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Integration of equitable resilience metrics into electric utility planning processes

A collaboration between the California Public Utilities Commission, Sandia National Laboratories, and Southern California Edison

Presented by Summer Ferreira, Sandia National Laboratories

November 20, 2024

Climate Adaptation Proceeding (R.18-04-019)
Climate Adaptation Equity Metrics Workshop

In partnership with:

SOUTHERN CALIFORNIA EDISON®

CALIFORNIA Public Utilities Commission

SAND2024-15202PE

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U.S. DEPARTMENT OF ENERGY

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Project Overview

Project Motivation: Developing an Equity Metric for Energy Resilience Planning in California

- **Sandia National Laboratories (Sandia), Southern California Edison (SCE), and the California Public Utilities Commission (CPUC) investigating how utilities could consider resilience needs within current infrastructure investment planning**
- Sandia, SCE, and CPUC are **investigating the use of Sandia's *Social Burden* metric in California** as a pilot metric reflecting equity considerations for energy resilience planning

Expected outcomes:

- ✓ Identifying **use cases** for the metric
- ✓ Documenting **benefits and drawbacks**
- ✓ Understanding use case **applications**

Potential use cases:

- ✓ **Informing IOUs** during the grid planning process
- ✓ **Informing stakeholders** about project prioritization
- ✓ **Allowing the CPUC to assess** regulatory considerations that include Environmental & Social Justice (ESJ) Action Plan items

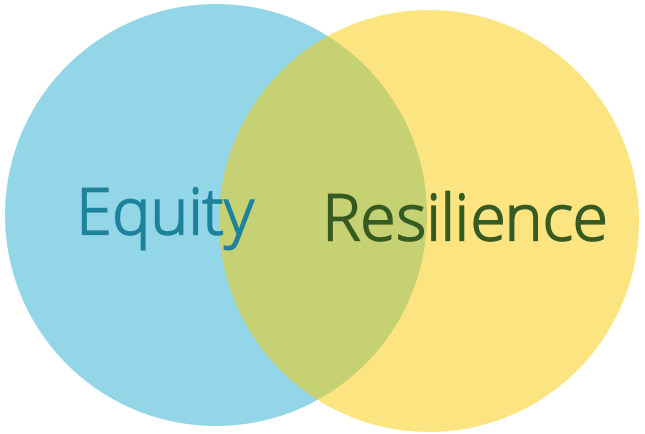
Equity and resilience are interdependent

Resilience is a component of equity

- Cannot have a truly equitable energy system if some communities are more resilient than others

However, equity is also a component of resilience

- Energy system is embedded in communities (social) and within other (physical) infrastructures
  - Embedded social inequalities independent of the energy system also impact equity
- Inequities are vulnerabilities
- Vulnerabilities reduce resilience
- Can escalate events from local concern to national security priority
  - e.g., New Orleans, Puerto Rico



Introduction to Social Burden

Social Burden measures the ability of the built environment to provide people with the critical services they need for health and wellbeing, relative to people's differing abilities to obtain those services.

In a grid resilience context, Social Burden can help prioritize resilience investments to mitigate disproportionate harm from outages. It is a quantitative metric to measure *both* resilience & equity.

Burden to acquire a service:

- Increases with distance to facilities
- Decreases with additional facilities (diminishing returns, non-linear)
- Decreases with ability (a study-specific combination of socioeconomic and other indicators: ***SCE's Community Resilience Metric**)

$$\textbf{Social Burden} = \textbf{Effort/Ability} \cong \frac{\textbf{Effort to Obtain Service}_{people,services}}{\textbf{Service Levels}_{facilities,services} \times \textbf{Baseline Capacity}_{people}}$$

Wachtel, A., Melander, D., & Jeffers, R. (2022). Measuring Societal Infrastructure Service Burden (No. SAND2022-2029R). Sandia National Lab.(SNL-NM), Albuquerque, NM (United States).

Calculating Social Burden

Relating Infrastructure to Critical Services:

$$E_{n,m} = \frac{1}{\sum_l \frac{S_{l,m}}{I_{n,l}}}$$

- $S_{l,m}$ = Infrastructure to Service relationship, a matrix of over infrastructure points (**l**) and infrastructure services (**m**)
- $I_{n,l}$ = Individual pairwise efforts between spatial elements (**n**) and infrastructure points (**l**).

