

# Perspectives on Equitable Energy Resilience



PRESENTED BY

Bobby Jeffers

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SAND2021-1377 PE



# Core Motivation

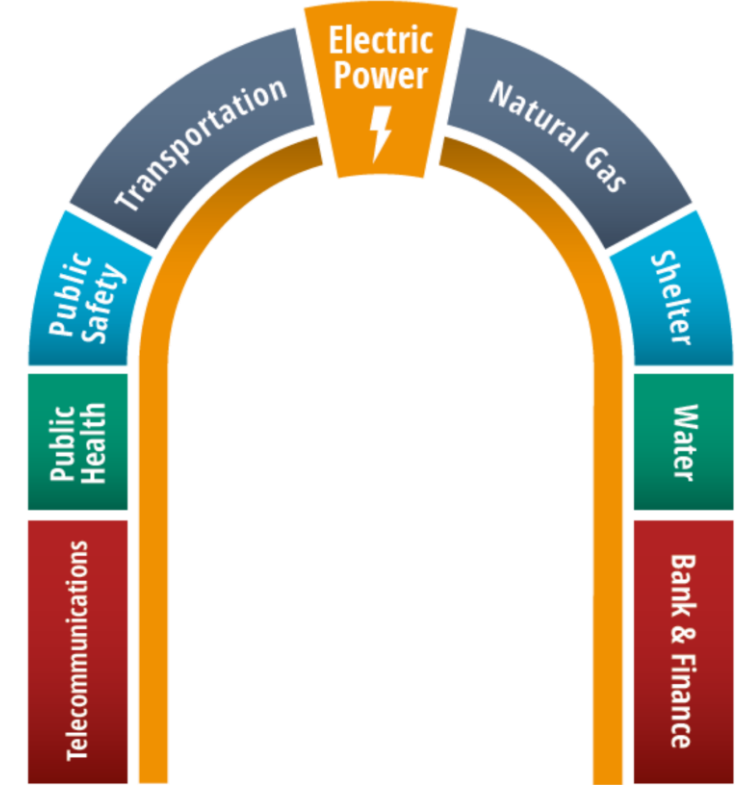
- The grid is the keystone infrastructure – central to the web of interconnected systems that support life as we know it.
- During extreme events, prices do not reflect the value of all the services (food, water, shelter, etc.) that electricity provides
  - Consequence-focused **resilience is an externality** in power markets
  - The performance of the economy, military, and **society as a whole** are all important consequences of losing power

## 9 months after Hurricane Maria, thousands of Puerto Ricans still don't have power

The grid is in worse shape than it was before Hurricane Maria.

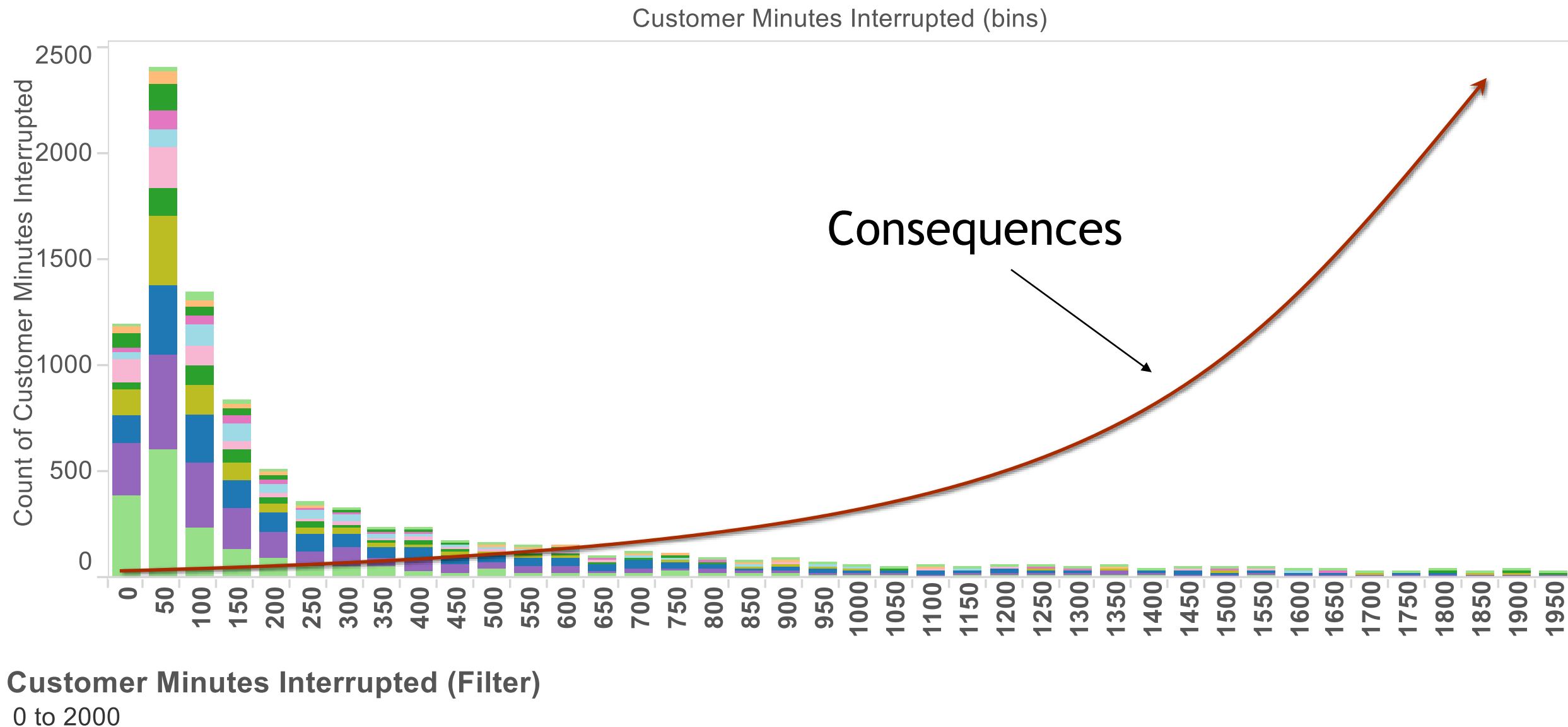
By Umair Irfan | Updated Jun 20, 2018, 8:06am EDT

“It took Cardona 11 days to find a working phone and a cellular signal to let her mother in Florida know that she was okay. In the weeks following the storm, she woke up at 2 am to get in line for diesel fuel to run the generator at her father’s home in Sabana Grande on the southwest coast of the island. After waiting for 13 hours, she went home empty-handed. She stood in lines that stretched blocks to get cash, since no electricity meant credit card readers weren’t running.”





