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Sandia National Laboratories

Balancing Co-Dependence: An Evaluation of Renewable Energy Production Resilience to Natural Disasters

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Society of Risk Analysis

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U.S. DEPARTMENT OF ENERGY | National Nuclear Security Administration

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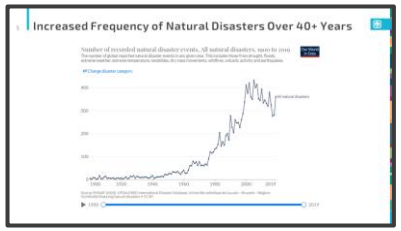
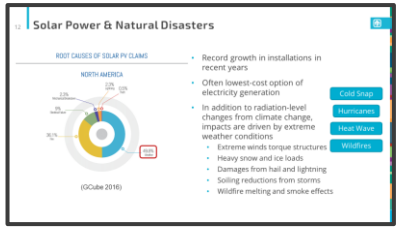
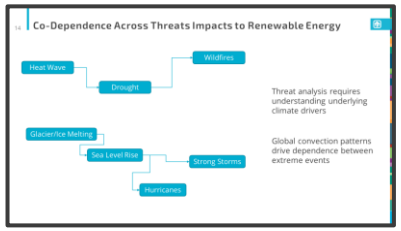
Outline