Burden aggregation:

- Per-service burden calculated for each population block
- Burden summed across blocks
- Total burden summed across services

Relating Ability and Service Availability:

$$B_{n,m} = \frac{E_{n,m}}{A_n}$$

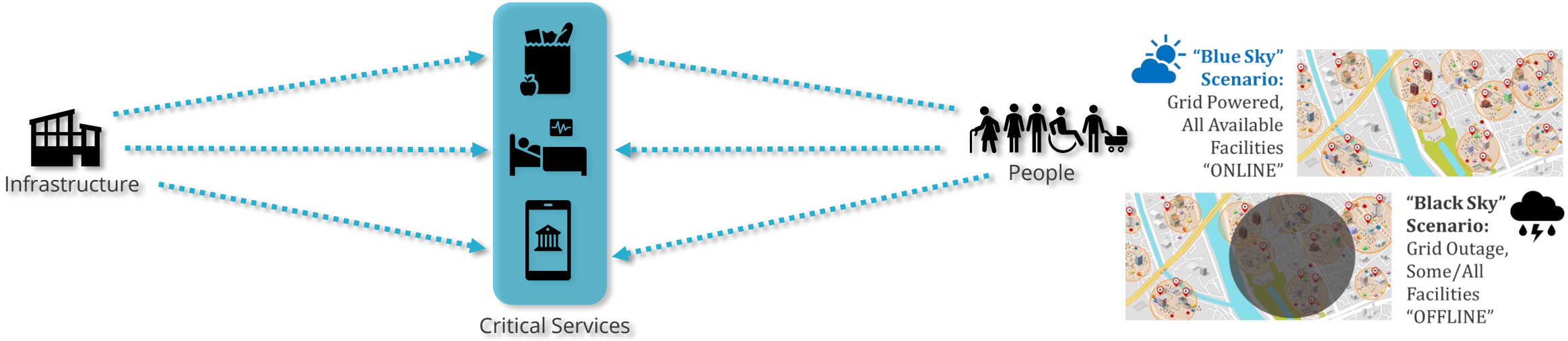
- $B_{n,m}$ = Societal Burden, a matrix over discrete space (**n**) and infrastructure services (**m**)
- $E_{n,m}$ = Attainment Effort, or how hard people have to work to attain their infrastructure service needs, also an **n x m** matrix
- A_n = Attainment Ability, or the resource people have at their disposal for attaining their infrastructure service needs, not dependent on the type of service, a vector length **n**

Wachtel, A., Melander, D., & Jeffers, R. (2022). Measuring Societal Infrastructure Service Burden (No. SAND2022-2029R). Sandia National Lab.(SNL-NM), Albuquerque, NM (United States).

Aggregating Resilience from the Facility to the Community Scale

Social Burden provides the framework to link resilience at individual buildings or facilities, to community resilience:

- People rely on infrastructure to provide them with critical services ("lifelines").
- When facilities lose power, their ability to provide critical services is diminished.
- The resilience of facilities to grid power outages can decrease loss of access to critical services.
- Facility-level resilience can *enhance* community resilience to grid power outages by decreasing service loss during outages.



Benchmarking the Relationship between Services and Facilities

The relationship between facilities and services is many-to-many:

- A single facility can provide multiple types of critical services;
- The same critical service can be provided at multiple types of facilities.
- Service levels can differ by facility type and by service.

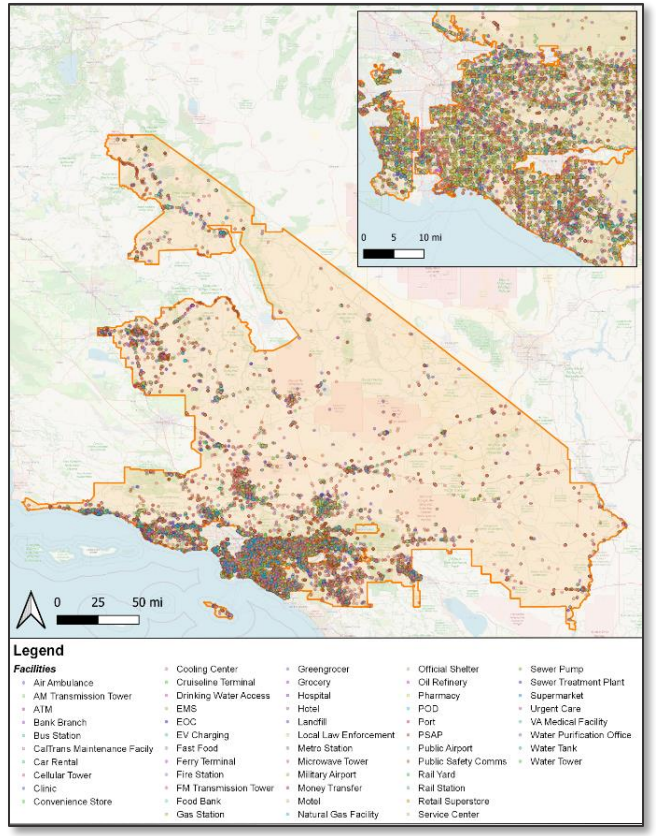
A GIS database was created for the SCE service area to represent this relationship between facilities and services:

- 54 types of facilities,
- Providing 15 different types of critical services,
- Representing over 33,000 individual facility locations.