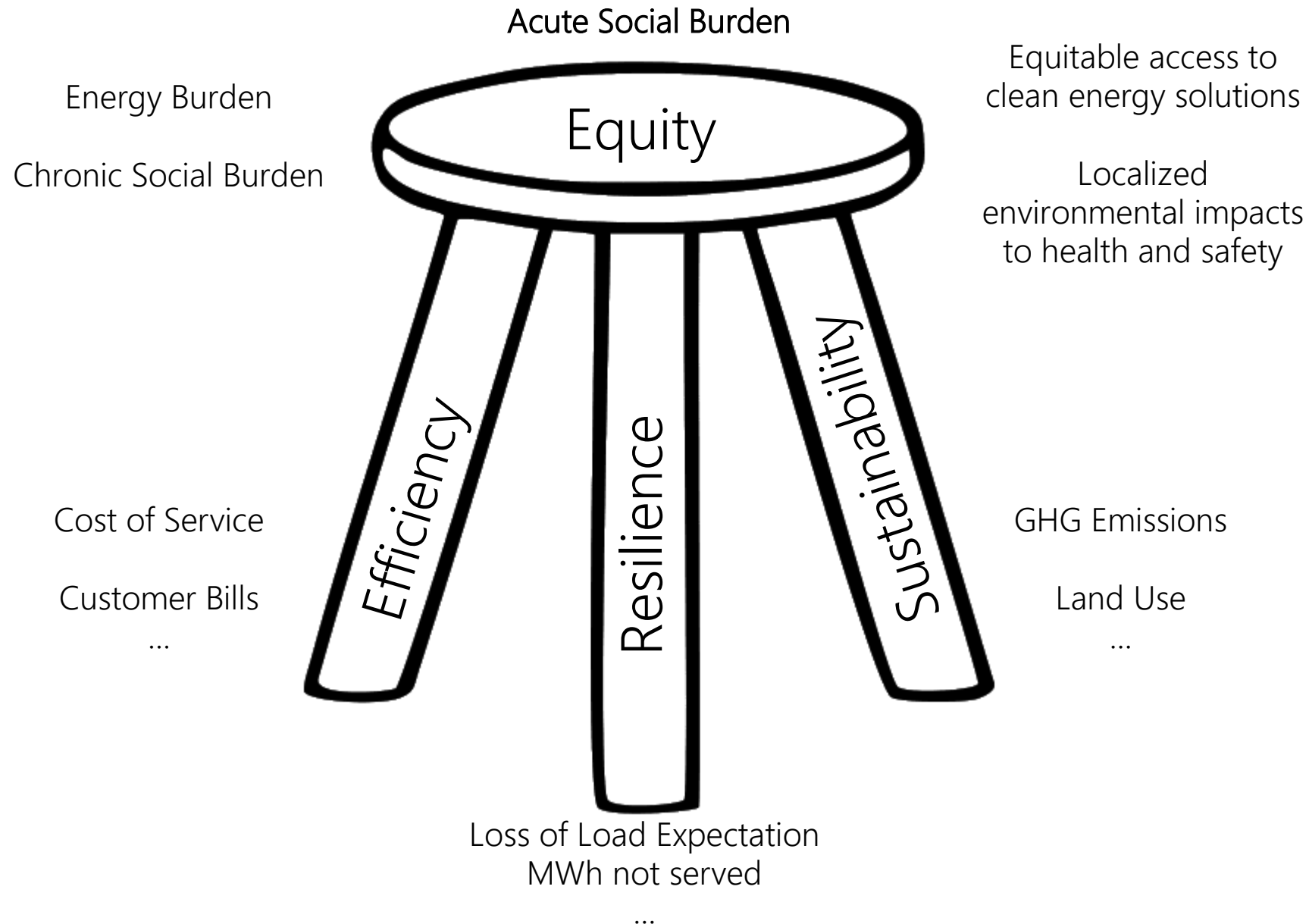
# Histogram of Customer Minutes Interrupted, Selected Causes







# Equity applies to every performance dimension







# Do we know what equitable resilience looks like?

**Texas 2021:** In some instances, downtowns remained powered and with gas while neighborhoods went without

- Employees of downtown businesses slept in their offices
- Critical load (hospitals and shelters) on the same circuit as non-critical
  - "This (downtown Austin) is a complicated, inter-connected network that includes critical buildings like the Dell Seton Medical Center, warming centers, the COVID-19 Alternate Care Site, Capitol Complex and Austin City Hall, as well as other critical infrastructure and government buildings," the city said in a news release. "Shutting down the downtown network would also cut off electricity to these critical buildings, which may also house vital communications equipment."
- Not clear what utilities use to define critical load in this situation
  - E.g. difference between economically critical and socially critical
- If social resilience metrics were used within AMI-enabled load shed scheme, what could be different?

## ***Texas Blackouts Hit Minority Neighborhoods Especially Hard***

As the freak winter storm raged, historically marginalized communities were among the first to face power outages, experts say.

<https://www.houstonchronicle.com/news/houston-texas/houston/article/Houston-skyline-lights-energy-conserve-weather-tx-15954535.php>

<https://spectrumlocalnews.com/tx/san-antonio/news/2021/02/16/some-say-privilege-factoring-into-which-communities-have-worst-power-issues->



Posted by u/Omarkhan1234 7 days ago

820



**While the rest of us freeze to death the empty office building and parking lot at Legacy West stays brightly shining undisturbed.**

Photo



138 Comments



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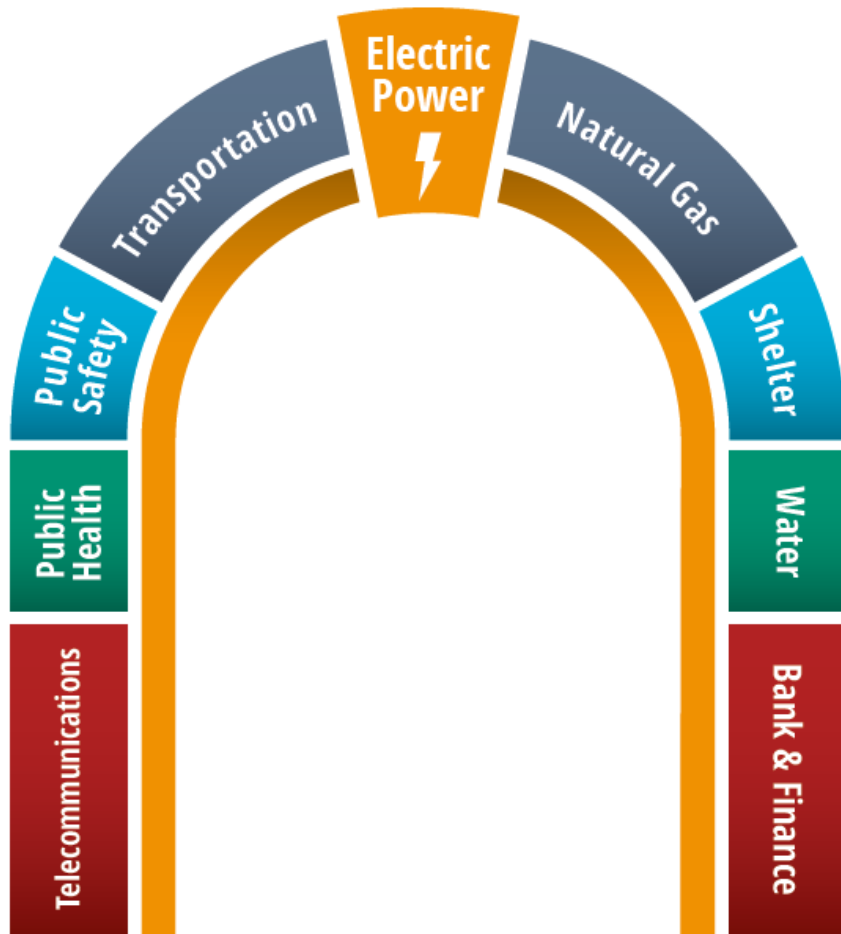
Report

95% Upvoted



# Dimensions of consequence

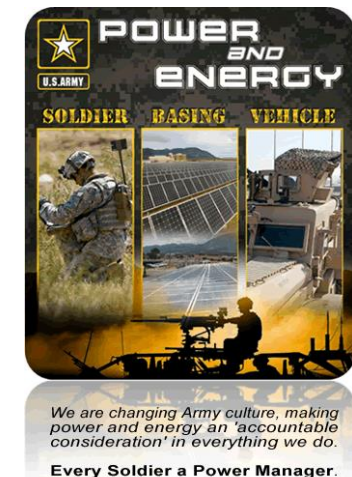
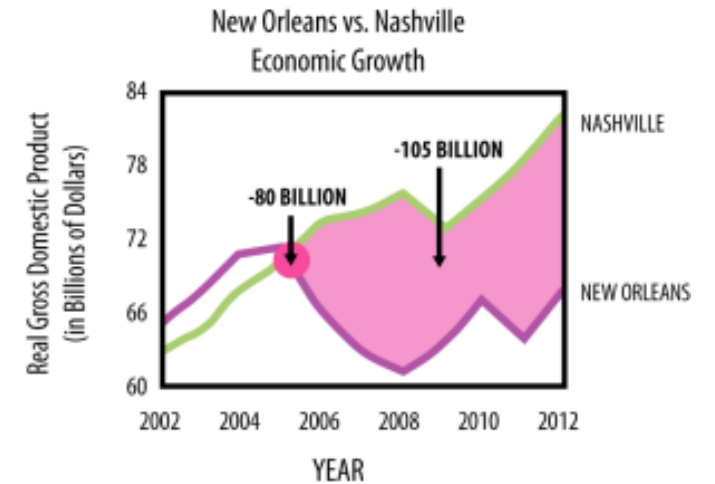
The grid is the keystone infrastructure – central to the web of interconnected systems that support life as we know it.



