Assessing Resiliency of NPPs

Impact of a changing climate

Nuclear

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Impact of Climate Change on the Operation of Nuclear Facilities
March 18th - 20th, 2025

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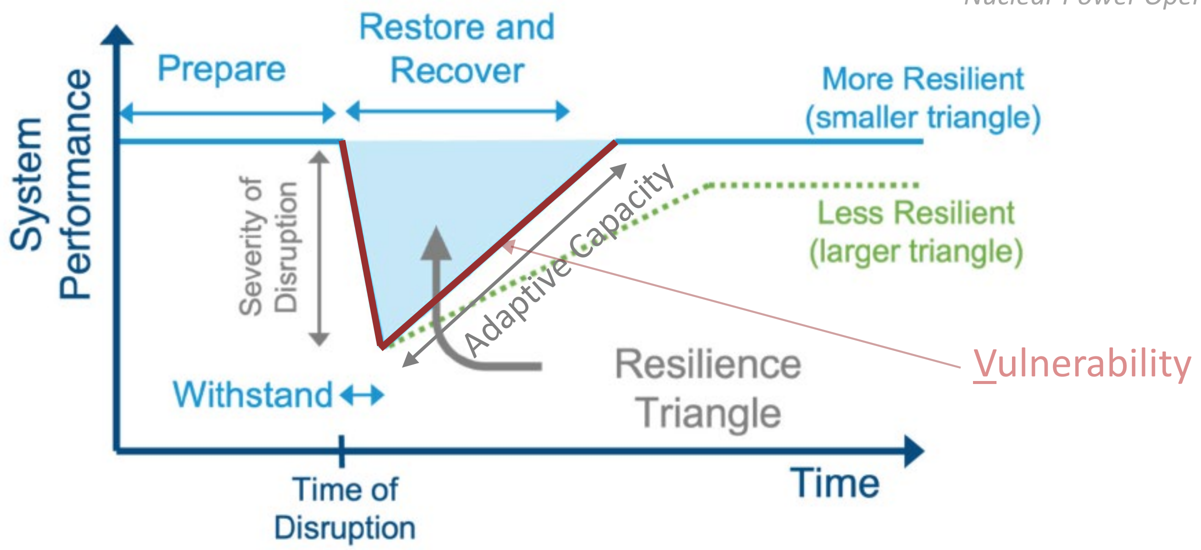
Evaluating Changes to External Hazards in Nuclear Power

- Continuously evaluate new hazard information or our understanding of new hazard information
- Acknowledge that future events may no longer be bounded by historical events.
- Periodic forward-looking assessments can prepare for unexpected events and enhance resiliency
- Understanding potential future risk can drive a more strategic response and decision strategy

Climate Risk and Resiliency

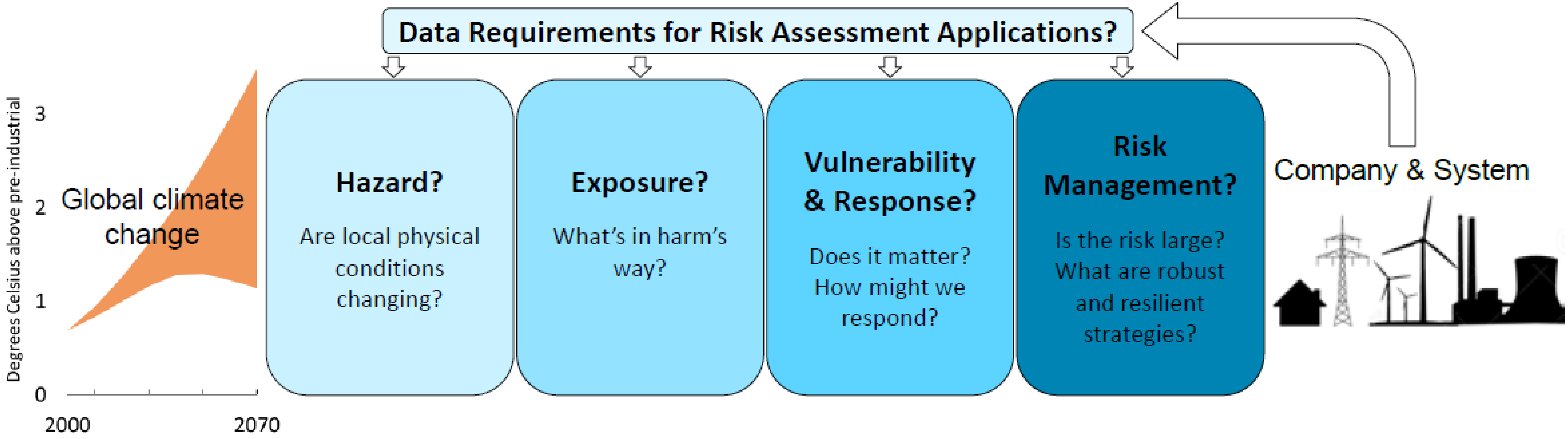
- Future events may not be bounded by past events
- Requires situational awareness - understanding of local conditions and plant design
- Prepare for the unexpected and uncertain
- Efficient response and recovery processes
- Continuously improve physical resilience of the plant through robustness and adaptive capacity

Courtesy of Institute of Nuclear Power Operations



What operational risk does a changing climate pose to nuclear plants?

