



Observations on Extreme Weather and Impacts on Nuclear Power Plants

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Nuclear Generation Assets/Infrastructure

- Nuclear has a long history of assessing physical hazards that can provide a foundation for improving resiliency to changing climate
 - Identification of External Hazards for Probabilistic Risk Assessments
 - Seasonal and Severe Weather Guidelines
 - Resilience of Nuclear Plants in the Face of Climate Change
 - Best Management Practices for Preventing Cooling Water Intake Blockage
 - Intake Operation, Maintenance and Optimization Interest Group
- Site-Specific Climate Hazard Information (2022) *New*
- Climate Risk Assessment Guidance for NPPs (2022) *New*
- Climate Resiliency and Adaptation Guidance for NPPs (2023) *New*



Existing and new research to improve resiliency

External Hazards Information Compilation and Analysis

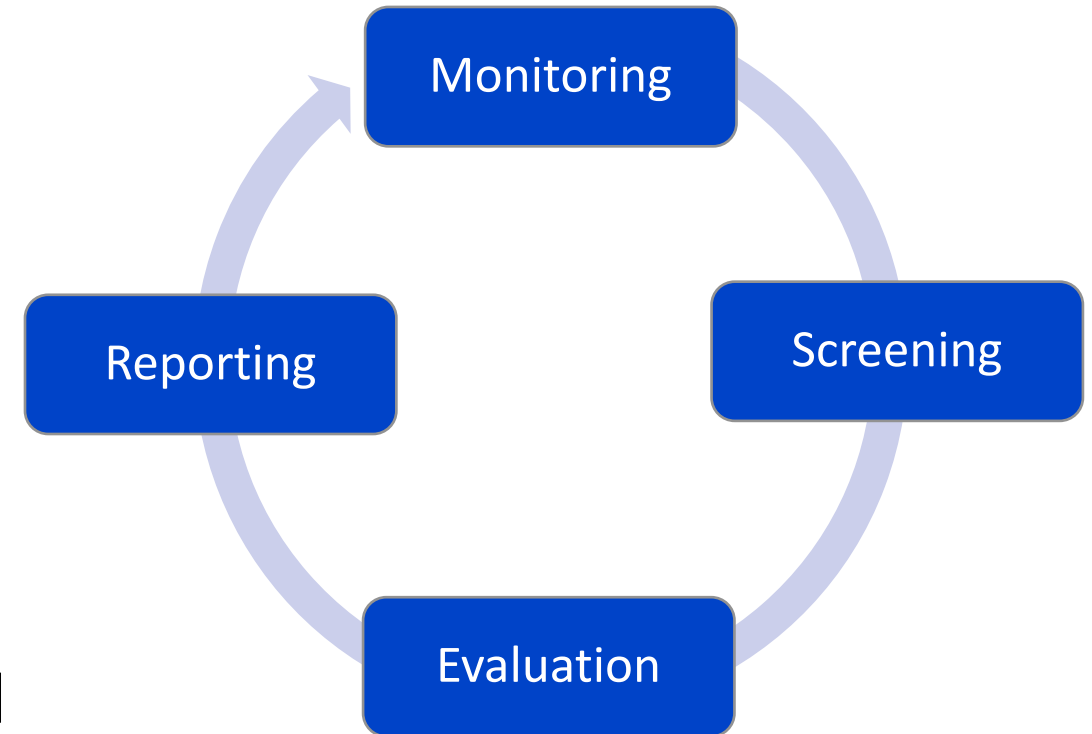
- Benefits nuclear power plants who commit to the implementation of Recommendation 2 of INPO Event Report (IER) L1-13-10 or similar external hazard monitoring program
- Considers Design Bases and FLEX Beyond DB assumptions for external hazards. Operational impacts are not in the scope of this project, but they are reviewed annually
- Provides a process to look for and respond to changes in external hazards over time is a key piece of nuclear power's resiliency
- In U.S, reviewing hazards seismic, flooding, high winds, extreme cold and heat
- NRC has a similar process "Process for the Ongoing Assessment of Natural Hazards Information (POANHI)"