● Society

● Economy

● National Security





## Capabilities framework, based on Sen and Nussbaum, applied to energy by Day et al.

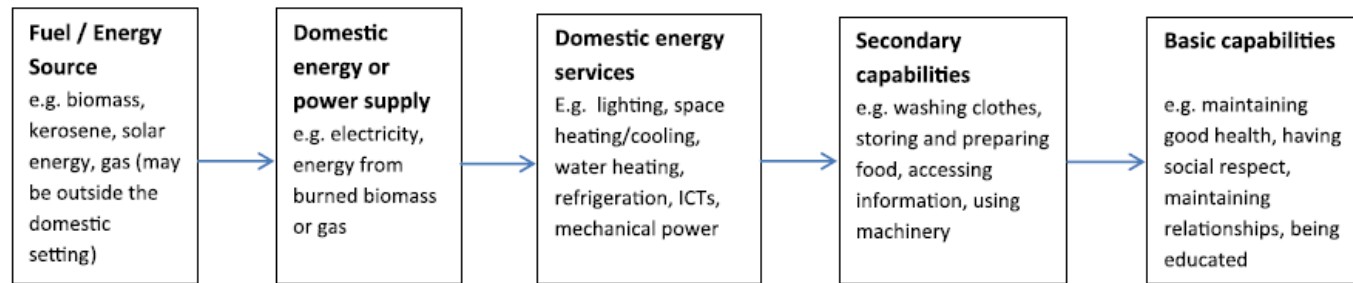


Fig. 1. Conceptualising the relationship between energy, services and outcomes.

We are utilizing this theory, but advancing/extending in two ways:

- **Chronic vs. Acute:** we are applying the capabilities framework to acute, post disaster scenarios, whereas previous literature focuses on chronic “blue sky” capabilities
- **Rigorous Quantification:** we are the first to apply a mathematical formulation to the theory





## Effort

Time + money spent  
to achieve basic level  
of human needs

## Ability

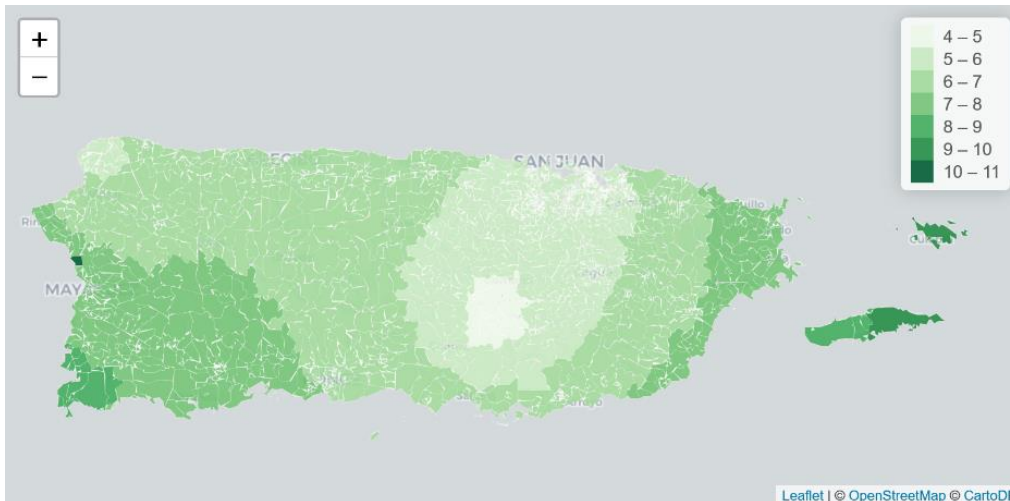
Median household  
income,  
additional predictors

## Social Burden

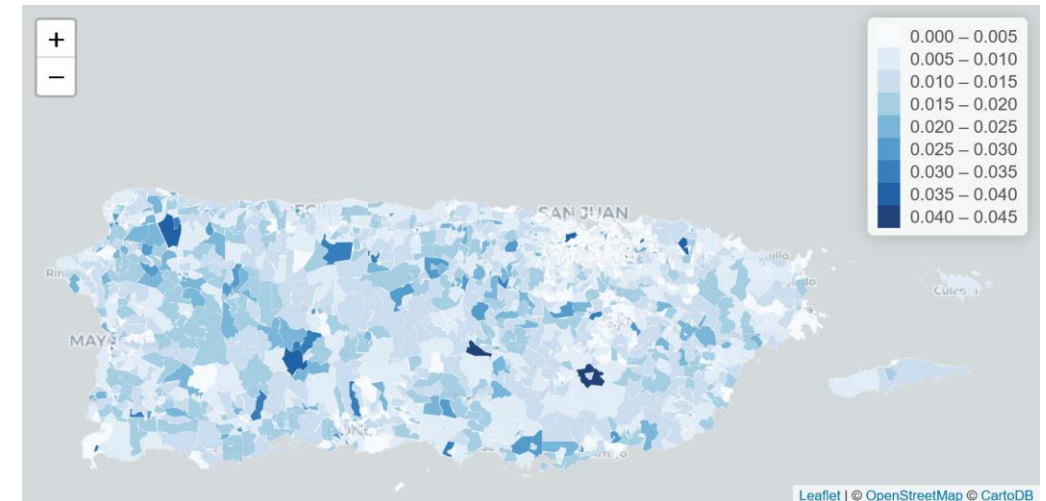
$$B_C = \sum_{inf} \sum_{pop} \frac{E_{inf,pop}}{A_{pop}}$$

1. Explicit ability
2. Variable need
3. Variable criticality
4. Relatability

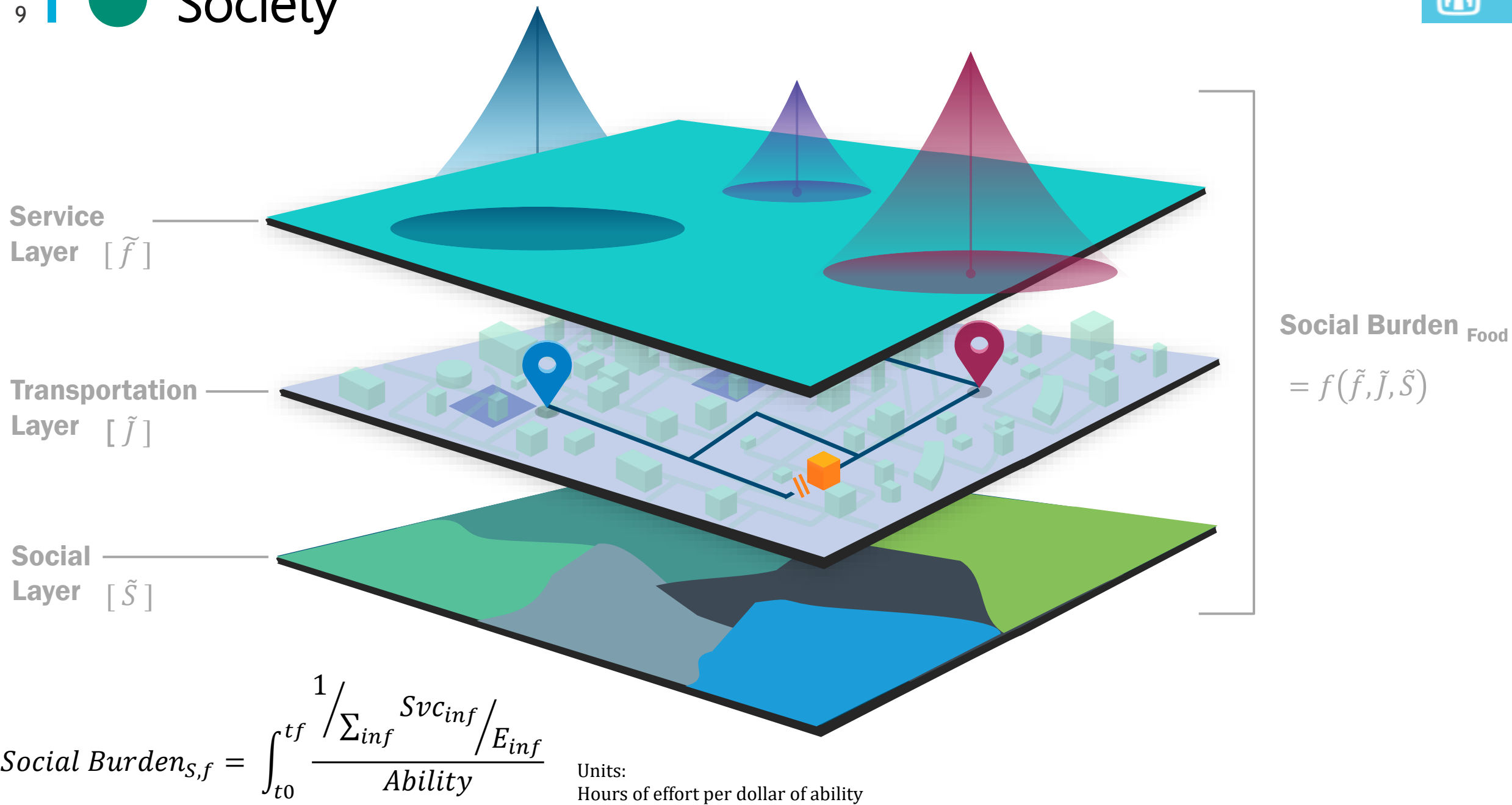
Effort during outage: 80 (out of 159 sited) microgrids



