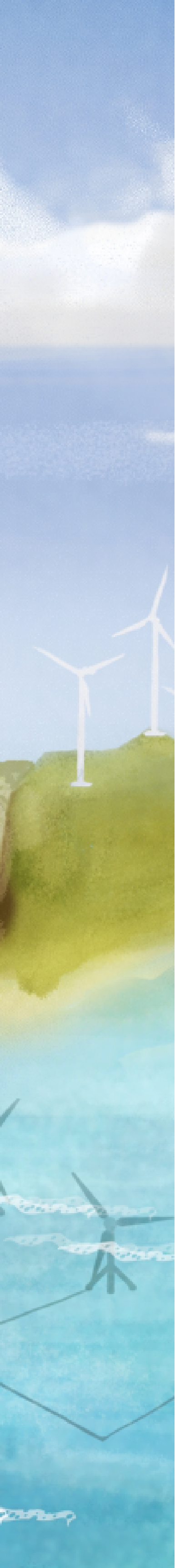

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Resilient and equitable climate-driven energy transitions

April 19, 2023

David R. Judi, Ph.D.
Director, Earth Systems Science Division
Energy and Environment Directorate

U.S. DEPARTMENT OF ENERGY BATTELLE

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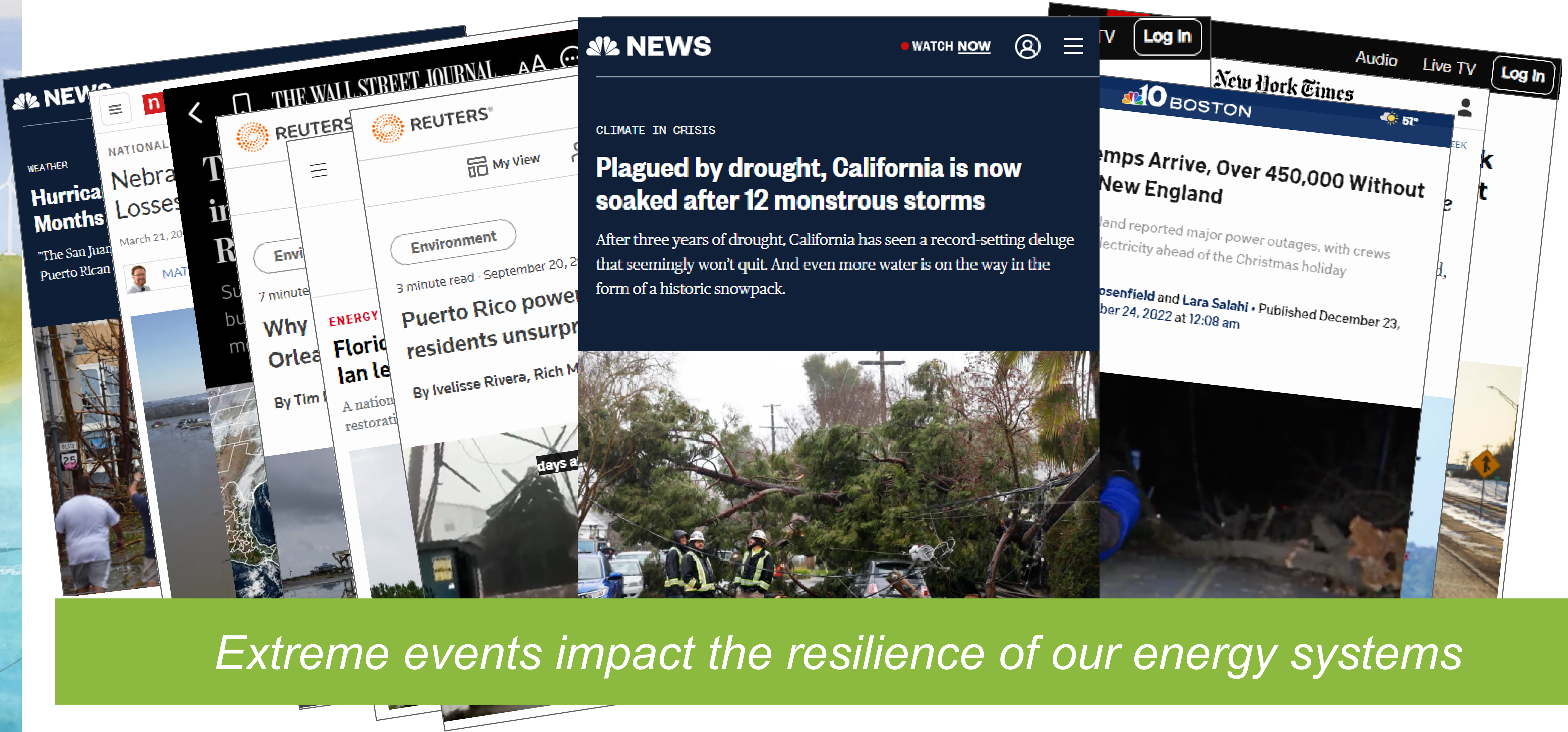
Implications of climate change manifest through an increasing trend of extreme events



Extreme events impact the resilience of our energy systems

Grand Challenge: developing a decarbonized energy system that is resilient and equitable

Energy systems are vulnerable to both extreme events and long-term changes

Mitigating climate change requires massive shifts in energy production, storage, and use

Climate change and energy transitions could have a disproportionate impact on disadvantaged groups

How does climate knowledge influence energy transitions?

?

How do climate and energy transitions impact people and the economy?

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Which models, tools, and data should I use to understand climate-infrastructure resilience?

- Is any data better than no data? How do we assess quality of data? Relevance to specific questions?
- Who are the users of the models, tools, and data (researchers vs. engineers vs. policy makers vs. community planners)?
- How do we “translate” climate information to a diverse set of users?
- Should we embrace multiple models, tools, and datasets to improve confidence in the decision making process?
- It’s not just about climate data! What about projections in human systems (population, socioeconomic changes, infrastructure changes)?

Identified climate resilience needs within the electric power community

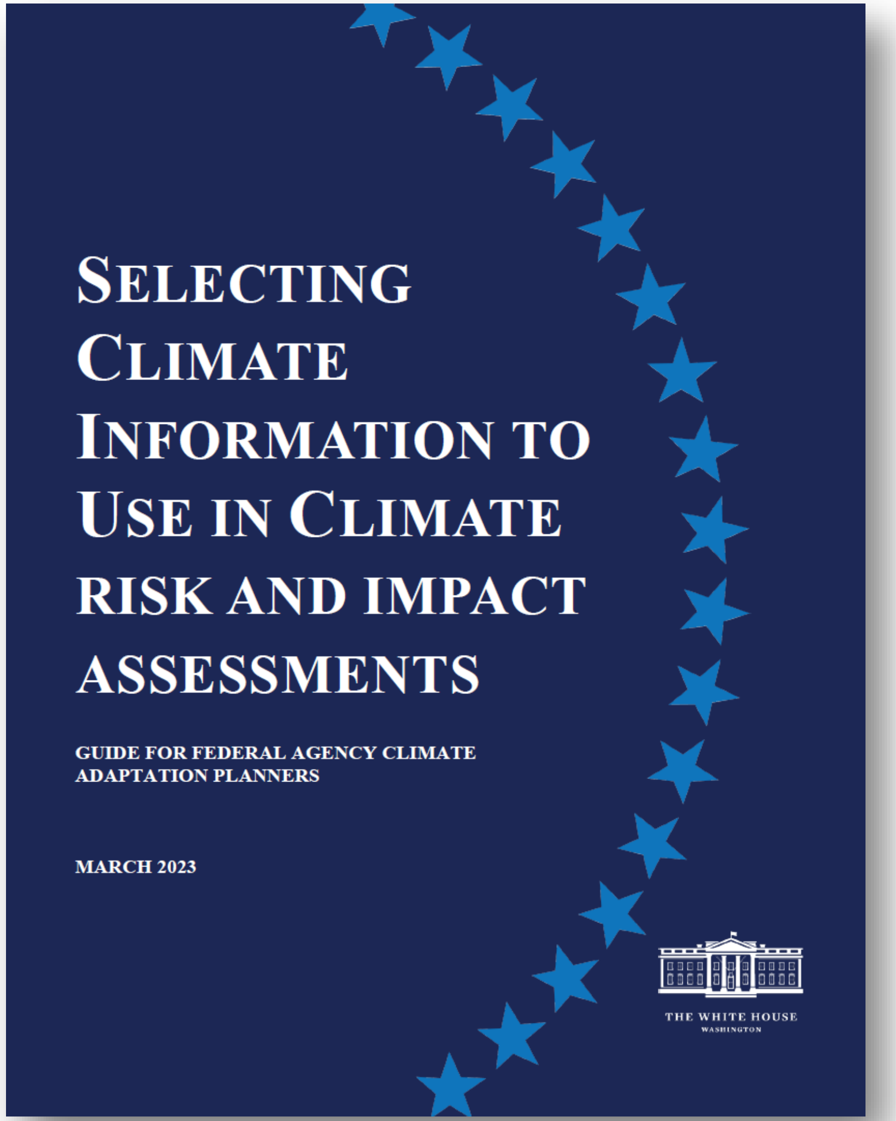
- Need for an updated, **common language** (e.g., definition of extreme events)
- Need **vetted, standardized, and accessible** climate and risk data
- Need to **translate climate science into investment planning** at investment time-scales
- Smaller utilities may require **technical assistance** for the application of climate science
- Climate-driven decisions must involve the **community** and be **equitable**

PNNL and Seattle City Light hosted a 3-day workshop in Nov. 2022 that brought together utilities, labs, academia, and policy makers to discuss grid resilience challenges

Newly issued guidance on selecting climate information

OSTP released a four-step process for selecting climate information to use in assessments of climate risks and resulting effects:

1. Understand current exposure to climate hazards...
2. Select climate scenarios for your assessment and decide whether downscaled data are relevant
3. Identify effects from other future climate-related hazards and stressors to assess
4. Select climate information resource(s) to use


SELECTING CLIMATE INFORMATION TO USE IN CLIMATE RISK AND IMPACT ASSESSMENTS

GUIDE FOR FEDERAL AGENCY CLIMATE ADAPTATION PLANNERS

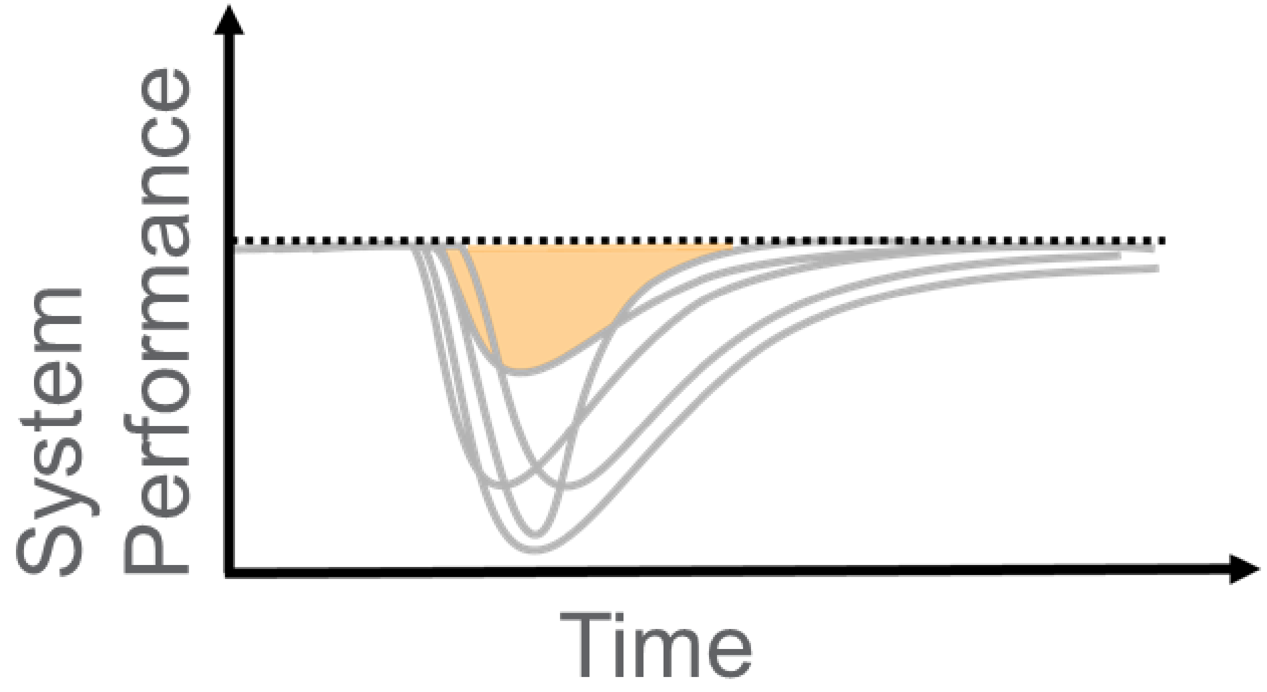
MARCH 2023

THE WHITE HOUSE
WASHINGTON

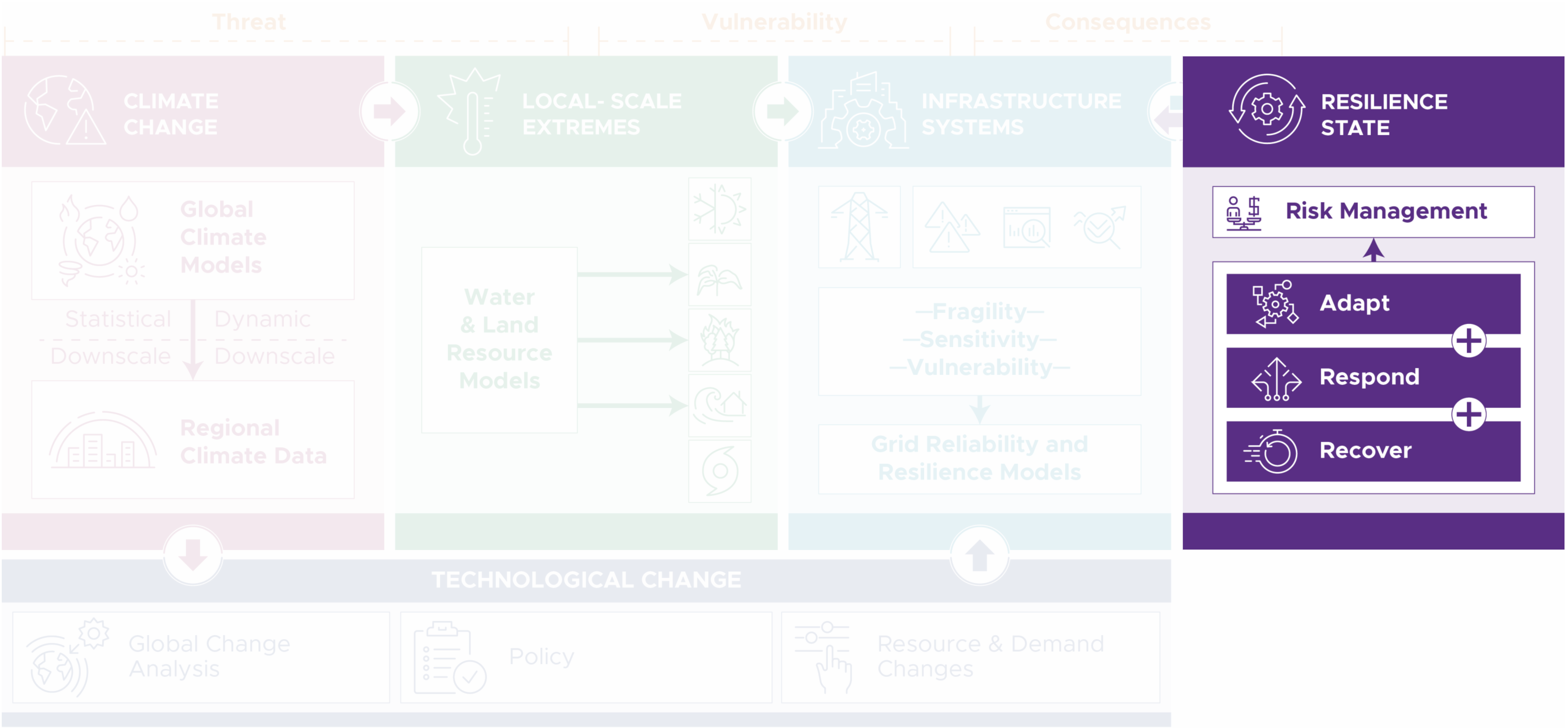
What is climate resilience?

Definitions

- EO 13653 (Preparing the US for the Impacts of Climate Change): The ability to **anticipate**, **prepare** for, and **adapt** to changing conditions and **withstand**, **respond** to, and **recover** rapidly from disruptions.
- FERC: The ability to **withstand** and **reduce the magnitude** and/or duration of disruptive events, which includes the capability to **anticipate**, **absorb**, **adapt** to, and/or rapidly **recover** from such event.
- DOE: The ability of a power system and its components to **withstand** and **adapt** to disruptions and rapidly **recover** from them.



