

# Geospatial Analytics for Energy and Resilience Analysis

Dr. Mark Deinert  
Colorado School of Mines  
United States  
28 November 2022



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## Meet the Presenter

Mark Deinert is an Associate Professor in the Nuclear Science and Engineering program at the Colorado School of Mines. He holds external appointments in Electrical Engineering at Cornell University and as a consultant with the World Bank on climate resilience. His research is focused on modeling and simulation of complex systems with applications to nuclear power, nuclear security, distributed energy systems and risk analysis.

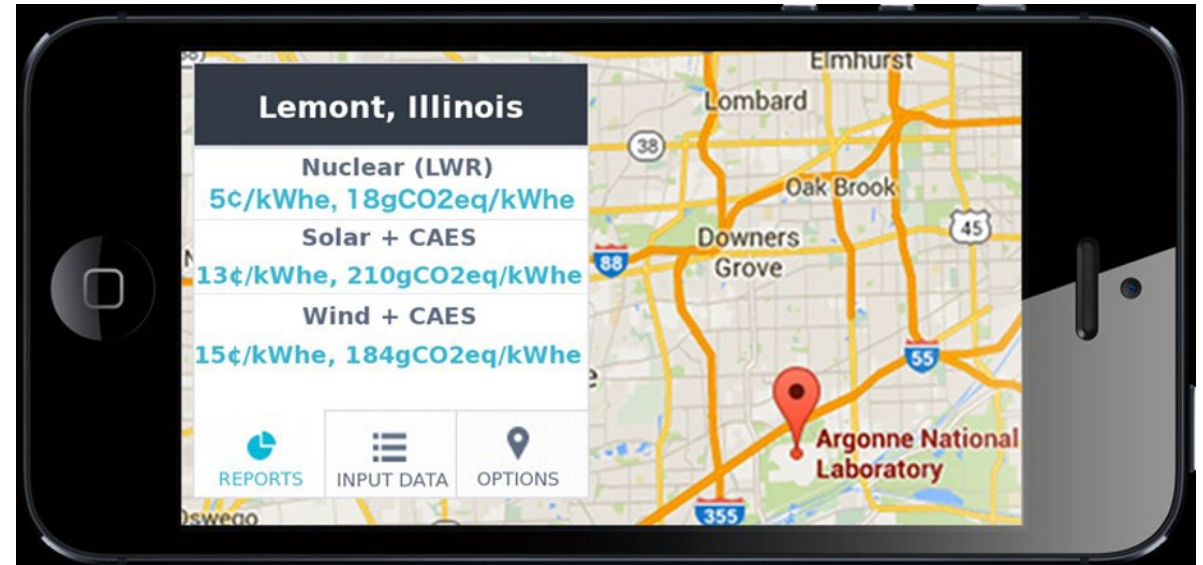


# Geospatial Analytics for Energy and Resilience Analysis



## Started NEUP project

- Develop a web-based visualization tool for comparing energy systems by location.
- Application programmer interface to enable third party developers to request data for educational, nonprofit or policy analysis uses.



Terra Analytics Energy Comparison Carbon Transition Risk Home Energy Independence Home Resilience API About Us

### Electricity by location

Click on the map or enter a location

Current electricity sources
Compare electricity sources

(2018)	Electricity cost	Comparison to US average
Residential	11.12 ¢/kWh	+11.2%
Commercial	2.68 ¢/kWh	-73.2%
Industrial	2.66 ¢/kWh	-73.4%

Statewide percentage of electricity production (% , 2018)

Replace  with  (reset)

Colorado emits 40.7% more CO2-eq than than the US average. ⓘ

[Show dispatch graph](#)

Terra Analytics Energy Comparison Carbon Transition Risk Home Energy Independence Home Resilience API About Us

### Electricity by location

Click on the map or enter a location

Current electricity sources **Compare electricity sources**

Report Comparison Inputs

Capacity Factor	%	92.0	21.2	63.3
LCOE	\$/kWh	0.0547	0.1135	0.0453
LCOE (with CO2 tax)	\$/kWh	0.0548	0.1144	0.0502
Land Use	m <sup>2</sup> /MWe	3.6	47209.2	1.4
Greenhouse Gas	gCO <sub>2</sub> /kWh	18.0	66.0	359.2
EX (capacity factor weighted)	\$/kWh	6168.6	11415.3	2507.0
CAPEX	\$/kWh	5675.1	2418.0	1587.3

# Energy Systems are Complex

- Land use restrictions
- Proximity to needed infrastructure or geology
- Proximity to skilled labor
- Receptive neighbors
- Potential hazards



# Energy Systems are Complex – Climate Change

How much damage can we expect, can we avoid it, and what are the associated costs?

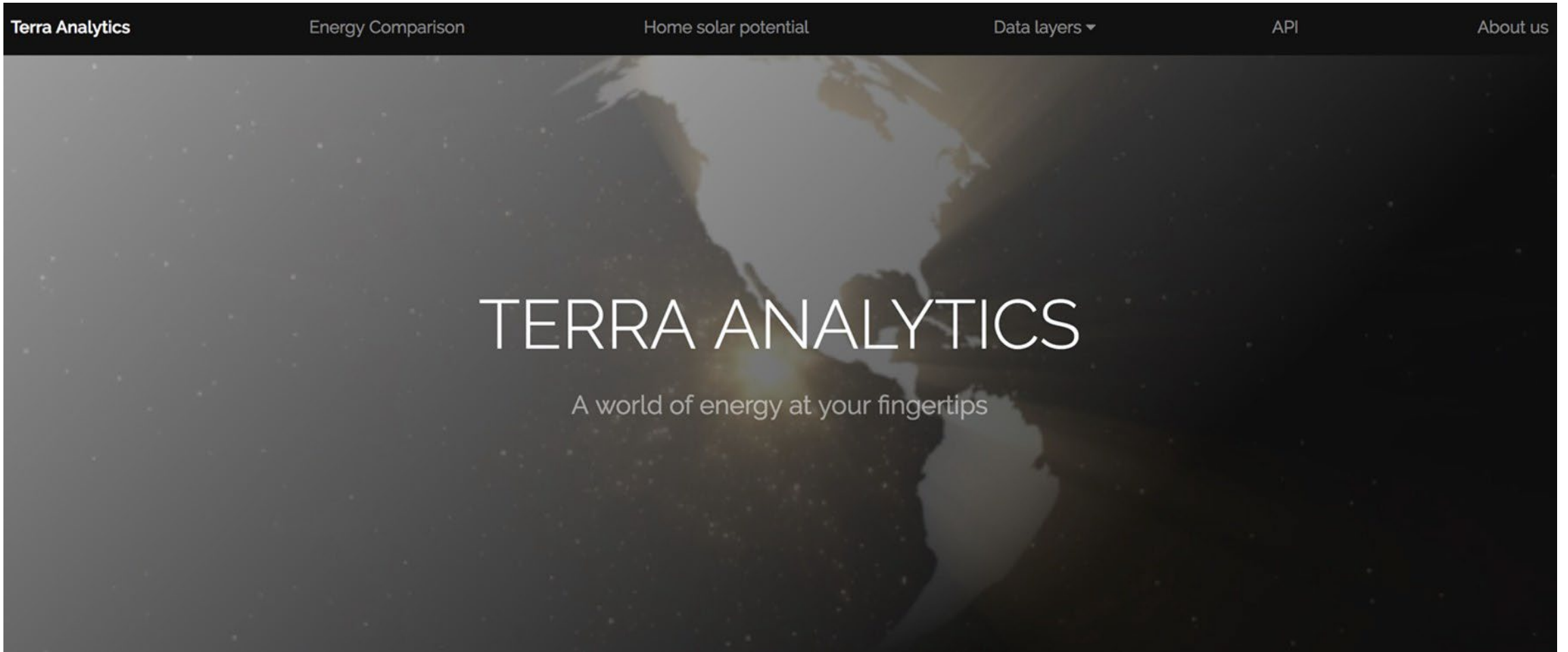
- *Direct financial costs* (asset damage)
- *Time cost* (repair)
- *Indirect financial cost* (supply chains)
- *Political, social costs* (fear, policy shifts)



# Energy Systems are Complex – Climate Change

- Changes in climate zone can affect construction codes
- Changes in heating and cooling days affect energy use
- Changes in river, ocean and lake temperatures can affect power systems
- Changes in coastline and flood plains can affect power systems
- Changes in precipitation can affect river flows and power systems

# Understanding Complexity



# Understanding Complexity - Data

## Resources

- Wind
- Solar
- Precipitation
- Aquifers
- Oil/Gas Fields
- Geology
- Soil

## Infrastructure

- Grid
- Generation
- Roads
- Pipelines
- Rail
- Air
- Ports
- Hospitals
- Schools
- Communication