Burden during outage: 80 (out of 159 sited) microgrids

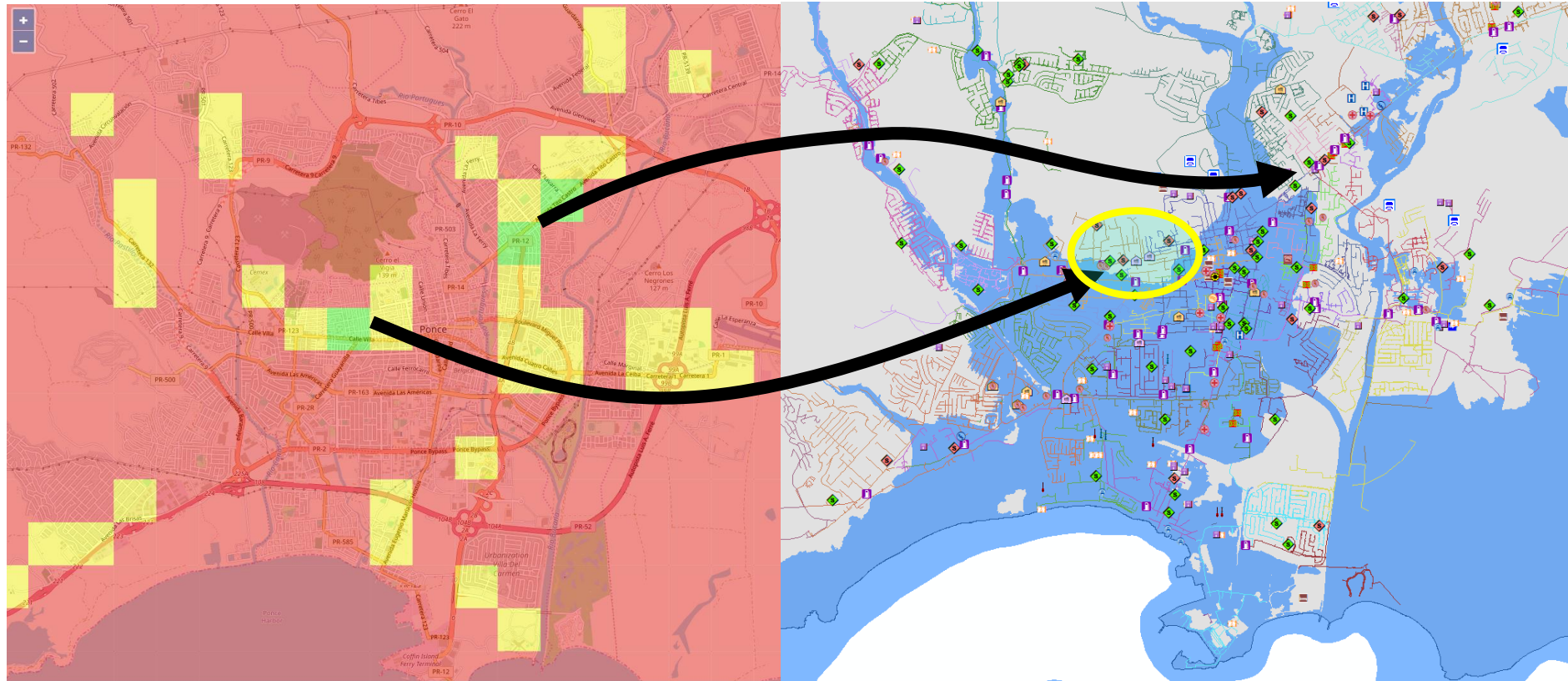






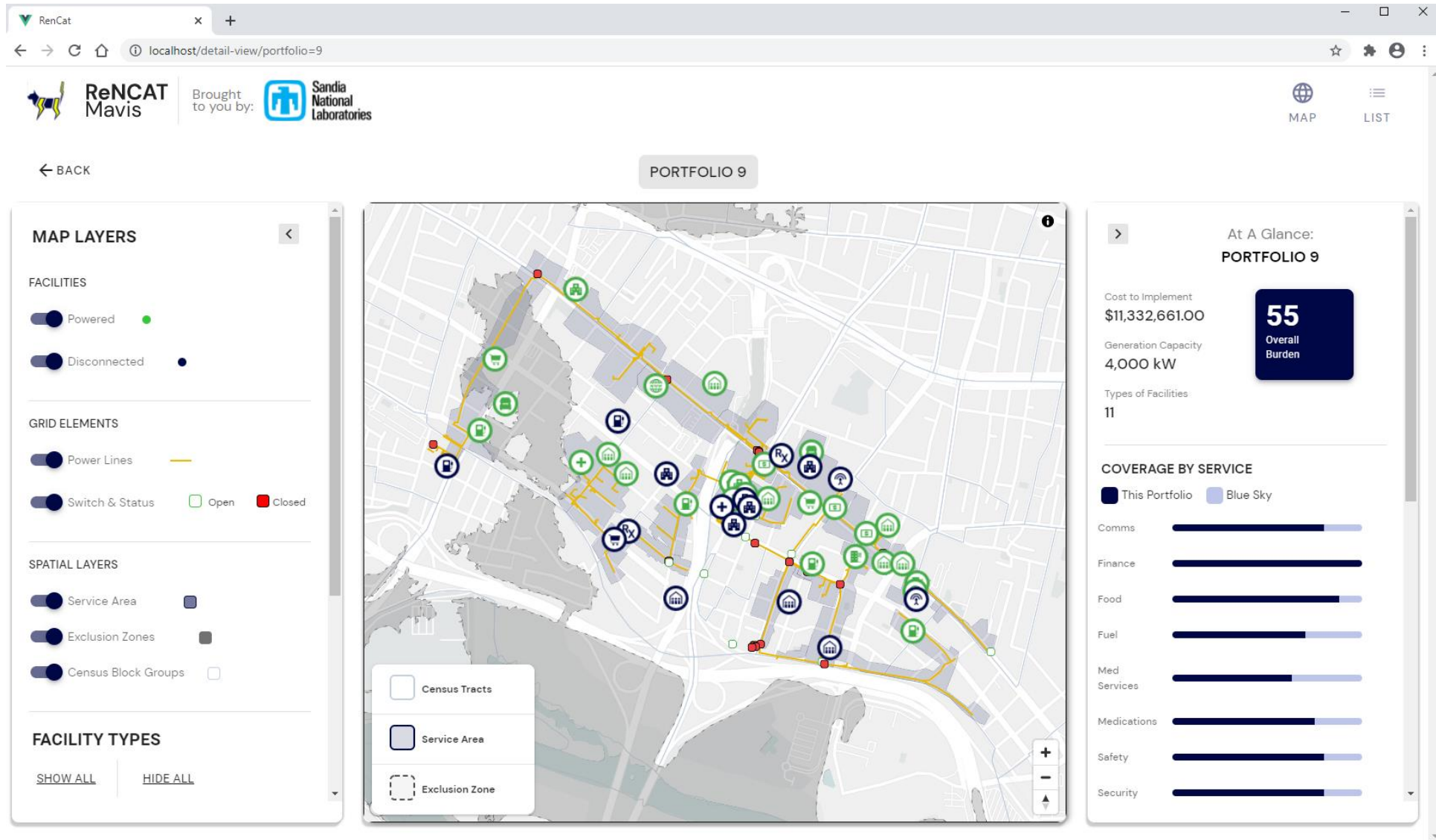


## Identifying Resilience Investments





# Automating equitable resilience planning - ReNCAT







## Current:

1. Surveying populations for their lived experiences during major power outages (Puerto Rico, San Antonio, All Texas)
2. Analyzing datasets of where people go and how long they stay during power outages vs. during normal days
3. Building a dynamic formulation that more accurately describes interactions between needs, abilities, and effort