An efficient, shared resource for understanding changes in external hazards

External Hazards Information Compilation and Analysis

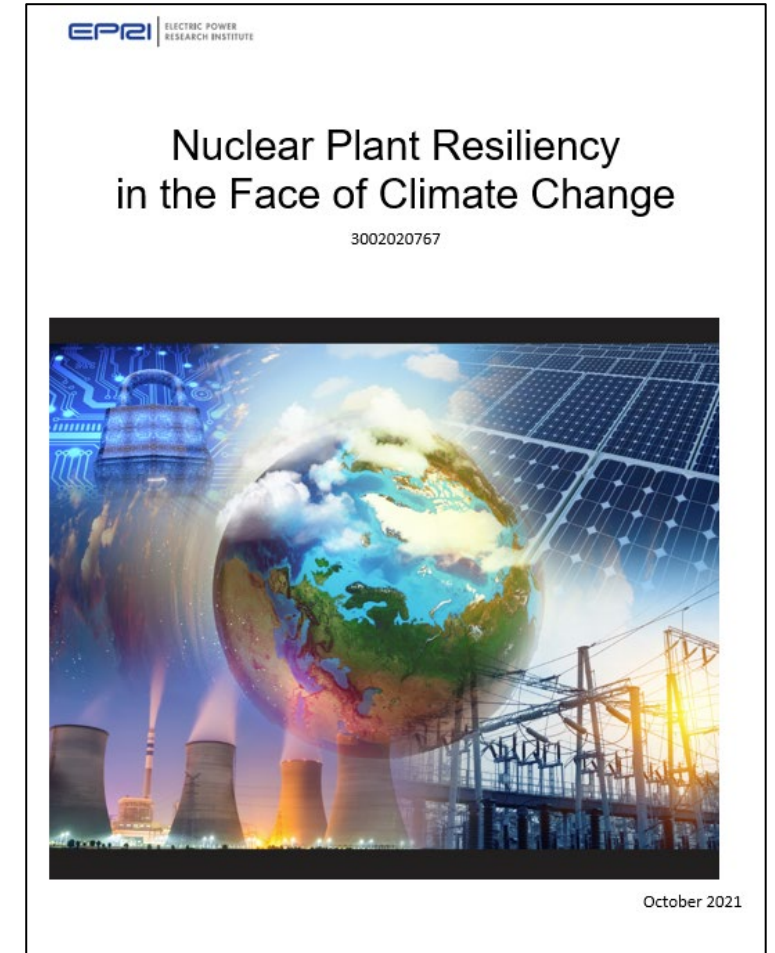
- Reviewed over 1000 pieces of new hazard information over the last 5 years
 - New precipitation studies
 - East Coast Tsunami potential
 - NIST Tornado Map Changes
 - Climate Change Studies/Observations
 - NGA East Earthquake
 - Operating Experience (Derecho, Frazil Ice, Hurricanes)
- No actionable “new information” related to weather identified to date



Nuclear plants maintain a robust design margin for safety

Recent Weather-related Investigations

- Distinction between nuclear safety and operational impacts
- Review of available US nuclear operating experience to weather-related events
- Develop climate variable projections for selected cities based on climate models
- Discuss future research regarding forward looking climate vulnerability assessments



“Resiliency of Nuclear Plants in the Face of Climate Change”
3002020767 – *EPRI White Paper*

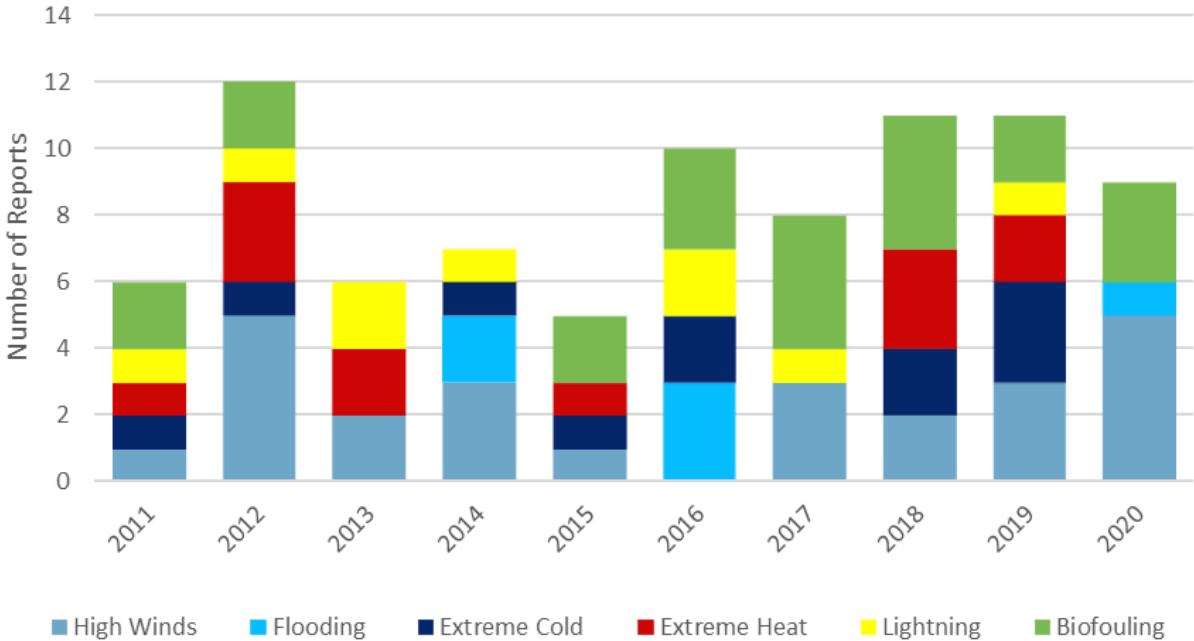
Weather Related Operating Experience (2010 – 2020)