## Hazards

- Wind
- Heat
- Drought
- Rain/Flood
- Fire
- Seismic
- Tsunami
- Climate

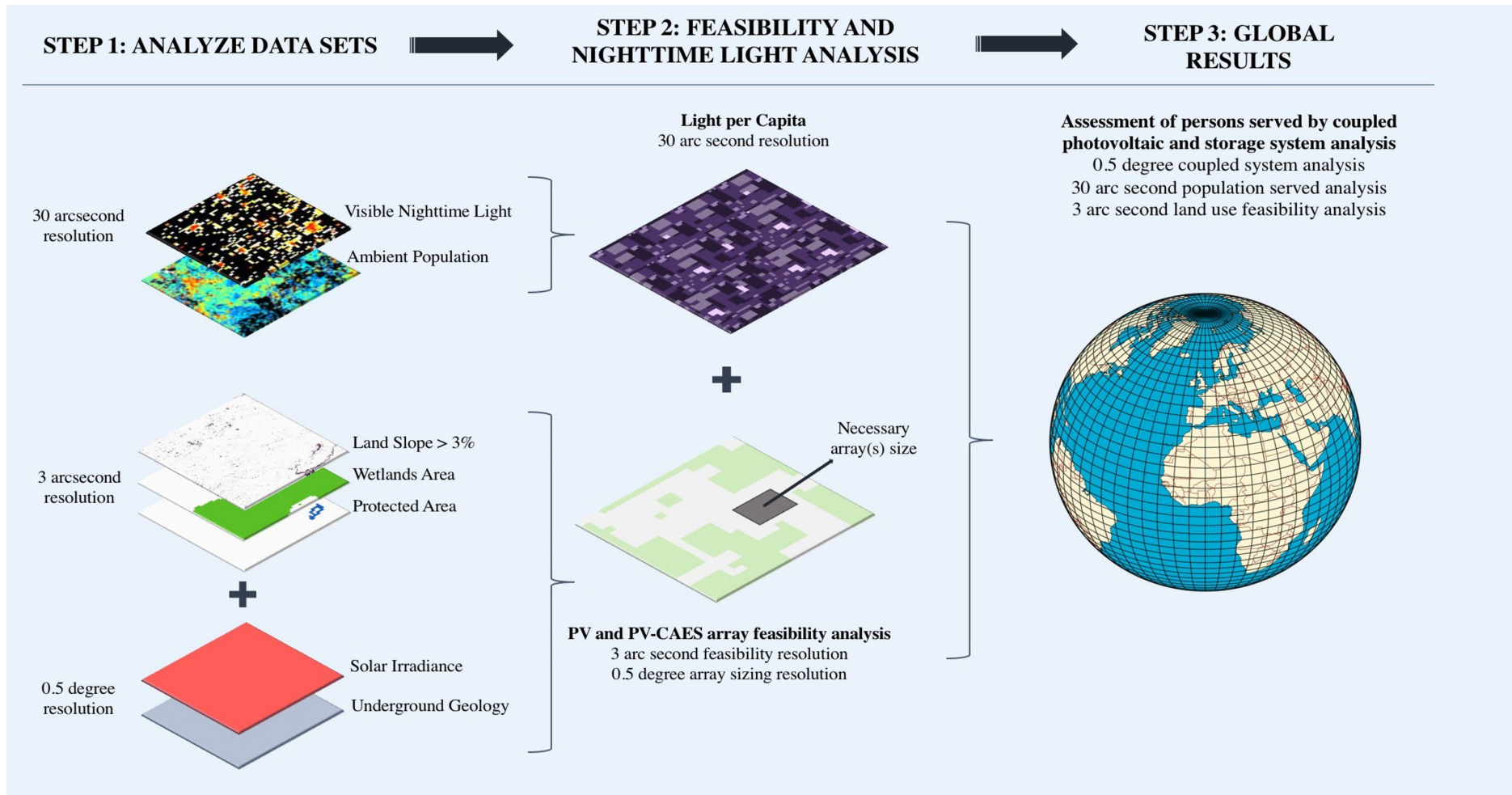
## Social

- Crime
- Conflict
- Education
- Longevity
- Employment
- Litigation rates
- HDI
- Costs

# Terra Analytics – Just Data?

- No
- Energy flow and economic models
- Data scaling for spatial and temporal analyses
- Algorithms for data filtering
- Algorithms for identifying climate sensitivity and natural hazards

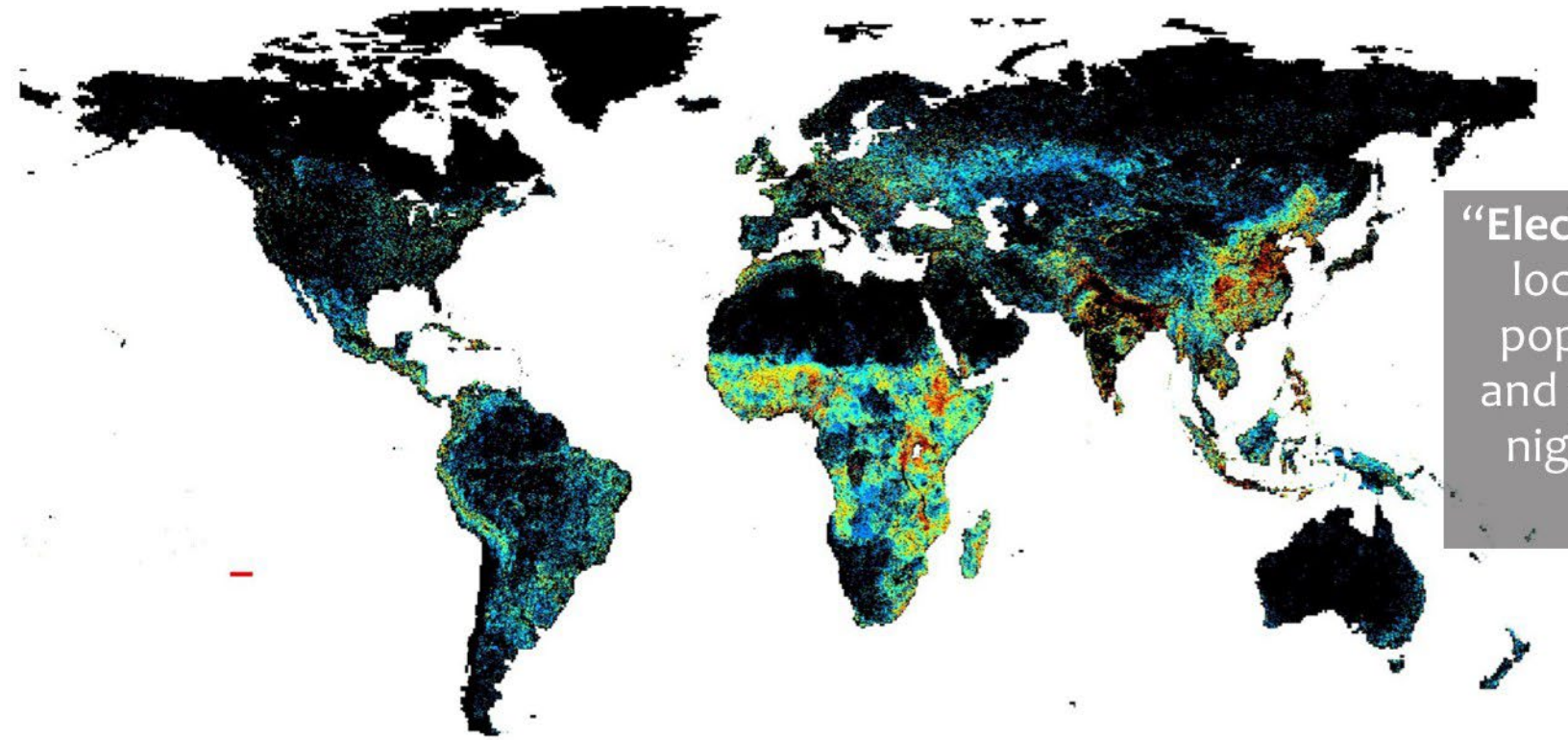
# Terra Analytics – Geospatial Analysis



- Global Data on natural hazards, infrastructure, resources demographics, climate change
- Risk disclosure
- Probabilistic risk analysis
- Decision analysis

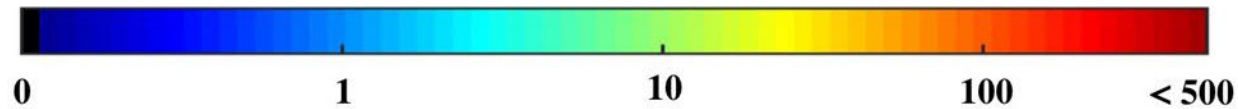


# Population Living in Electricity Poverty



“Electricity Poverty”  
locations where  
population exists  
and no measurable  
nighttime light is  
visible

