# 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**

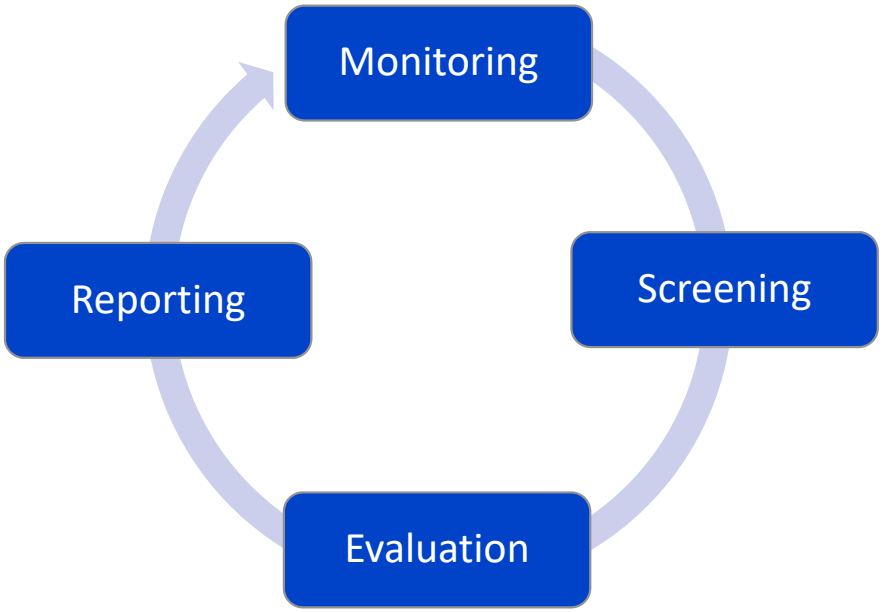
# External Hazards Information Compilation and Analysis

- 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

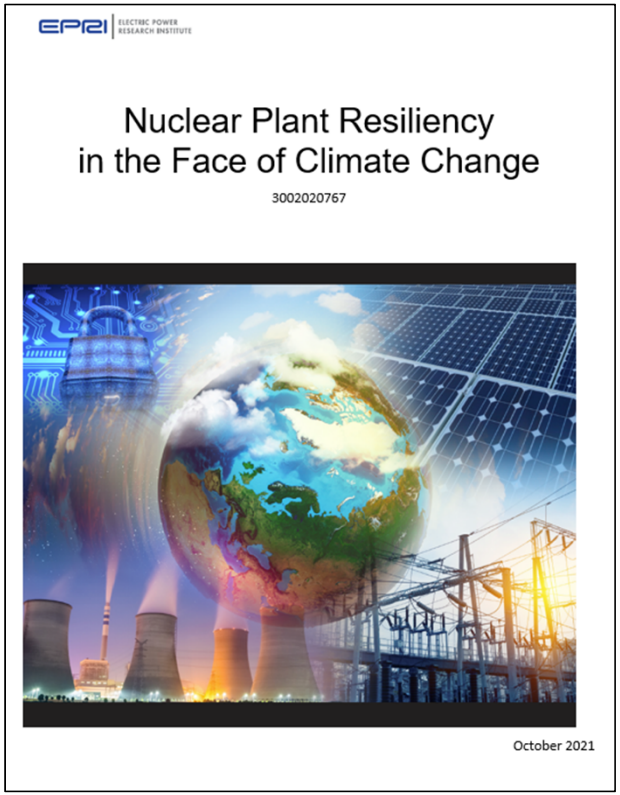
- Reviewed over 1000 pieces of new hazard information over the last 5 years
  - New precipitation studies
  - East Coast Tsunami potential
  - NIST Tornado Map Changes
  - Climate Change Studies/Observations
  - NGA East Earthquake
  - Operating Experience (Derecho, Frazil Ice, Hurricanes)
- No actionable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

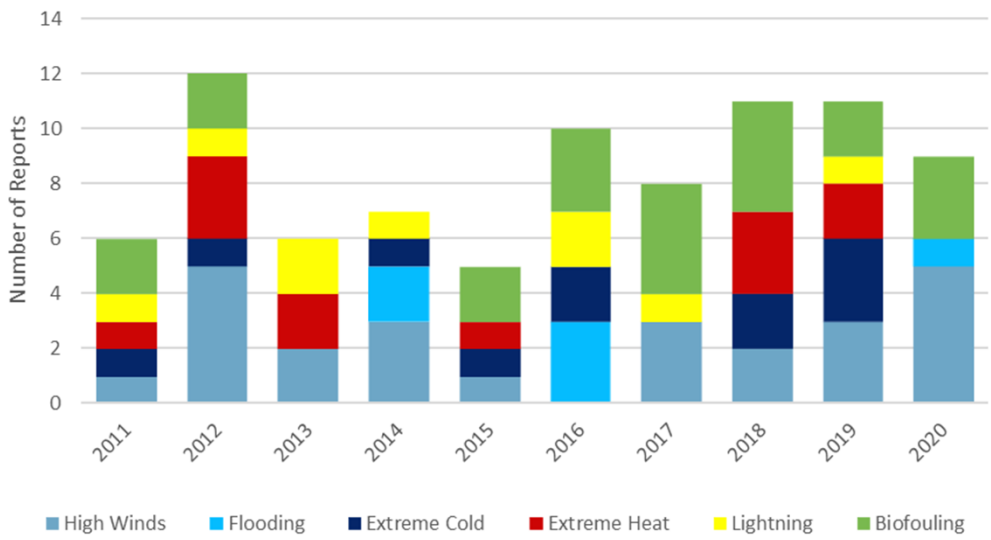
# Weather Related Operating Experience (2010 – 2020)