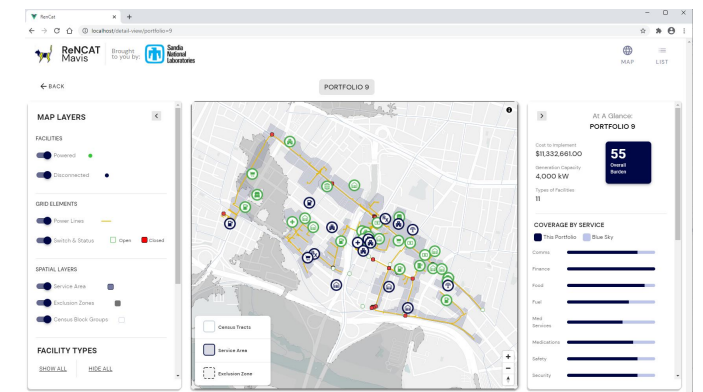
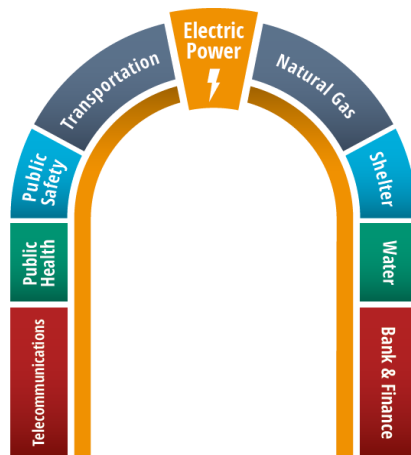
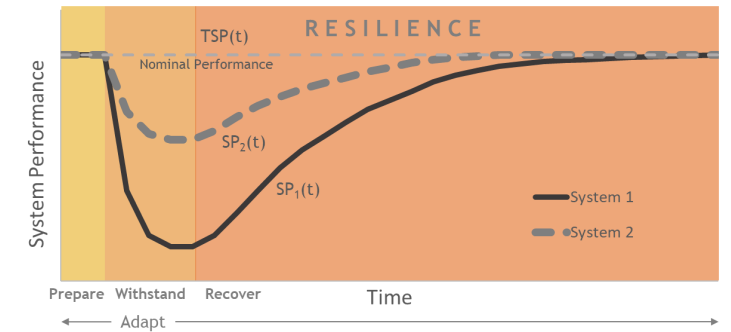
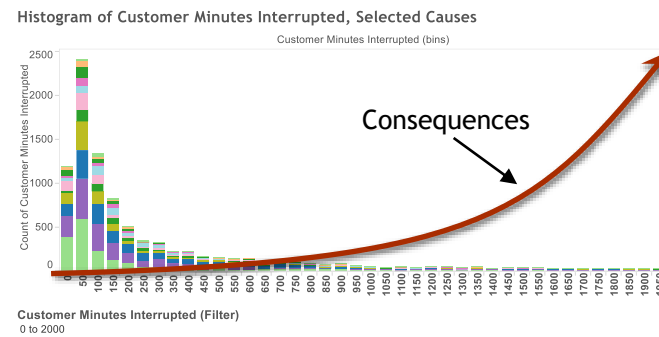
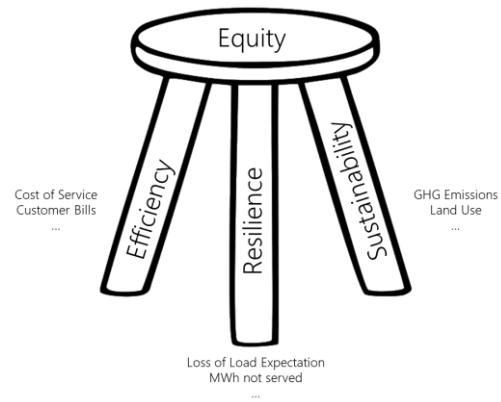
## Future:

1. How do we ensure a decarbonized grid is an equitably resilient one?
2. Can social capital build resilient societies?
3. Can resilient infrastructure improve social capital?
4. Who pays for social resilience?





[rfjeffe@sandia.gov](mailto:rfjeffe@sandia.gov)