What does climate change mean for a company/system?

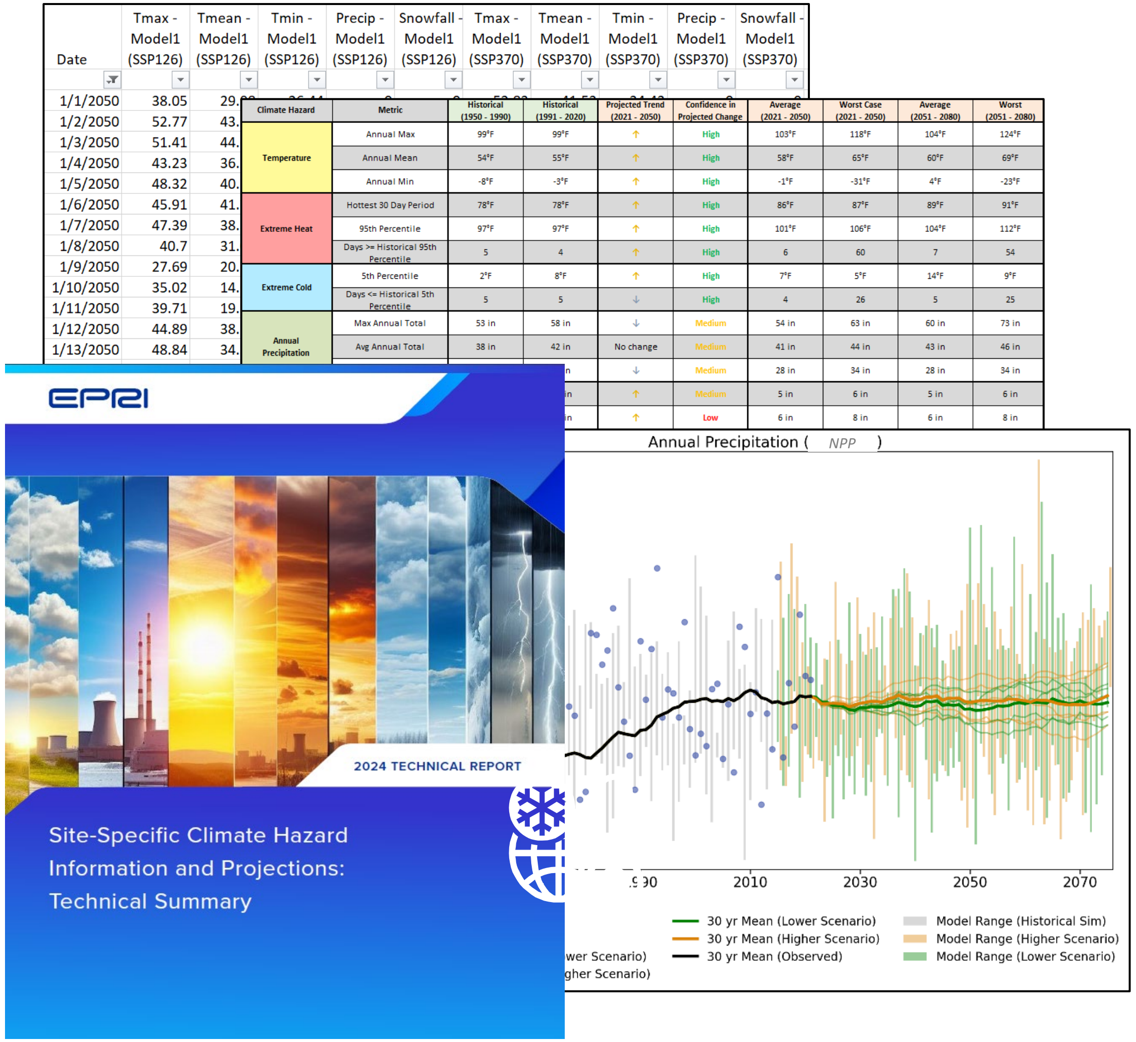


EPRI Climate READi

"Set of assessments needed to evaluate risk of physical climate change for a company of system"

Forward Looking Assessments – Natural Hazard

Site-Specific Climate Hazard Information and Projections (CHIP)



- Identify site specific natural hazards and how they may change in the future
- Are local physical conditions changing?
- Not all hazards have projections
- All hazards have uncertainty
  - Natural Variability – biggest component
  - Model Choice – different physics
  - Climate Scenarios – long term uncertainty
  - Downscaling – locations specific / microclimates
- Provide engineers with usable information to assess operating/design envelop

Variables Included in Assessment

- Not all hazards have projections
- All projections have uncertainty, some hazards more than others
- It's not cost effective and potentially misleading to project changes in variables with high levels of uncertainty

For more info, check out the uncertainty chapter in the [READi Climate Data User Guide]