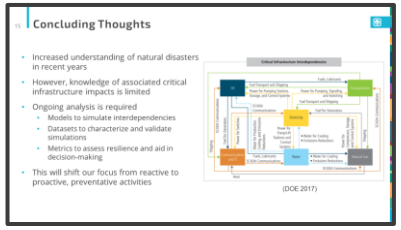
Problem Motivation



Extreme Weather Impacts on Renewable Energy

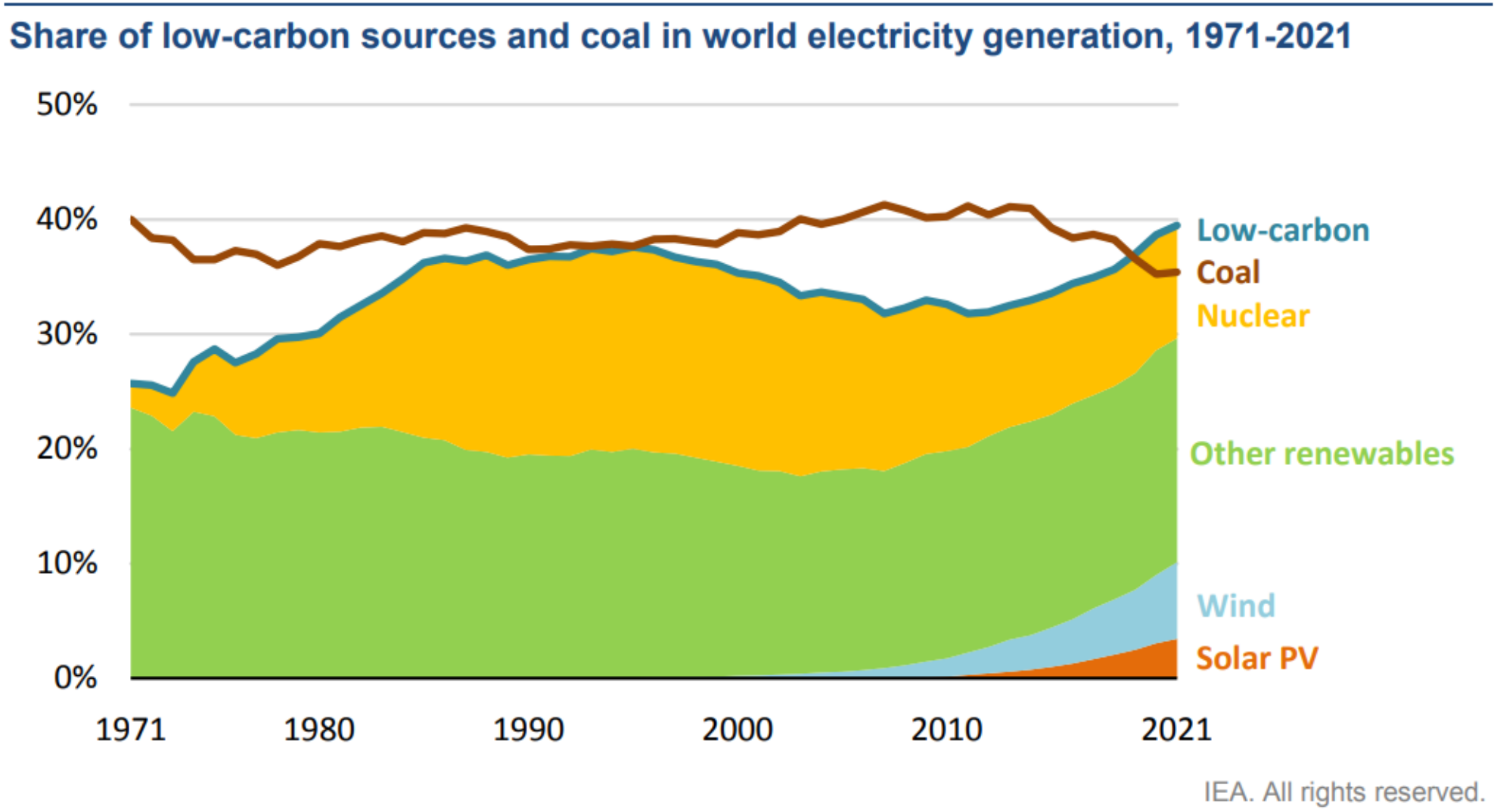


Co-Dependence Analysis



Concluding Thoughts

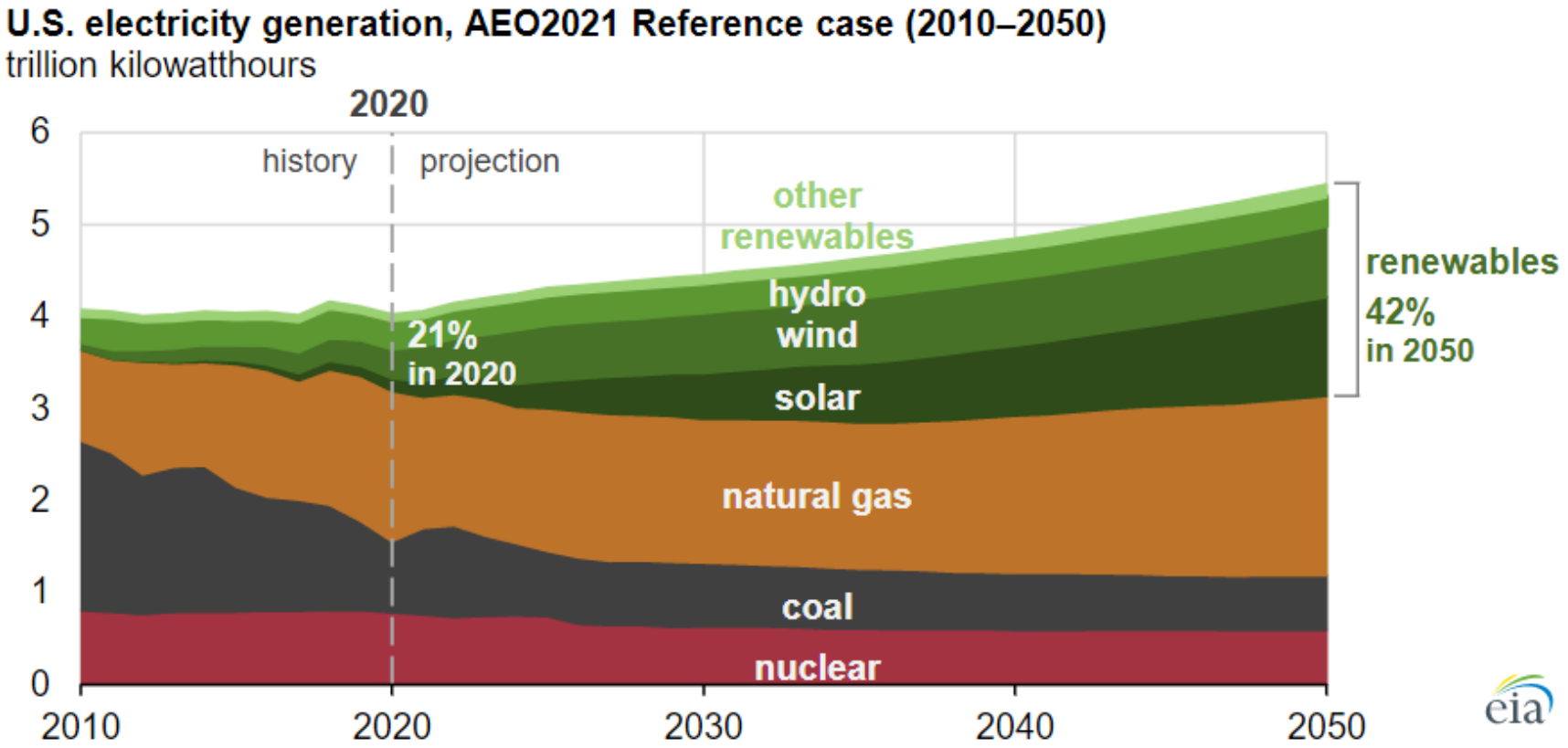