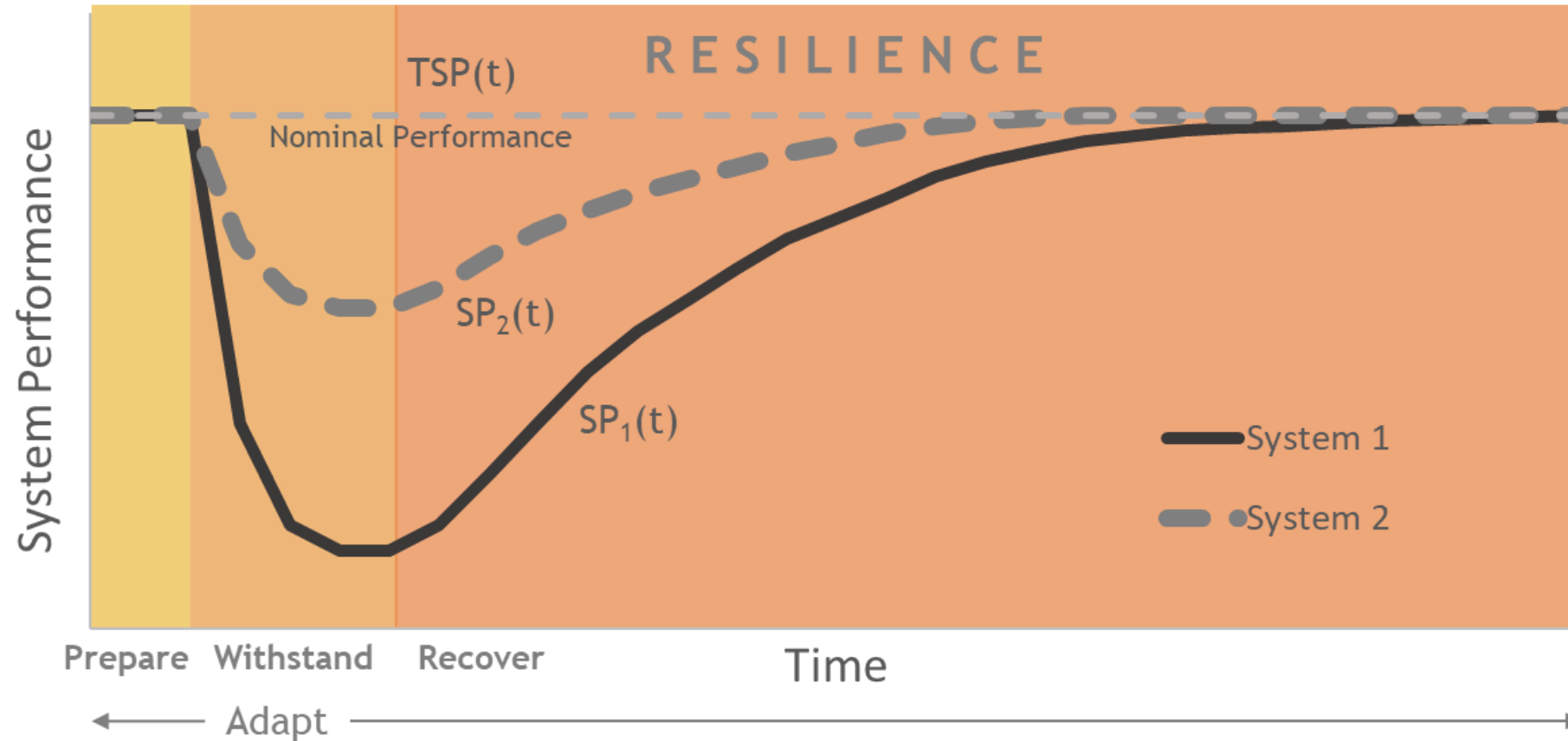




## Backup slides



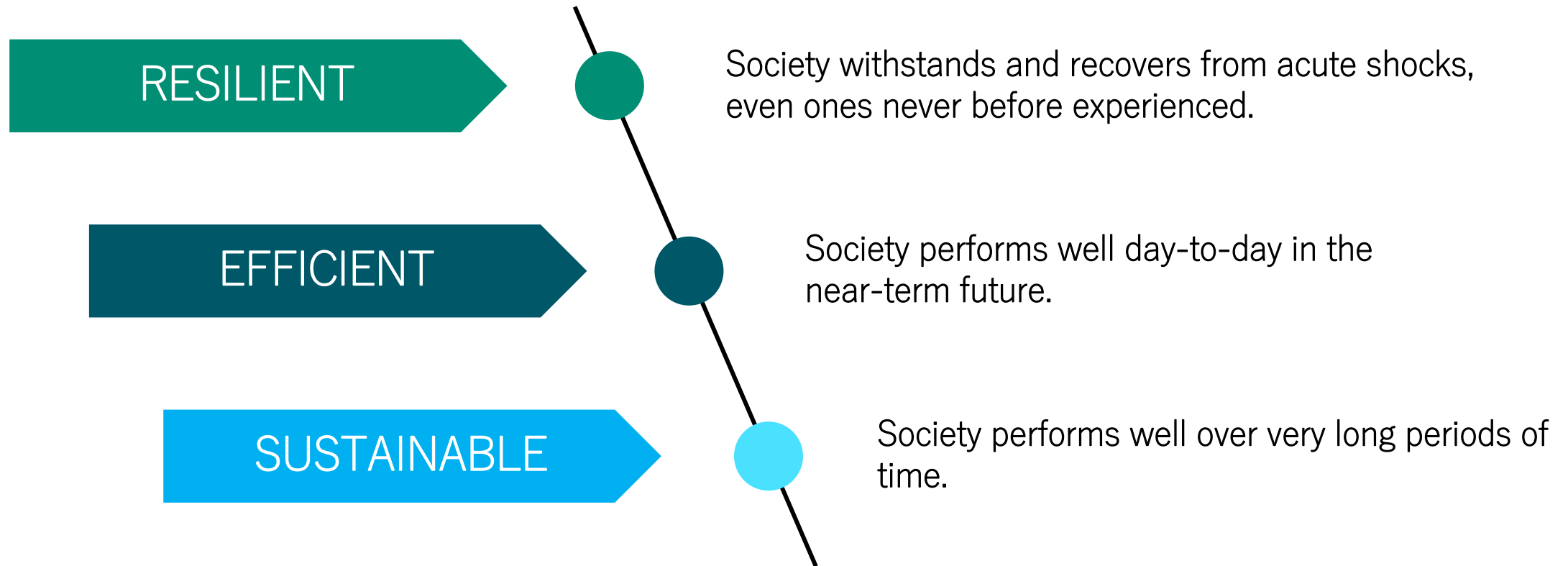
# Measuring and forecasting resilience



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



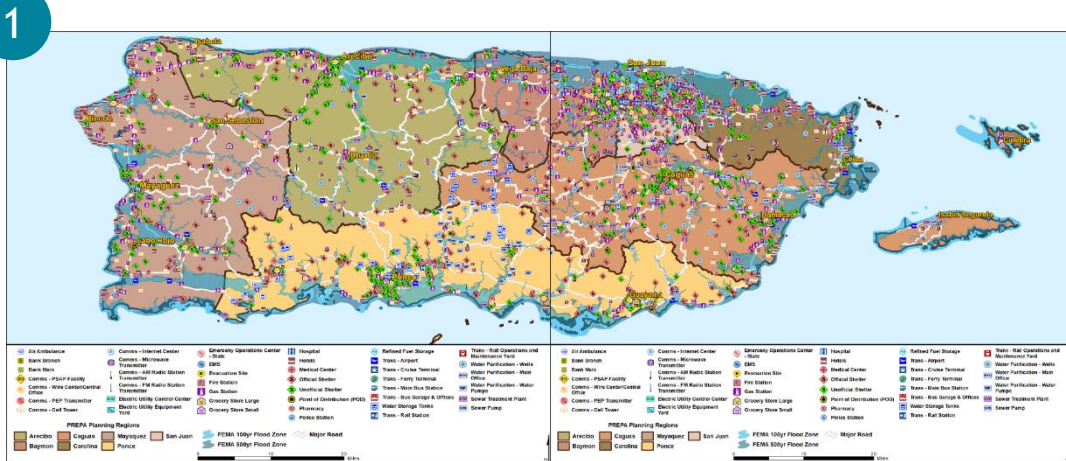


At all scales (T, D, Buildings), there are very real tradeoffs between performance in these dimensions.