Number of persons per  
30 arc second region

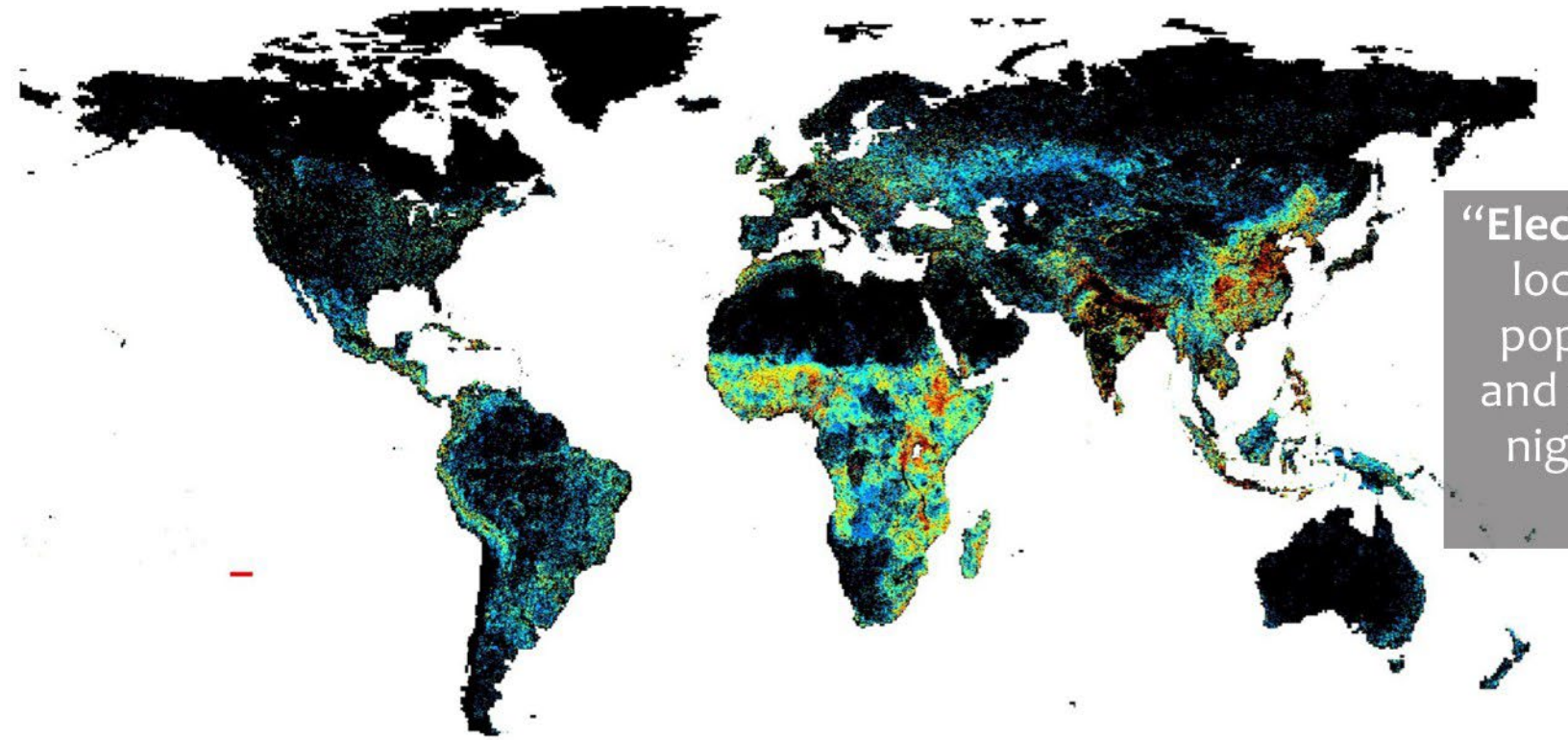


Schweikert, AE., Osborne, AG. Stoll, B., Deinet, MR” 2022. *In Review*



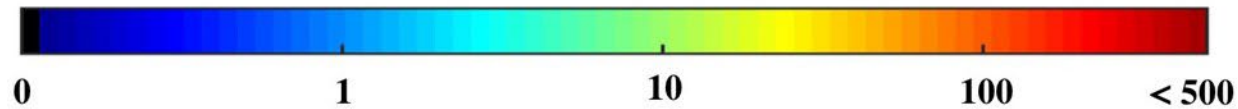
# Population Living in Electricity Poverty

~1.75 Billion people  
~20% of world population



“Electricity Poverty”  
locations where  
population exists  
and no measurable  
nighttime light is  
visible

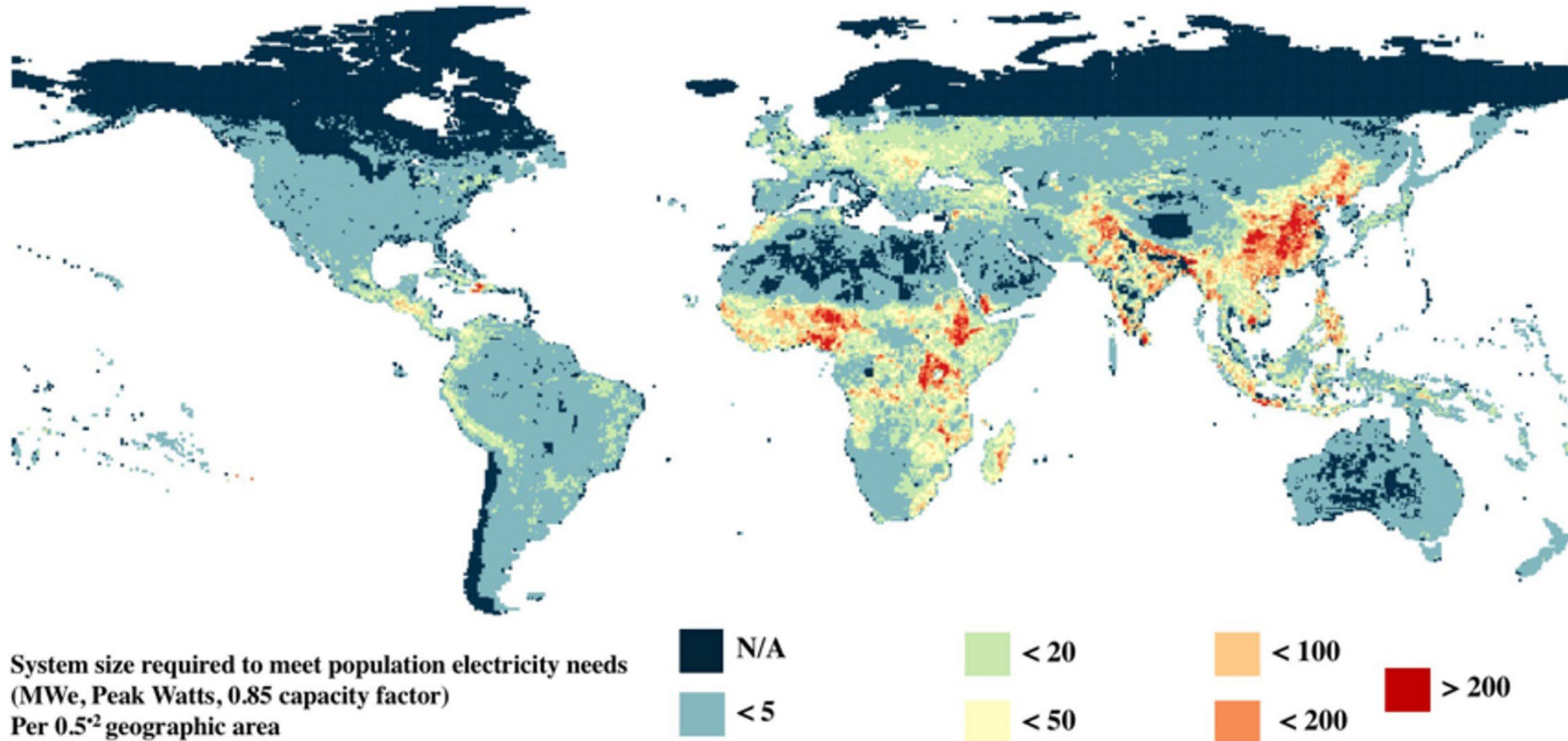
Number of persons per  
30 arc second region



Schweikert, AE., Osborne, AG. Stoll, B., Deinet, MR” 2022. *In Review*

# Meeting (Defining) Electricity Demand

Annual Demand at 3MWh per capita



Schweikert, AE, Osborne, AG, Stoll, B., Deinert, MR, 2022. *In Review*

# The Potential – Annual Market Size

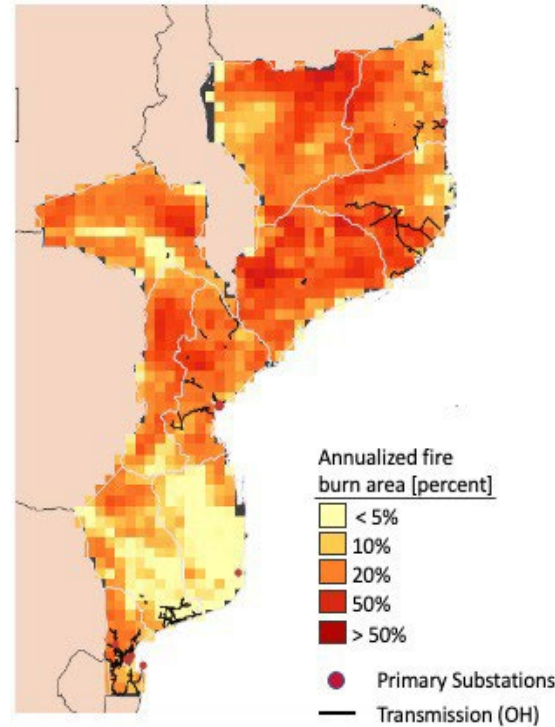
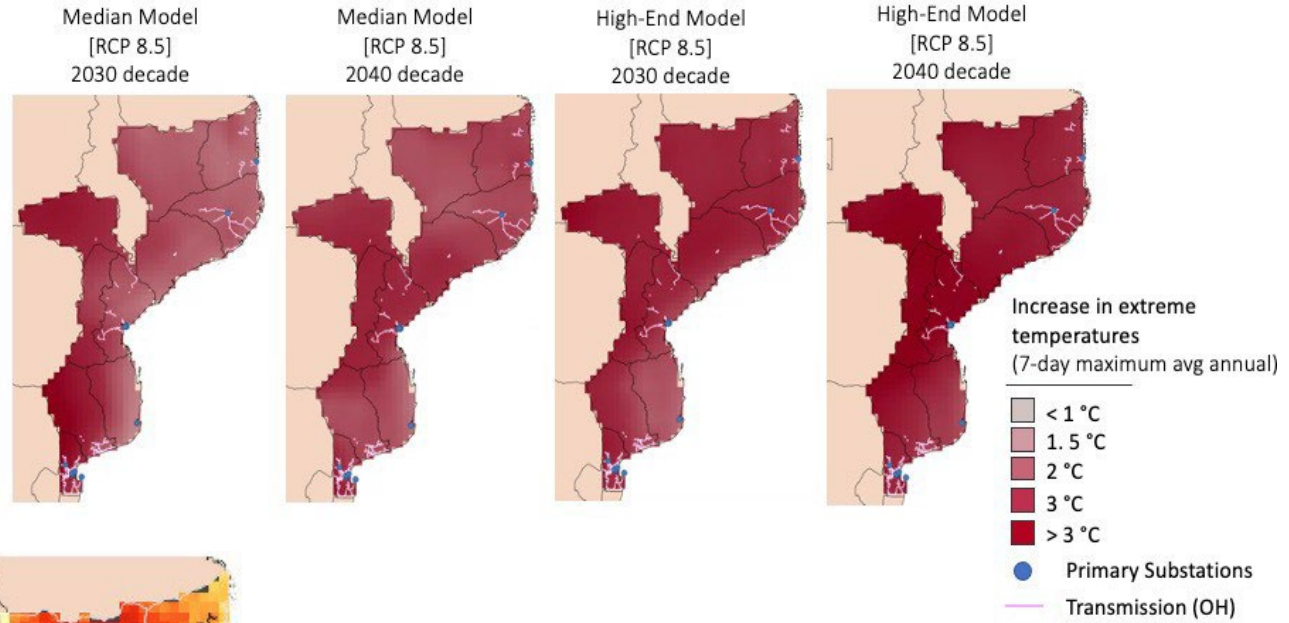
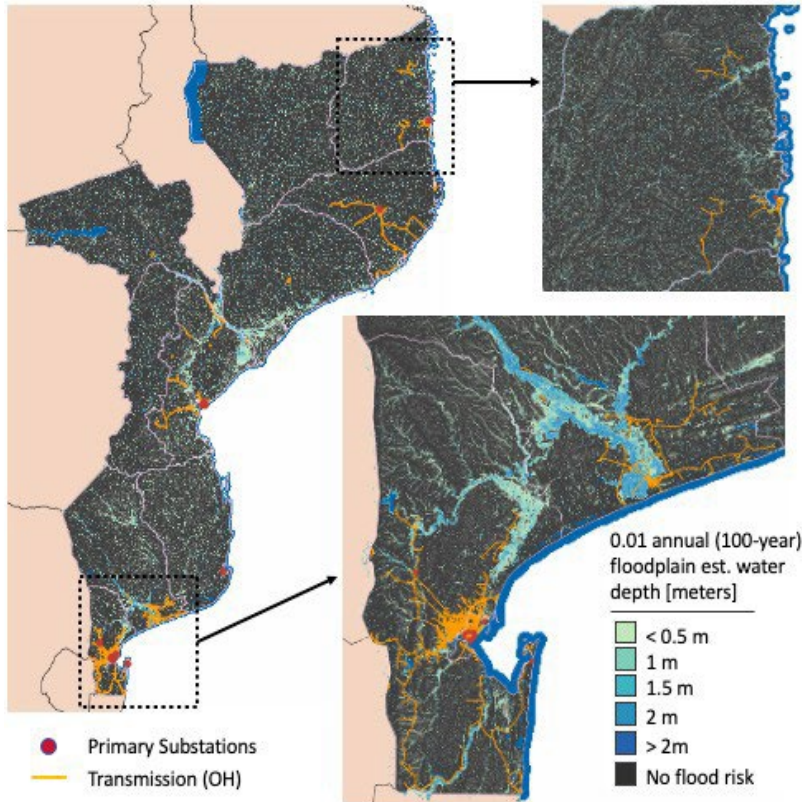
**1.75 billion persons**  
*currently living in*  
**Electricity Poverty**