			Quality of Observational Record			Confidence in Projected Change		
Climate Hazard	Data Availability 1900 1950 2023 2100	Level of Analysis	Length	Coverage	Accuracy	Quality of Observations	GCMs can Simulate	Driver of Change Known
Temperature		Included	High	High	High	High	High	High
Extreme Heat		Included	High	High	High	High	High	High
Extreme Cold		Included	High	High	High	High	High	High
Annual Precipitation		Included	High	Medium	High	High	Medium	Medium
Extreme Precipitation		Included	High	Medium	Medium	Medium	Medium	Medium
Annual Snowfall		Included	High	Medium	Medium	Medium	Medium	Medium
Extreme Snowfall		Included	High	Medium	Medium	Medium	Medium	Medium
Icing		*Not Included*	Medium	Medium	Medium	Medium	Medium	Low
Drought		Included	High	Medium	High	High	Medium	Medium
Streamflow/Lake Levels		Included	Low	Medium	High	Medium	Low	Low
Flooding		*Qualitative Only*	Medium	Low	Medium	Medium	Low	Low
Water Temperature		Included	Low	Medium	High	Medium	Low	Low
Water Quality/Biofouling		*Not Included*	Low	Medium	High	Medium	Low	Low
Tornadoes		*Included, historical only*	High	Medium	Low	Medium	Low	Low
Hurricanes		*Included, historical only*	High	Medium	Low	Medium	Low	Low
Lightning		*Not Included*	Low	Low	Medium	Low	Low	Low
Storms/High Wind Events		*Not Included*	Low	Low	Medium	Low	Low	Low
Compound Events		*Not Included*	Medium	High	Medium	Medium	Medium	Medium
Wildfires		*Not Included*	Medium	High	Medium	Medium	Low	Medium

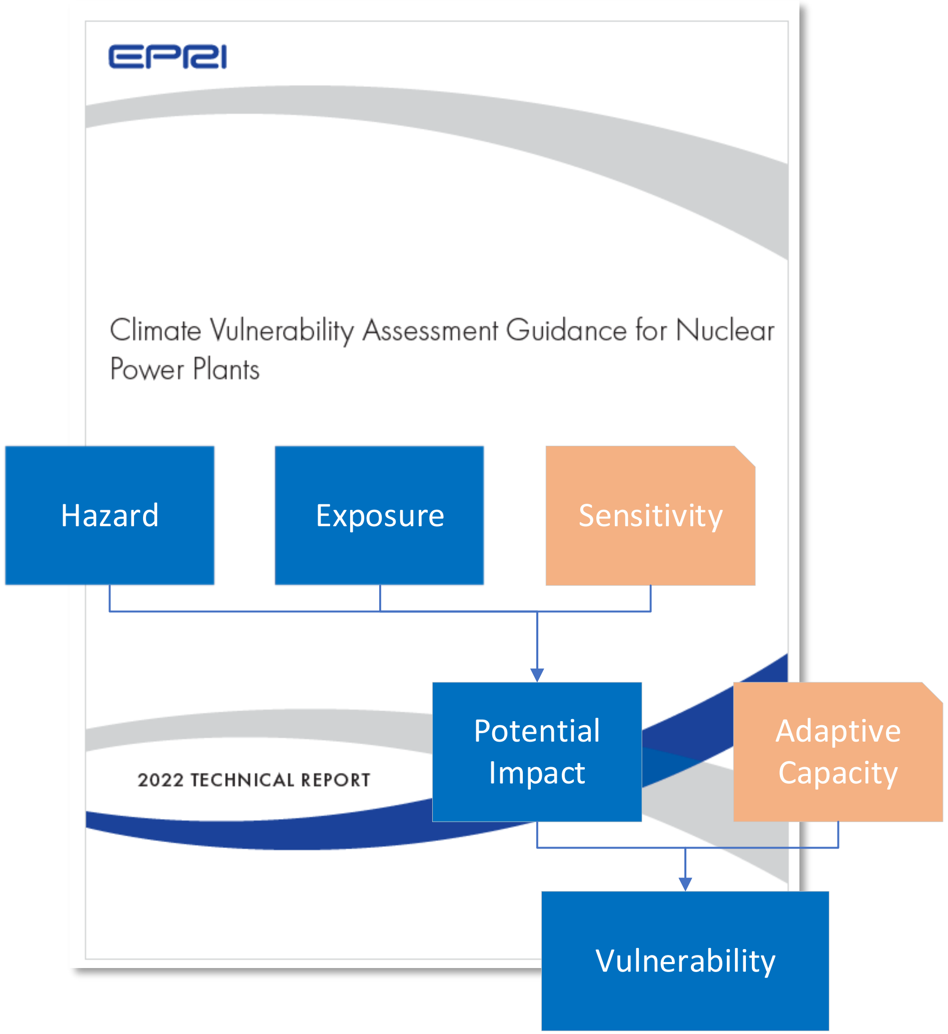
Historical | Limited Data | Projected | Secondary Model

Note: The above characterizations (low, med, high) are our initial attempt to add transparency to climate information. This was part of a larger effort and peer reviewed by the National Oceanic Administration, NASA, the National Center for Environmental Predication, multiple National Labs and universities, as well as numerous Climate READi technical advisor.