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**

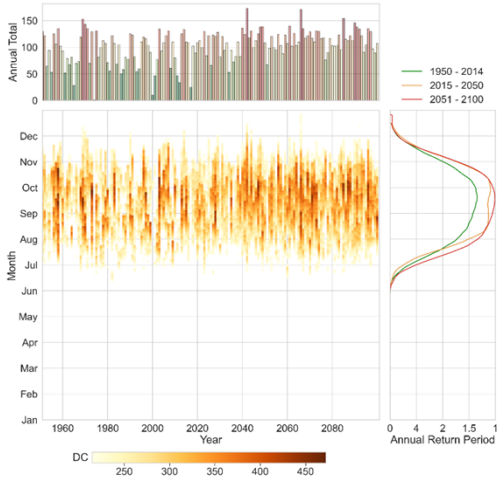
# Climate Variable Projections – New Research

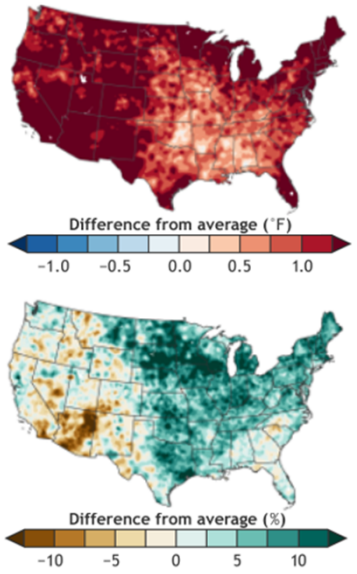
*Challenges:*

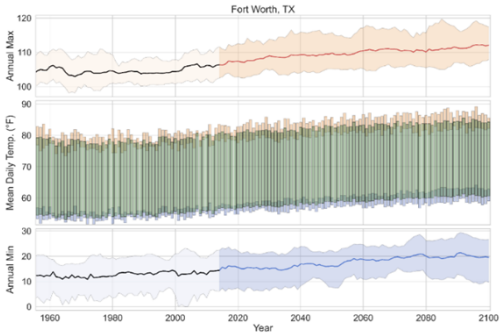
- ✓ *Changing Weather and Extreme Events*
- ✓ *Seasonal Readiness and Climate Impact Assessments*
- ✓ *What climate data to use and how much margin?*

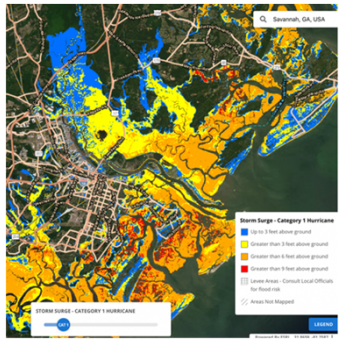
*Improved Climate Hazard Information:*

- *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



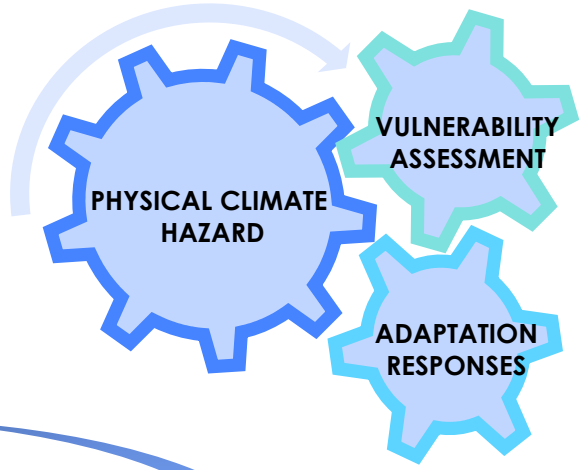




## Site-Specific Climate Hazard Information (3002023431)

# 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** |
| • Identify application needs<br>• Assess and provide data<br>• Address data gaps | • Develop risk framing<br>• Assess vulnerability at the component, system and market levels<br>• Identify mitigation options<br>• Enhance design / hardening | • Assess societal impacts: resilience metrics and value measures<br>• Identify optimal investment priorities<br>• Develop cost-benefit analysis and adaptation strategies |

Deliverables: Common Framework "Guidebooks"

- Climate data and guidance
- Vulnerability assessment
- Mitigation strategies
- Recovery planning
- Hardening technologies
- Adaptation planning
- Research priorities

**Guidebooks for Assessing Climate Resiliency**

# Key takeaways

- NPPs are specifically designed to safely withstand extreme weather events far more severe that 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