	Market Size (GWh)	Market Size - USD (at: 10.84 cents/kWhe*)
ESMAP (T5) 3 MWhe	5.25 million GWh	\$ 569 billion
US Access 10.8 MWhe	18.9 million GWh	\$2.05 trillion

\* Lowest Cost US Region, *West South Central*, Residential US July 2018

# Hazards

## FLOOD RISK



# Often Neglected Complications

1. Multi-hazard events – the intersection of multiple hazards simultaneously, or in quick succession, complicates response and can extend damages or damage repairs
2. Strains on institutional capacity – resilience
3. Overlap of conflicts and infrastructure shocks – Conflict can make it impossible to get to areas where shocks have damaged infrastructure

# Conflict

## MAP KEY

— Infrastructure asset

● Conflict event

Population Density  
(persons per km<sup>2</sup>)

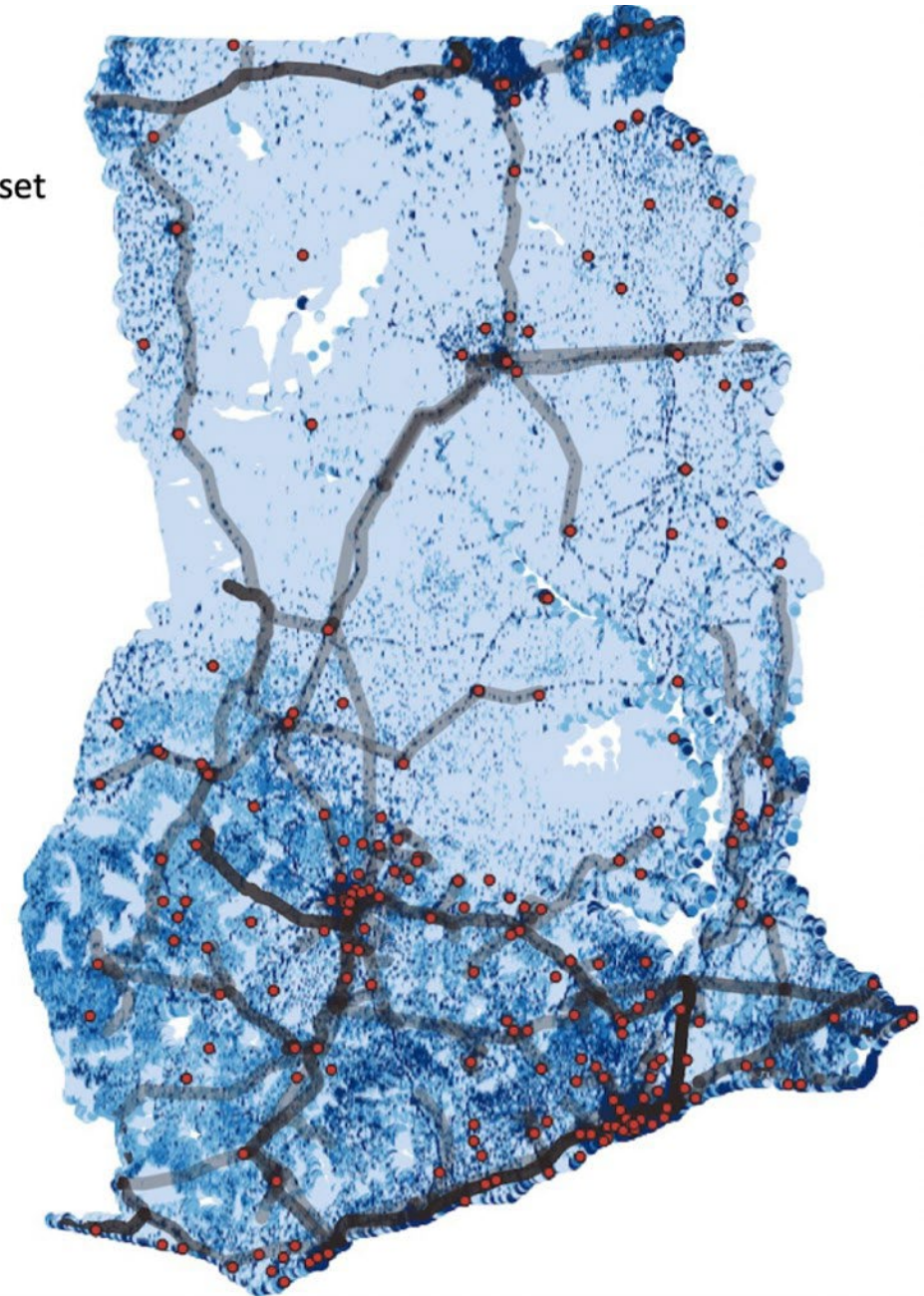
□ 0

□ < 10












□ < 50

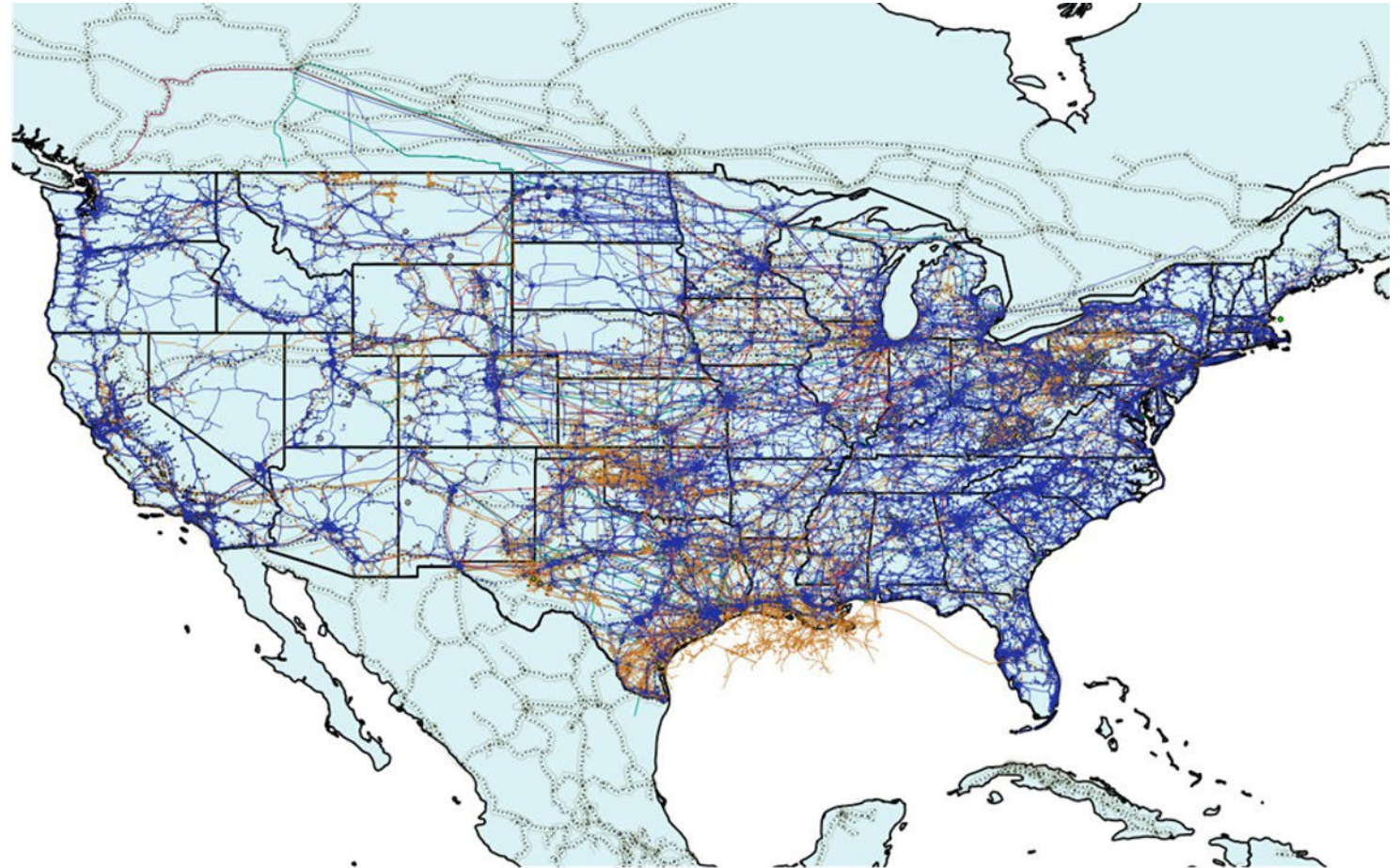
□ < 100

□ > 100



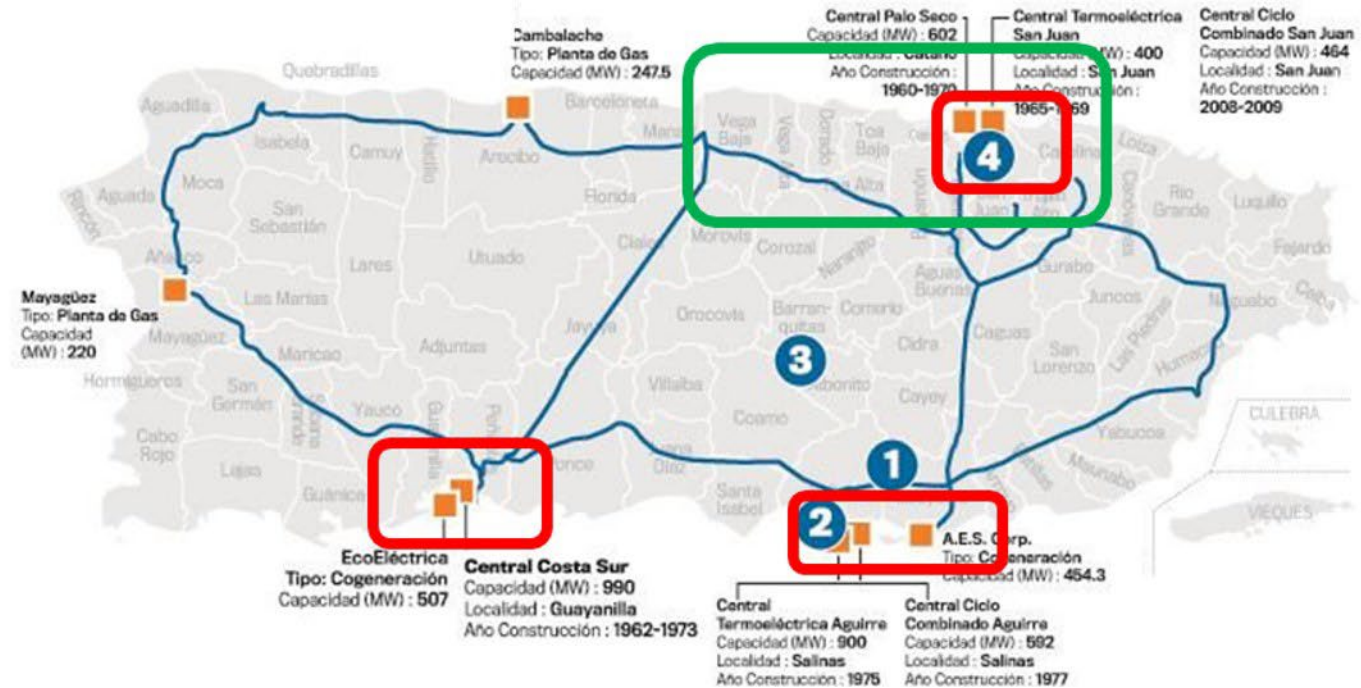