Framework connecting climate risks with infrastructure resilience



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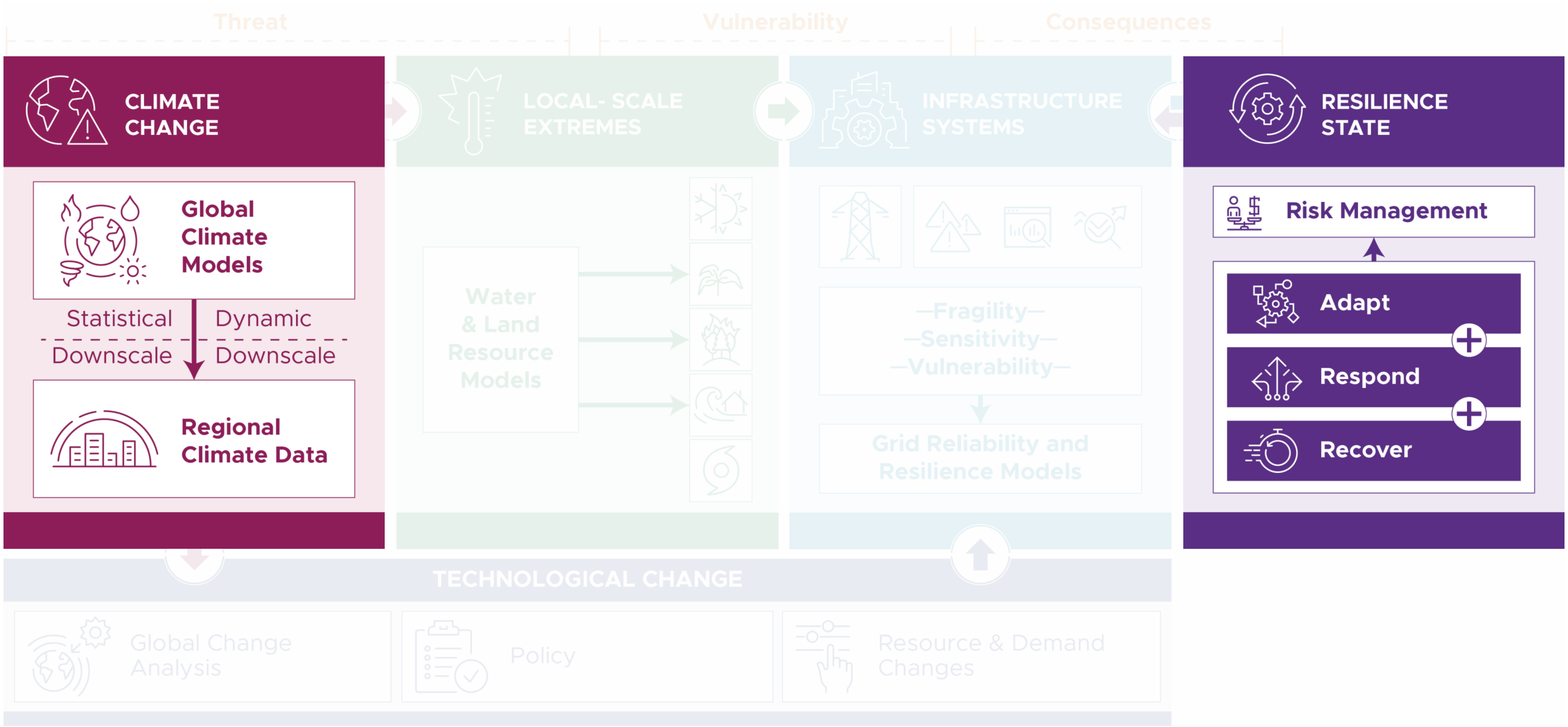

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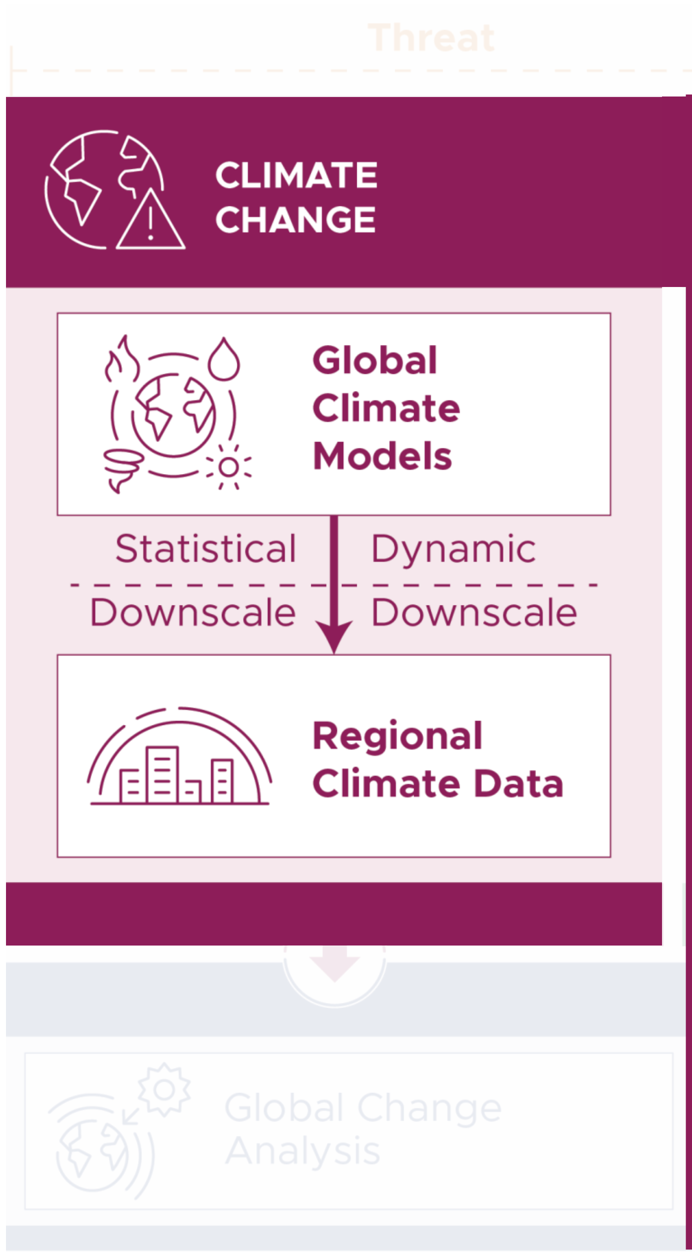
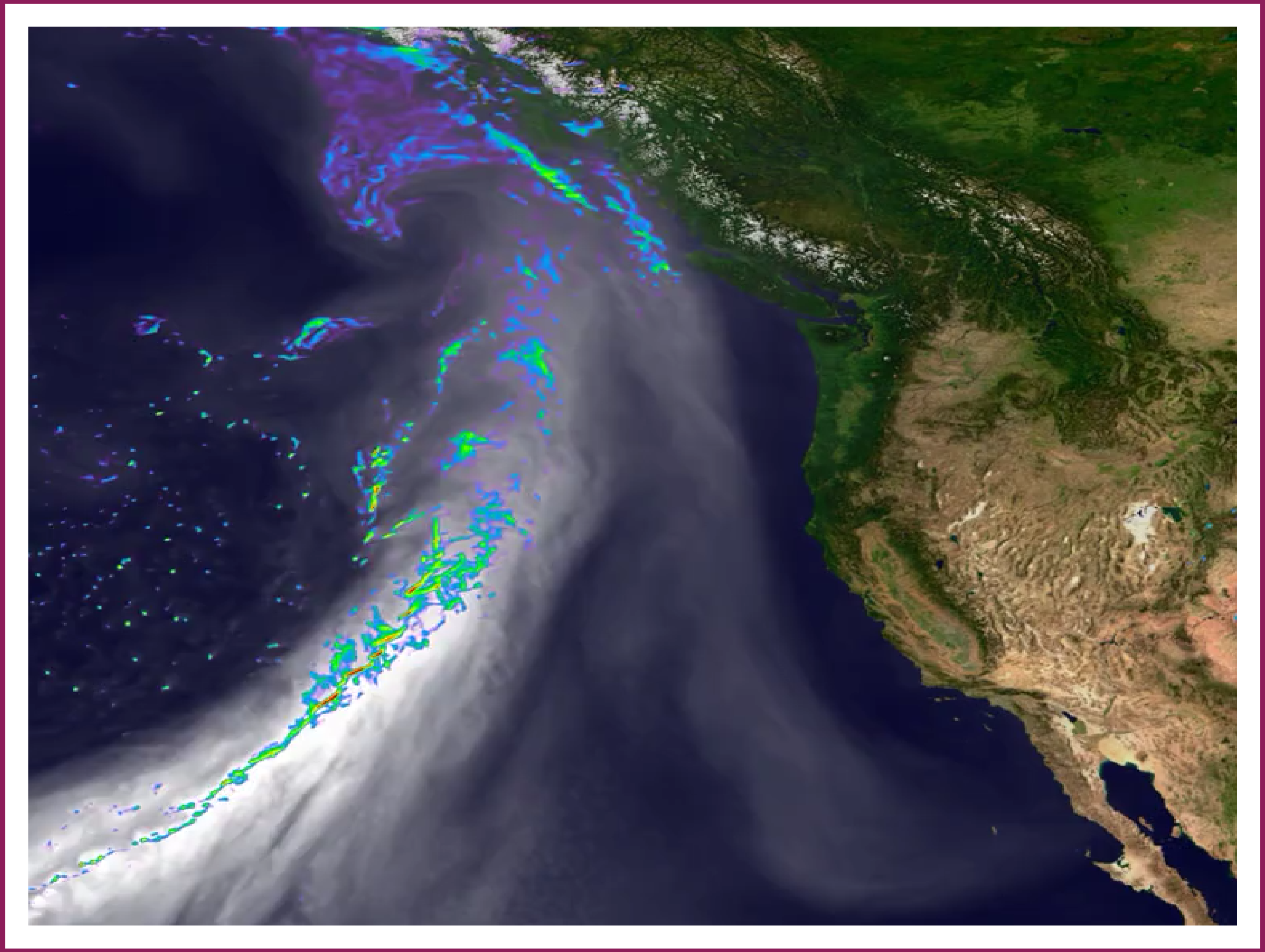
Framework connecting climate risks with infrastructure resilience

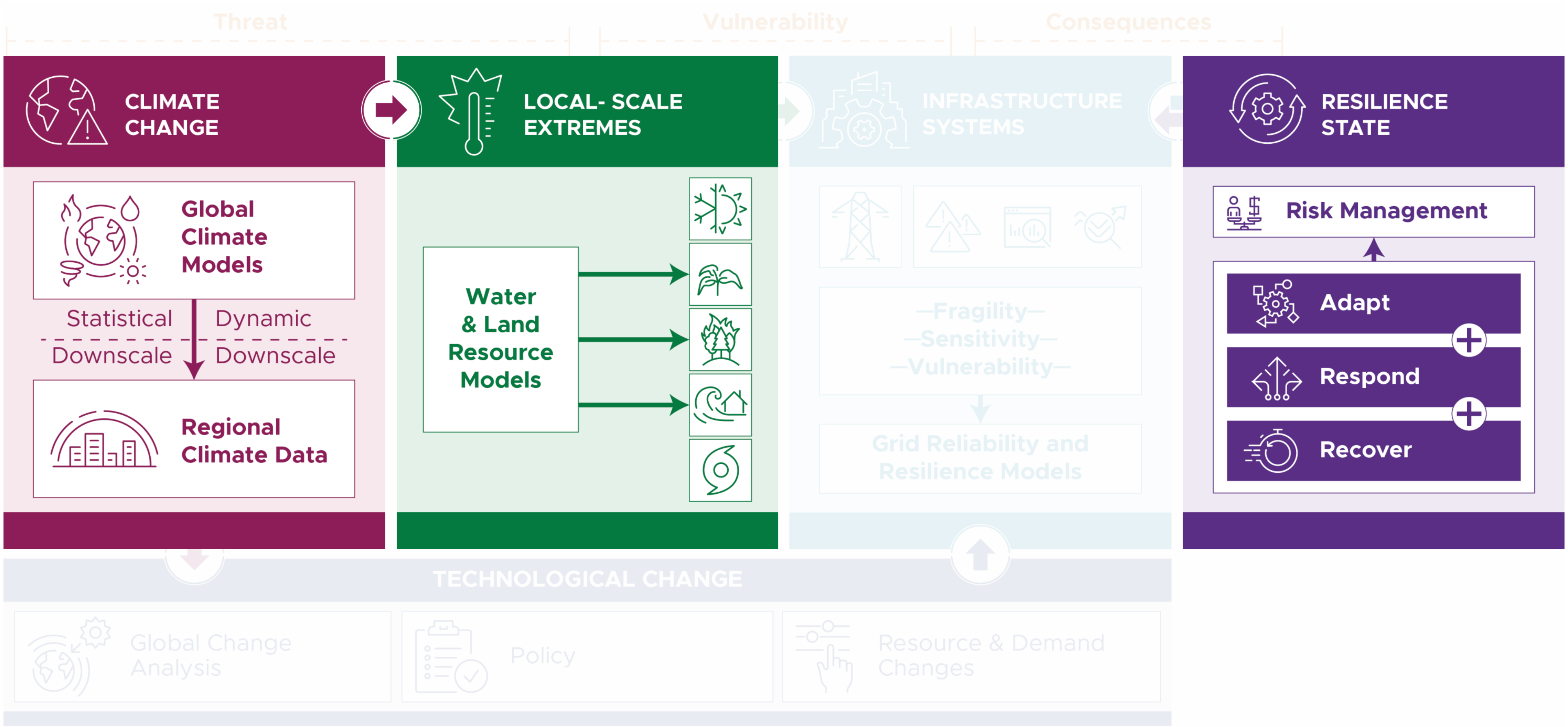




Earth System models represent key atmospheric, land, ocean, and cryosphere processes. These models, such as the **Energy Exascale Earth System Model (E3SM),** are used to understand changes in weather patterns and variables (e.g., temperature, precipitation). This includes changes to atmospheric rivers that impact flooding and drought conditions.

Graphic credit: Caldwell et al. (2021)