Shifting Energy Profile



Similar Patterns Observed within the United States

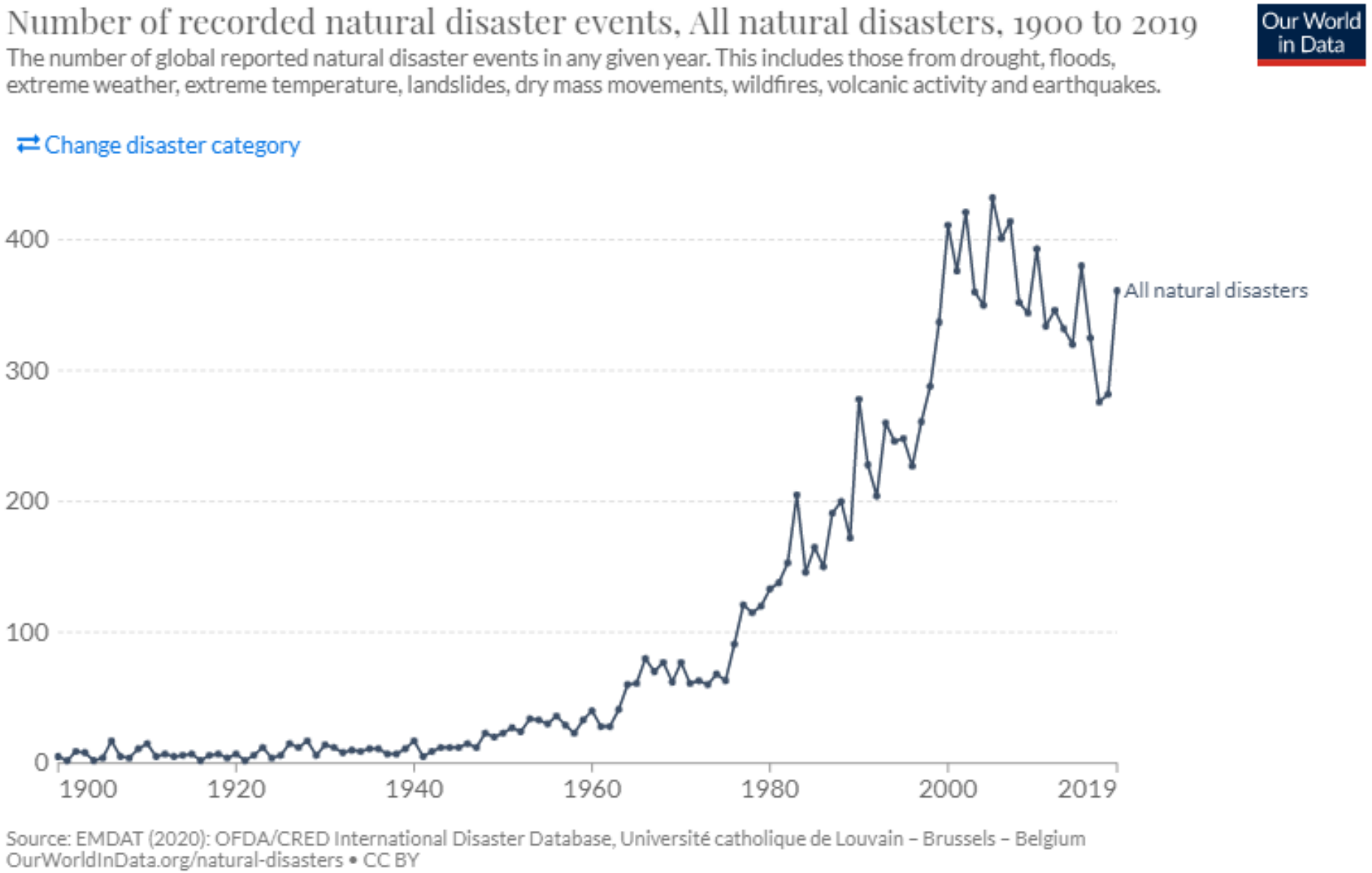
FEBRUARY 8, 2021

EIA projects renewables share of U.S. electricity generation mix will double by 2050