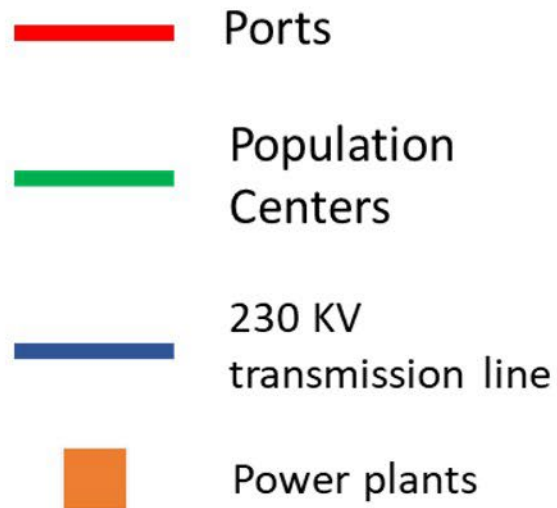
# Where Shocks Happen Matters

-  Railroad lines
-  Transmission grid
-  Power plant >1 MW
-  Petroleum product pipeline
-  Natural gas market hub
-  Natural gas pipeline
-  LNG Import/Export Terminal
-  HGL pipeline
-  Crude Oil Rail Terminal
-  Crude Oil Pipeline
-  Coal Mine



# Where Shocks Happen Matters – Puerto Rico

## PUERTO RICO POWER SYSTEM



Island states present unique challenges:

- Diversity of providers, operations matter
- Supply chain of fuel is critical (port closures – dependent on oil imports)



# Recovery Depends on Infrastructure Networks

1. Port closures for fuel delivery
2. Road damages for fuel delivery / repair operations
3. Backup generators requiring diesel stored on site



# Recovery Depends on Infrastructure Networks

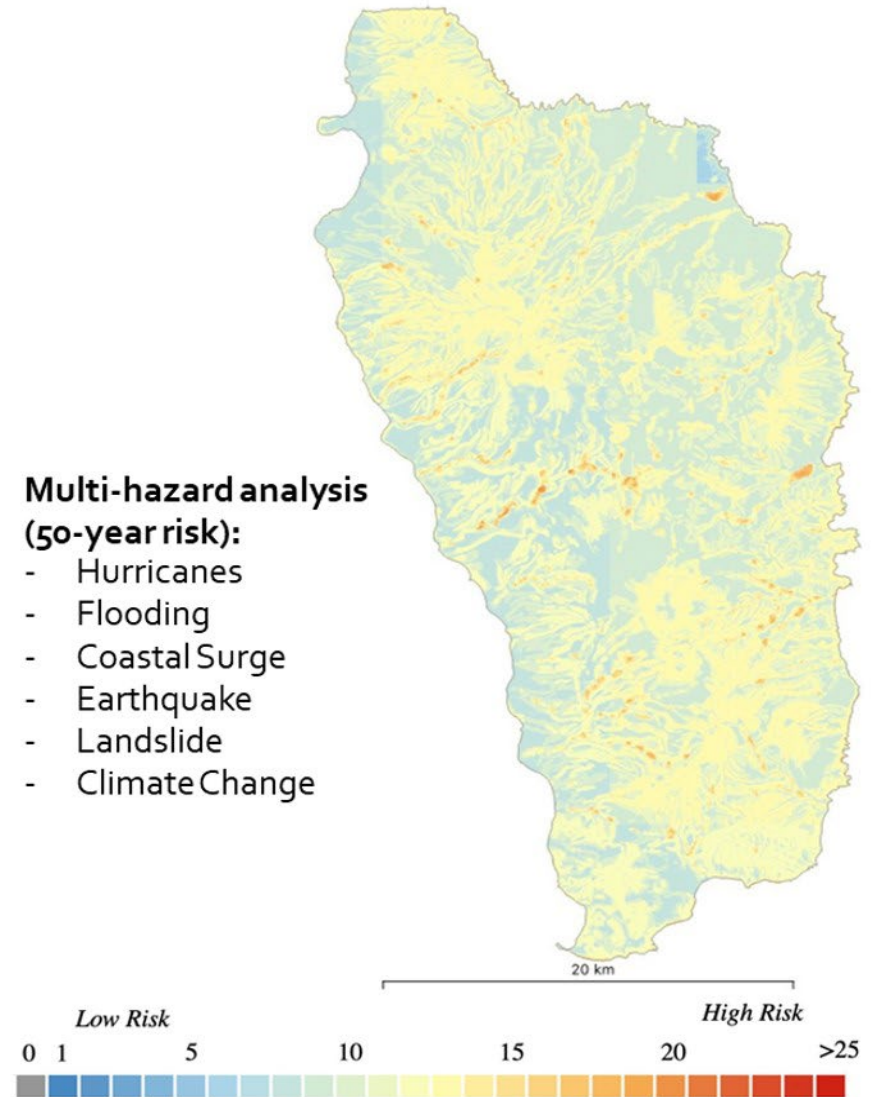
Project looking at Caribbean region (SIDS) resilience to natural hazards and climate change

“What infrastructure should we most prioritize?”