Forward Looking Assessments – Climate Vulnerability

- What ***natural hazards*** are relevant to the site?
- What systems, structures or components are ***exposed*** to these climate hazards that could impact plant safety or operations?
- Quantify the relationship between the hazard intensity and resulting ***impact***
- Requires and understanding of how ***sensitive*** is the SSC to the hazard intensity (e.g., two pieces of equipment are exposed to the hazard but at different elevations)
- Are there any built-in ***adaptation strategies*** that may be challenged in the future?
- Resulting ***vulnerability*** assessment provides how operating/design margins may change in the future

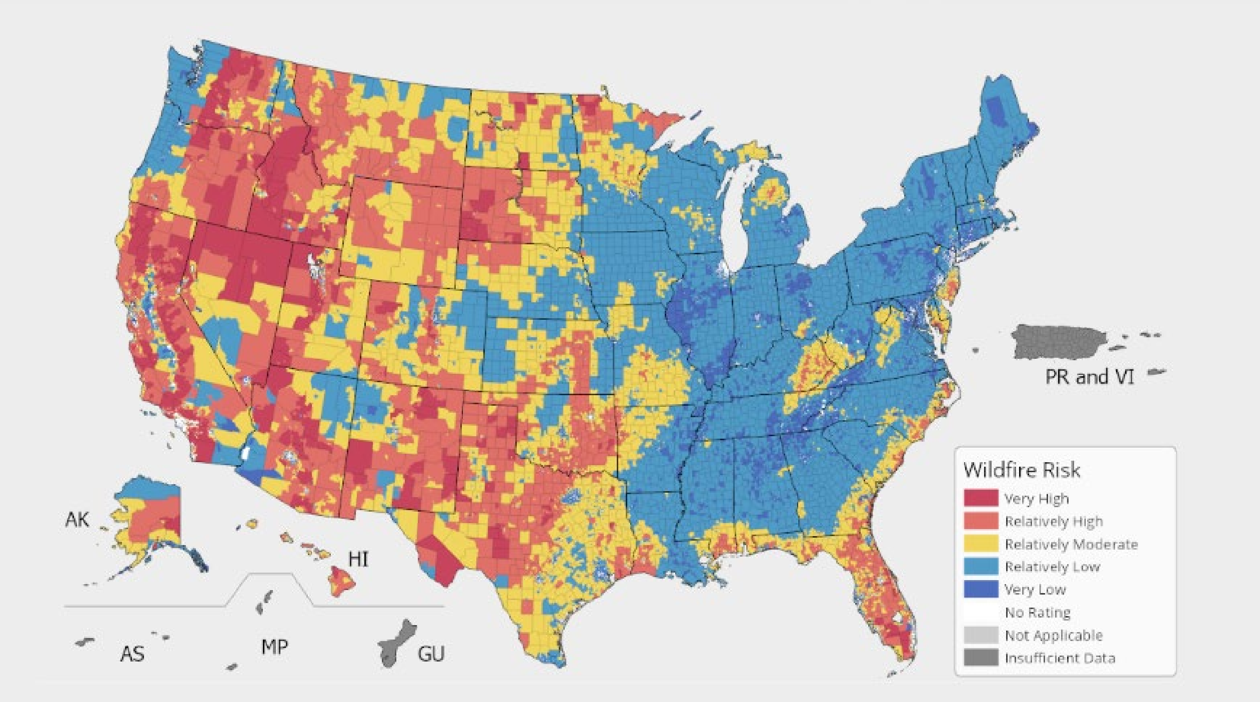
Climate Vulnerability Assessment Guidance for NPPs (3002023814)



Wildfire Exposure and Vulnerability

How might a plant assess their vulnerability and risk due to a wildfire? Is there an increased risk at nuclear plants due to potential increase in wildfires?

- Research:
  - How to assess the vulnerability and risk of a wildfire hazard on an NPP?
  - What are the contributors to a wildfire hazard and how are these affected by future climate conditions?
- Suggested Process:
  - Evaluate available operating experience
  - Evaluate landscape surrounding operating nuclear power plants to assess vulnerability to wildfires and post-fire debris flows
  - Perform potential consequence scenarios of wildfires given change in climate conditions on loss of grid, loss of heat sink, access/egress, emergency planning, etc.
  - Develop guidance for NPPs to screen and evaluate the specific impact on their facilities