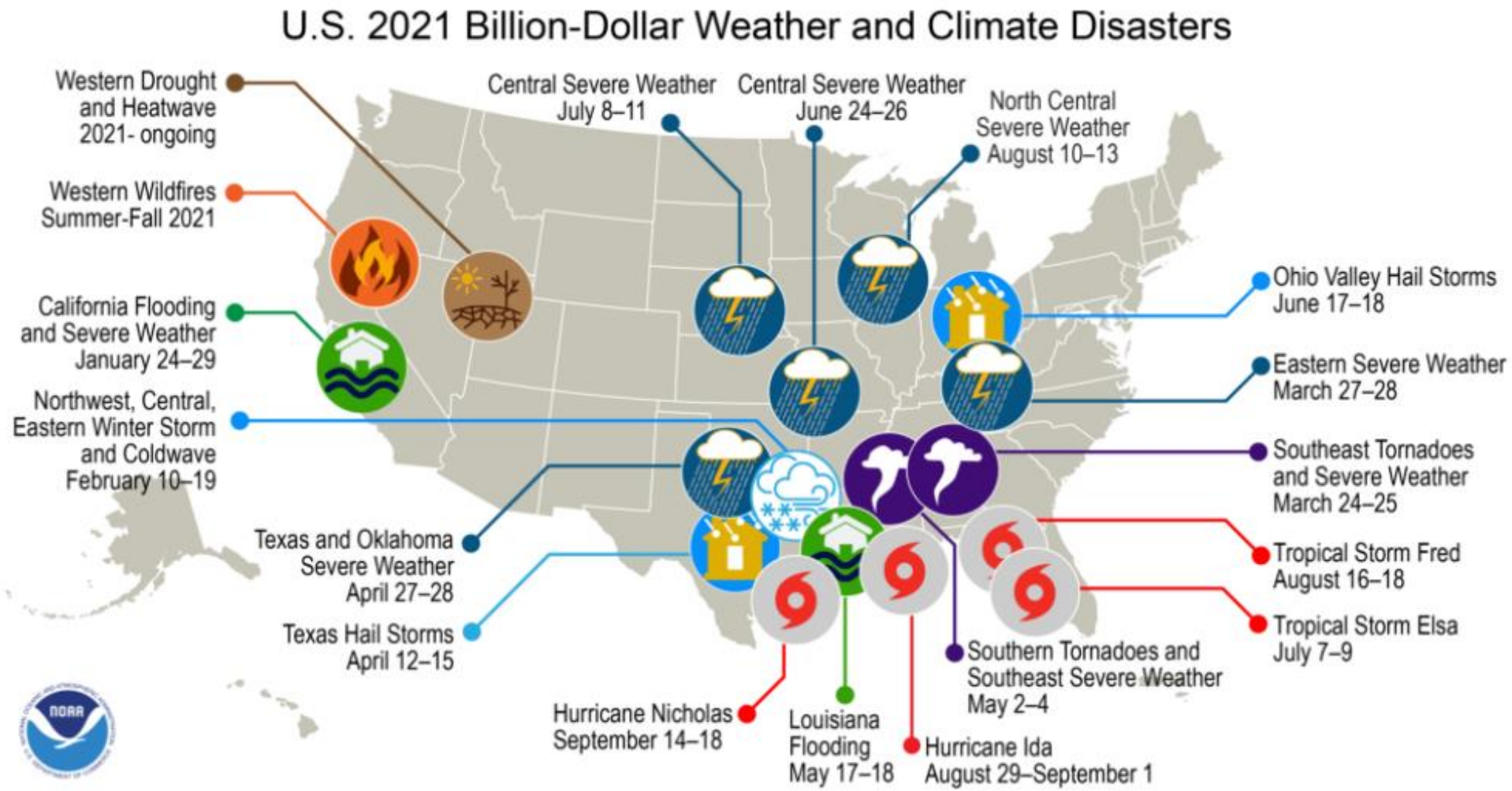


Source: U.S. Energy Information Administration, *Annual Energy Outlook 2021* (AEO2021)

Increased Frequency of Natural Disasters Over 40+ Years



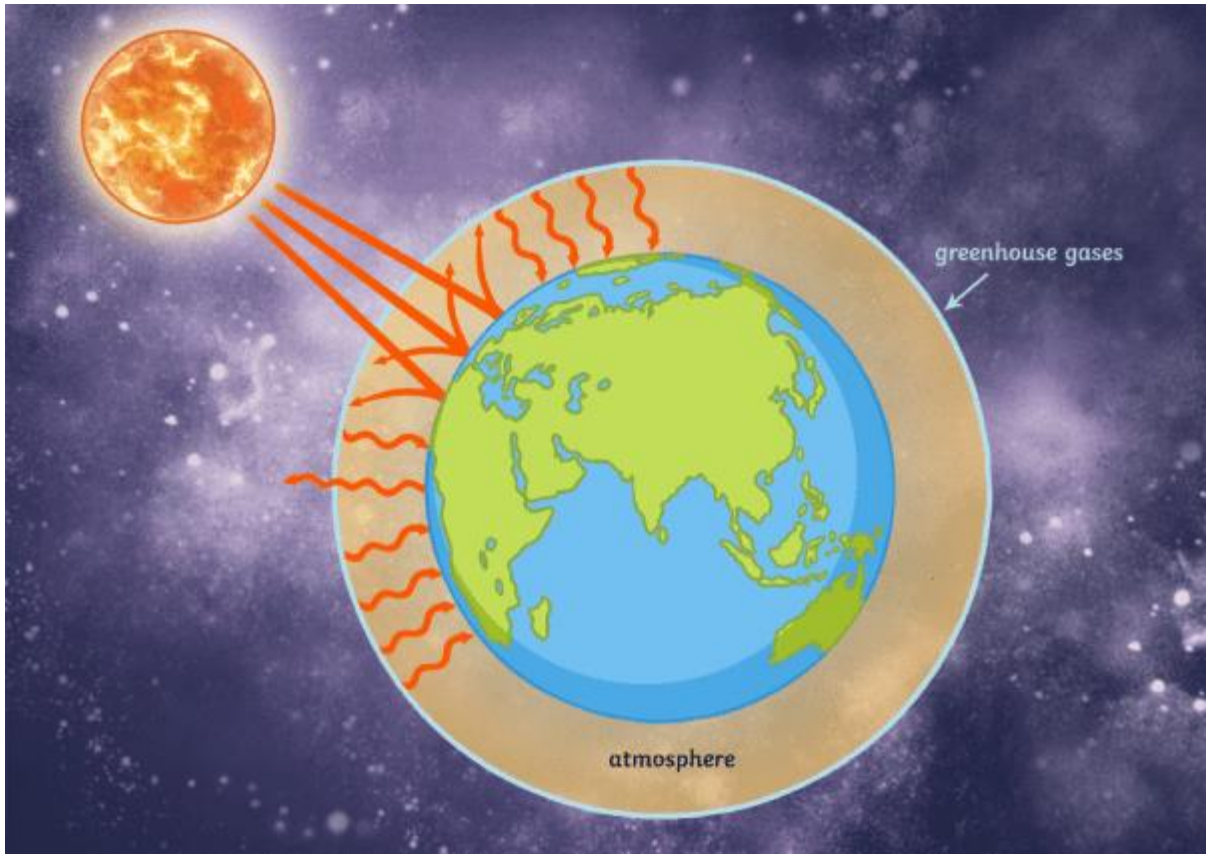
Extreme Weather Events Vary Over Space



*This map denotes the approximate location for each of the **18 separate billion-dollar weather and climate disasters that impacted the United States January–September 2021**.*

How resilient are our renewable energy systems to climate change?

