Detecting Social and Spatial Disparities in Managed and Hazard-Induced Power Outages

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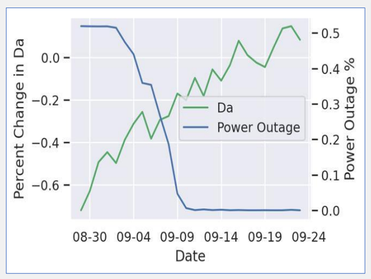
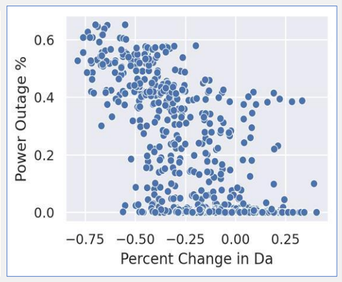
Introduction

- The energy sector is vulnerable to extreme climatic events.
- Current restoration approaches focus on the number of outages and populations which neglect social and spatial vulnerabilities.
- The research studied hazard-induced power outages caused by Hurricane Ida (2021) and managed power outages caused by Winter Storm Uri (2021).

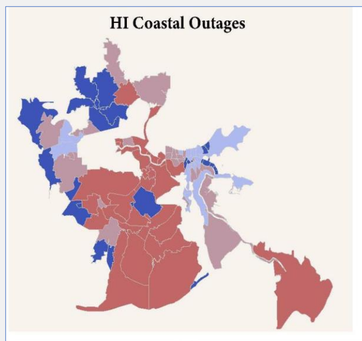
Data Collection

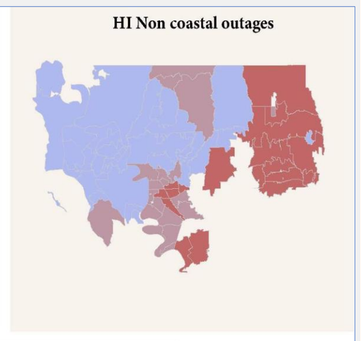
- The research team collected 4-hour power outage from Entergy company for Louisiana.
- Despite the concerted efforts of the research team, we were unable to collect direct outage data. Instead, Mapbox activity index data was deemed a reliable measurement for areas of extreme outages in Harris County, Texas

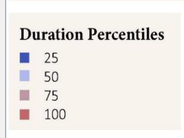


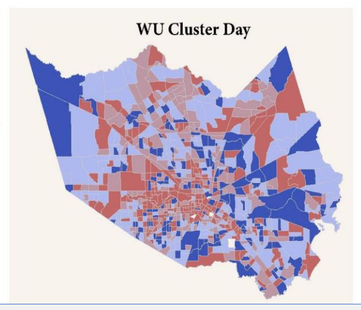


- For Winter Storm Uri, the 75th percentile is greater than 7 days. For Hurricane Ida, the 75 the percentile is greater than 16 days for coastal areas and greater than 7 days for non-coastal areas.



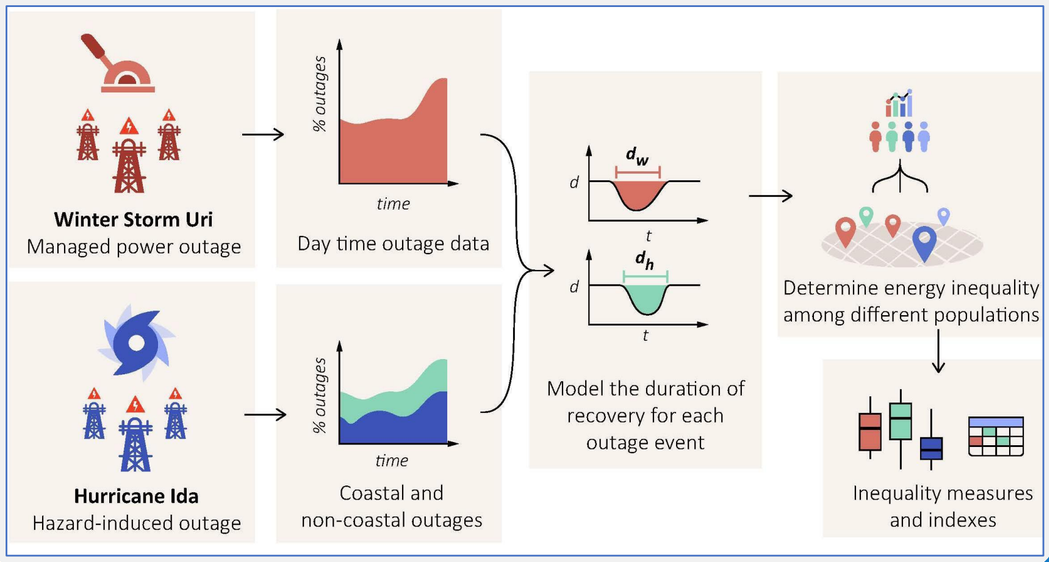






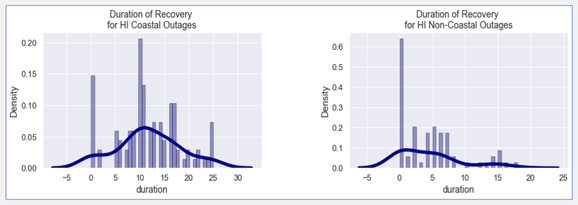
Methodology

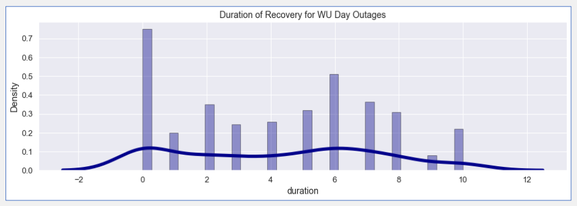
Data Collection | **Processing** | **Recovery** | **Inequality Metrics**