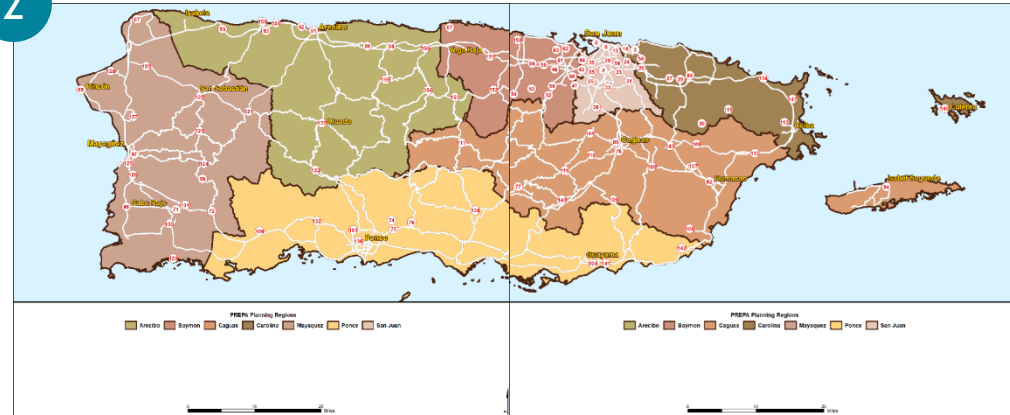
# Society

- 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

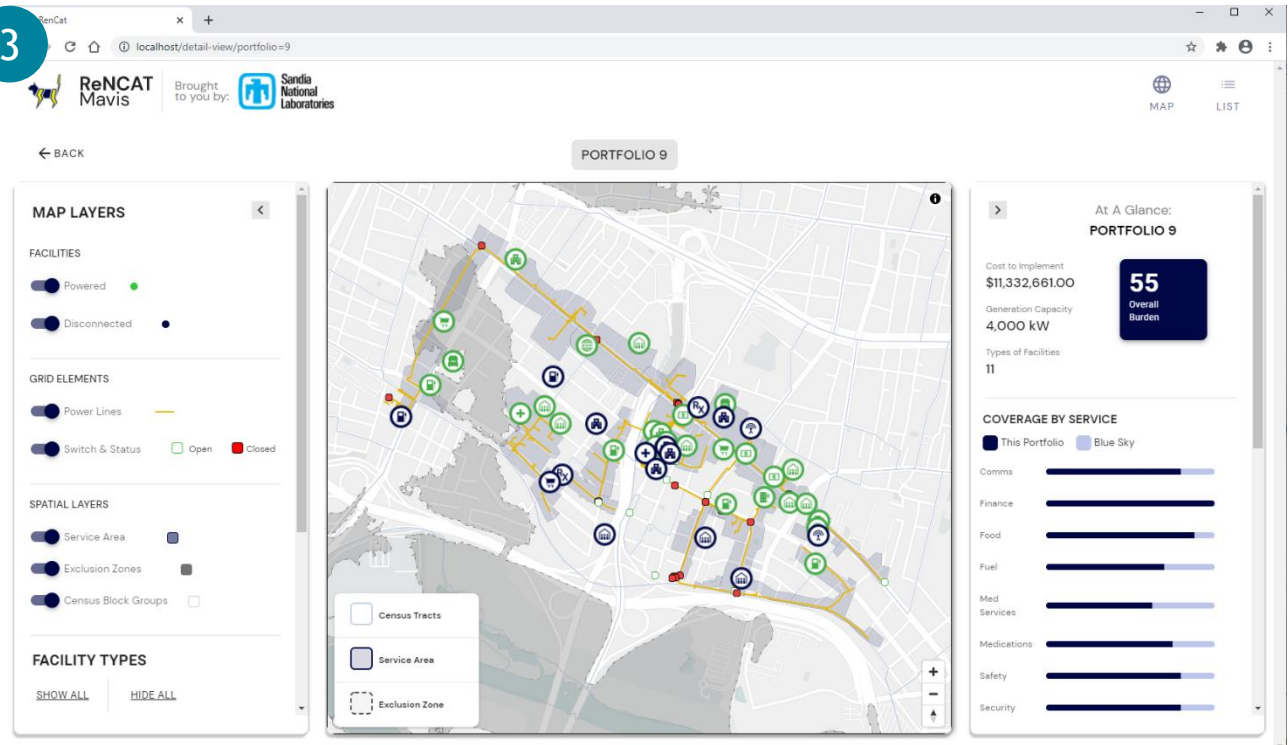


Jeffers et al. (2018) Analysis of Microgrid Locations Benefitting Community Resilience for Puerto Rico. SAND2018-11145

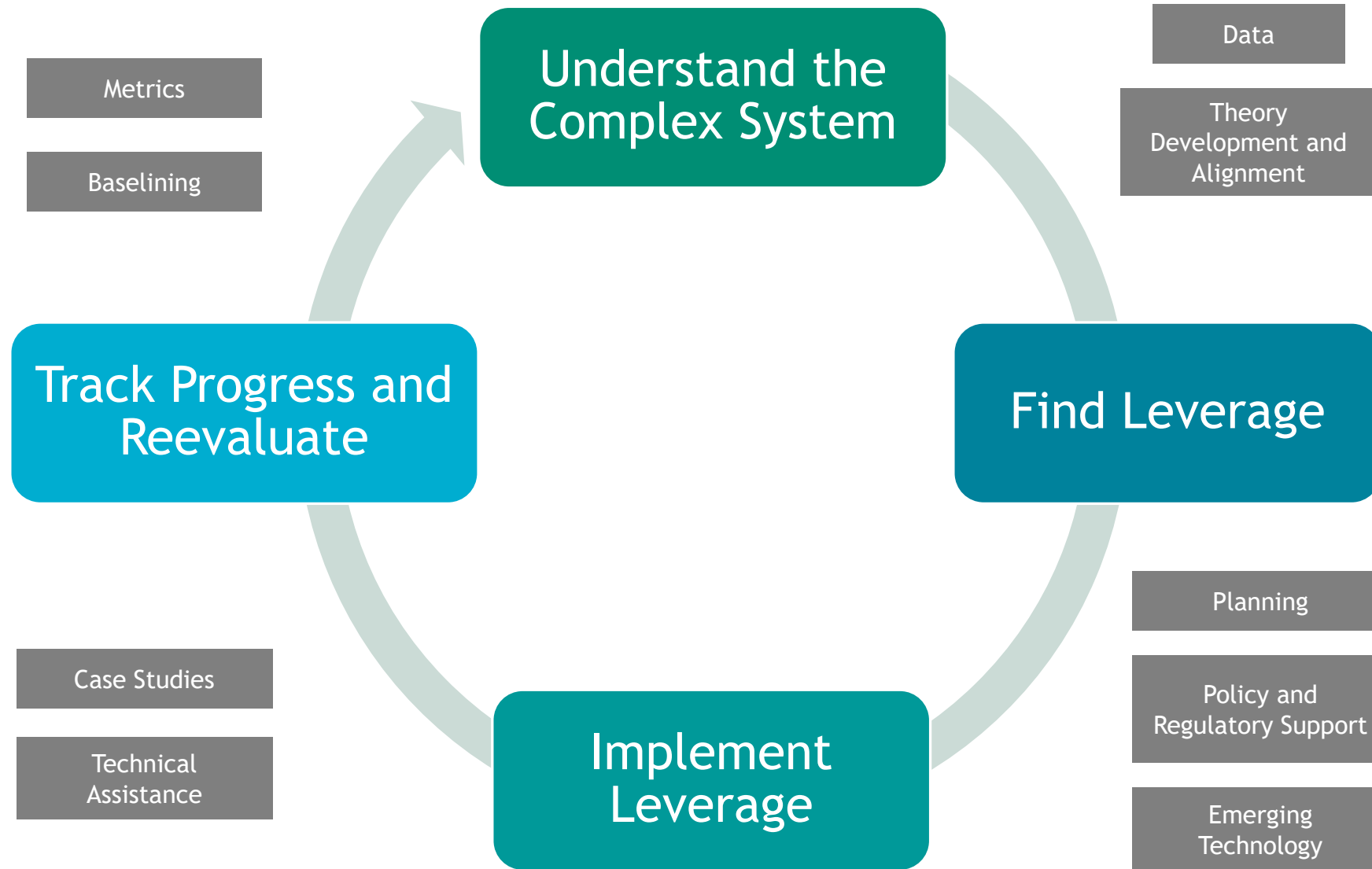
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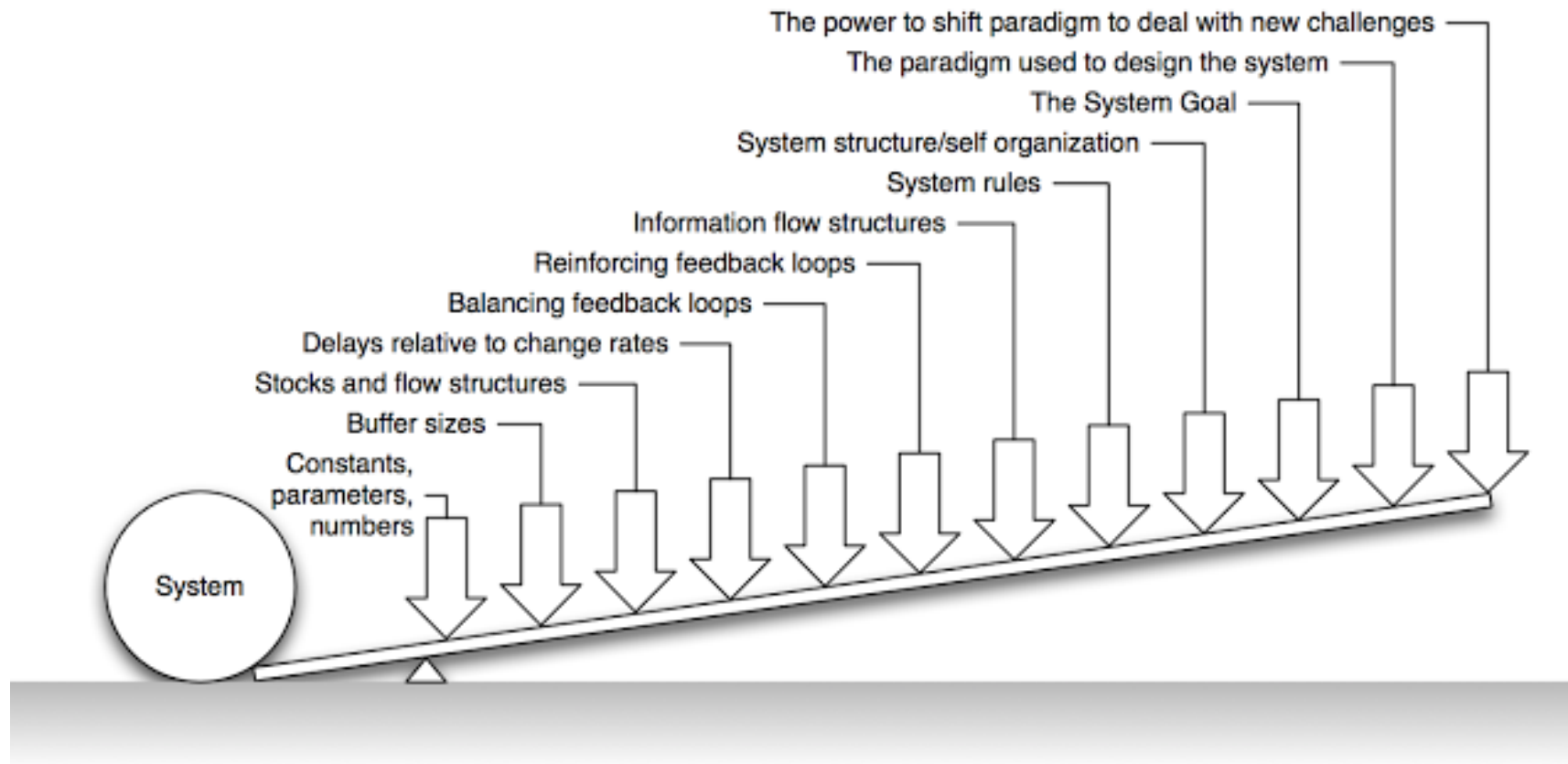