Framework connecting climate risks with infrastructure resilience



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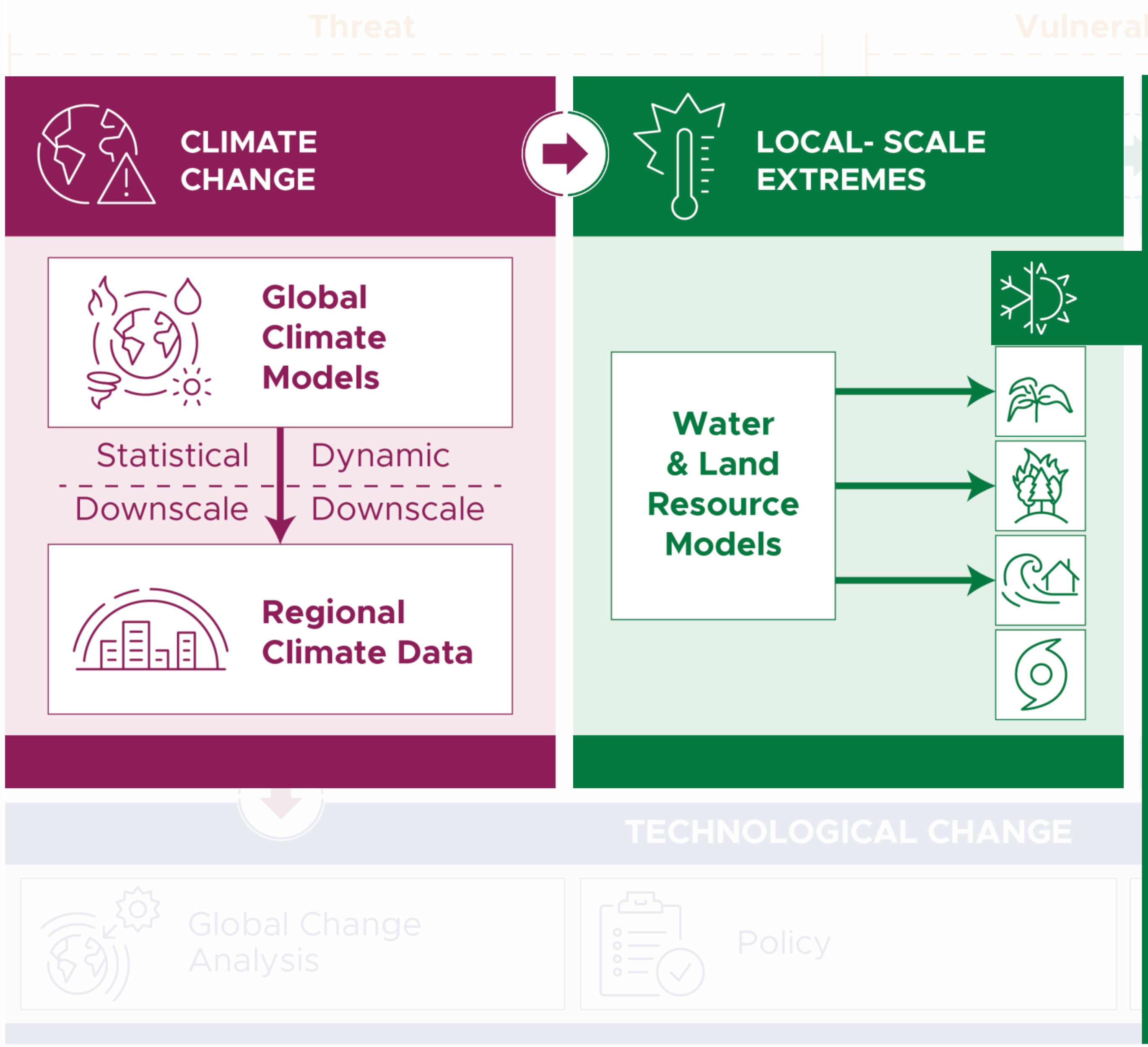
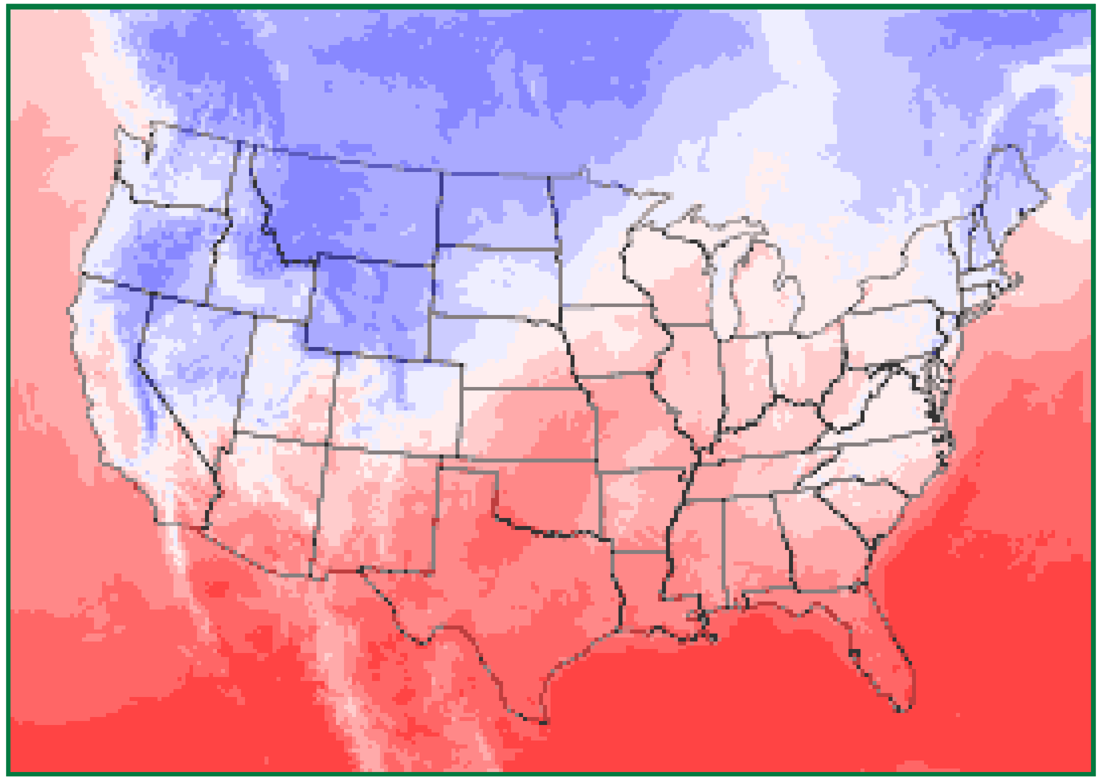
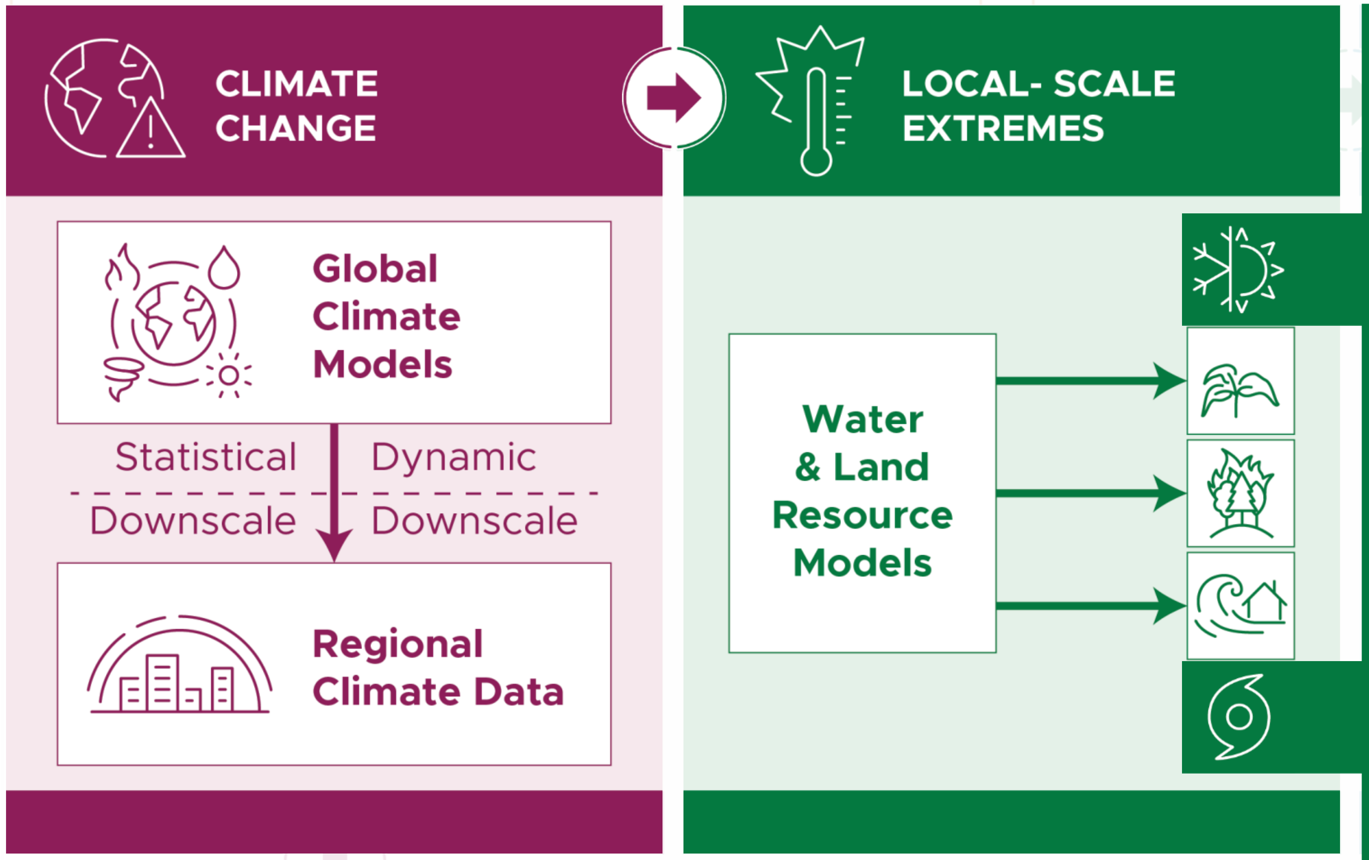


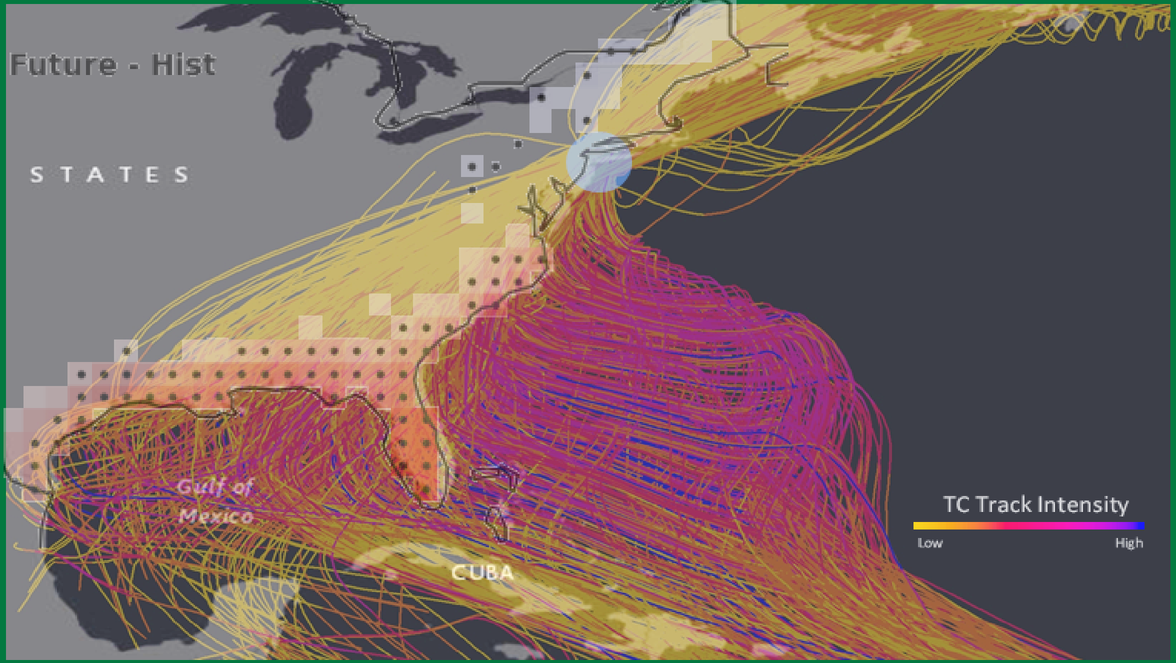


Regional climate models, such as **Weather Research and Forecasting (WRF)**, are being used in support of DOE SC (HyperFACETS/IM3) to understand the impact of extreme temperature change on human systems, including electric power. These findings are important in the design of resilient energy systems.

Graphic credit: Jones et al. (In prep)

Framework connecting climate risks with infrastructure resilience

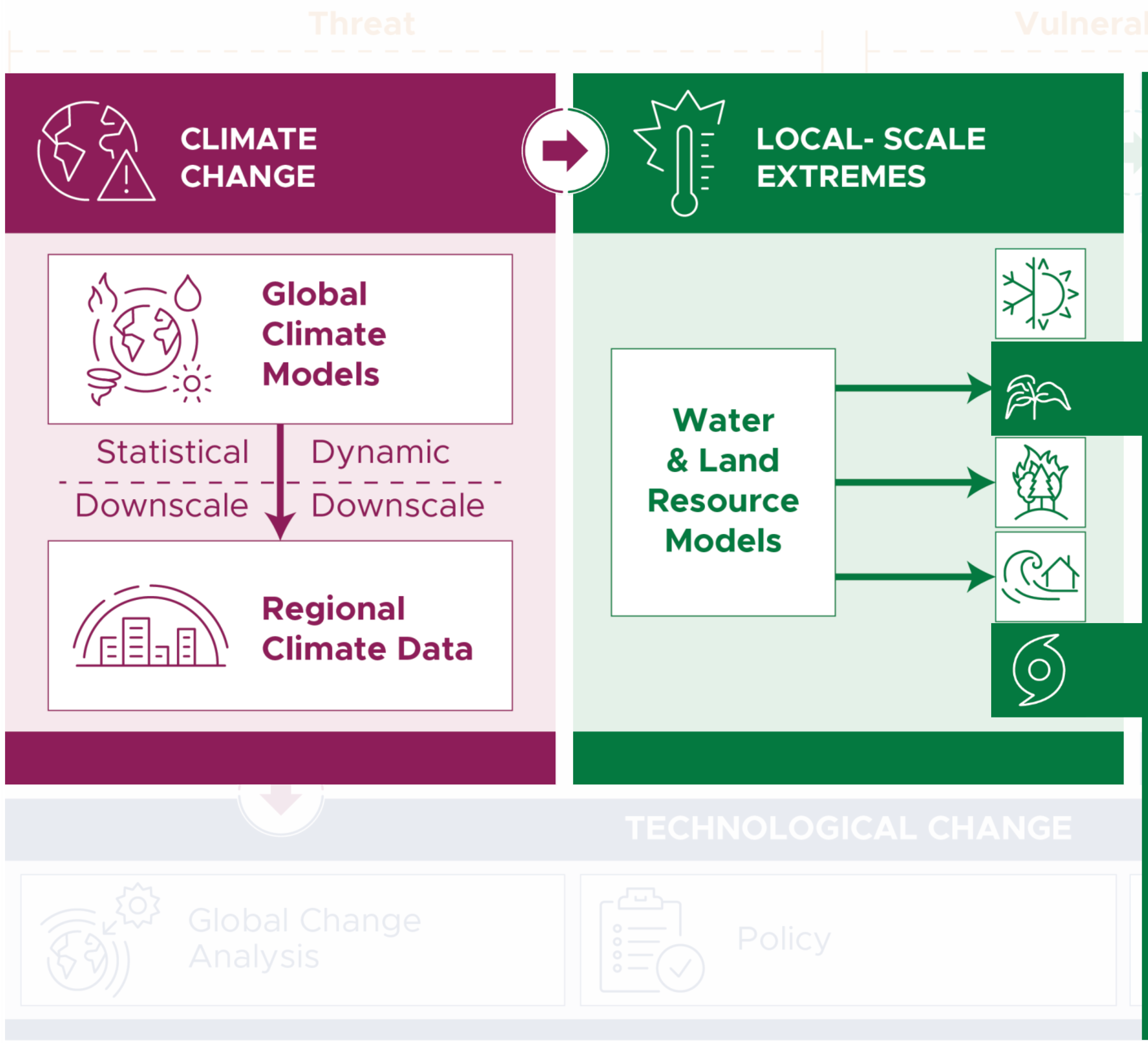




Fully dynamical models provide insight to changes in tropical cyclone behavior but are expensive. Alternative approaches that combine dynamics and AI/ML, such as the **Risk Analysis Framework for Tropical cyclones (RAFT)** are being used to develop large ensembles and project future changes in hurricane intensification, precipitation. These same tools can be used to support resilient infrastructure engineering design.

Graphic credit: Xu et al. (In prep)

Framework connecting climate risks with infrastructure resilience



Understanding long-term availability of wind, solar, and water resources is critical for the design of resilient decarbonized energy systems. Researchers uses regional to local scale **water resource models (VIC, DHSVM, MOSART, WM)** in support of DOE SC, EERE, and utilities to characterize the long-term availability of water for hydro and thermo-electric generation.

