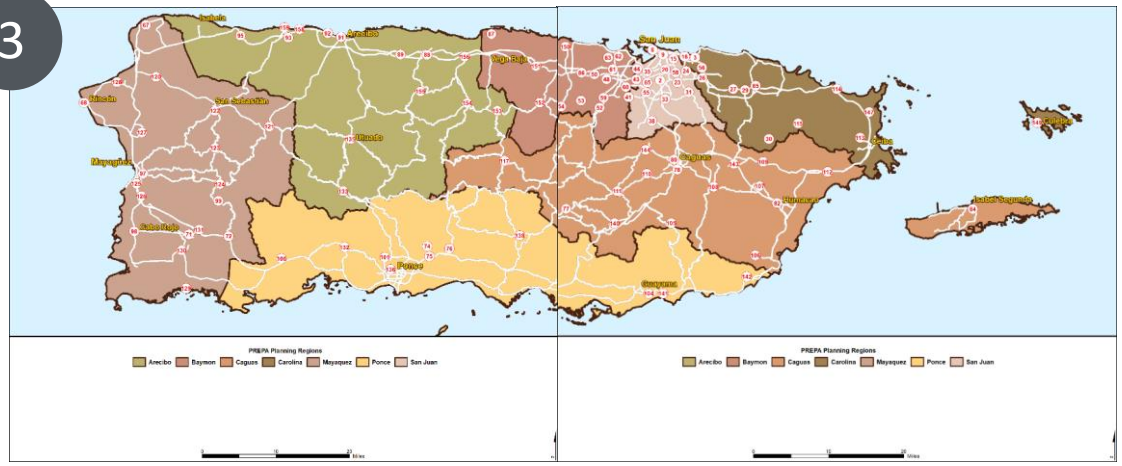

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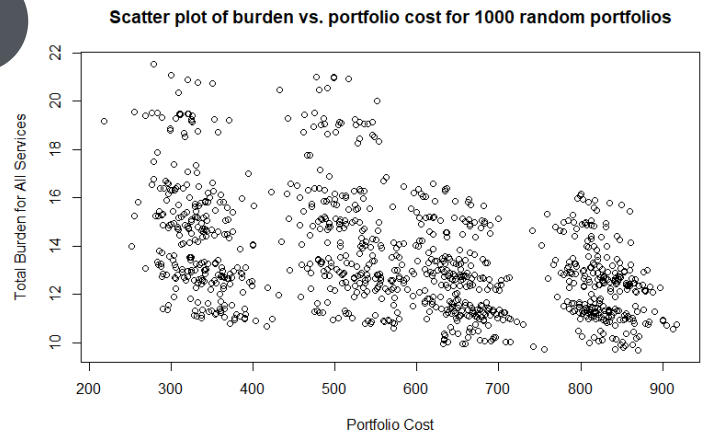
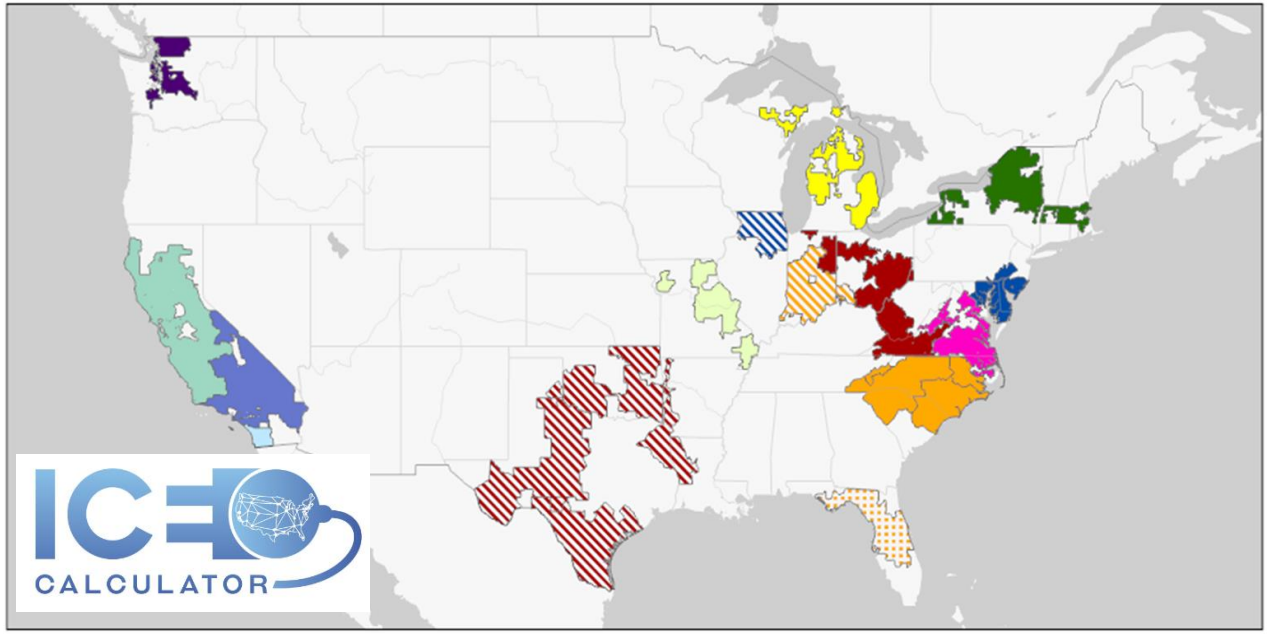