# Find Leverage

# Implement Leverage



For more about leverage in complex systems:

<http://donellameadows.org/archives/leverage-points-places-to-intervene-in-a-system/>



## Consult Stakeholders to Understand Needs



Images from Efrain O'Neill, "Efrain O'Neill et al Resilience Week 2019"



**"S.O.S WE NEED WATER/FOOD!"**

"The first step was to visit Jayuya and speak with its mayor...From that initial visit, three priority projects were identified: the oasis, a communications antenna to bring internet and convert the day care center for the elderly into a solar installation disconnected from the Electric Power Authority (PREPA)",

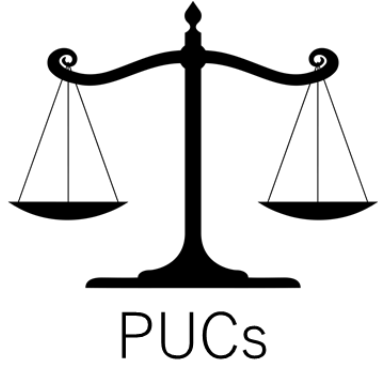
**Yiamar Rivera Matos**

[translated from <http://admin.uprm.edu/portada/article.php?id=4077>]

Images from Rachid Darbali, "Puerto Rico Hurricane Maria Presentation"



## Society





## ● Economy



Insurance  
Industry



State + Federal  
Agencies



PUCs



Local  
Government



Electric Utilities



## ● National Security



DoD

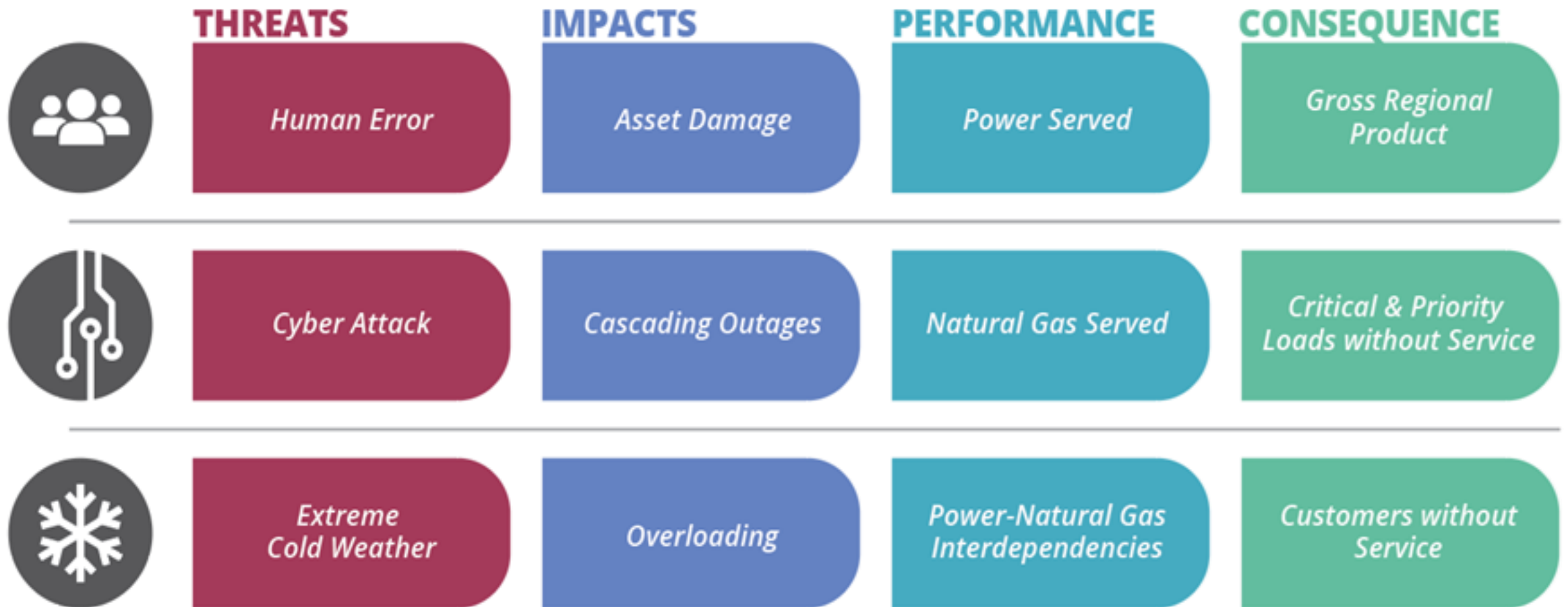


PUCs



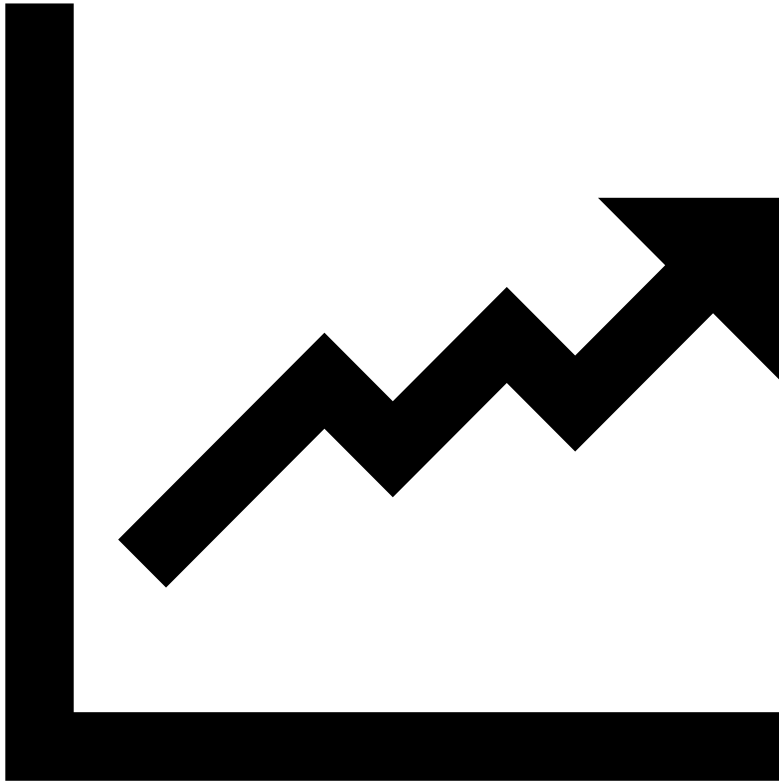
Electric Utilities







# Building Datasets over Time



Willingness to pay

Infrastructure performance

Human movement

Human sentiment

Social dependency

Economic behavior