Multiple Dimensions of Climate Change



Temperature- and Precipitation-Driven Impacts

Days

Weeks

Months

Years

- Cold Snap
- Strong Storms
- Heat Wave
- Hurricanes
- Wildfires
- Glacier/Ice Melting
- Drought
- Sea Level Rise
- Biodiversity Loss
- Ocean acidification

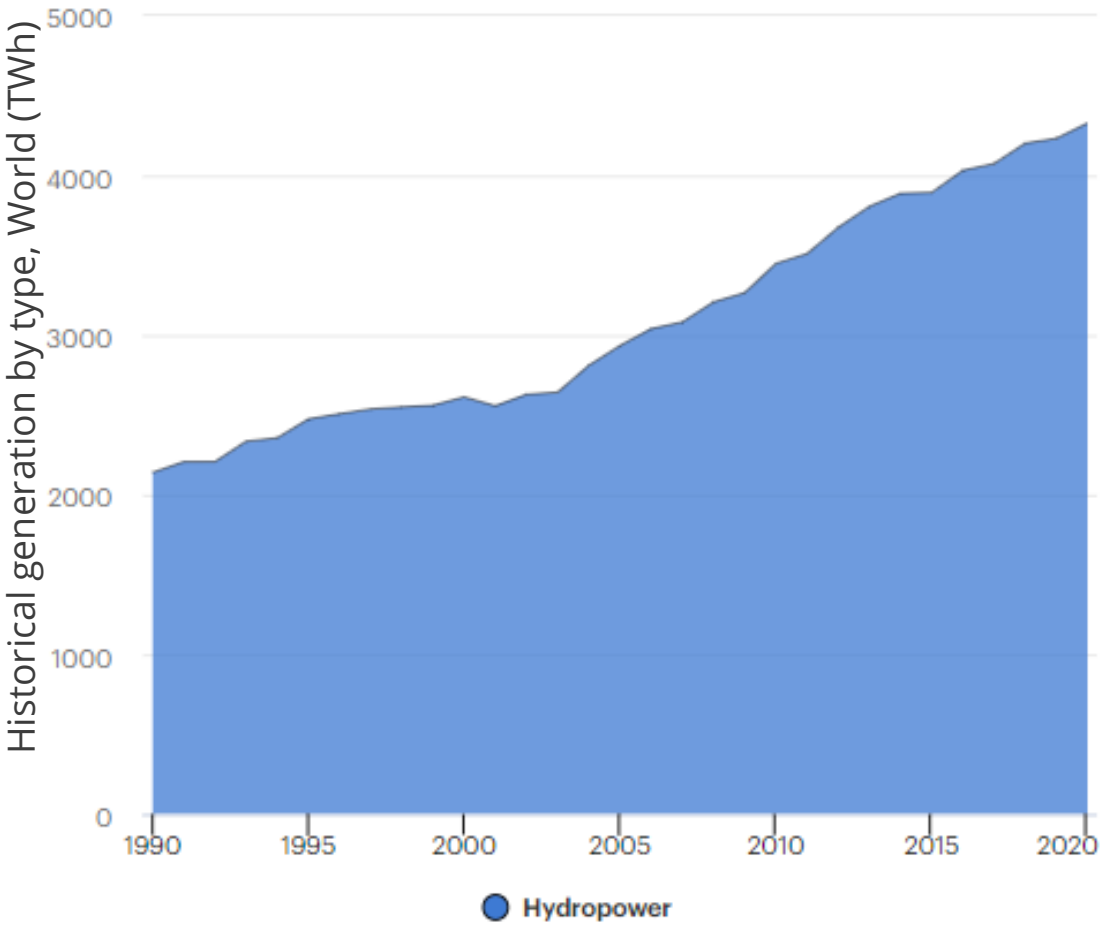
Other Natural Disasters

- Landslides
- Earthquakes
- ...

Renewable Energy Sources

- Hydropower
- Wind Energy
- Solar Energy
- Marine Energy
- Geothermal
- ...