Jeffers et al. (2018) Analysis of Microgrid Locations Benefitting Community Resilience for Puerto Rico. SAND2018-11145

# Valuing *Reliability*: Public-Private Partnership to Update Berkeley Lab's Interruption Cost Estimate (ICE) Calculator

- 11 sponsors (12 contracts)
- 15 distinct survey activities
- 26 investor-owned utility distribution service territories represented



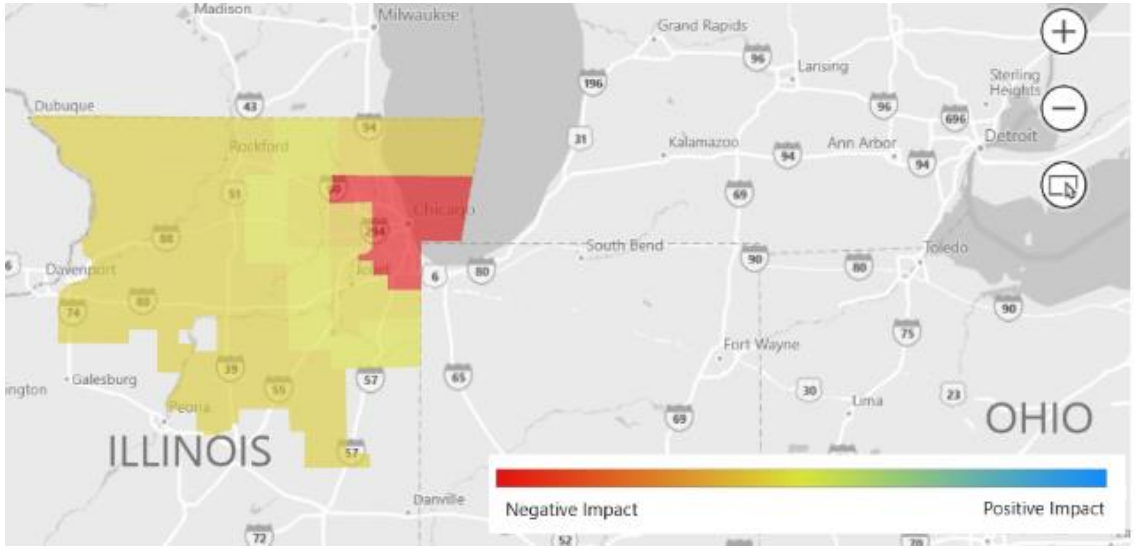

- Berkeley Lab's Interruption Cost Estimate (ICE) Calculator is the leading and only publicly-available tool for estimating the customer cost impacts of power interruptions
- Reliance on the ICE Calculator has been challenged because the surveys are:

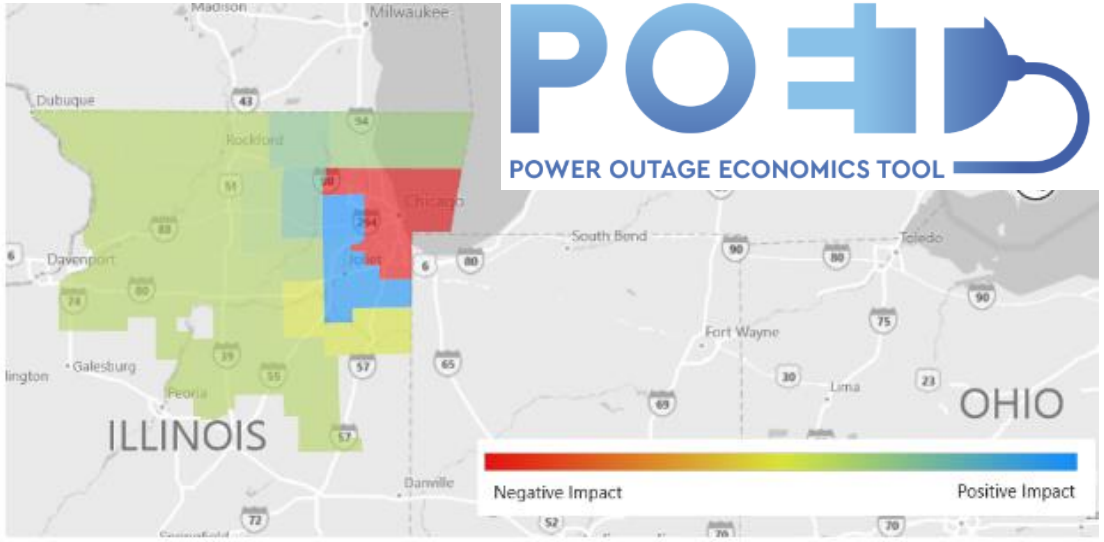
  *Dated—many of the surveys are 25+ years old*

  *Not statistically representative of all regions of the U.S.*

  *Not appropriate for estimating costs of widespread, long-duration (> 24 hour) interruptions*
- With encouragement and support from the U.S. DOE-OE, Berkeley Lab is updating the ICE Calculator through direct funding by sponsoring U.S. utilities.

# Valuing *Resilience*: Power Outage Economics Tool (POET)




- Berkeley Lab, in conjunction with ComEd, has demonstrated an innovative new tool that estimates the regional economic impacts of widespread and long-duration (WLD) power interruptions (1-, 3-, and 14-day interruptions of varying extent)
- POET is a state-of-the-art, regional economic model that incorporates both survey information on ComEd customers' preparedness for WLD power interruptions and economic information for a three state region that includes and surrounds ComEd's service territory

# Performance-based resilience

**For Each Customer Category**

- Tier I: Critical Community Services
- Tier II: Critical Individual Services
- Tier III: Non-Critical

**Report the Following**

**CUSTOMERS AND LOAD**

- Number of Customers
- Percent of Customers
- Total Load (kWh)
- Percent of Load
- Average Customer Size

- Critical Customers
- Percent of Critical Customers
- Critical Load (kWh)
- Percent of Critical Load