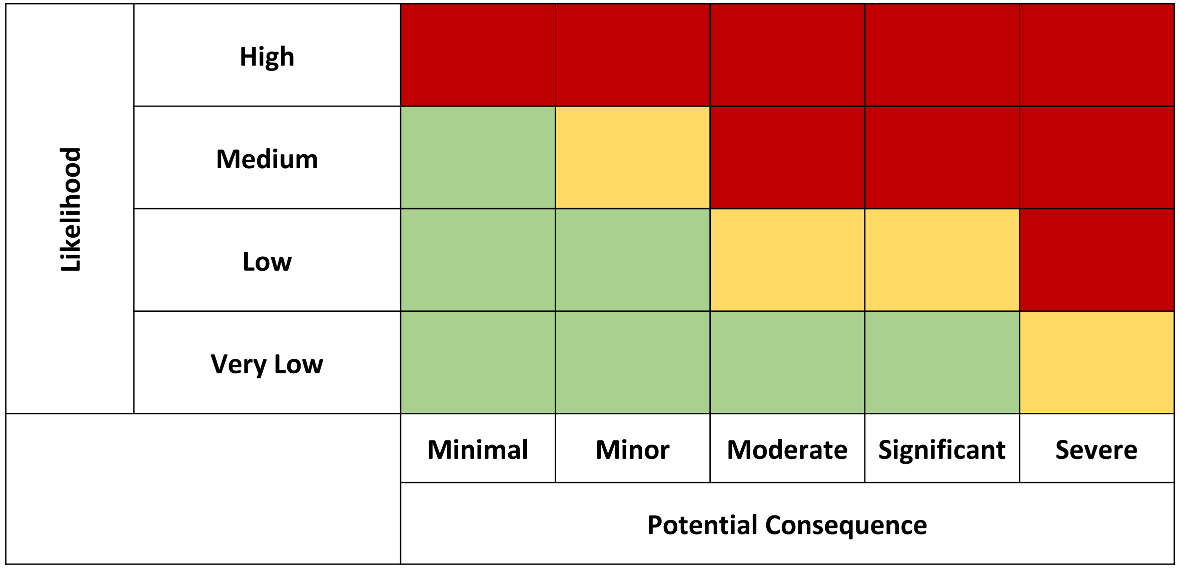


Courtesy: https://hazards.fema.gov

From vulnerability to climate risk assessment…

- Risk will require assessment on a likelihood criteria for the site-specific climate hazard / variable and vulnerability
- Realign vulnerabilities / consequences based on climate hazard /variable
  - Biological > Eel/lake grass increases/fouling
  - Excessive Heat > Reduced life and increased maintenance
- Use vulnerability assessment results as inputs to
  - Preliminary risk ranking by climate hazard
    - Systems most susceptible to least susceptible
    - Communicate “top 5”
  - Inform adaptation strategies

Risk analysis matrix approach for climate hazards impacting asset performance.

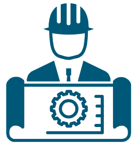


Forward Looking - Adaptive Strategies for NPPs

- *We can reduce risk by increasing robustness (reducing sensitivity) and adaptive capacity – decreasing the vulnerability*
- Components of Adaptive Capacity
  - Technical capacity
  - Organizational capability
  - Financial capacity (cost/benefit)
- Types of adaption plans
  - Ranges of options
  - Situational awareness
  - New technologies
  - Time to act
  - Pathway approach

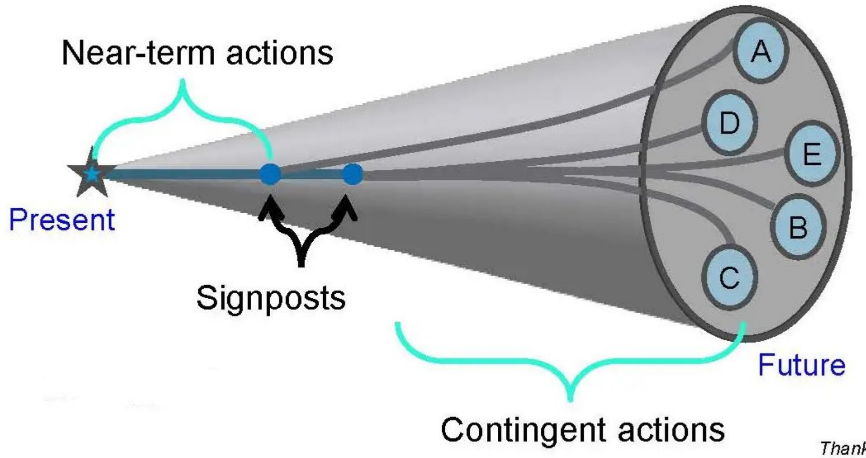
Forthcoming publication on adaptation of operating nuclear plants to climate and environmental challenges

- Challenges include typical climate hazards witnessed over past decade
- Case studies from NPPs world-wide on technical adaptions to SSCs critical to reliable generation of power
- Types of technical adaptions presented include:
  - Analytical margin recovery
  - Changes to operation procedures
  - Installation of prediction and monitoring systems
  - Changes to maintenance programs
  - Plant modifications

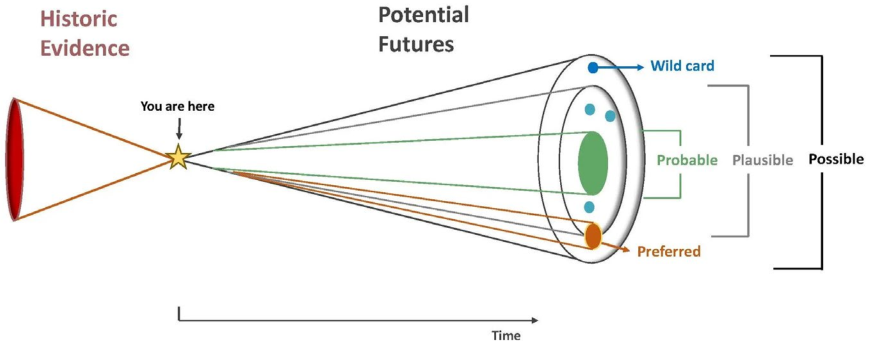


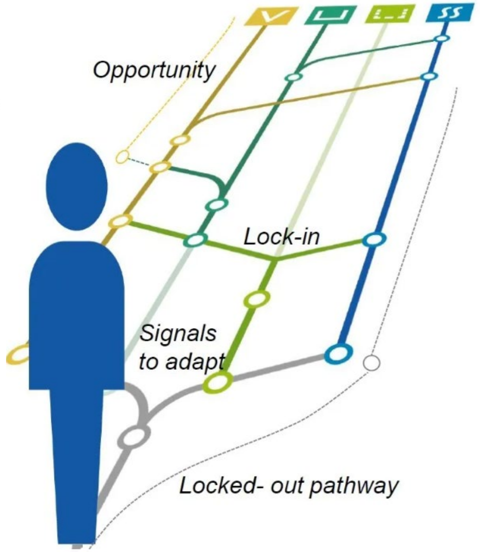
Visualizing Forward-Looking Decision Making