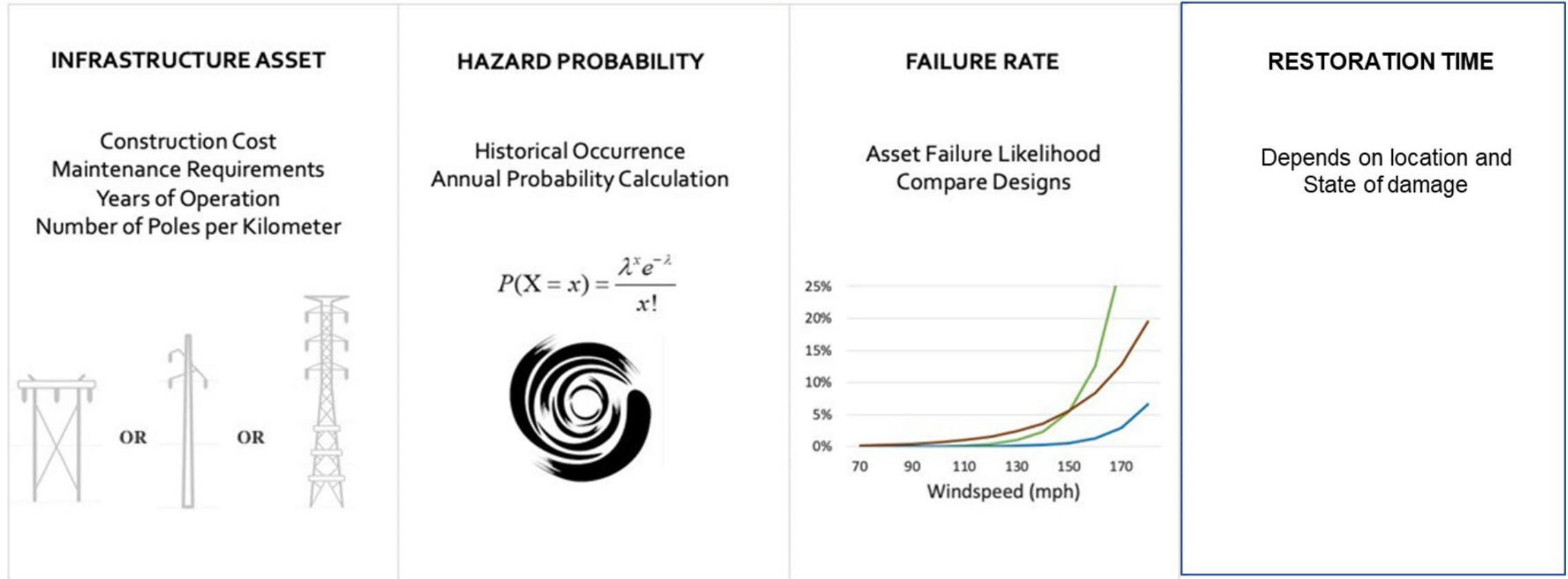
- Invest in roads?
- Invest in hospitals?
- Invest in flooding reductions (dams)?

Schweikert, A. E., G. F. L'Her, and M. R. Deinert. "Simple method for identifying interdependencies in service delivery in critical infrastructure networks." *Applied Network Science* 6, no. 1 (2021): 1-13

Commonwealth of Dominica



# Recovery Depends on Infrastructure Networks



# Recovery Depends on Infrastructure Networks

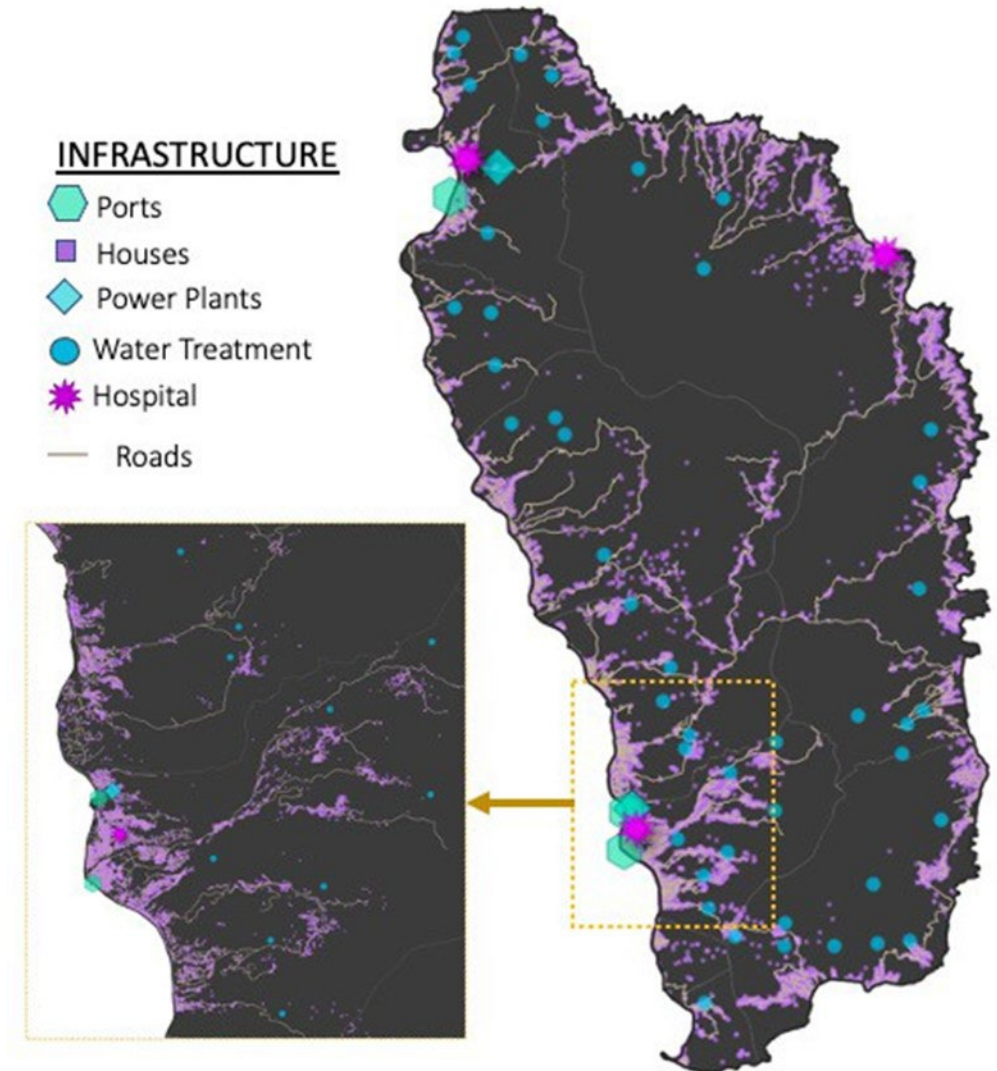
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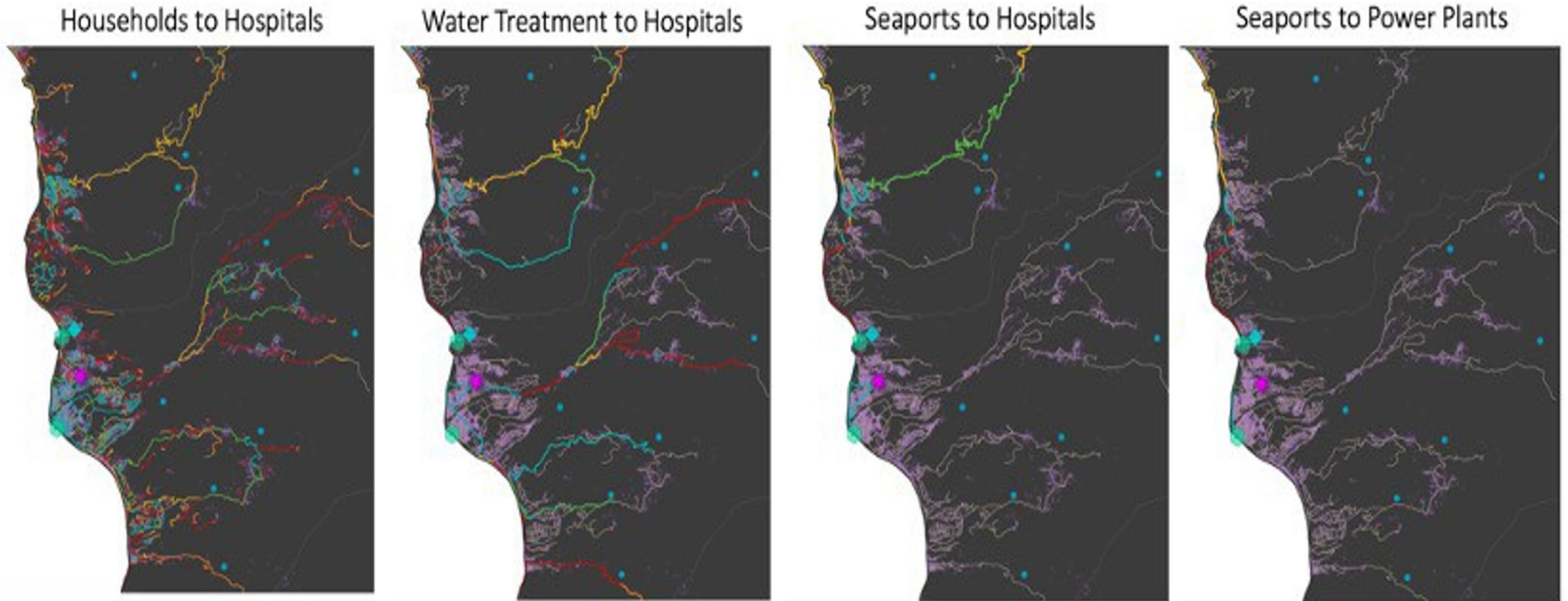
# Recovery Depends on Infrastructure Networks

## ROAD SEGMENT CRITICALITY [QUINTILES]

- Not used
- 1<sup>st</sup> (Lowest)
- 2<sup>nd</sup>
- 3<sup>rd</sup>
- 4<sup>th</sup>
- 5<sup>th</sup> (Most important)