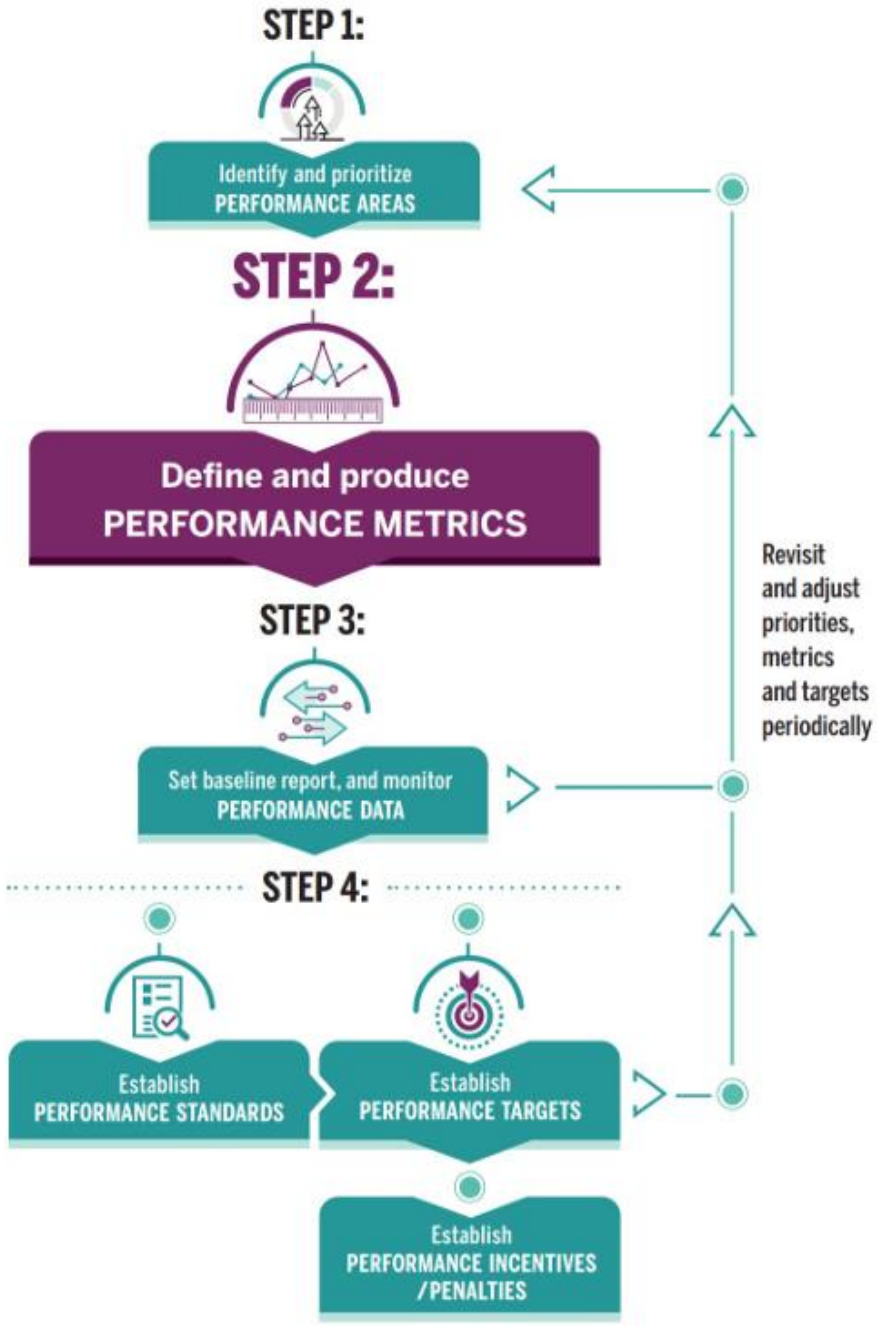
**ISLANDABLE RESOURCES**

**Number of customers with any islandable resources:**
- Total
- FOM Supply source provided by the utility
- BTM solar PV + storage generator
- BTM battery storage system (no solar PV)
- BTM natural gas generation
- BTM diesel generation
- BTM propane generation

**Percent of customers with any islandable resources:**
- Total
- FOM Supply source provided by the utility
- BTM solar PV + storage generator
- BTM battery storage system (no solar PV)
- BTM natural gas generation
- BTM diesel generation
- BTM propane generation

**CUSTOMER RESILIENCE**

| | CAIDI | | CAIFI | |
|---|---|---|---|---|
| | Reporting Period | Baseline Period | Reporting Period | Baseline Period |
| Normal Days | | | | |
| Major Event Days | | | | |
| Resilience Event Days | | | | |
| All Days | | | | |




https://www.synapse-energy.com/sites/default/files/Performance_Metrics_to_Evaluate_Utility_Resilience_Investments_SAND2021-5919_19-007.pdf