Critical Service	Short Description
Communications	Infrastructure contributing to communication services such as cell phone towers, cable systems, TV and radio, satellite, and internet.
Emergency Logistics	Infrastructure and personnel enabling and carrying out logistics during emergency situations, including emergency systems such as alerts, warnings, 911 and dispatch, responder networks, enabling government organizations, and the responders themselves.
Evacuation	Services helping residents leave areas posing a threat to their wellbeing.
Finance	Banking services, including money transfer and cash withdrawals.
Food	Emergency food distribution and places where food is available for purchase.
Fuel	Processing, storage, and distribution of fuels (gas stations, refuel points)
Medical Service	Facilities providing medical care outside the home such as hospitals, long-term health facilities, dialysis, etc.
Medications	Over-the-counter and prescription pharmaceuticals.
Restoration	Services that help with the coordination, supply, and/or execution of restoration activities.
Safety	Primarily fire departments and search and rescue; services that enable them to operate, and services that help prevent threat-related impacts within the community.
Security	Primarily police stations and the services that enable them to operate.
Shelter	Official and unofficial shelters that can be used to shelter residents who have evacuated their homes.
Transportation	Services that enable transportation, including taxis, rental cars, public transportation networks (such as buses, trains, metros), electric vehicle charging locations, airports, and ports.
Waste Management	Solid waste and wastewater systems that serve the community.
Water	Drinking water utilities (intake, treatment, storage, distribution), emergency drinking water distribution, bottled water available for purchase, and drinking water access points.

Facility Type
Emergency Operations Center
Point of Distribution, Public Safety Answering Point (PSAP), Public Safety Communication Site
Hospital, Urgent Care, VA Medical Facility, EMS, Air Ambulance, Clinic
Local Law Enforcement
Fire Station
Shelter, Cooling Center, Hotel, Motel
Food Bank, Convenience Store, Greengrocer, Grocery Store, Supermarket, Retail Superstore (e.g., Walmart), Fast Food
Water Storage Tank, Water Purification Main Office, Water Tower, Drinking Water Access Point
Pharmacy
Bank Branch, ATM, Money Transfer
AM/FM Transmission Tower, Cellular Tower, Microwave Tower
Service Center
Landfill, Sewer Pump, Wastewater Treatment Plant
Port, Public Airport, Military Airport, Metro Station, Bus Station, Car Rental, Cruiseline Terminal, EV Charging Point, Ferry Terminal, Rail Station, CalTrans Maintenance Facilities, Rail Yard
Oil Refinery, Gas Station, Natural Gas Facility