Events including Grid Impacts

Weather Events	Average Recovery (days)	Range of Recovery (days)	Number of Events over 10 years	Total Number of Production Days Lost (days)
High Winds / Storms	4	0 to 32	48	207
Extreme Cold	3	0 to 10	17	55
Flooding	7	0 to 16	6	44
Biofouling	2	0 to 6	22	34
Lightning	1	0 to 6	15	22
Extreme Heat	2	0 to 13	12	22
		Total	120	384

Events excluding Grid Impacts

Weather Events	Average Recovery (days)	Range of Recovery (days)	Number of Events over 10 years	Total Number of Production Days Lost (days)
High Winds / Storms	2	0 to 18	25	52
Extreme Cold	3	0 to 10	11	19
Flooding	7	1 to 16	6	44
Biofouling	2	0 to 6	22	34
Lightning	2	0 to 6	9	19
Extreme Heat	2	0 to 13	12	22
		Total	85	190



Lost generation due to weather-related events in the US nuclear fleet is less than 0.1%.

Nuclear plants are currently very resilient and need to maintain this performance

Key Climate Variables Impacting Nuclear Plant Operation

AMBIENT AIR TEMPERATURE

Rising temperatures could impact plant power output through reduced thermal efficiency.

Source: Linnerud, 2011



EXTREME STORM EVENTS

- High Winds (Hurricanes, Tornados, Derechos)
- Water Stress (Flooding, Drought)
- Extreme Temperatures.



SEA LEVEL RISE

Rising sea levels could increase flooding risks from storm surges and exacerbate coastal erosion.

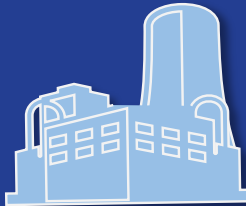
Source: Fourth U.S. National Climate Assessment (NCA4), 2018



COOLING WATER

Cooling water temperature and water availability are related to ambient air temperature and to other climate changes.

There is significant variability in plant design, margin available , and Technical Specification temperature limits.



Current Research – Climate Risk Assessment Guidance for Nuclear Power Plants



1. Identify climate hazards and future climate change-related trends and extremes at the site
2. Identify plant assets at risk and likely to be impacted by weather-related variables
3. Identify vulnerabilities or risk from climate hazards critical assets and infrastructure
4. Develop adaptation plan to reduce vulnerabilities and improve resilience