# Designing Resilient Communities

**Stakeholders**

Electric Utilities*

Municipal Governments*

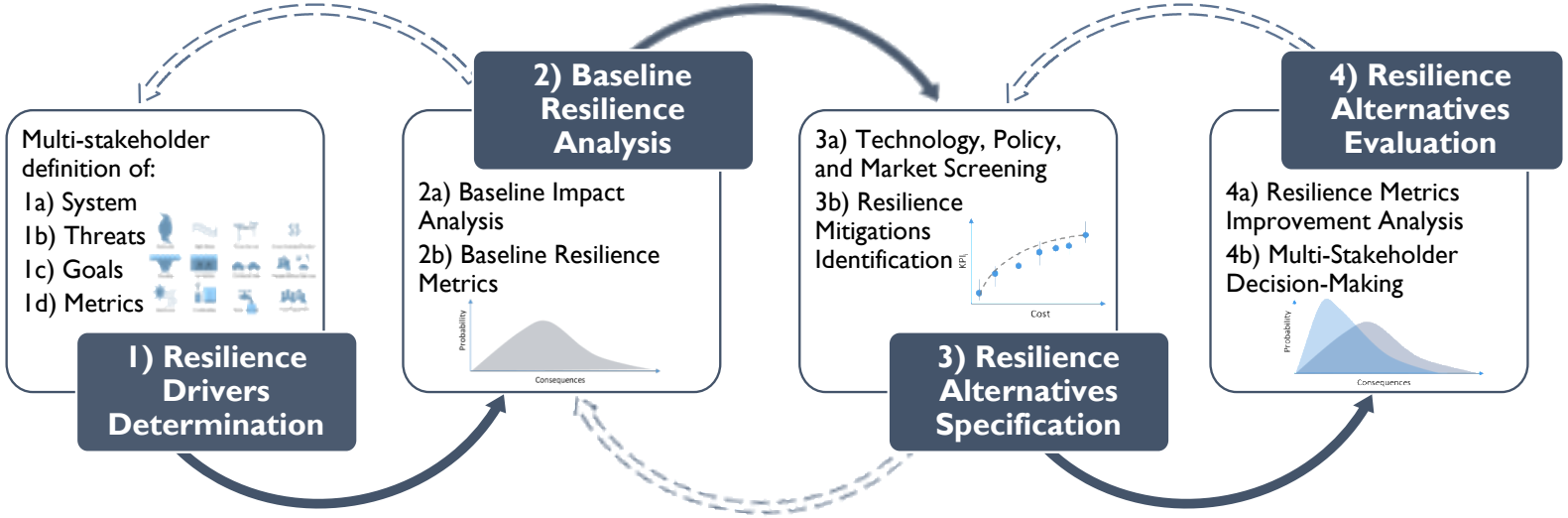
State and Local Regulators*

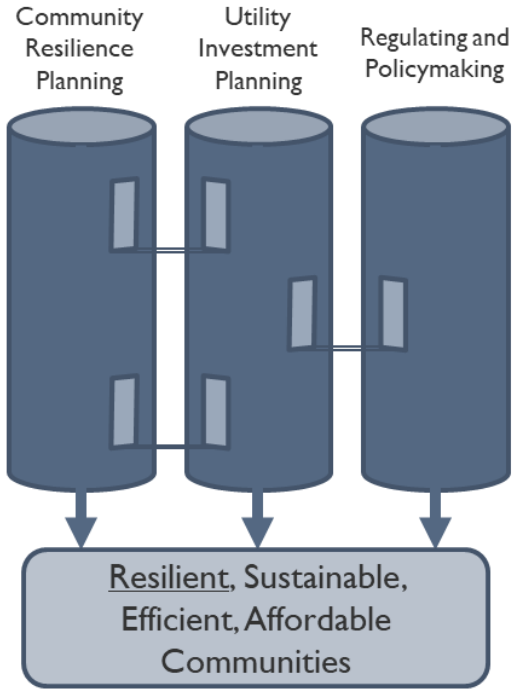
Infrastructure Owners and Operators

Community, Customer, and Environmental Interests

Commercial and Industrial Interests

Data and Service Providers




Technology, Policy, and Market Evolution

**Phase 1: Technology Investments**

**Phase 2: Regulatory Frameworks**

**Phase 3: Utility Business Models**

# Discussion questions

- Where do states need the most help on resilience metrics?
  - Data? Methods? Decision tools? Direct technical assistance?…
- From reliability to resilience. Remaining challenges:
  - Resilience performance is jumpy year-over-year. Makes for a poor PIM.
  - We do a poor job predicting power system performance under extreme shocks. Is stress testing an option?
    - What about a hybrid that uses both attributes and performance metrics?
  - Extending to social and economic resilience quantification
    - Are we driving toward a different quality of service for different customers?
- Incorporating into investment planning and evaluation
  - Do we need a monetary value on the social dimension?
  - Where is the line between taxpayer vs. ratepayer funded resilience?