- Forward-looking decision making involves anticipating various future outcomes.
- It utilizes adaptive pathways to create contingency plans.
- Break into manageable steps, adjust as needed and how the future unfolds
- What actions do we need to take now and what actions can we postpone until the future?
- Signposts for decision makers – adaptation tipping points



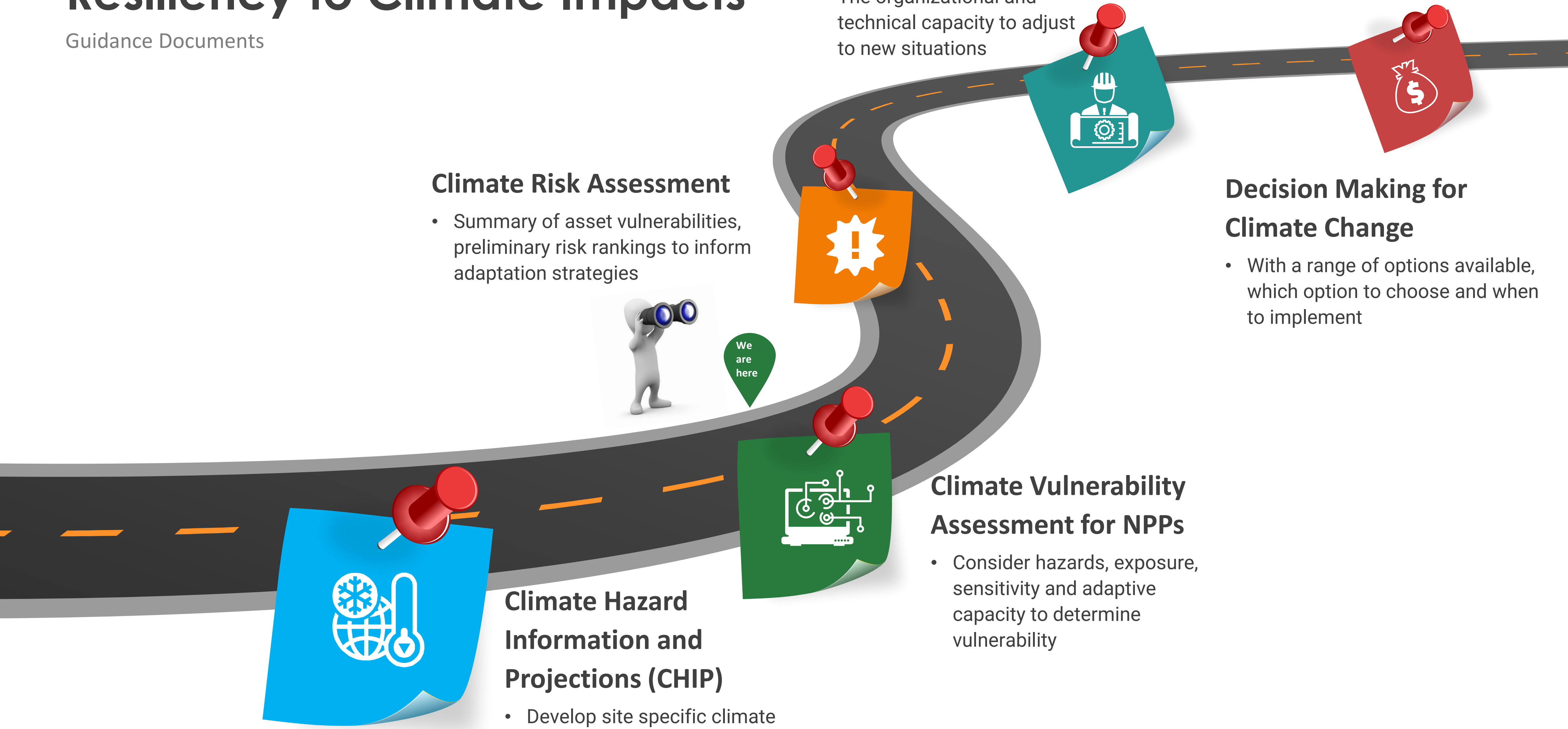
Thanks to Laurna Kaatz





Resiliency to Climate Impacts

Guidance Documents



Climate Hazard Information and Projections (CHIP)

- Develop site specific climate hazards considering effects of future climate changes

Climate Risk Assessment

- Summary of asset vulnerabilities, preliminary risk rankings to inform adaptation strategies

Climate Vulnerability Assessment for NPPs

- Consider hazards, exposure, sensitivity and adaptive capacity to determine vulnerability