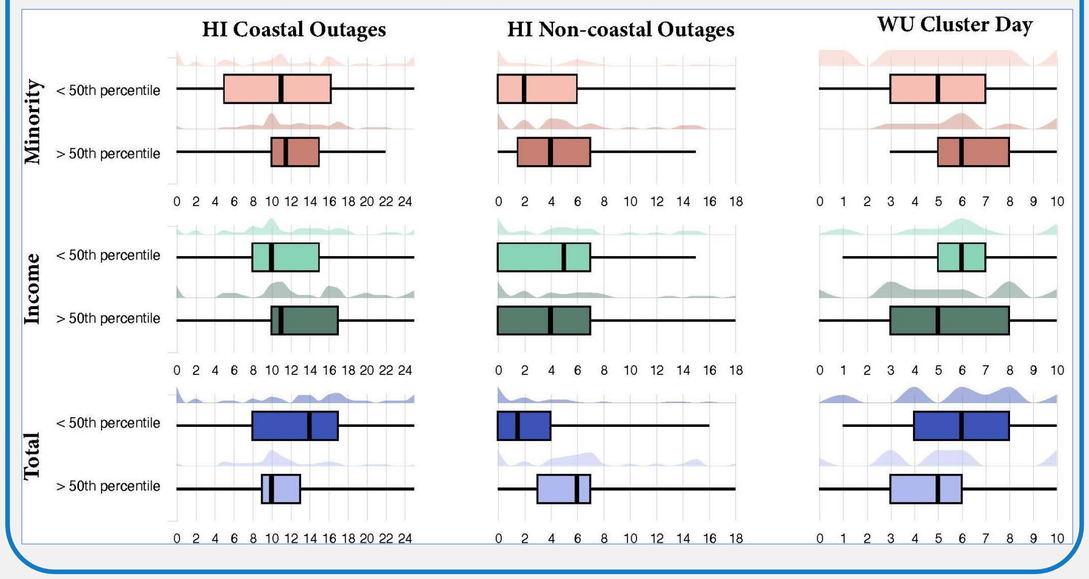
Social Inequalities to Energy Disruptions

- The duration of recovery was calculated at a 10% threshold, confirmed by a sensitivity test.
- The distribution curve for WU Day outages and non-coastal outages were not normally distributed ($p<0.05$) with specific peaks.
- Coastal outages was normally distributed with the longest duration of recovery.





- Higher percentage of black populations showed disparity in coastal and non-coastal areas while lower income had disparity in coastal areas.
- Lower income and higher percentage of Hispanic populations had a greater median of recovery in extremely impacted outages of the winter storm.



Inequality Measures

$$G = \frac{\sigma_i \, \sigma_j \, w_{i,j} |x_i - x_j|}{2n^2 \underline{x}} + \frac{\sigma_i \, \sigma_j \, (1 - w_{i,j}) |x_i - x_j|}{2n^2 \underline{x}}$$

$w_{i,j}$ is a value one when w_i and w_j are neighbors and is zero otherwise.

- **Spatial Gini** co-efficient values and percent differences for the duration of recovery show there is moderate to high level of spatial inequalities.

	Spatial Gini	% diff. to WU Day	%diff. to HI Coastal	%diff. to HI Non-Coastal
WU Day	0.4214*		42.14	-21.61
HI Coastal	0.2727*	-42.85		-63.00
HI N-Coastal	0.5235*	21.61	63.00	

$$I = \frac{\sigma}{\sqrt{\mu(1-\mu)}};\ 0 < \mu < 1$$

where μ is the mean of power outages (y) and σ is the standard deviation of power outages(y)

- **Infrastructure inequality** was the highest for managed power outages, then non-coastal areas, and lastly coastal areas. This suggests that hazard exposure alone does not contribute to inequalities.

	Infra-structure Inequality	% diff. to WU Day	% diff. to HI Coastal	% diff. to HI Non-Coastal
WU Day	0.638		19.78	3.49
HI Coastal	0.523	-19.78		-16.31
HI N-Coastal	0.616	-3.49	16.31	

Contributions

- Greater investment in collecting and processing perishable data at a granular scale
- Incorporate social and spatial disparities into the restoration strategies
- Advise community leaders on the allocation of limited resources to restore disrupted energy systems
- Study the city morphology and distribution of critical facilities in relation to power restoration

Acknowledgments

NSF

mapbox