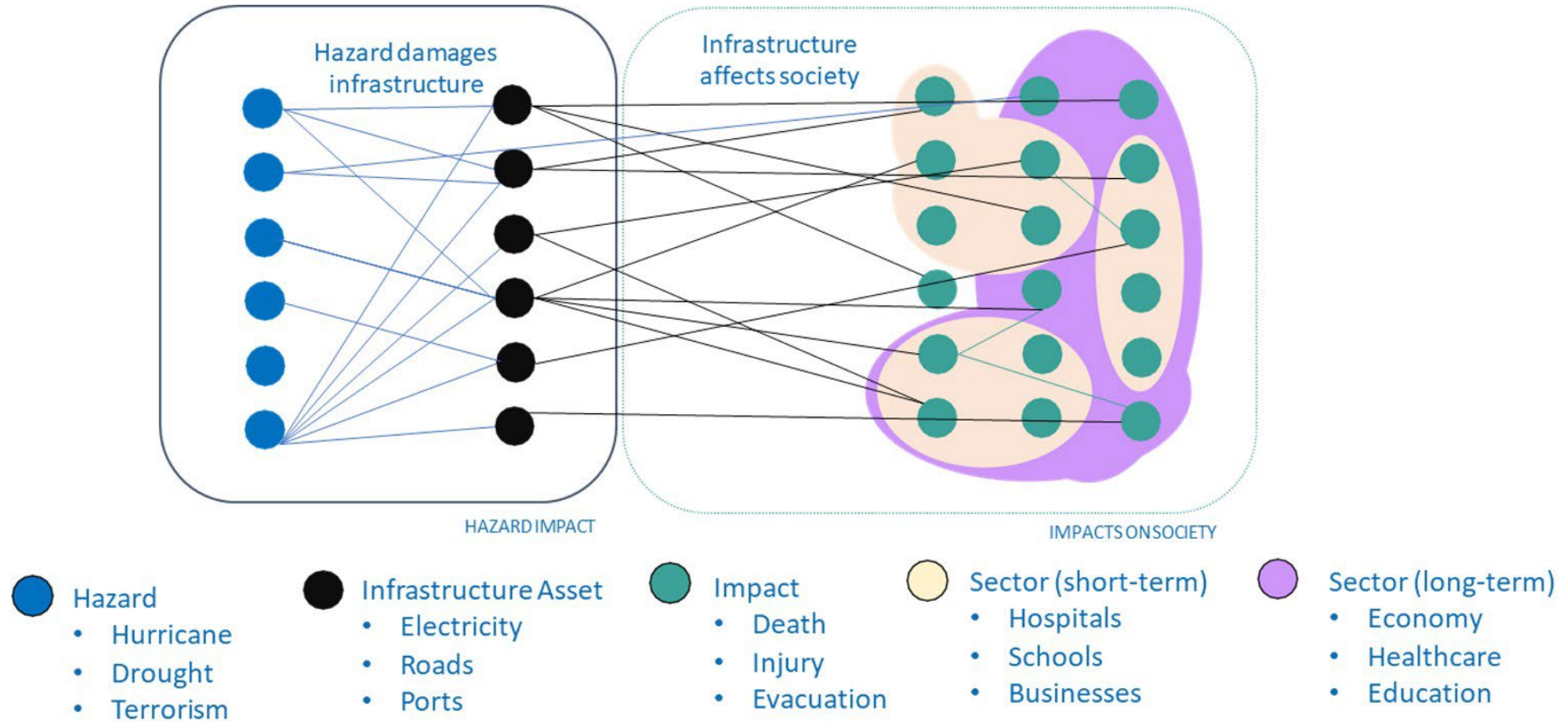
## INFRASTRUCTURE

- ⬡ Ports
- ⬡ Houses
- ⬡ Power Plants
- Water Treatment
- ✳ Hospital
- Roads



Road segment criticality shown in quintiles. More critical segments indicate that the loss of this segment increases overall travel cost for the origin-destination pair in each perspective.

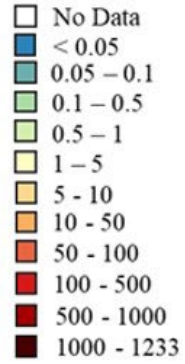
# Recovery Depends on Infrastructure Networks in General



# Sustainability has Value

- ESG (Environmental Social and Governance) has become a significant factor in many industries
- Climate change is a major factor in ESG
- "Can you make money by integrating ESG into a business? No, but you can lose money by not doing it"

Millions USD(2019)  
 7% discount rate  
 8.5% annual chance of fixed  
 carbon price going into effect  
 over 30 years.



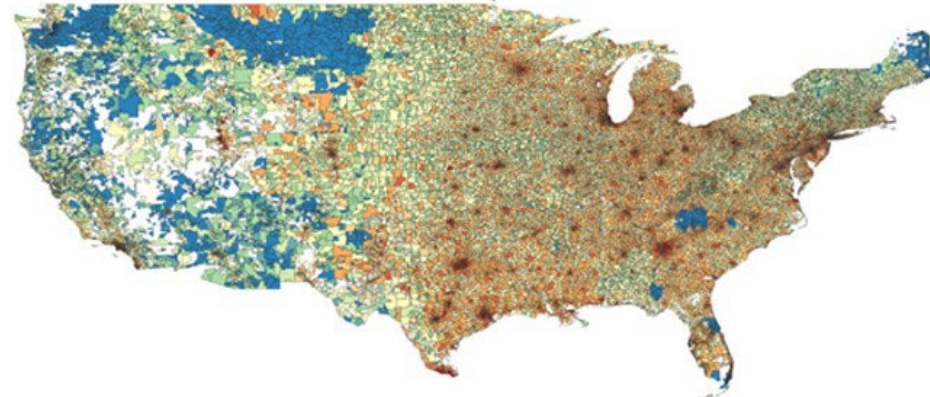
[A] Maximum Cost per Zip Code



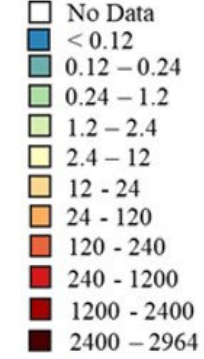
[B] Median Cost per Zip Code



[C] Minimum Cost per Zip Code



Millions USD(2019)  
 7% discount rate  
 8.5% annual chance of escalating  
 carbon price going into effect  
 over 30 years.





# Sustainability has Value

- 61% of home buyers are ‘very’ or ‘somewhat’ interested in sustainability<sup>1</sup>
- 70% residential [74% commercial] Agents reported that promoting energy efficiency is ‘somewhat’ or ‘very’ valuable<sup>1</sup>
- 1.9 million US homes are estimated to be underwater due to climate change by 2100<sup>2</sup>
- Hurricane Florence, which made landfall in North Carolina in September 2018, affected properties owned by 94 U.S. REITs<sup>3</sup>

1) 2021, <https://www.nar.realtor/research-and-statistics/research-reports/realtors%C2%AE-and-sustainability>

2) Bretz, Lauren. Climate Change and Homes: Who Would Lose the Most to a Rising Tide? Oct. 18, 2017 <https://www.zillow.com/research/climate-change-underwater-homes-2-16928/>

3) Kok, N., and A. Ayoub. Storm Watch! REITS and CMBS Deals Most Exposed to Hurricane Florence. Medium. 12 September 2018. <https://medium.com/geophy-hq/storm-watch-these-reits-and-cmbs-deals-are-most-exposed-to-hurricane-florence-aae2292d8e36>

# Real Estate Sustainability

- Risk Dashboard
  - Address-Based Climate and Hazard Analytics (HouseHazard.org)
- “Solar Score” & “Sustainability Score”
  - Building-specific renewable energy potential

# Location Based Profile

## DASHBOARD

*Discover your risks at a glance*

- Current risks
- Climate change impacts
- Insurance considerations











### House **Hazards**

Know the risks.  
Be Ready.







Try another address...

966 10th St, Boulder, CO 80302, USA

#### Current Hazard Risks

	Hailstorms	<b>Very High</b>
	Flooding	<b>Low</b>
	Hurricanes	<b>Very Low</b>
	Wildfires	<b>Click for Info</b>
	Drought	<b>Click for Info</b>
	Heat Index	<b>Very Low</b>
	Earthquakes	<b>Very Low</b>
	Landslides	<b>Low</b>
	Air Quality	<b>Low</b>
	Internet	<b>Very Low</b>

#### Climate Change Impact

	Change to Hailstorm Frequency	<b>High</b>
	Change to Flooding	<b>Very Low</b>
	Change to Hurricanes	<b>Very Low</b>
	Change to Wildfire Frequency	<b>Moderate</b>
	Change to Drought Index	<b>Moderate</b>
	Change to Heat Index	<b>High</b>

# Location Based Profile

## CLIMATE and COOLING RISK

*For the 2030 Decade:*

“Low” Risk: +5 to 15% increase

“Moderate” Risk: +15 to 30% increase

“High” Risk: > 30% increase











### House *Hazards*

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	Change to Wildfire Frequency	<b>Moderate</b>
	Change to Drought Index	<b>Moderate</b>
	Change to Heat Index	<b>High</b>

# Location Based Profile

## FLOOD RISK

“Low” Risk: Minimal flood hazard zone (no quantified risk for 100 or 500-year flood)

“Moderate” Risk: within 500-year zone

“High” Risk: within 100-year zone











### House *Hazards*

Know the risks.  
Be Ready.







Try another address...