Adaptation Strategies

- The organizational and technical capacity to adjust to new situations

Decision Making for Climate Change

- With a range of options available, which option to choose and when to implement

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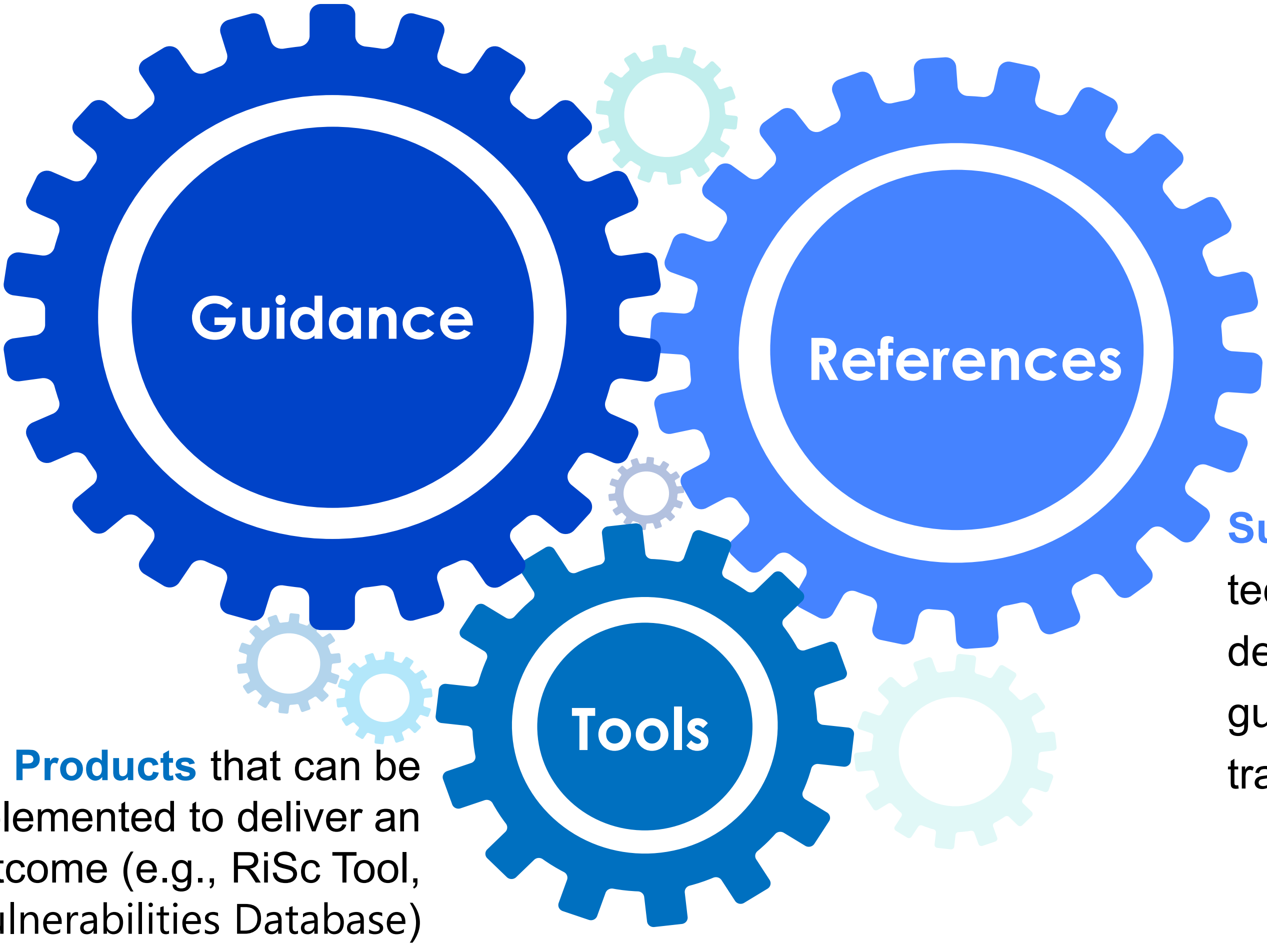
Responding to future changes in natural hazards

- Industry has a significant amount of experience in evaluating impacts of natural hazards
- Numerous guidance and tools available for assessing margins, risk and defense in depth to changing hazard information
- Plants maintain a robust design margin relating to nuclear safety
- Operating experience and high capacity factors show that plants also have operational resilience to extreme events
- Forward looking assessments can allow for strategic decision making to ensure continued safe and reliable performance

THE *Climate READi: Power Framework*

While there are many deliverables from Climate READi: Power, key **Framework** products are categorized and mapped as guidance, references, and tools.



How-to documents for executing a climate resilience assessment for a system or question of interest (e.g., Local Climate Hazard and Exposure Assessment: Technical Guidance and Considerations)

Support resources providing technical rationale and deeper understanding of guidance and/or tools (e.g., training modules, methodologies)

Products that can be implemented to deliver an outcome (e.g., RiSc Tool, Asset Vulnerabilities Database)

The Final Countdown!