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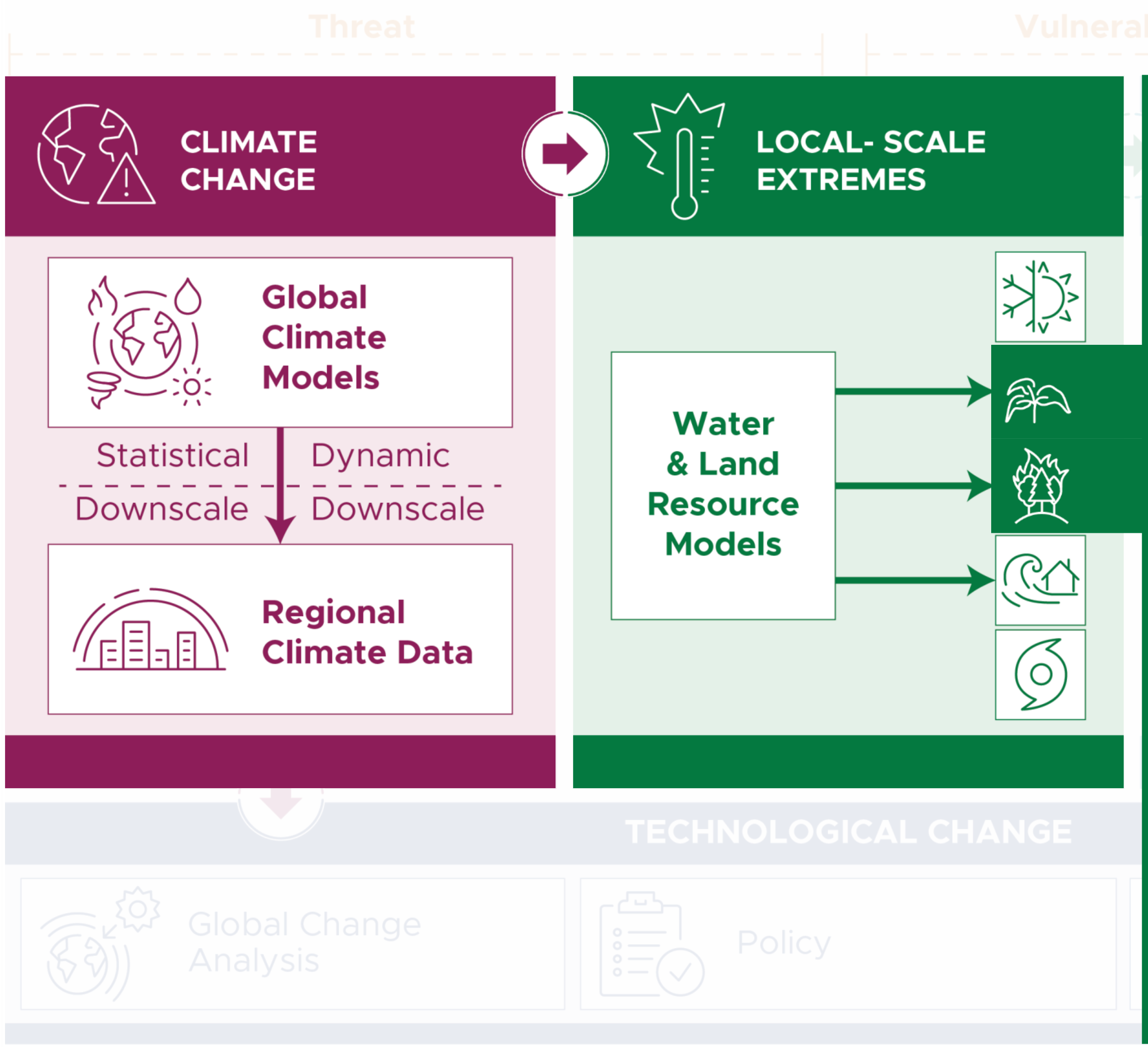
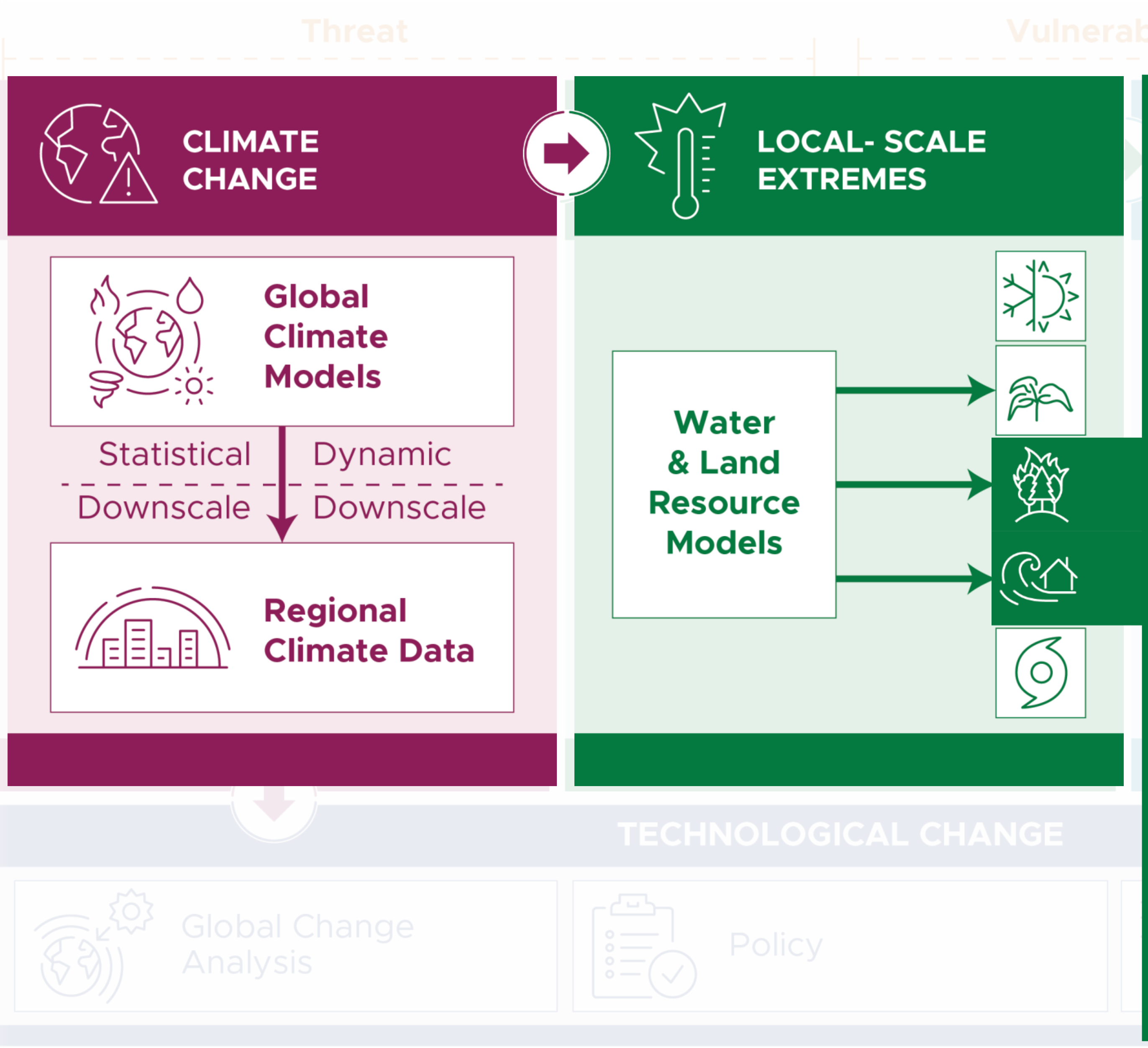
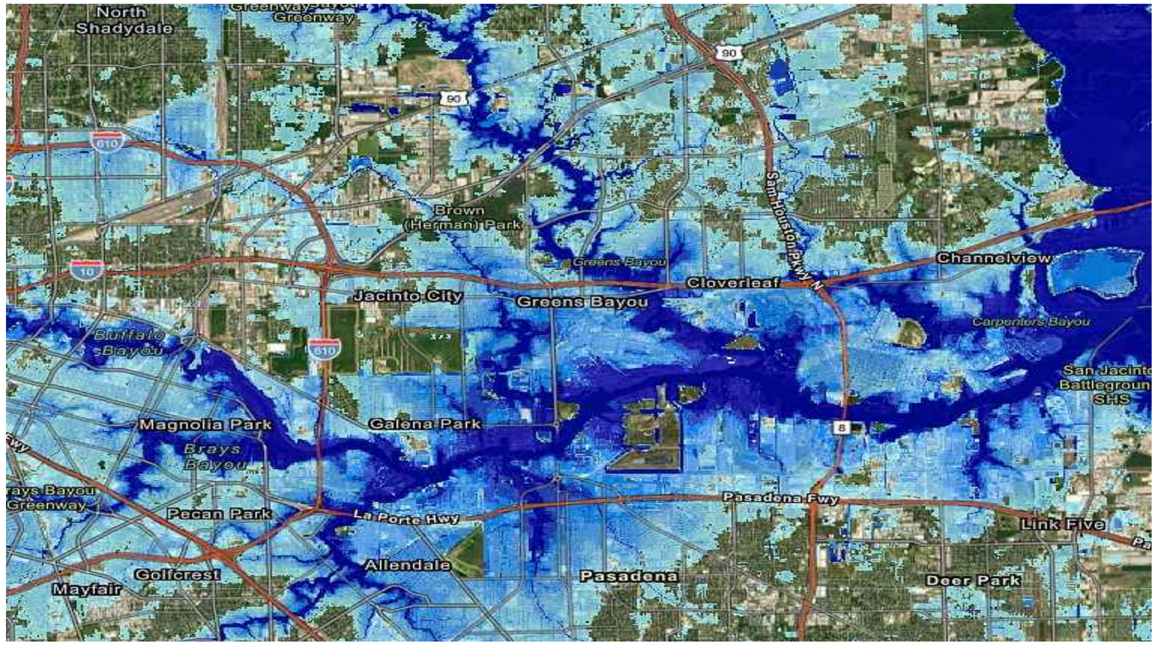
Framework connecting climate risks with infrastructure resilience



New research has led to the development of machine learning approaches to identify predictors of long-term wildfire potential for DOE SC. Tools such as the **Rapid Analytics for Disaster Response-Fire (RADR-Fire)** tool suite use AI/ML combined with remote sensing observations to monitor active wildfire behavior (DOE, DOD) and develop seasonal utility fire risk management plans.

Framework connecting climate risks with infrastructure resilience

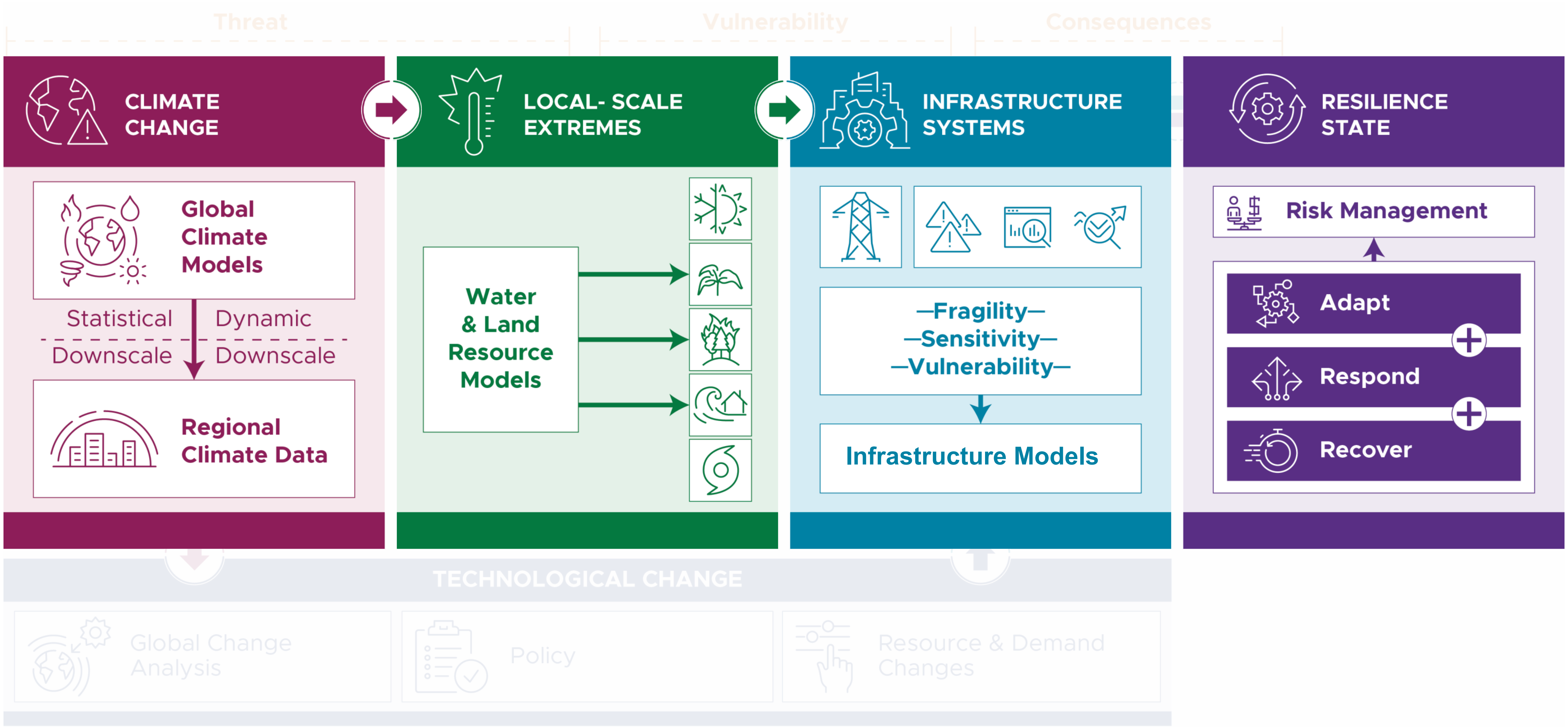




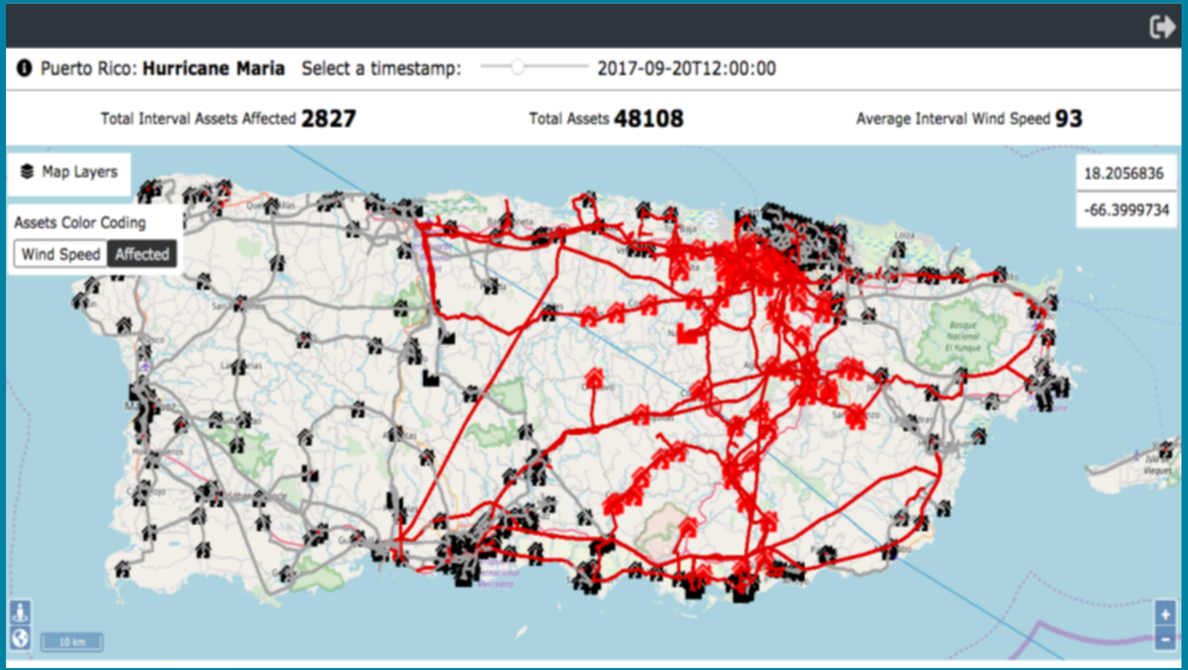
PNNL has developed the **Rapid Infrastructure Flood Tool (RIFT)**, used to support federal (DHS, FEMA), state, and local stakeholders plan, respond, and recover from major hurricane events.

RIFT is also used to support DOE SC to understand future flood risk in coastal environments.

Framework connecting climate risks with infrastructure resilience

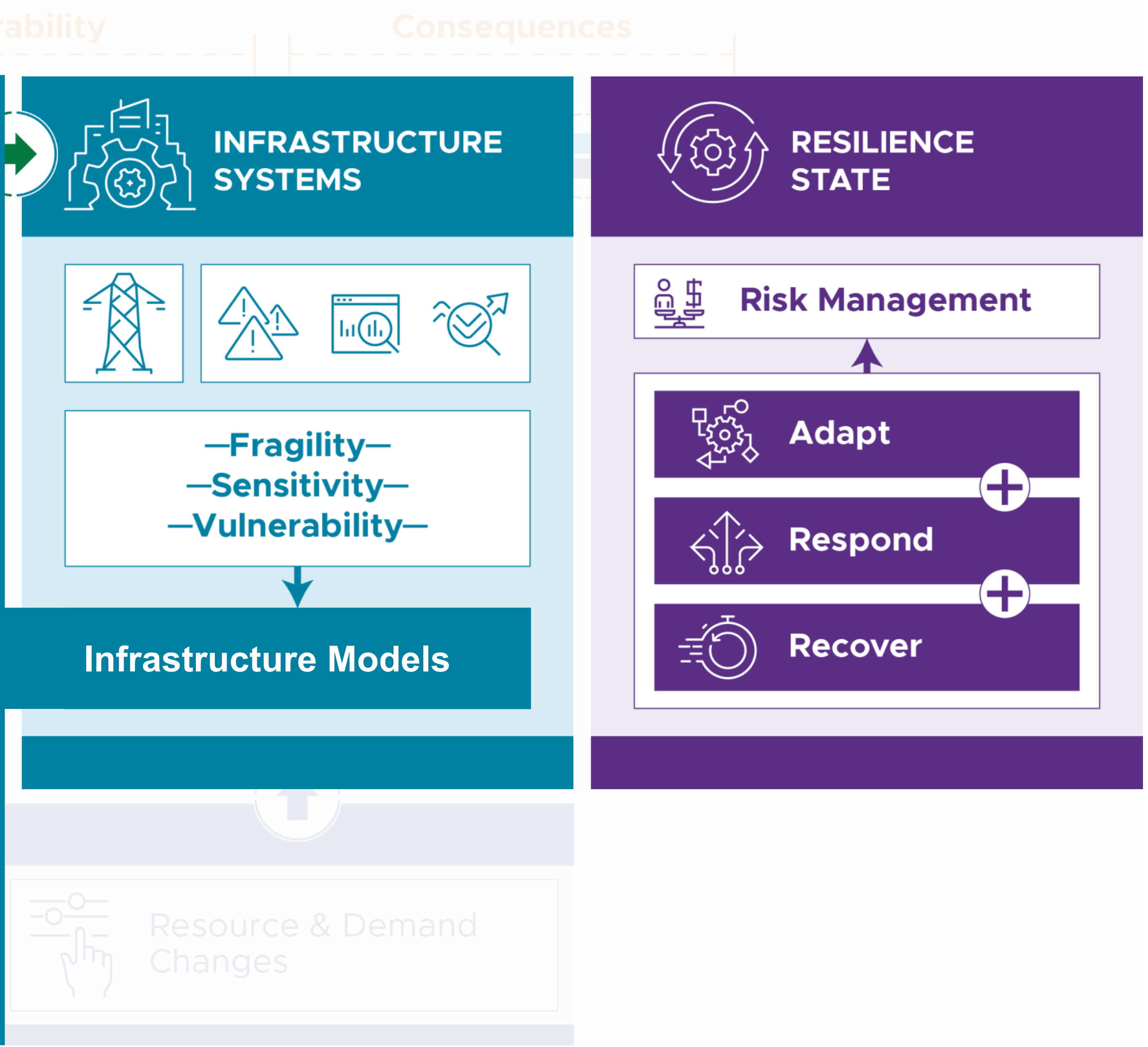


Framework connecting climate risks with infrastructure resilience



PNNL has developed the **Electrical Grid Resilience and Assessment System (EGRASS)**, a decision support tool that identifies and evaluates critical grid assets at risk of failure.