Tools and Templates to Support Vulnerability Assessments

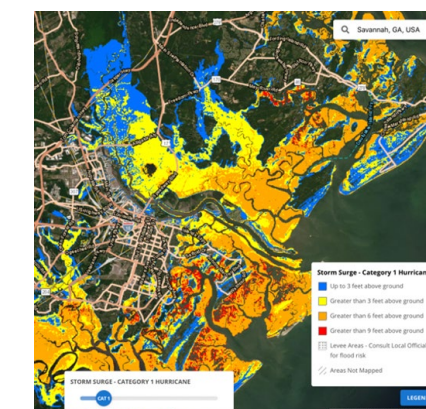
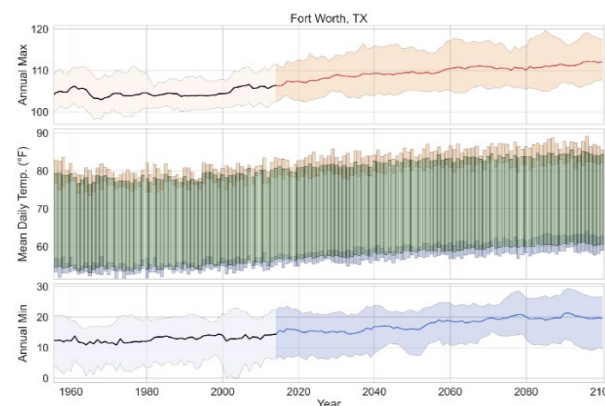
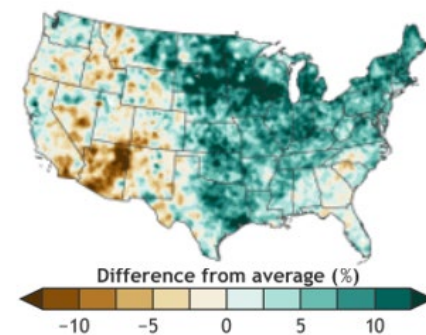
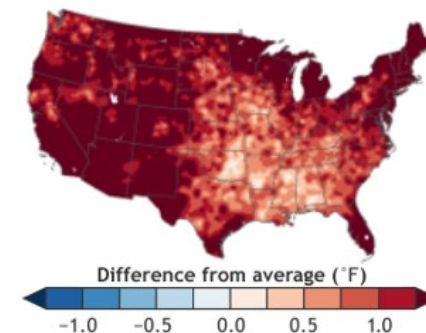
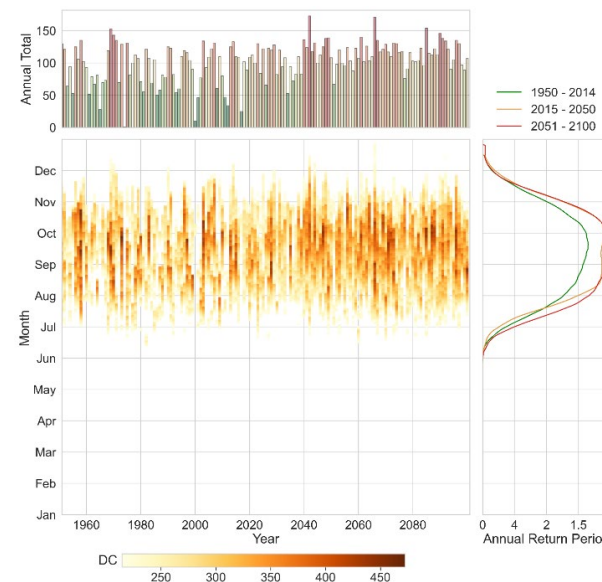
Climate Variable Projections – New Research

Challenges:

- ✓ *Changing Weather and Extreme Events*
- ✓ *Seasonal Readiness and Climate Impact Assessments*
- ✓ *What climate data to use and how much margin?*

Improved Climate Hazard Information:

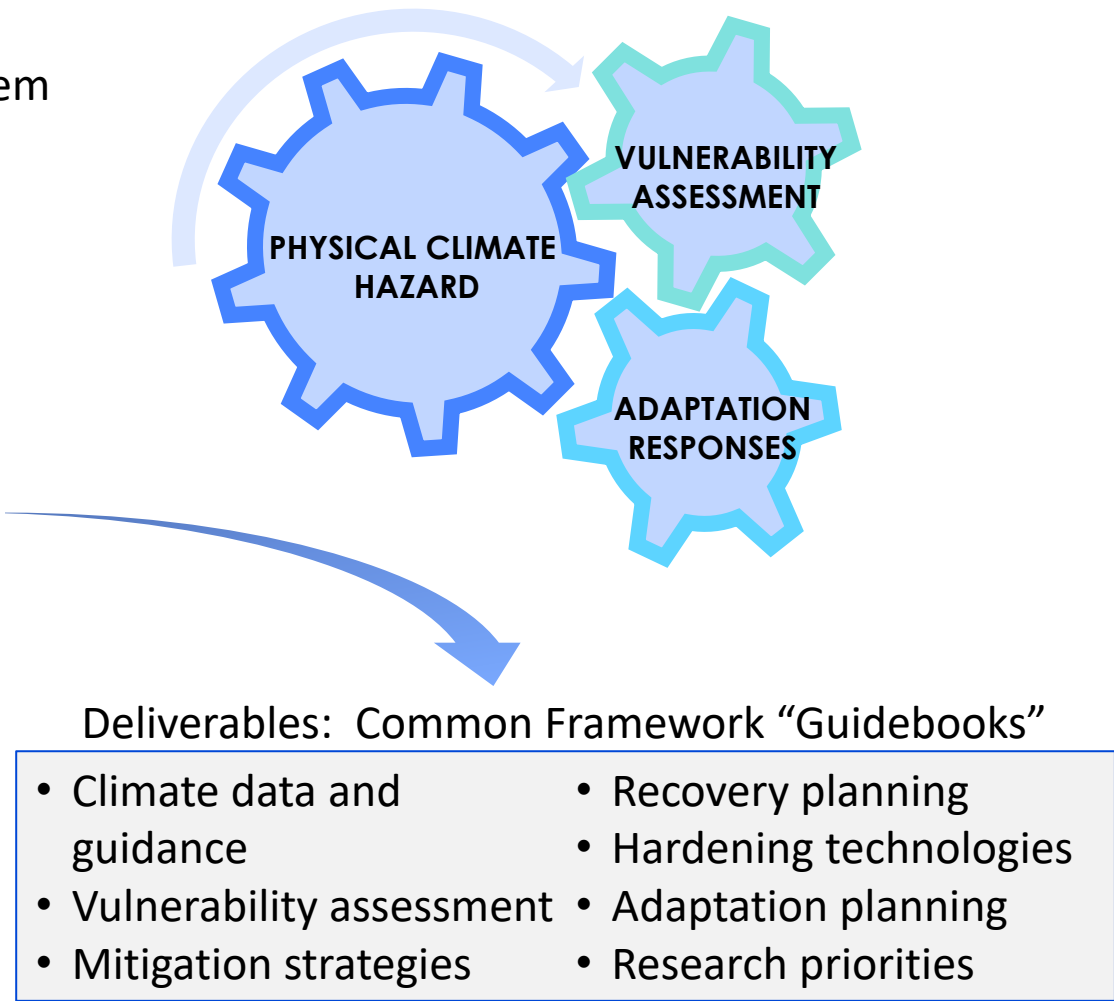
- *Site-specific estimates* of key climate-related variables based on latest generation climate model projections
- *Interpretation and analysis* of climate information to support technical insights and clarify potential uncertainties or limitations associated with current climate modeling state-of-practice
- *Workshops* to enhance understanding of climate hazards, data, timeframes, resources, and applications
- *Documented guidance* and technical basis upon which to conduct climate risk and vulnerability assessments



Site-Specific Climate Hazard Information (3002023431)

EPRI Climate Resilience and Adaptation Initiative (READi)

- Development of a Common Framework across the Power System
- Integrated and consistent approach to localized climate risk assessment & strategic resilience planning
- Applicable to the assessment of physical risk at the asset, infrastructure and operational level due to climate hazards



Workstream 1	Workstream 2	Workstream 3
Physical Climate Data and Guidance	Energy System Vulnerability	Resiliency/Adaptation Planning & Prioritization
<ul style="list-style-type: none">• Identify application needs• Assess and provide data• Address data gaps	<ul style="list-style-type: none">• Develop risk framing• Assess vulnerability at the component, system and market levels• Identify mitigation options• Enhance design / hardening	<ul style="list-style-type: none">• Assess societal impacts: resilience metrics and value measures• Identify optimal investment priorities• Develop cost-benefit analysis and adaptation strategies

Guidebooks for Assessing Climate Resiliency

Key takeaways

- NPPs are specifically designed to safely withstand extreme weather events far more severe than most critical infrastructure
 - NPPs have demonstrated operational resilience to extreme events
 - Significant amount of operating experience in adapting to challenges
- Weather-related hazard severities are likely to change over the next two decades as a result of climate change (region-specific)
 - Nuclear plants must remain resilient against extreme weather events
 - Adaptation plans provide resiliency to future climate extremes

Questions or Comments



A blue-tinted photograph of four people standing in a row. From left to right: a man with curly hair and glasses wearing a white lab coat with an EPRI logo; a man with glasses wearing a white lab coat with an EPRI logo; a woman wearing a white hard hat and a dark polo shirt with an EPRI logo; and a man with glasses and a beard wearing a light blue button-down shirt. They are all smiling and looking towards the camera.

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