	Effort Parameters		Critical Services														
Facility Type	Zero Distance Effort	Effort Per Foot	Evacuation	Food	Water	Waste Management	Shelter	Medical Service	Medications	Security	Safety	Restoration	Fuel	Finance	Emergency Logistics	Communications	Transportation
Air Ambulance	0.4	0.05	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
AM Transmission Tower	0.005	0.005	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
ATM	0.4	0.05	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Bank Branch	0.4	0.05	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Bus Station	0.4	0.05	3	0	0	0	0	0	0	0	0	0	0	0	0	0	4
CalTrans Maintenance Facilities	0.01	0.01	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Car Rental	0.4	0.05	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Cellular Tower	0.01	0.005	2	0	0	0	0	0	0	2	2	0	0	0	2	4	0
Clinic	0.4	0.05	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0
Convenience Store	0.4	0.05	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0
Cooling Center	0.4	0.05	0	2	2	1	3	0	1	0	0	0	0	0	1	0	0
Cruiseline Terminal	0.4	0.05	3	2	2	0	0	0	0	0	0	0	0	0	0	0	2
Drinking Water Access Points	0.4	0.05	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
EMS	0.4	0.05	0	0	0	0	0	4	0	0	3	0	0	0	0	0	0
EOC	0.4	0.05	2	0	0	0	0	0	0	0	0	0	0	0	5	0	0
EV Charging	0.4	0.05	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Fast Food	0.4	0.05	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
Ferry Terminal	0.4	0.05	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Fire Station	0.4	0.05	0	0	0	0	0	2	0	0	4	0	0	0	0	0	0
FM Transmission Tower	0.005	0.005	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Food Bank	0.4	0.05	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0
Gas Stations	0.4	0.05	0	1	1	0	0	0	1	0	0	0	4	0	0	0	0
Greengrocer	0.4	0.05	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0
Grocery	0.4	0.05	0	4	3	0	0	0	2	0	0	0	0	0	0	0	0
Hospital	0.4	0.05	0	0	0	0	0	5	3	0	0	0	0	0	0	0	0
Hotel	0.4	0.05	0	1	1	0	4	0	0	0	0	0	0	0	0	0	0
Landfill	0.01	0.01	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Local Law Enforcement	0.4	0.05	2	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Metro Station	0.4	0.05	3	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Microwave Tower	0.005	0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Military Airport	0.4	0.05	4	4	2	0	0	0	2	0	0	3	2	0	0	0	5
Money Transfer	0.4	0.05	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Motel	0.4	0.05	0	1	1	0	4	0	0	0	0	0	0	0	0	0	0
Natural Gas Facility	0.01	0.01	0	0	0	0	0	0	0	0	0	2	5	0	0	0	0
Official Shelter	0.4	0.05	0	2	2	1	4	0	1	0	0	0	0	0	1	0	0
Oil Refinery	0.01	0.01	0	0	0	0	0	0	0	0	0	2	5	0	0	0	0
Pharmacy	0.4	0.05	0	1	1	0	0	1	4	0	0	0	0	0	0	0	0
POD	0.4	0.05	0	4	4	0	0	0	2	0	0	0	0	0	2	0	0
Port	0.4	0.05	4	3	2	0	0	0	0	0	0	3	2	0	0	0	5
PSAP	0.01	0.005	0	0	0	0	0	0	4	5	0	0	0	0	0	0	0
Public Airport	0.4	0.05	4	4	2	0	0	0	2	0	0	3	2	0	0	0	5
Public Safety Comms Sites	0.01	0.005	4	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Rail OM Yard	0.2	0.01	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Rail Station	0.4	0.05	3	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Retail Superstore	0.4	0.05	0	4	3	0	0	0	2	0	0	0	0	0	0	0	0
Service Center	0.01	0.01	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
Sewer Pump	0.01	0.01	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Sewer Treatment Plant	0.01	0.01	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Supermarket	0.4	0.05	0	4	3	0	0	0	2	0	0	0	0	0	0	0	0
Urgent Care	0.4	0.05	0	0	0	0	0	5	3	0	0	0	0	0	0	0	0
VA Medical Facilities	0.4	0.05	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0
Water Purification Main Office	0.01	0.01	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Water Storage Tank	0.01	0.01	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Water Tower	0.01	0.01	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0