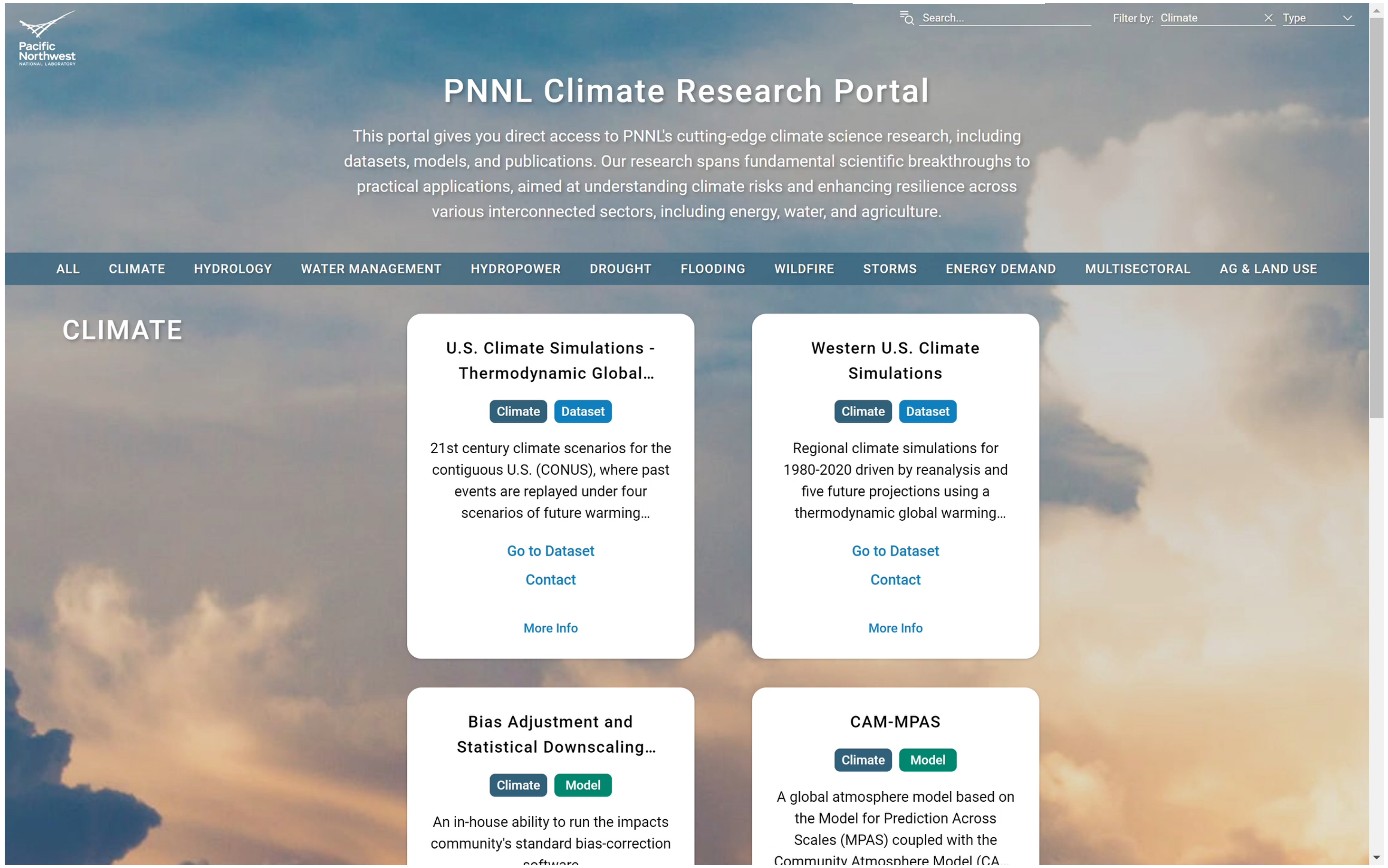
EGRASS is based on the **Dynamic Contingency Analysis Tool (DCAT)** and has been used to support Puerto Rico recovery efforts.

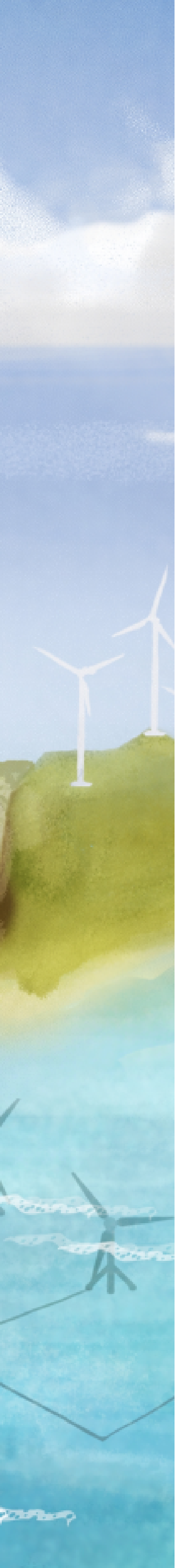


Making climate models, tools, and data available at PNNL

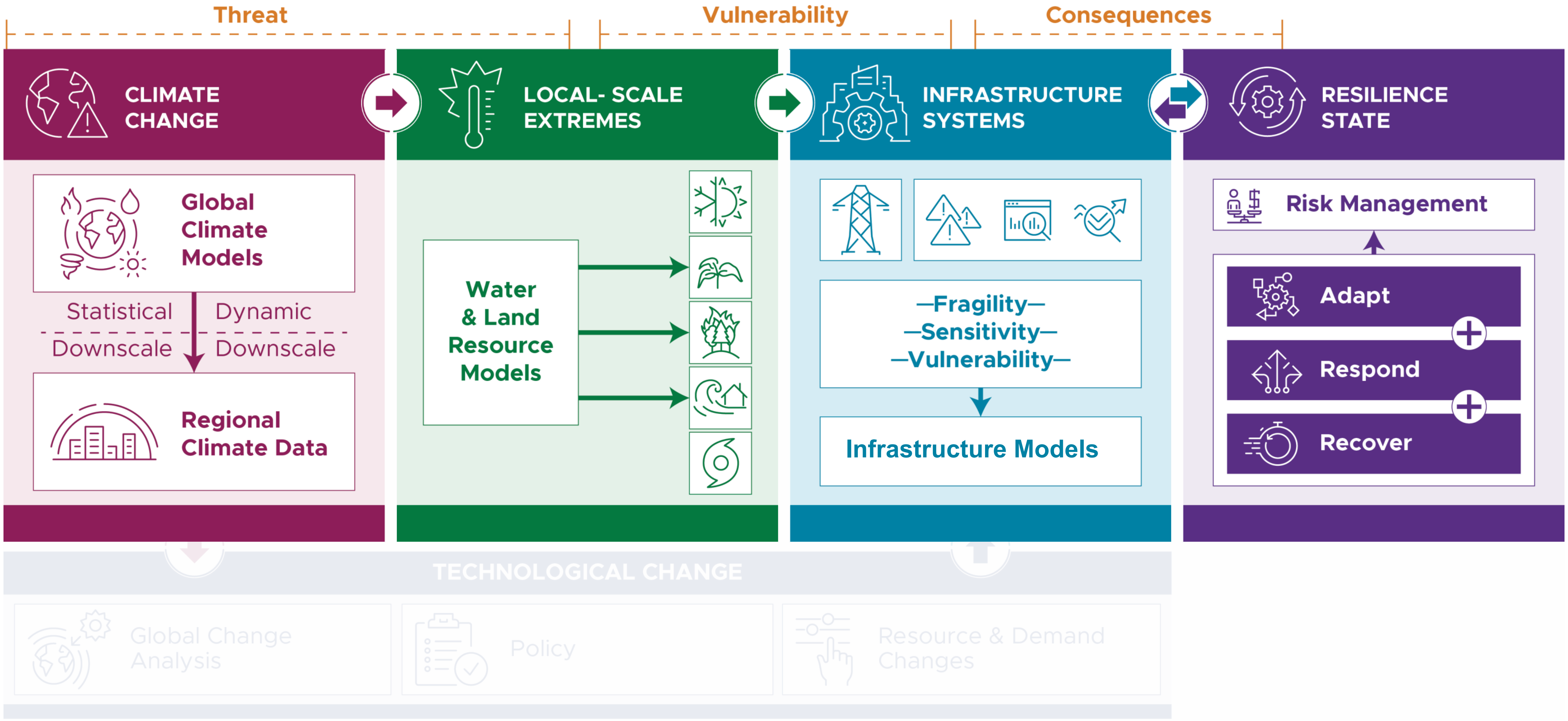
https://climate.pnnl.gov

- Direct access to models and data developed at PNNL
  - Represents research products developed working across the federal government in fundamental and applied research programs
- Many topical categories spanning climate, local scale extremes, and human system datasets
- Future extensions to add guidance on model and data usage





Framework connecting climate risks with infrastructure resilience



Adaptation: Clean energy goals set to combat climate change

THE WHITE HOUSE

100%

carbon pollution-free electricity by

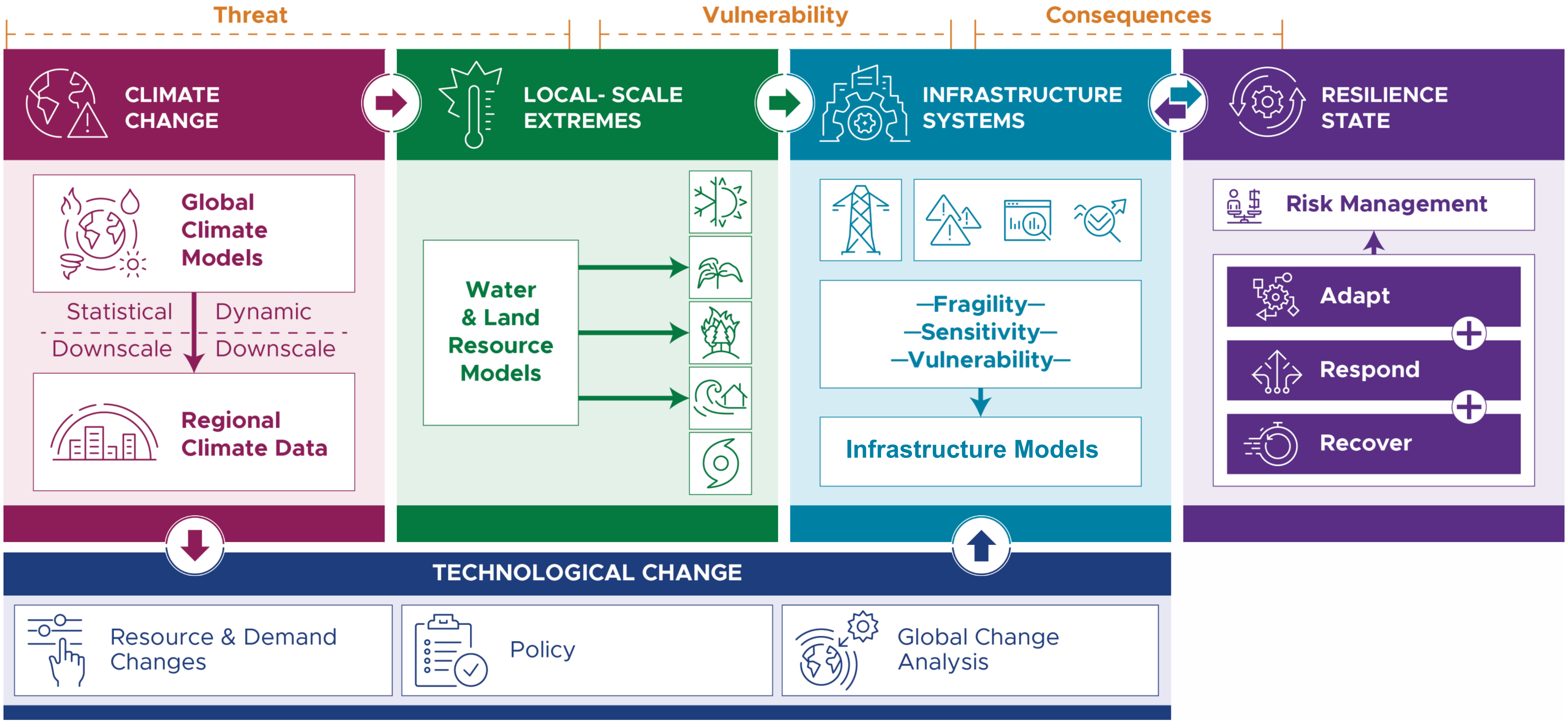
2035

Net-zero

emissions no later than

2050

Framework connecting climate risks with infrastructure resilience



Framework connecting climate risks with infrastructure resilience

Threat | Vulnerability | Consequences

CLIMATE CHANGE

Global Climate Models

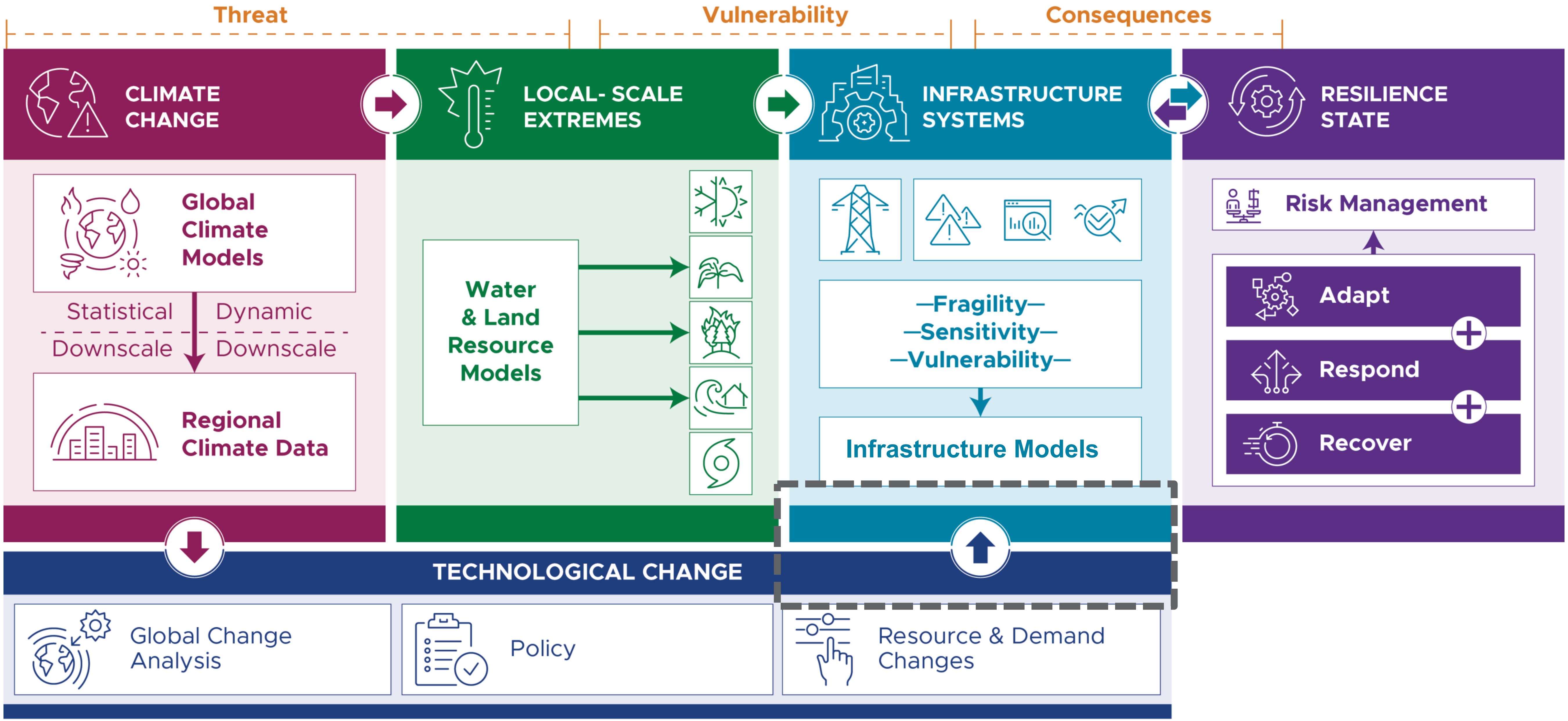
Statistical Downscale | Dynamic Downscale

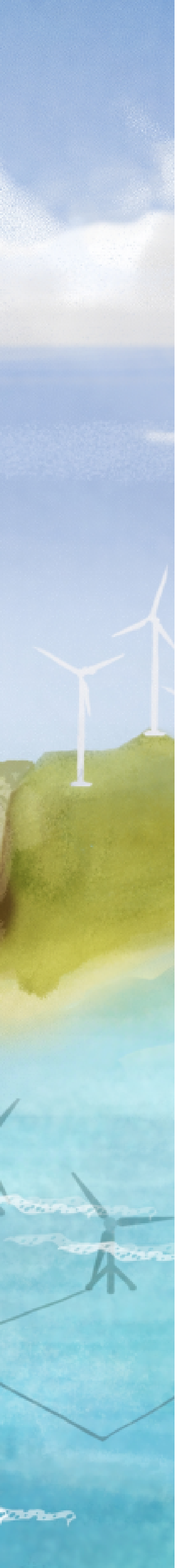
Regional Climate Data

Resource & Demand Changes

PNNL has developed the **Global Change Analysis Model (GCAM)** to support DOE SC in understanding dynamics between energy, water, land, economy, and climate at global, regional, and state scales. GCAM supports EPA and DOE EERE in the exploration and impacts of decarbonization policies.