Hydropower & Natural Disasters



(IEA 2020)

- Provides 1000+ GW of installed capacity around the globe
- Significant potential still being developed in parts of Asia, America, and Africa
- Impacts arising from a number of extreme weather conditions
  - Changing rainfall patterns (reduced water availability, higher intensity flows)
  - Extreme temperatures (dynamic ice flows, evaporation losses)
- Impacts can range from reduced power production to equipment and structural failures

Cold Snap

Heat Wave

Strong Storms

Wildfires

Drought

Glacier/Ice Melting

Wind Power & Natural Disasters

(DOE 2018)

- 8% of the U.S. electricity supply; 20%+ in 10 states
- Shift towards bigger and taller blade designs
- In addition to shifting wind patterns, extreme temperature and wind effects dominate impacts
  - Turbine icing
  - Turbulence intensity and wind shearing
  - Offshore farms impacted by drifting sea ice and sea level rise
- Seismic impacts vary as a function of turbine geometry, load directionality, and damping ratios

Cold Snap

Hurricanes

Heat Wave

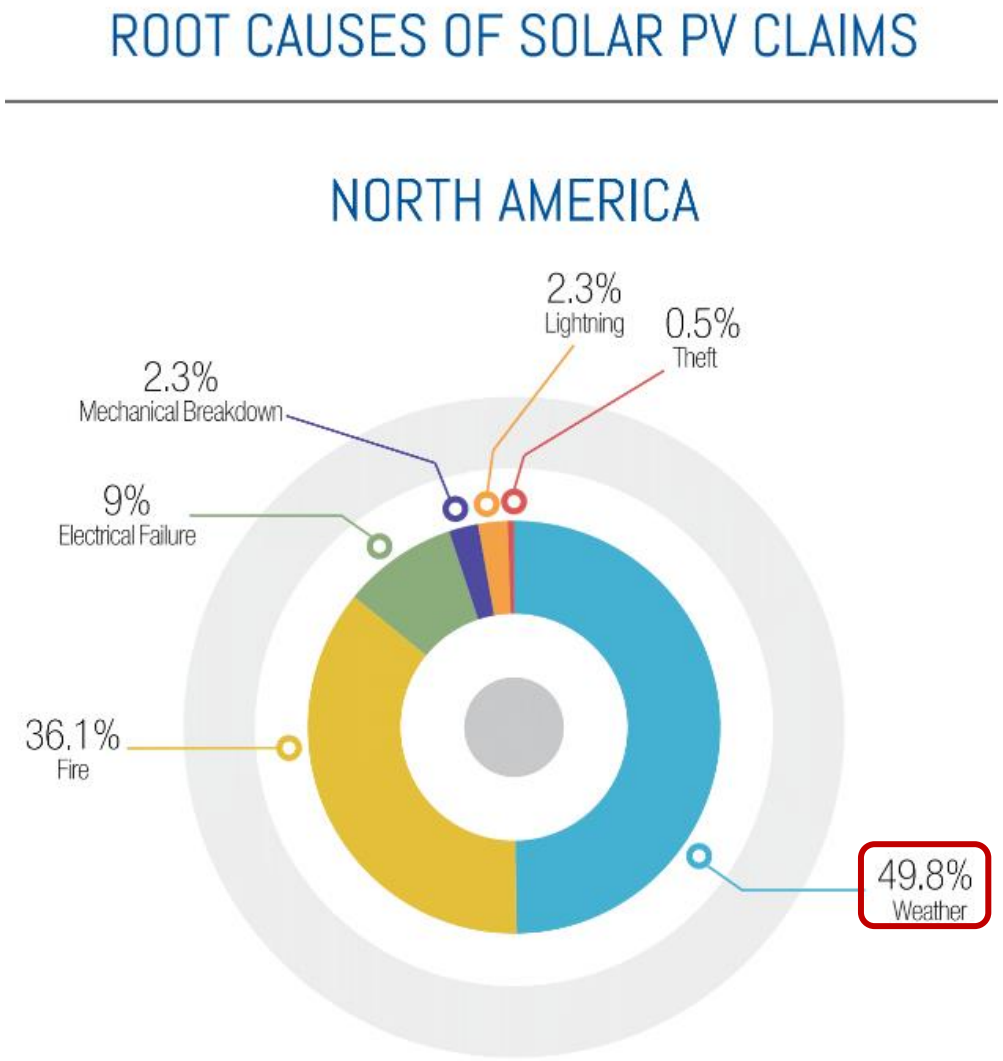
Wildfires

Glacier/Ice Melting

Sea Level Rise

Ocean acidification

Solar Power & Natural Disasters



(GCube 2016)

- Record growth in installations in recent years
- Often lowest-cost option of electricity generation
- In addition to radiation-level changes from climate change, impacts are driven by extreme weather conditions
  - Extreme winds torque structures
  - Heavy snow and ice loads
  - Damages from hail and lightning
  - Soiling reductions from storms
  - Wildfire melting and smoke effects