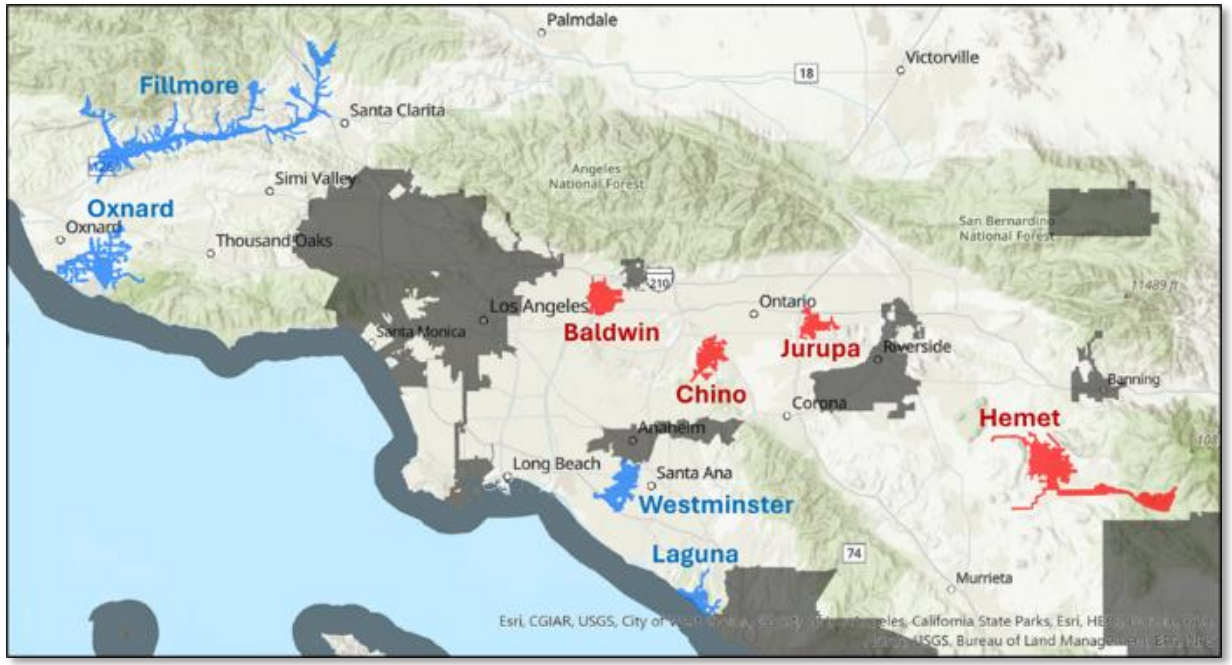


Hart, O., Wachtel, A., Sorge, M., McCombs, A., Brockway, A., and Chwierut, A. (2024) Integration of Equitable Resilience Metrics into Climate-Informed Electric Utility Planning Processes: Phase One Results (No. SAND2024-15090). Sandia National Lab. (SNL-NM), Albuquerque, NM (United States).

Evaluating Community Resilience to Climate Scenarios

- A “black-sky” scenario in Social Burden analysis can represent any partial or total outage on the grid.
- The outages can be hypothetical or based on real (historic or projected) events.
- In this study, the outage scenarios were hypothetical and based on SCE’s prior analysis of potential climate impacts in its service area as documented in the 2022 CAVA.

Hazard	Scenario Name	County	CRM	Rural	Customer Count	IWMS Risk
Temp	Hemet	Riverside	High	Low	Medium	Medium
Temp	Chino	San Bernardino	High	Low	Medium	Medium
Temp	Baldwin	Los Angeles	Low	Low	High	Low
Temp	Jurupa	San Bernardino	Low	Low	Low	Low
Flood	Laguna	Orange	High	Low	Medium	High
Flood	Oxnard	Ventura	Low	Low	High	Low
Flood	Fillmore	Ventura	Medium	Medium	Low	High
Flood	Westminster	Orange	Medium	Low	Medium	Low



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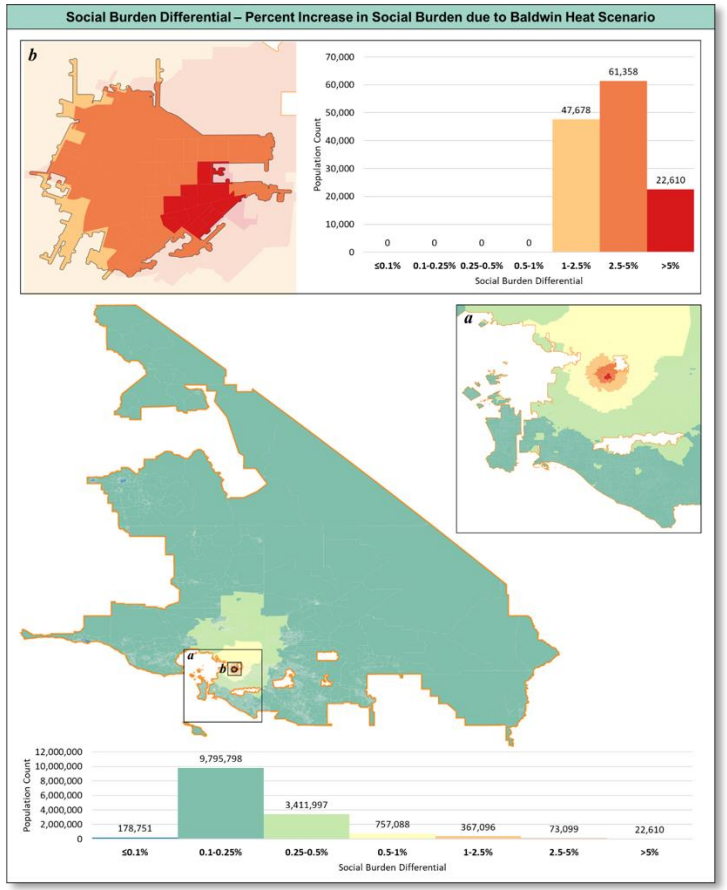
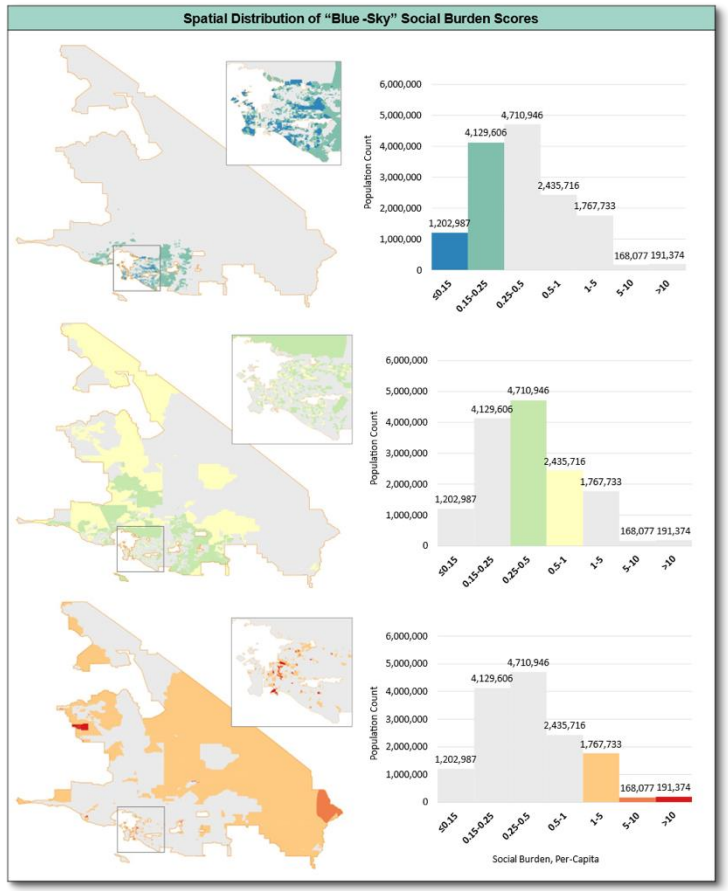
Helping Quantify Impacts, Explore Root Causes