Framework connecting climate risks with infrastructure resilience





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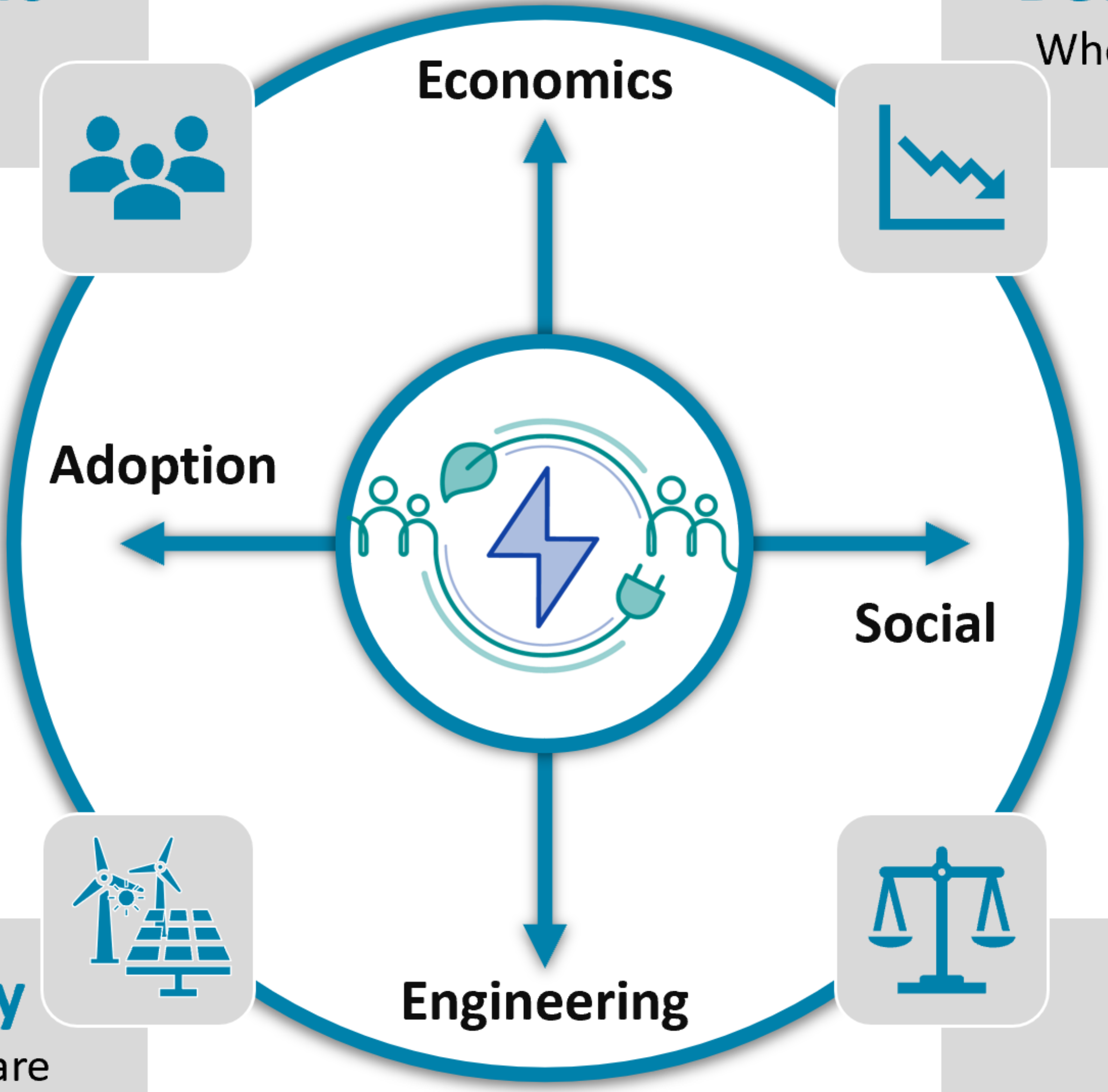
Developing a holistic approach to exploring decarbonization

Empowered Stakeholders

Transfer of methods, tools, datasets, and use cases

Decarbonization Pathways

Whole economy decarbonization with interactions across global markets



GODEEEP
Grid Operations, Decarbonization, Environmental and Energy Equity Platform
@PNNL

Resilience and Reliability

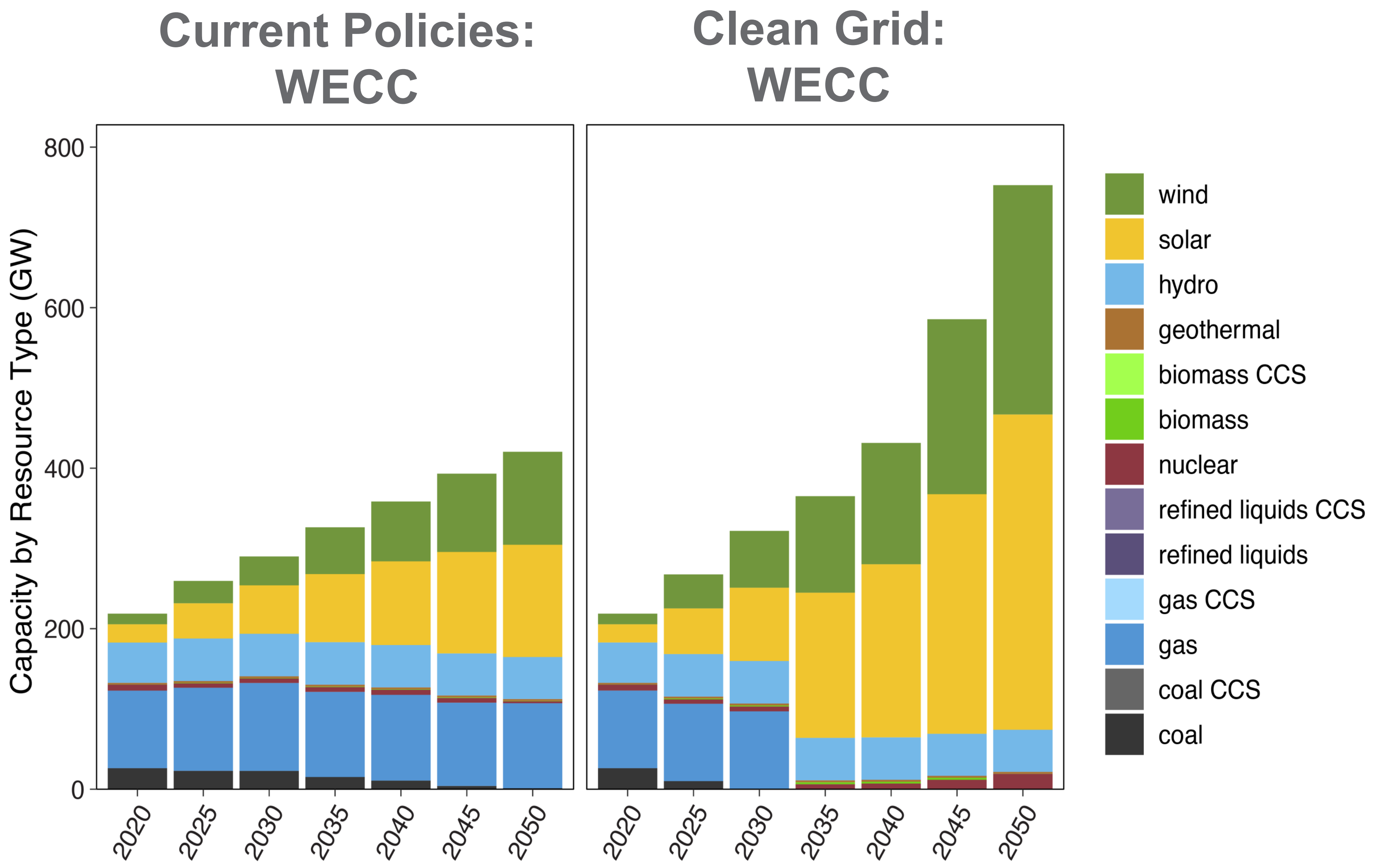
Infrastructure and operations that are responsive to climate change

Justice and Equity

Environmental and energy equity impacts of decarbonization

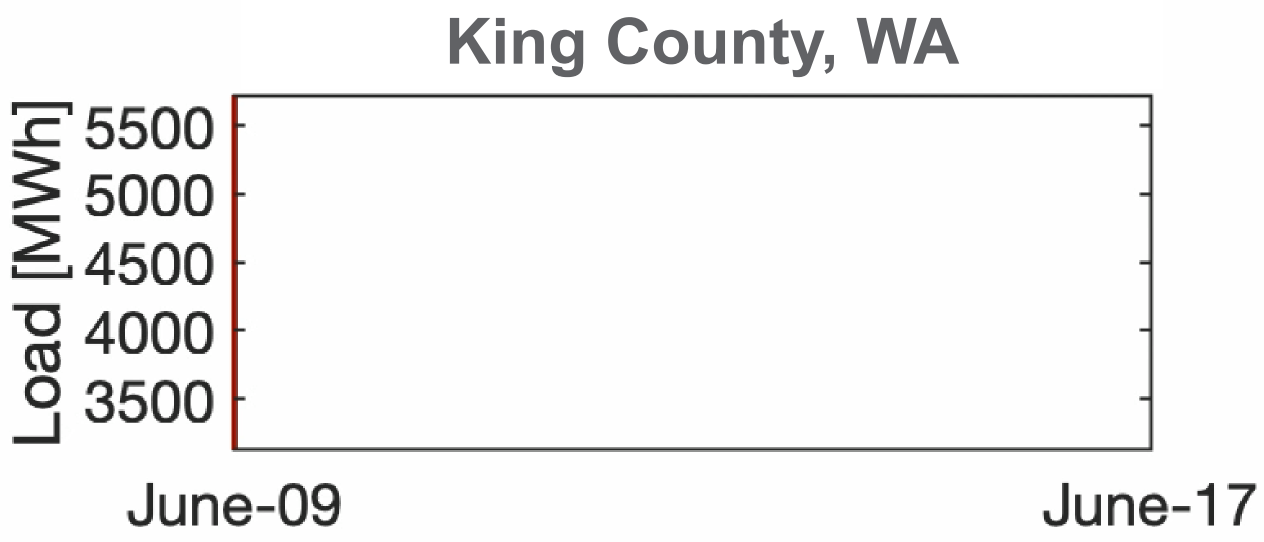
Collaborating with industry to develop clean electricity grid scenarios

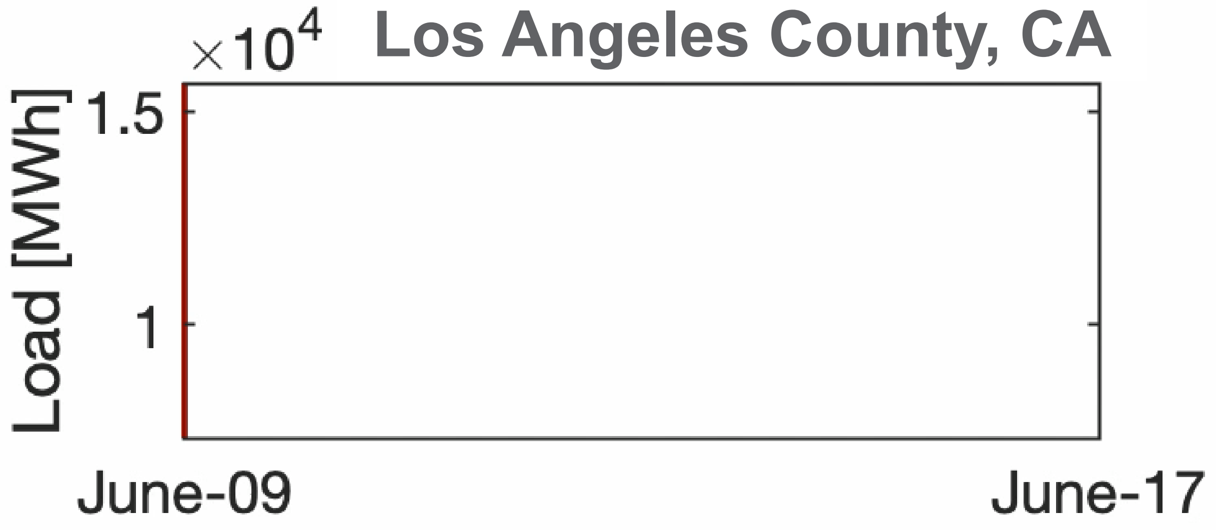
- A clean grid by 2035 requires a small increase in capacity, but a drastic change in portfolio:
- Solar x 2
- Wind x 2+
- Gas fully retired
- Coal fully retired

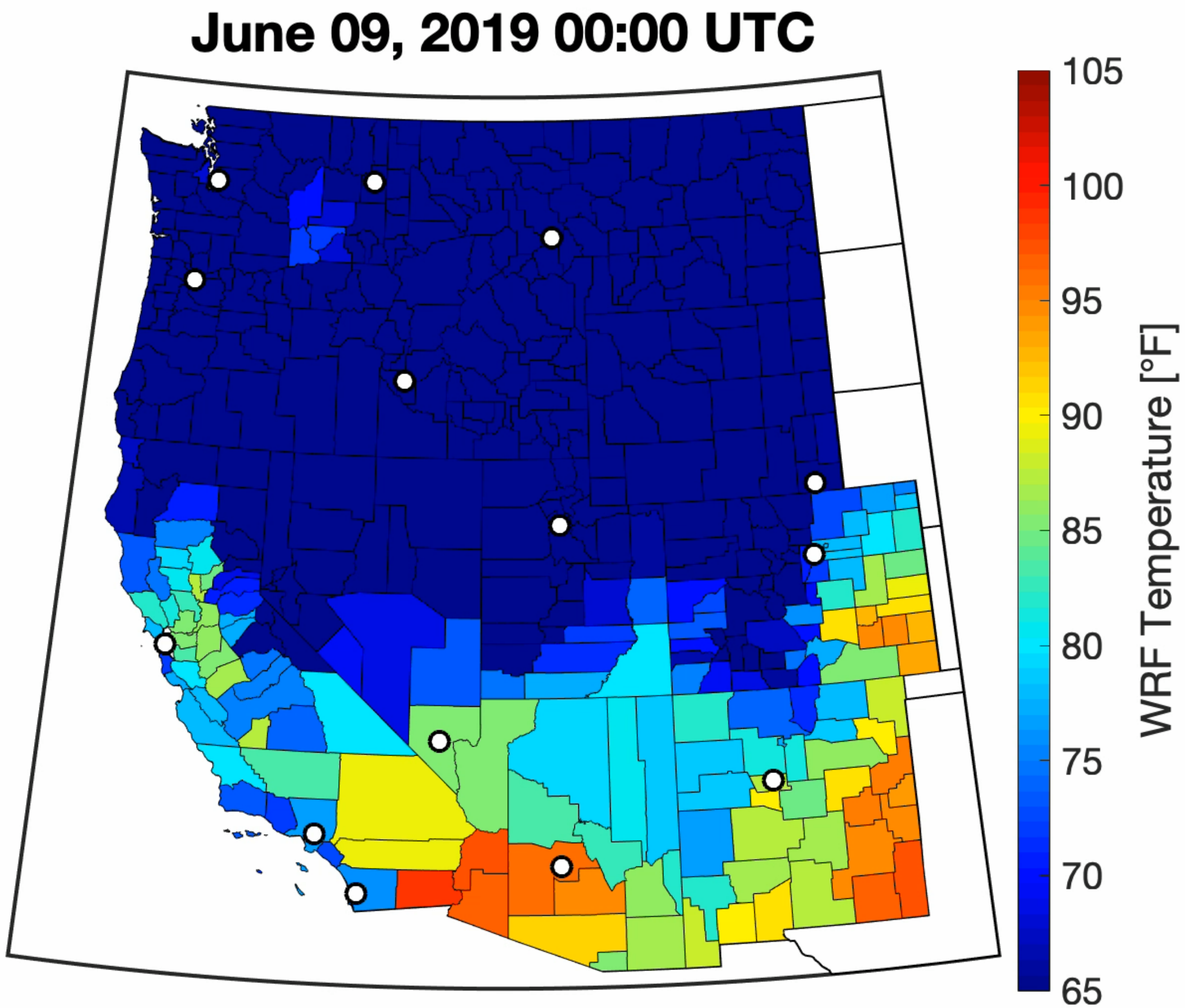


Scenarios developed using the Global Change Analysis Model (GCAM)