966 10th St, Boulder, CO 80302, USA

#### Current Hazard Risks


	Hailstorms	<b>Very High</b>
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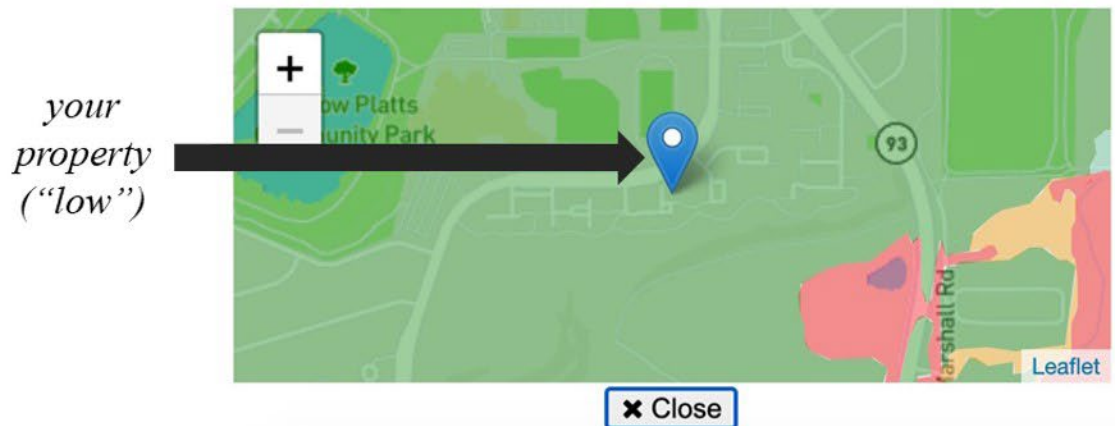
# Location Based Profile

FLOOD



LOW RISK

Minimal flood hazard zone. Less than 1% chance of flooding in the next 10 years.  
(last assessed: 2019-08-15)



*your property ("low")*

Close

## NEXT STEPS

*Contextualize, compare, prepare*

- Your property & what's nearby
- Links for more information

# Location Based Profile

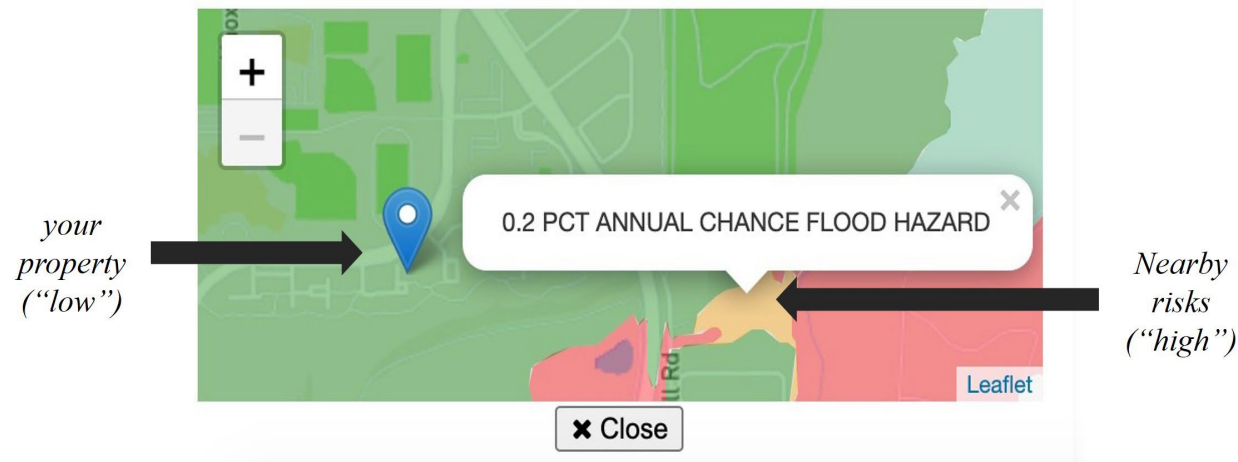
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## NEXT STEPS

*Contextualize, compare, prepare*

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# Solar Sustainability Score

- Solar Score

- Address-based (every building in Google Maps)
- Uses 10 years of historical (hourly) solar data, along with rooftop pitch and panel angle to sun
- Identifies: Payback period (years), profit over lifetime (\$) and rate of return on your investment (% of cost), avoided CO2 emissions based on local energy provider (tons)

- Sustainability Score

- Address-based (every building in Google Maps)
- Provides relative ranking of the 'sustainability' of the property, including local electricity providers' carbon footprint



# Solar Sustainability Score

Terra Analytics

Energy Comparison

Carbon Transition Risk

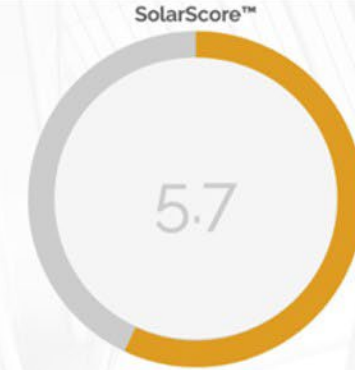
Home Energy Independence

Home Resilience

API

About Us

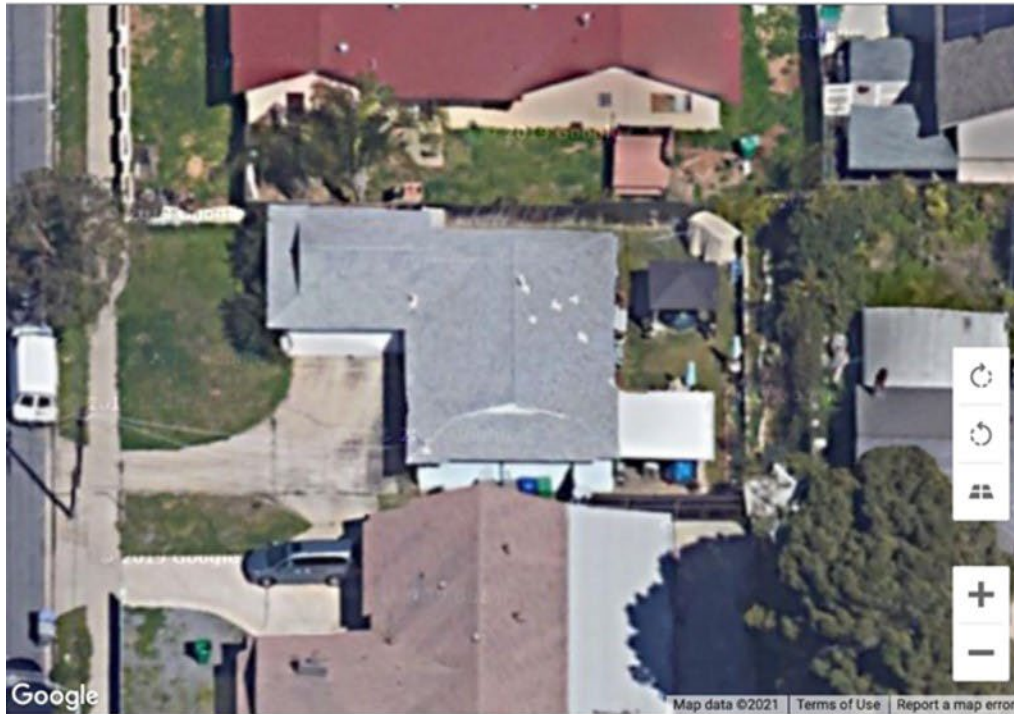
16306 Candlerock Ct, Houston, TX, USA



Savings	
Payback period	22 years
Profit (25 years)	\$1066
Rate of return	0.336%
Environment	
CO2 Avoided	4.6 tons of CO2 per year

# Solar Sustainability Score

1001 Avocado Avenue, El Cajon, CA, USA



Savings	
Payback period	7 years
Profit (25 years)	\$25208
Rate of return	4.395%

Environment	
CO2 Avoided	2.6 tons of CO2 per year

# Acknowledgments

Dr. Andrew Osborne

Dr. Guillaume L'Her

Dr. Robert Flanagan

Dr. Amy Schweikert

Mr. Bhupinder Singh, DOE, Office of Nuclear Energy

Dr. Temi Taiwo, Argonne, National Laboratory

Dr. Bo Feng, Argonne National Laboratory

# Upcoming Webinars

Date	Title	Presenter
14 December 2022	The Mechanisms Engineering Test Loop (METL) facility at Argonne National Lab	Dr. Derek Kultgen, Argonne National Laboratory, USA
25 January 2023	Molten Salt Reactors Taxonomy and Fuel Cycle Performance	Dr. Jiri Krepel, Paul Scherrer Institute, Switzerland
22 February 2023	Safe Final Disposal of Spent Nuclear Fuel in Finland	Mr. Mika Pohjon and Ms. Mari Lahti, Posiva Solutions Oy, Finland

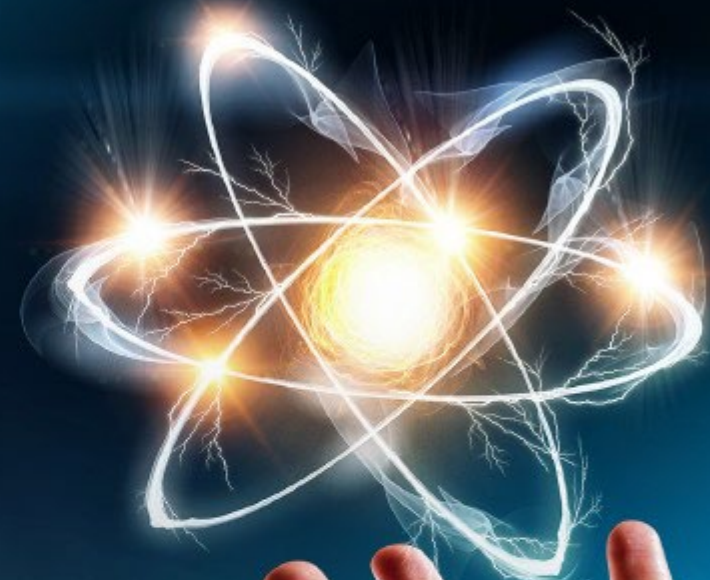
**GEN IV** International  
Forum

Expertise | Collaboration | Excellence



ATTENTION JUNIOR  
RESEARCHERS!  
GET READY TO...

**PITCH YOUR  
GEN IV RESEARCH**



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[https://www.gen-4.org/gif/jcms/c\\_173183/pitch-your-generation-iv-research-competition](https://www.gen-4.org/gif/jcms/c_173183/pitch-your-generation-iv-research-competition)

## 2023 Pitch Your GEN IV Research

- Are you a current PhD student or did you complete your PhD after January 1, 2021?
- Was your PhD research related to Generation IV Advanced Nuclear Energy Systems?
- Can you explain your research in four minutes?

If you answered YES to those questions, you may be interested in the **2023 Pitch Your GEN IV Research competition.**

For research related to GEN IV Advanced Nuclear Energy Systems enter by submitting your one-page executive summary by **January 15, 2023.**

**For more details, visit:** [www.gen-4.org/gif/pitch-your-generation-iv-research](http://www.gen-4.org/gif/pitch-your-generation-iv-research)

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