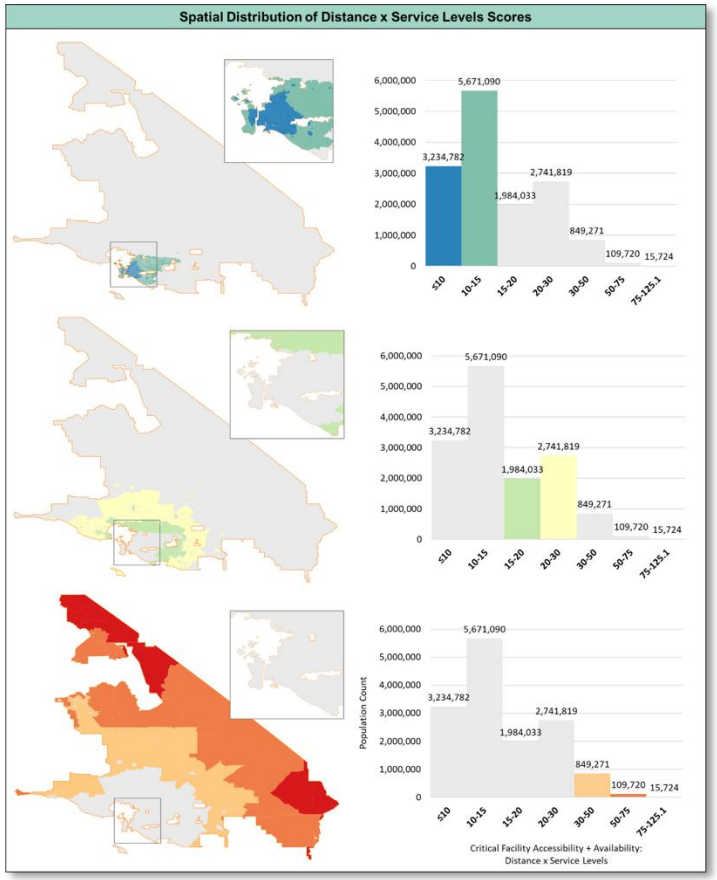
Q: How do outage impacts propagate and how sensitive are people within particular hypothetical outage extents?



Q: Which parts of the service area start off more burdened, before any outages add increased burden?



Q: Where would community resilience be enhanced by additional investment in critical services?



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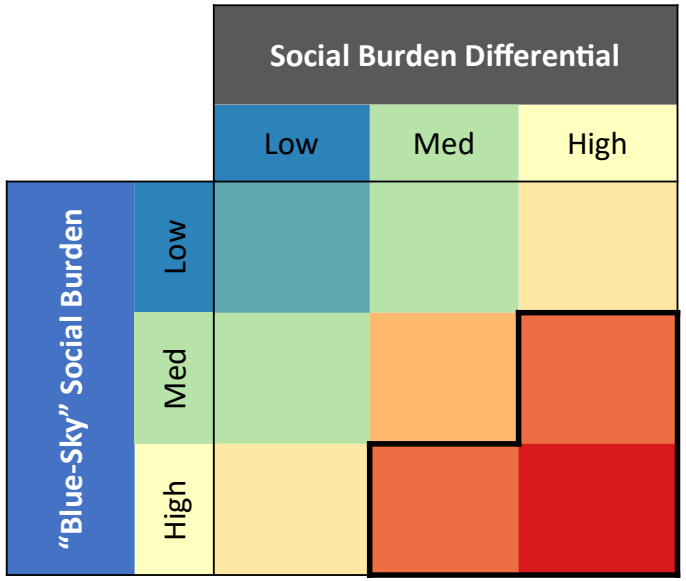
Implications for Planning and Alternatives Evaluation



"Black-Sky" Social Burden		
	Extremely High	Extremely low community resilience to power outage
	Very High	Very low community resilience to power outage
	High	Low community resilience to power outage
	Medium	Moderate community resilience to power outage
	Low	High community resilience to power outage

Bold outline at left denotes recommended focus for grid-based interventions, where electric utilities can make impactful improvements to communities' resilience to power outages.