Projecting loads that are responsive to extreme weather

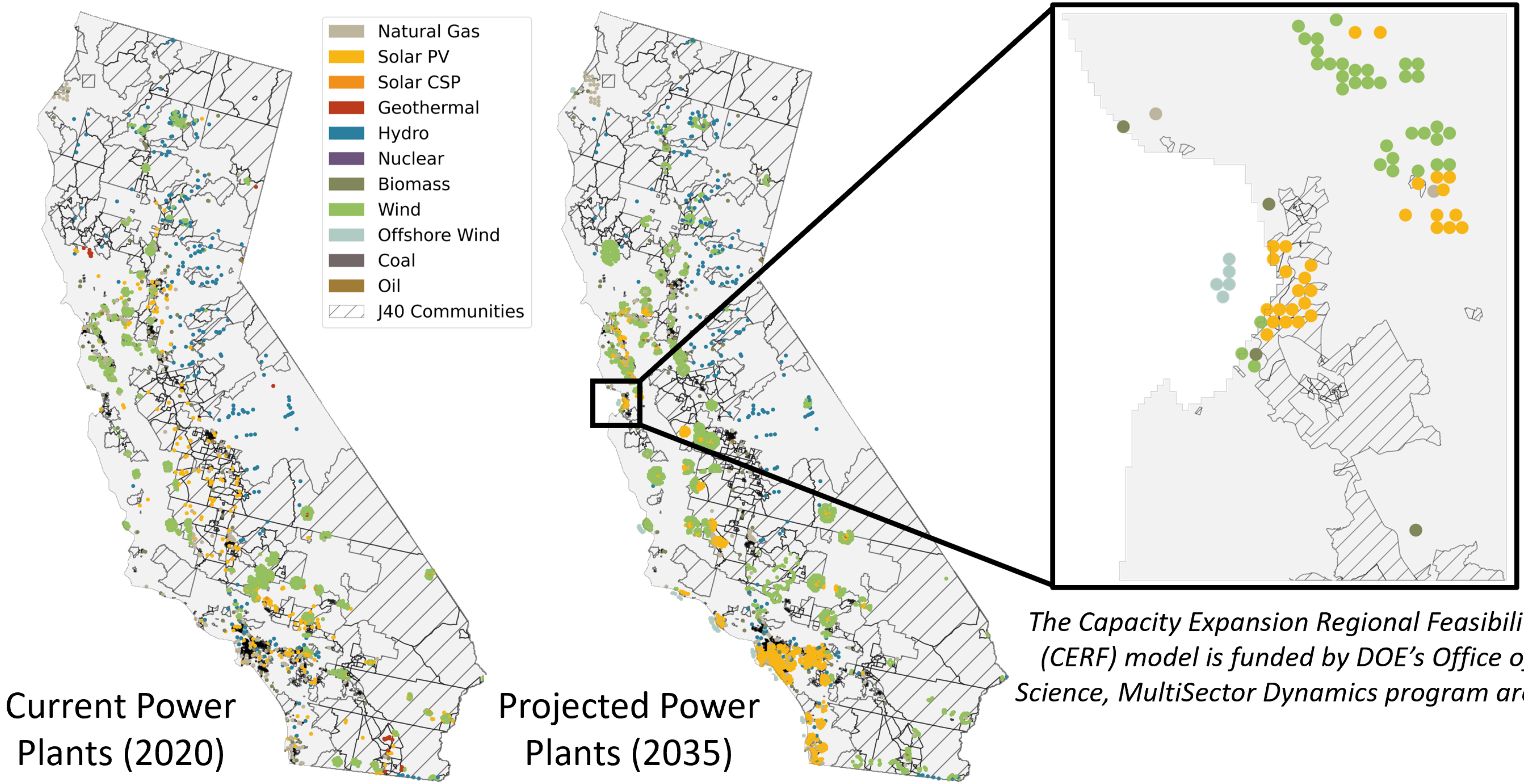






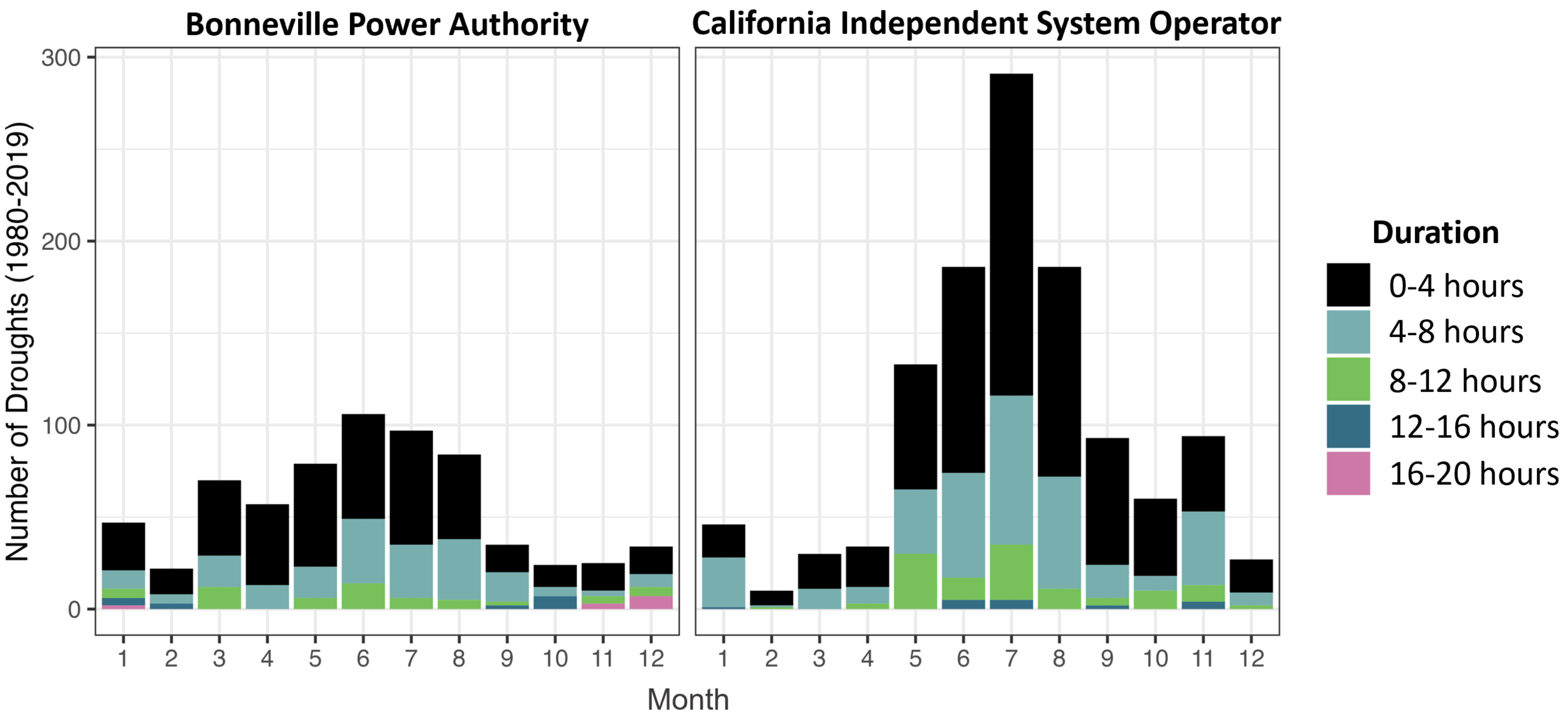
Electricity loads projected using the Total ELectricity Loads (TELL) model

Developing projections capacity siting considering equity



The Capacity Expansion Regional Feasibility (CERF) model is funded by DOE's Office of Science, MultiSector Dynamics program area.

Using coincident solar and wind data to understand future energy droughts



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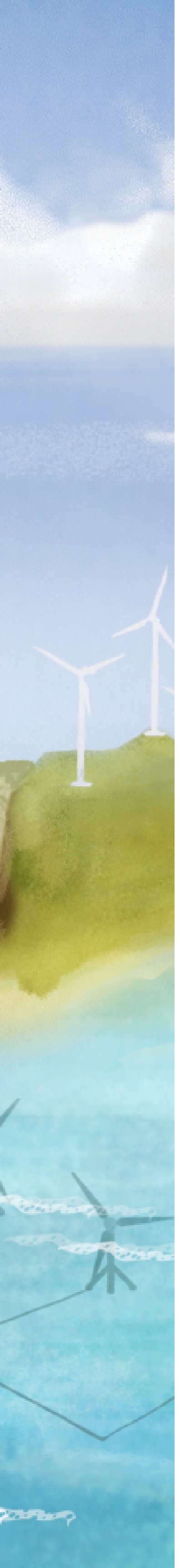
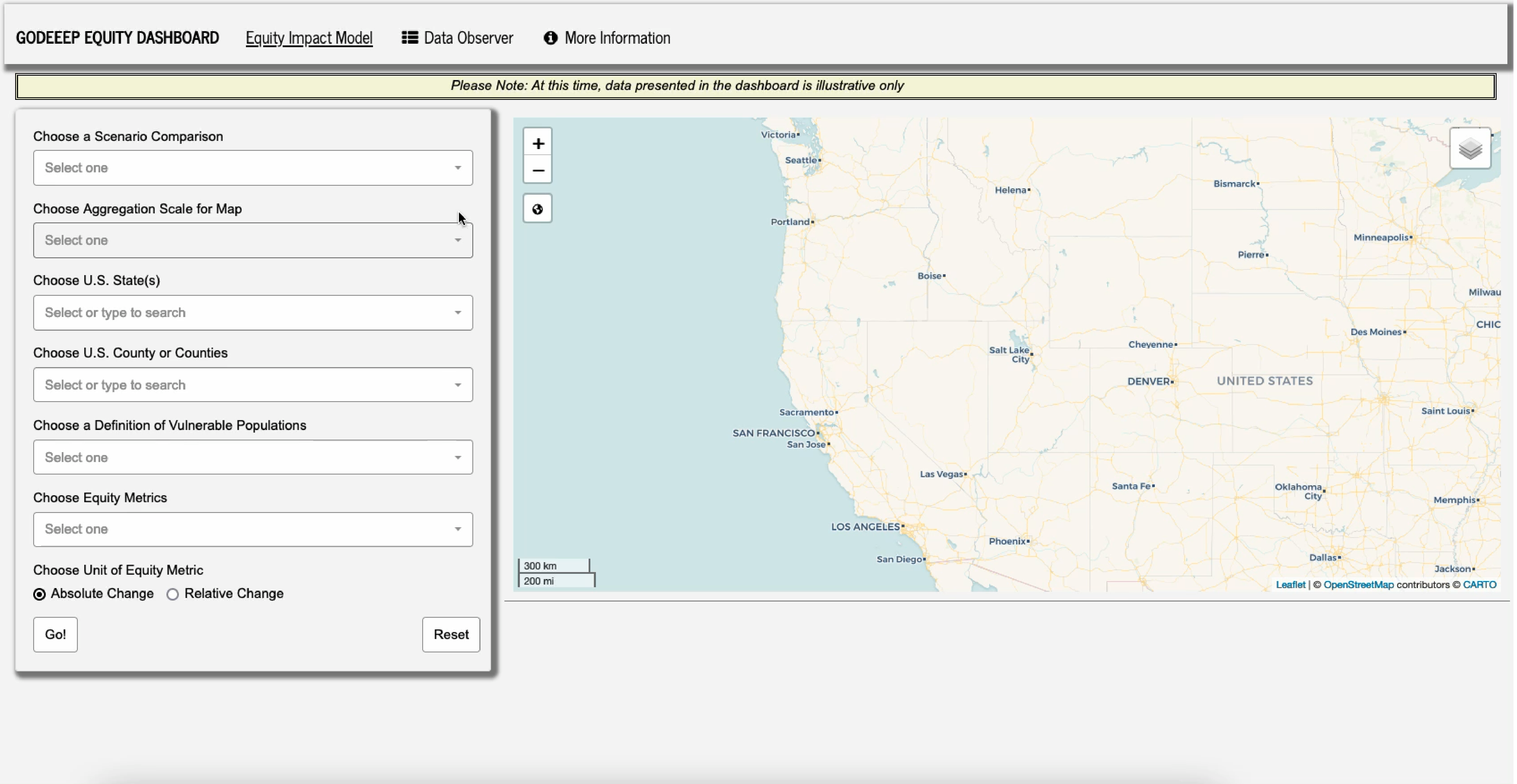
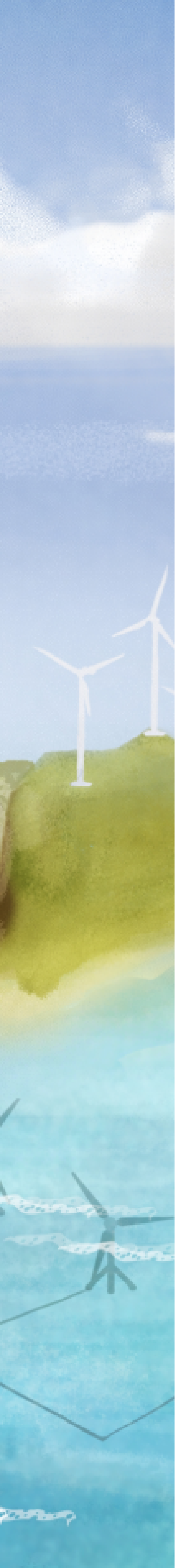
Engaging stakeholders and communities by making scenarios available through a dashboard

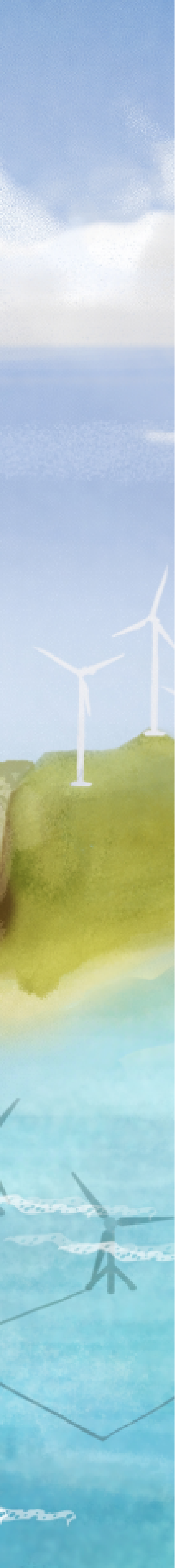






Summary

- Climate-driven extreme events continue to impact infrastructure systems
- The US has set aggressive clean energy goals to combat climate change, introducing new challenges in the context of resilience
- Presents an opportunity to include new considerations in climate resilience, such as equitable energy transitions
- Researchers, utilities, communities, and policy makers must work together to reach these goals