NOW - December

- Socialize and write remaining *Climate READi: Power Framework* documents
  - Guidance
  - References
  - Tools
- Focus on Case Study application to stress and stretch the Framework
- Continue Engagement
  - ✓ Final Regional Workshop – Aug.
  - ✓ WS1 Workshop – Sep.
  - ✓ READi Annual Meeting – Oct.

2025 Q1

- FINALIZATION…
  - *Climate READi: Power Framework*
    - Member and CRAG Comment Period
    - Reconciliation of Feedback
    - Online Resource Development
  - Case Study Story Map Resource Center
  - ‘READi Research Roadmap’

2025 Q2 – Q4

- April Framework Launch
  - Soft launch at EU Week
  - Official Launch at Battelle Innovations in Climate Resilience Conference
  - Virtual Webcast Lunch
- Focused Framework elevation and application
- Transition READi into EPRI research portfolio

Links to ERPI Climate READi Deliverables & Ongoing Projects

Workstream 1 - Physical Climate Data and Guidance

- READi Insights: Extreme Heat Events and Impacts to the Electric System
- Climate Vulnerability Assessment Guidance for Nuclear Power Plants
- Grounding Climate Risk Decisions: Physical Climate Risk Assessment Scientific Foundation and Guidance for Companies – Initial Key Company-Level Insights, Technical Principles, and Technical Issues
- Climate 101: Physical Climate Data (Modules 1-3) | Physical Climate Data 101 Course Overview
    - READi Insights: Types of Climate Data and Potential Applications within the Electric Power Sector
    - READi Insights: Unpacking Climatological and Power System Operating Extremes
- READi Insights: Impacts of the El Niño-Southern Oscillation on Hurricanes and Summer Temperature
- READi Insights: The Fifth National Climate Assessment — Key Insights and Connections to Climate READi
- Climate Hazard, Exposure, and Vulnerability Assessment 101 (Modules 4-6) | Course Overview
- READi Insights: Downscaling
- Climate Data Inventory v1.0.0
- Climate Data Users Guide v1.0.0 | Climate Data Users Guide v1.0.0 Overview Brief
- Story Map: Evaluating Local Climate Change Impacts
- Assessment of Wildfire Hazard Risk Screening Tools
- Compound Hazards and the Power Sector in a Changing Climate
- Climate Data Gap Analysis

In Progress

- Relational Database
- Climate Data 101 Part III
- Hazard and Exposure Assessment Guidance

Workstream 2 – Energy System and Asset Vulnerability Assessment

- Operating Dynamics of Heating and Cooling Systems During Extreme Temperatures—Thermal and Power System Considerations
- Climate Vulnerability Assessment Guidance for Nuclear Power Plants
- Climate Vulnerability Considerations for the Power Sector: Nuclear Generation Assets
- Climate Vulnerability Considerations for the Power Sector: Non-Nuclear Generation Assets
- Climate Vulnerability Considerations for the Power Sector: Health and Safety, Environmental Justice, and Ecological Patterns
- Climate Vulnerability Considerations for the Power Sector: Transmission and Distribution Infrastructure
- Asset Vulnerability Assessments: Considerations and Resources
- Climate Vulnerability Considerations for the Power Sector: End Use Assets and DER
- Extreme Cold Weather Temperature Calculation for EOP-012 Compliance

In Progress

Story Maps: Hydropower | WIRES | Nuclear| Fragility Curve Development

- Technical Report: Tree Management
- Fragility Curve Generation Guidance
- Inventory of Weather-Related Standards: Technical Brief
- Cold Weather Preparedness Planning for EOP-012 Compliance
- Ecological Change Workshop Proceedings
- Projecting Soil Conditions that Accelerate Corrosion Risk
- Emergency Management Framework for Climate Events
- Nature-Based Solutions as Climate Adaptations

Links to EPRI Climate READi Deliverables & Ongoing Projects

Workstream 3 – Resilience and Adaptation Planning and Prioritization

- Costs and Benefits of Proactive Climate Adaptation in the Electric Sector
- Climate-Informed Planning and Adaptation for Power Sector Resilience
- READi Insights: Approaches to Future Hourly Time Series for Climate-Resilient Power System Planning
- READi Insights: Planning for Extreme Weather Events Across Time Scales
- Story Map: Projected changes in hurricane-induced power outages in a future climate
- Practices for Representing Climate Impacts in Bulk Electric System Models
- READi Insights: The Importance of Grid Asset Data in Support of Distribution Resilience Planning

In Progress

- Story Maps: Texas | Midwest | Resilience Metrics Natural Gas Modeling
- Workstream 3 Guidance Document
- RiSc Screening Tool
- Cost Benefit Analysis Guidance Document

Programmatic and Onboarding Materials

Member Companies

- Executive Summary
- 2024 Member Engagement Calendar
- Technical Advisor Engagement Guide
- READi Oversight Committee (ROC) Summary
- How to Find Past Webcast and Workshop Materials (log-in required):
    - Board-led Working Group (BWG)
    - READi Oversight Committee (ROC)
    - Workstream 1
    - Workstream 2
    - Workstream 3

Climate READi Affinity Group (CRAG)

- Executive Summary
- Affinity Group Engagement Guide
- 2024 Affinity Group Engagement Calendar
- Box Resource Folder

In Progress

- Climate READi: Power Framework and Overarching Guidance
- Climate READi Research Roadmap

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