Intervention Categories and Representative Examples		Will Reduce High Black-Sky Social Burden by Driving Down:	
		Blue-Sky **Social Burden**	**Social Burden *Differential***
Electric Infrastructure Owners & Operators	Microgrids, line hardening, undergrounding, prioritized restoration		✓
Non-Electric Infrastructure Owners & Operators	Expansion of services and construction of new facilities	✓	
Non-Electric Infrastructure Owners & Operators	Installation of backup generators		✓
Local Jurisdictional Authorities	Rezoning, economic development initiatives, public health supports	✓	
Local Jurisdictional Authorities	Expansion of Community Resilience Hubs, Cooling Centers		✓

Principal Findings and Future R&D Needs

Social Burden integrates into and extends existing utility equity planning processes within climate adaptation

Continue working towards formal integration of Social Burden into utility planning

- **Apply Social Burden to evaluate specific <u>outage *and climate*</u> interventions;** test Social Burden's ability to represent "intersectional" benefits of non-resilience investments
- **Develop <u>variable-duration</u> Social Burden metric**; apply to different duration outage scenarios to understand impacts of climate-related outages intersected with extreme weather
- **Develop <u>coupled socio-economic framework</u> for (e)valuation of variable-duration outages and intervention prioritization**
- **Develop and operationalize a framework for the <u>integration of Sandia's Social Burden metric into the SCE Climate Adaptation investment planning process</u>.**

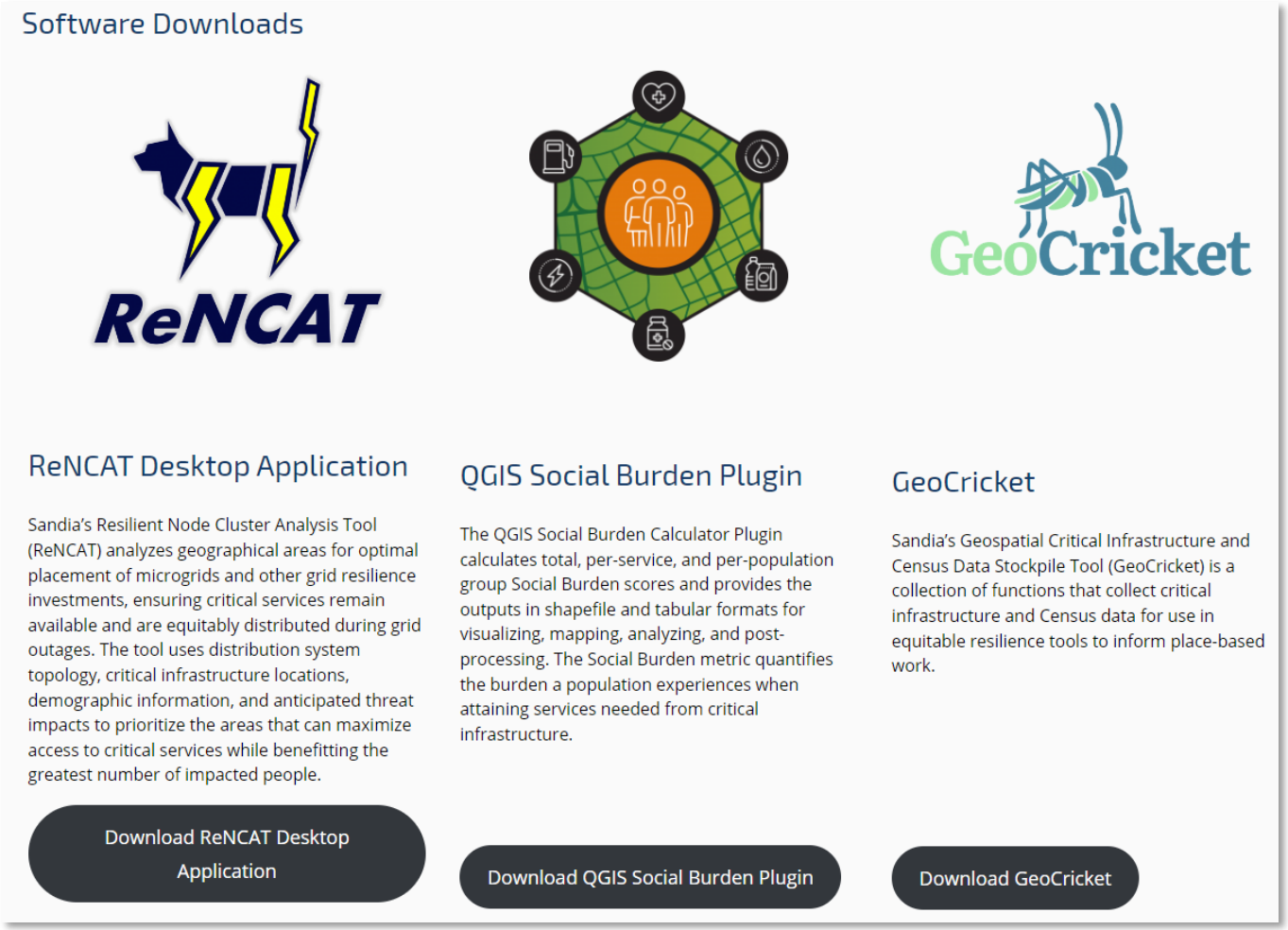
- **Community engagement to inform metric and ground-truth results**
- **Analytic support for outage extent prediction**
- **User-friendly GUIs for utility adoption**