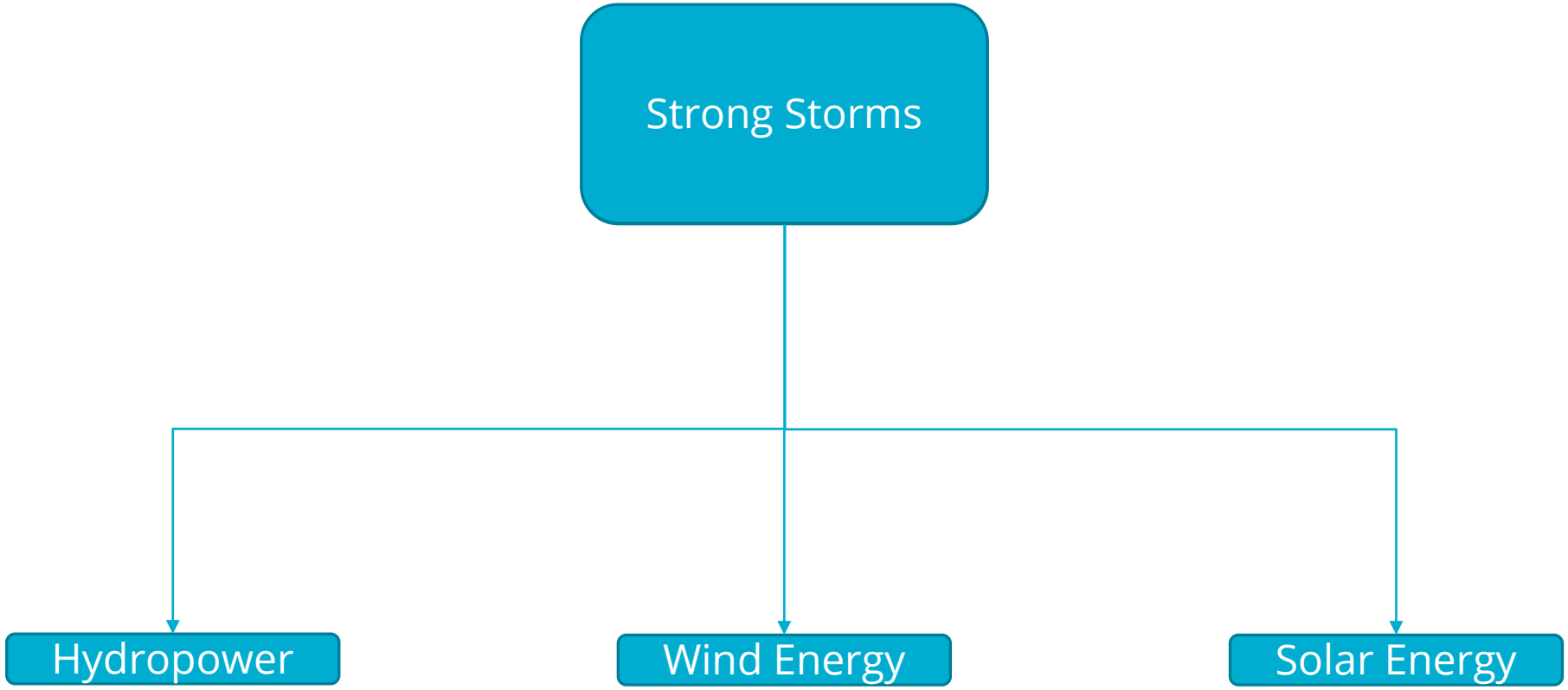
Cold Snap

Hurricanes

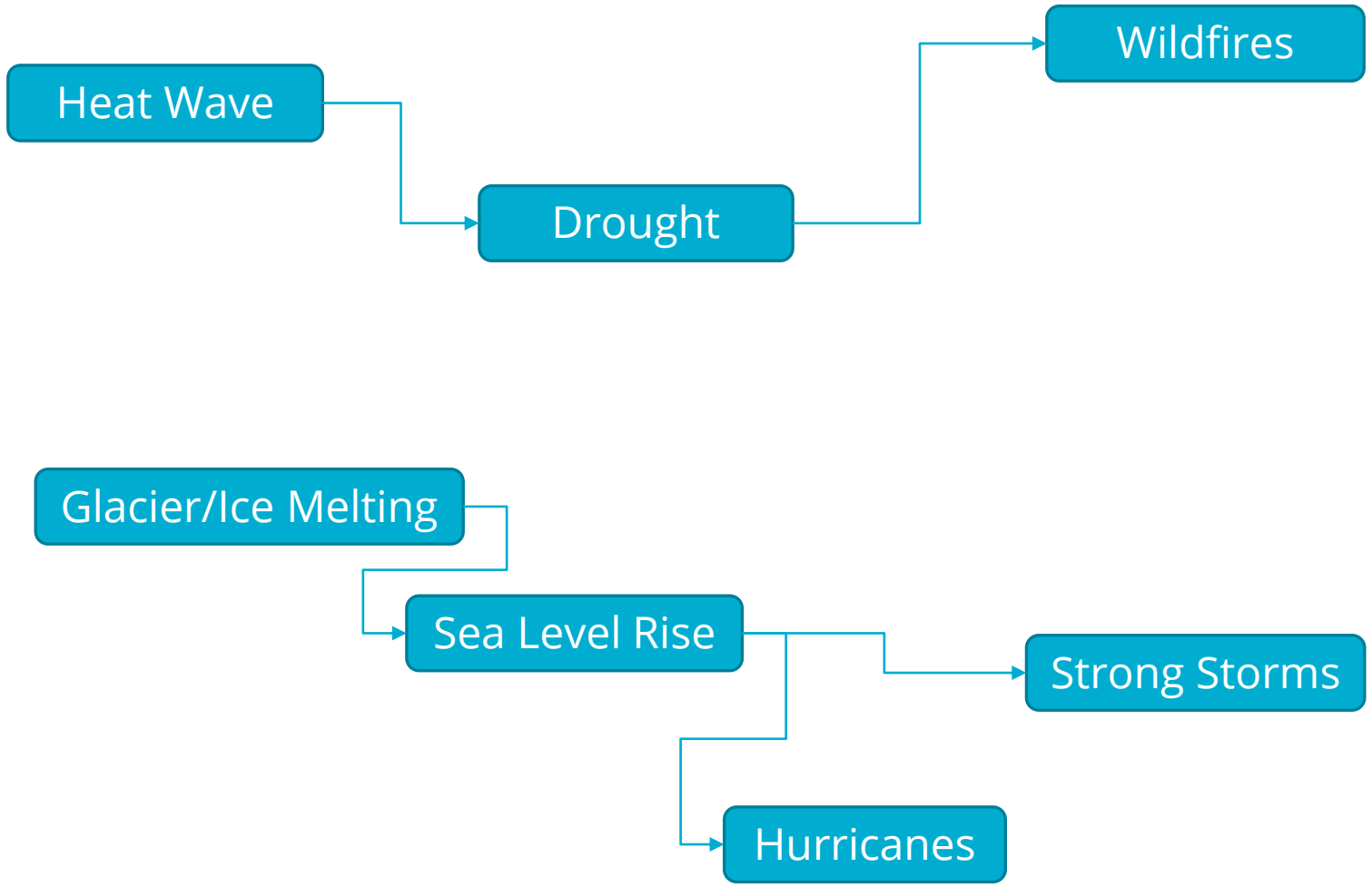
Heat Wave

Wildfires

Single Threat Can Impact Multiple Renewable Energy Sectors



Co-Dependence Across Threats Impacts to Renewable Energy

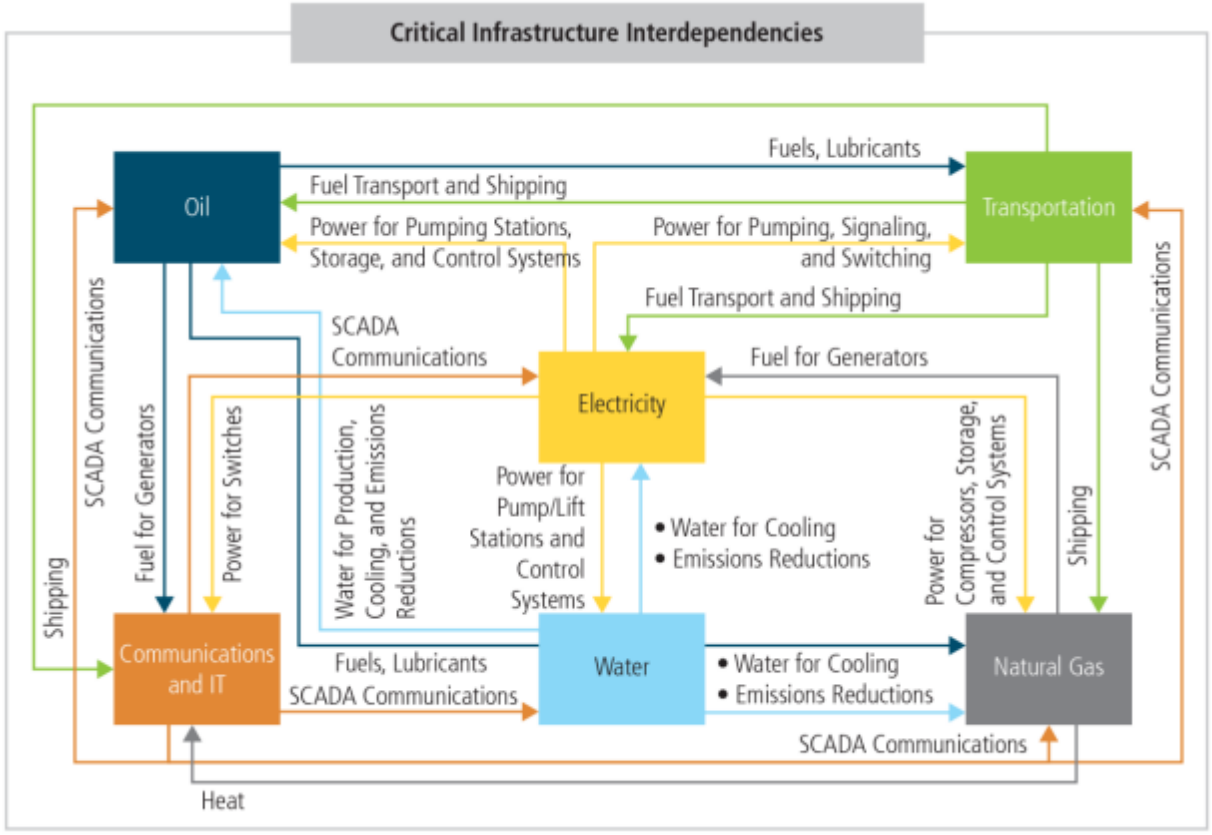


Threat analysis requires understanding underlying climate drivers

Global convection patterns drive dependence between extreme events

Concluding Thoughts

- Increased understanding of natural disasters in recent years
- However, knowledge of associated critical infrastructure impacts is limited
- Ongoing analysis is required
  - Models to simulate interdependencies
  - Datasets to characterize and validate simulations
  - Metrics to assess resilience and aid in decision-making
- This will shift our focus from reactive to proactive, preventative activities



(DOE 2017)

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Thank you for your time!

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