# Thank You

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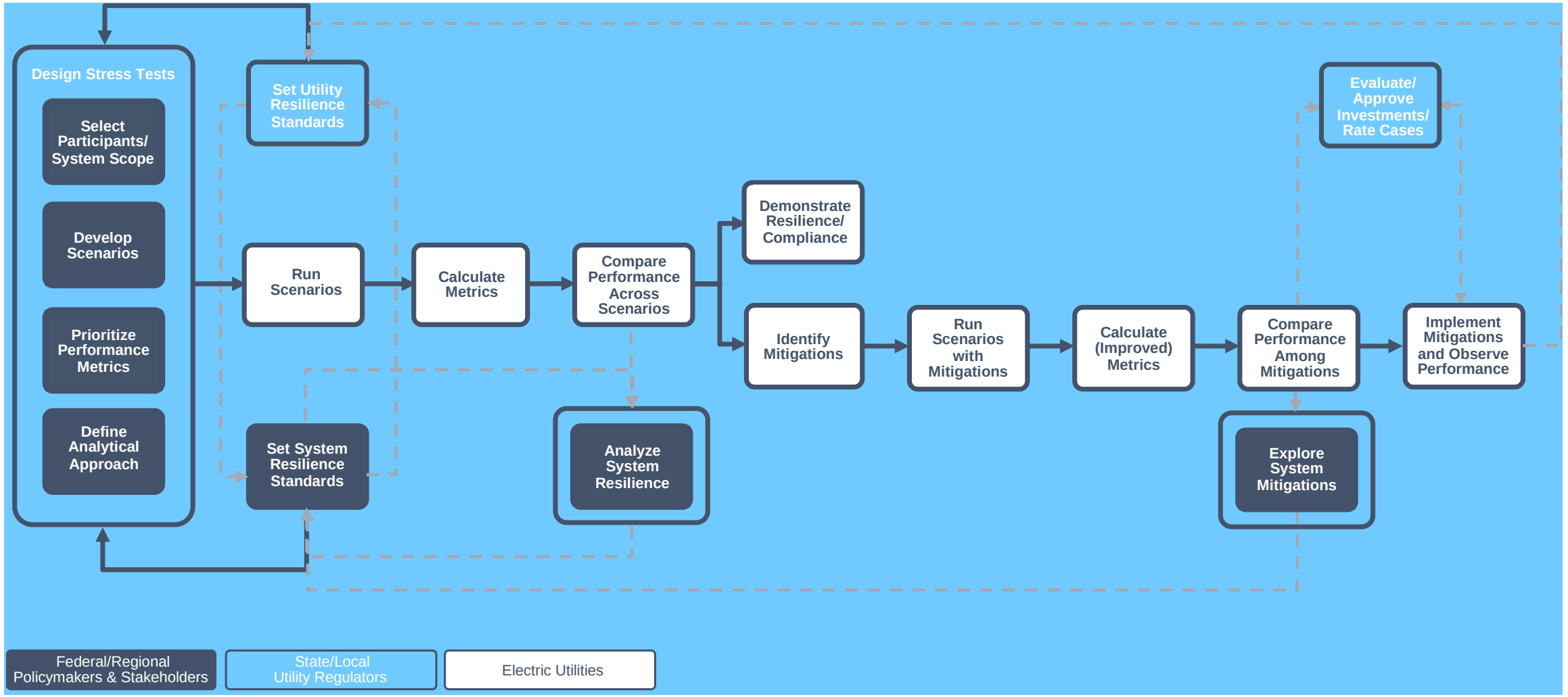
Peter Larsen (phlarsen@lbl.gov)

www.nrel.gov

NREL
Transforming ENERGY

# Stress testing to regulate for resilience




https://www.tandfonline.com/doi/abs/10.1080/23789689.2021.2015833