A growing ecosystem of user-friendly tools

In addition to the ReNCAT desktop application, the *ReNCAT ecosystem* now includes several **new** user-friendly, open-source tools that enable users – from communities to energy planners – to collect their own critical infrastructure data and perform Social Burden analyses and to visualize and overlay results in a GIS application.

ReNCAT, and the QGIS Social Burden and GeoCricket plugins can be downloaded online from:

https://energy.sandia.gov/resilient-node-cluster-analysis-tool/



Additional Resources

Project report:

Hart, O., Wachtel, A., Sorge, M., McCombs, A., Brockway, A., and Chwierut, A. (2024) *Integration of Equitable Resilience Metrics into Climate-Informed Electric Utility Planning Processes: Phase One Results* (No. SAND2024-15090). Sandia National Lab. (SNL-NM), Albuquerque, NM (United States). https://www.osti.gov/servlets/purl/2477038

Public webinar recordings:

- Hart, O., Wachtel, A., Melander, D., and Bresloff, C. (July 2022) *Resilience Node Cluster Analysis Tool (ReNCAT).* CPUC Microgrid Proceeding – Track 5 Value of Resiliency: Economic and Equity Impacts of Large Disruptions – Social Burden Index. *https://www.youtube.com/watch?v=QKM_L9YcHmg*
- Hart, O., Wachtel, A., Melander, D., Brockway, A., and Blagaich, M. (July 2023). *Sandia's Social Burden and Southern California Edison's Community Resilience Metric*. CPUC Microgrid Proceeding – Track 5 Value of Resiliency: Economic and Equity Impacts of Large Disruptions – Social Burden Index. *https://www.youtube.com/watch?v=6eD-dUGaWXk&t=588s*
- Hart, O., Wachtel, A., Melander, D., Brockway, A., and Torres, S. (November 2023). *Evaluating Social Burden in California: Final Results*. CPUC Microgrid Proceeding – Track 5 Value of Resiliency: Economic and Equity Impacts of Large Disruptions – Social Burden Index. *https://www.youtube.com/watch?v=e0ZXqXuCLyg*

Further Reading on Social Burden and ReNCAT theory and applications:

- Wachtel, A., Melander, D., & Jeffers, R. (2022). *Measuring Societal Infrastructure Service Burden* (No. SAND2022-2029R). Sandia National Lab.(SNL-NM), Albuquerque, NM (United States).
- Wachtel, A., Melander, D., & Hart, O. (2022). *ReNCAT: The Resilient Node Cluster Analysis Tool* (No. SAND2022-10888R). Sandia National Lab.(SNL-NM), Albuquerque, NM (United States).
- Gunda, T., Wachtel, A., Khadka Mishra, S., & Moog, E. (2023). Quantitative approaches for including equity in risk and resilience infrastructure planning analyses. *Risk Analysis*.
- Hart, O., Wachtel, A., Jones, K., Jimenez, T., Lucas, H., Gregory, P., and Tam, D. (In Revision) Moving towards a more comprehensive valuation of resilience investments: case study in a tribal context. *Energy Research and Social Justice*.

Download ReNCAT:

https://energy.sandia.gov/news/download-sandias-resilient-node-cluster-analysis-tool-rencat/

Path Forward: SCE Perspective