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Thank You

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EARTH SYSTEMS SCIENCE

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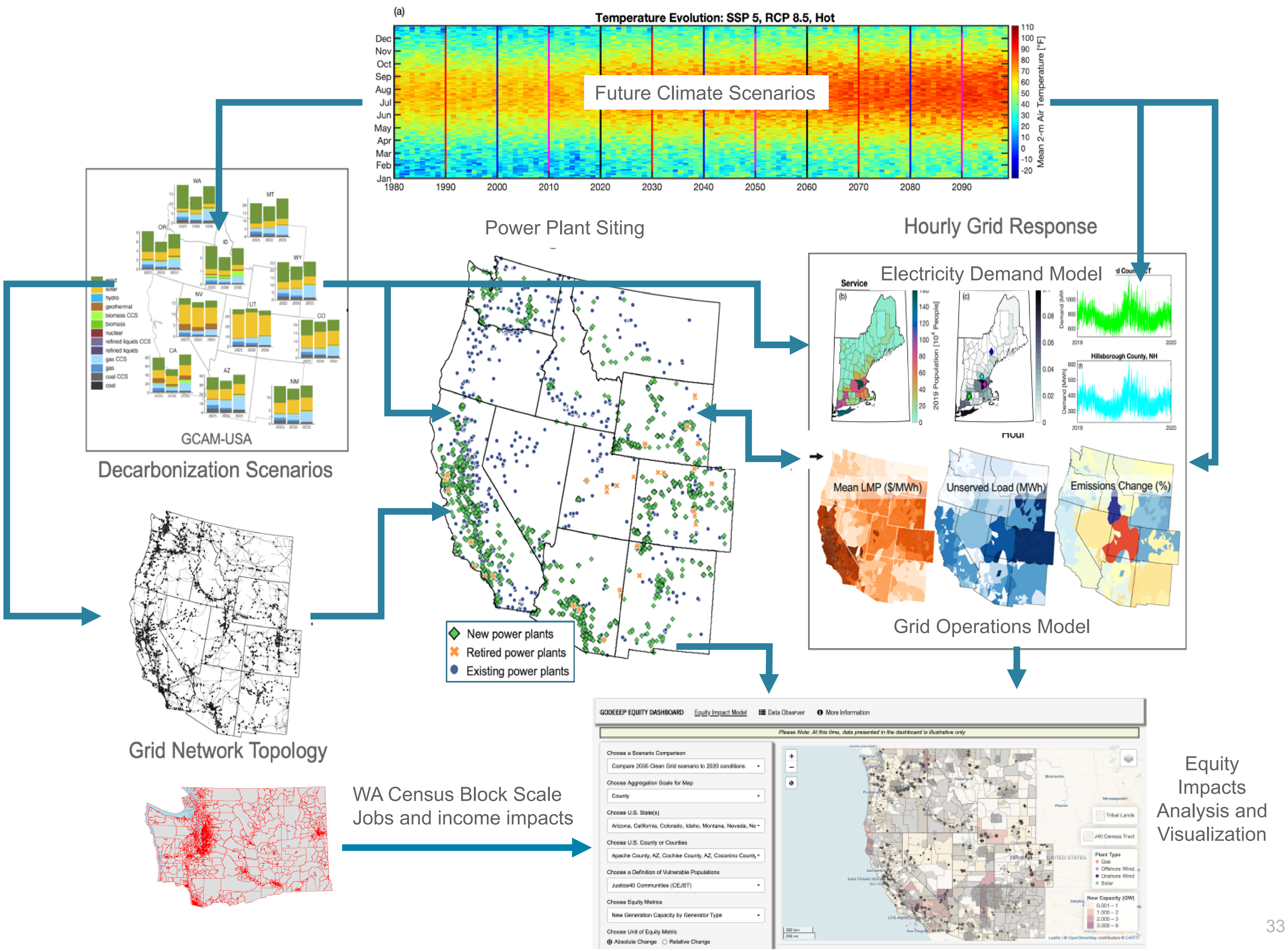
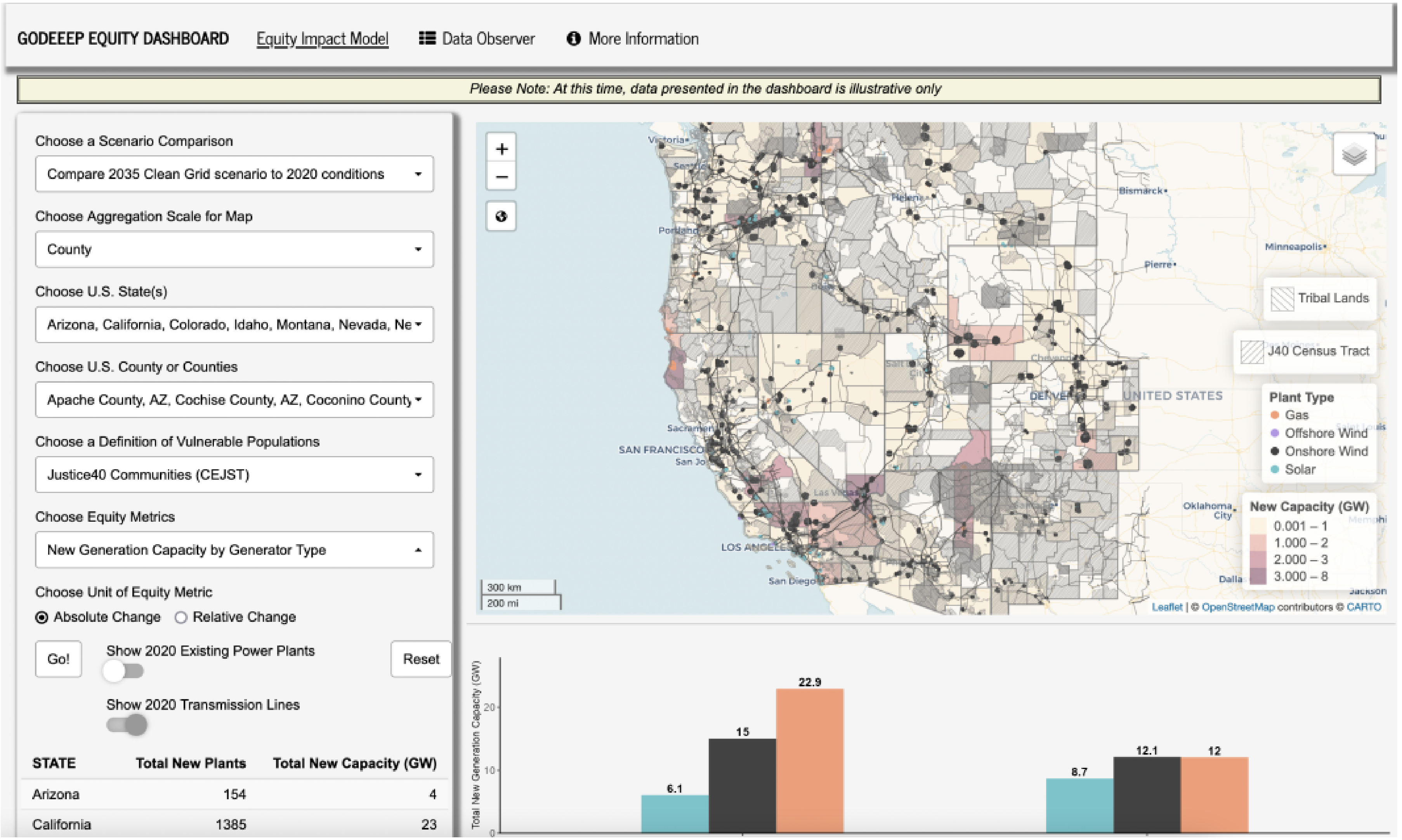
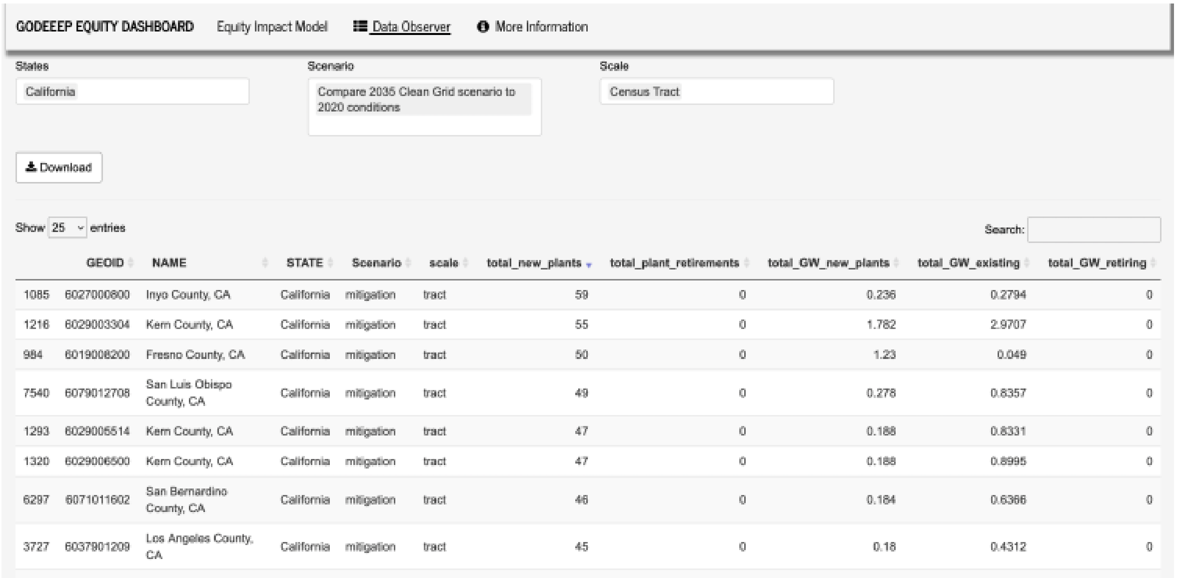
GODEEEP Modeling Platform



GODEEEP Equity Dashboard

- Visualize impacts of decarbonization scenarios across scales
  - New and retired capacity
  - Emissions
  - Unserved Energy
- Identify changes within different definitions of disadvantaged communities
- View, filter, and download associated datasets





	GEOID	NAME	STATE	Scenario	scale	total_new_plants	total_plant_retirements	total_GW_new_plants	total_GW_existing	total_GW_retiring
1085	6027000800	Inyo County, CA	California	mitigation	tract	59	0	0.236	0.2794	0
1216	6029003304	Kern County, CA	California	mitigation	tract	55	0	1.782	2.9707	0
984	6019008200	Fresno County, CA	California	mitigation	tract	50	0	1.23	0.049	0
7540	6079012708	San Luis Obispo County, CA	California	mitigation	tract	49	0	0.278	0.8357	0
1293	6029005514	Kern County, CA	California	mitigation	tract	47	0	0.188	0.8331	0
1320	6029006500	Kern County, CA	California	mitigation	tract	47	0	0.188	0.8995	0
6297	6071011602	San Bernardino County, CA	California	mitigation	tract	46	0	0.184	0.6366	0
3727	6037901209	Los Angeles County, CA	California	mitigation	tract	45	0	0.18	0.4312	0

Please Note: At this time, data presented in the dashboard is illustrative only

Choose a Scenario Comparison

Compare 2035 Clean Grid scenario to 2020 conditions

Choose Aggregation Scale for Map

County

Choose U.S. State(s)

Arizona, California, Colorado, Idaho, Montana, Nevada, Ne

Choose U.S. County or Counties

Apache County, AZ, Cochise County, AZ, Coconino County

Choose a Definition of Vulnerable Populations

Justice40 Communities (CEJST)

Choose Equity Metrics

New Generation Capacity by Generator Type

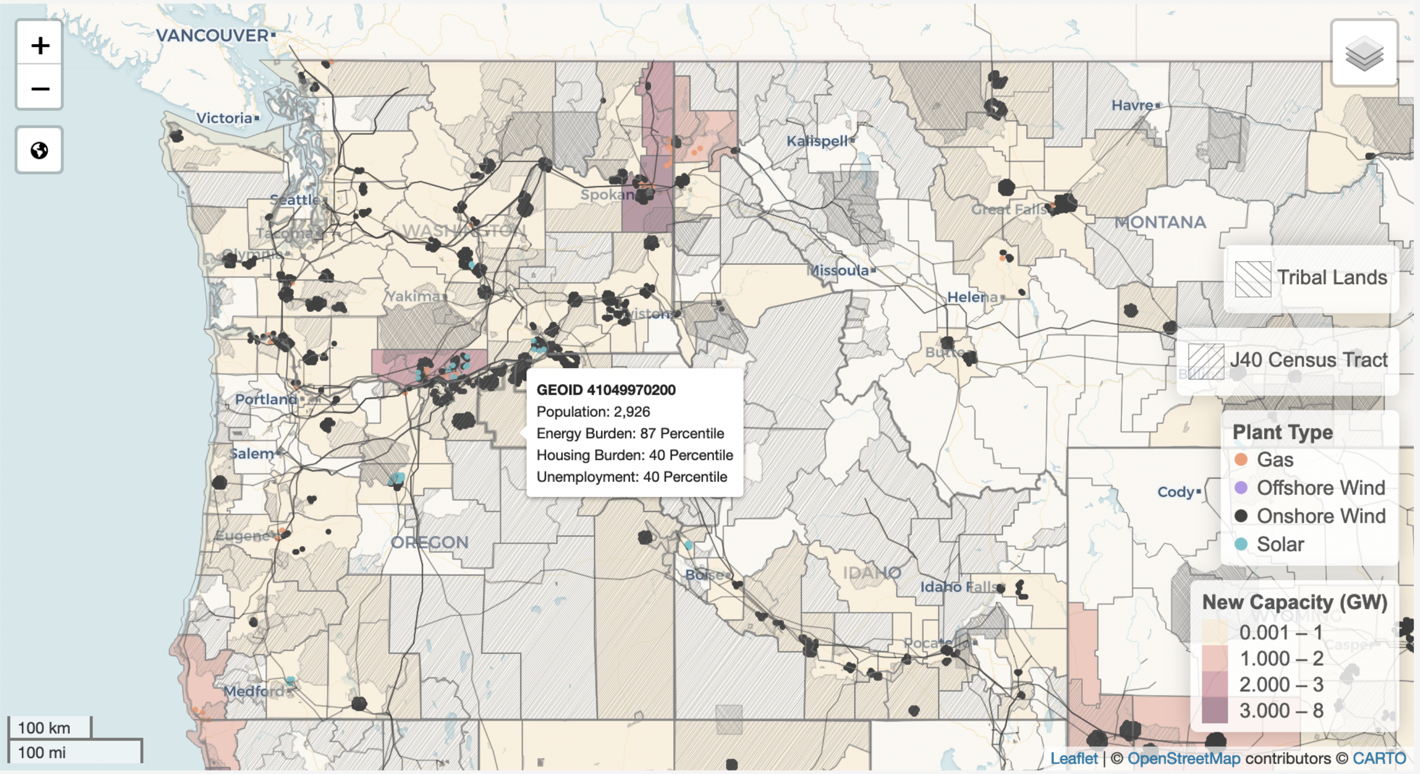
Choose Unit of Equity Metric

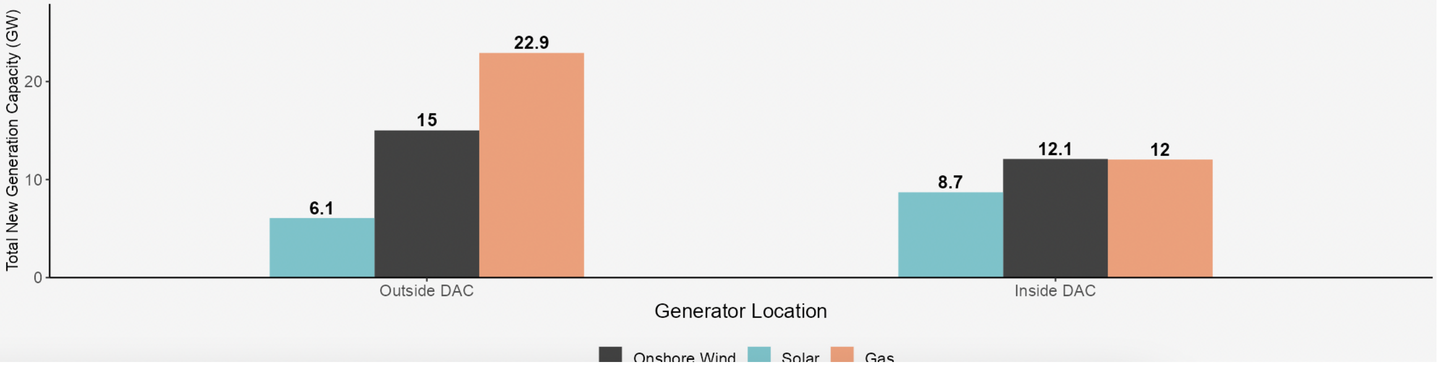
(•) Absolute Change ( ) Relative Change

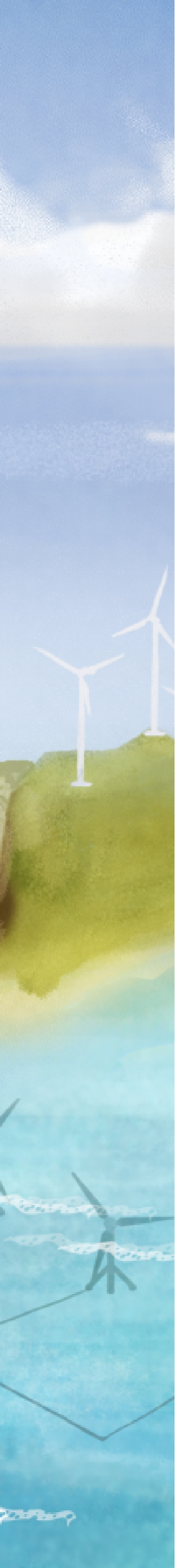
Go! Show 2020 Existing Power Plants Reset

Show 2020 Transmission Lines

STATE	Total New Plants	Total New Capacity (GW)
Arizona	154	4
California	1385	23
Colorado	442	7
Idaho	178	2







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GODEEEP EQUITY DASHBOARD Equity Impact Model Data Observer More Information

States: California

Scenario: Compare 2035 Clean Grid scenario to 2020 conditions

Scale: Census Tract

Download

Show 25 entries

Search:

	GEOID	NAME	STATE	Scenario	scale	total_new_plants	total_plant_retirements	total_GW_new_plants	total_GW_existing	total_GW_retiring
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3727	6037901209	Los Angeles County, CA	California	mitigation	tract	45	0	0.18	0.4312	0