Climate READi

Project Overview and Intro to Climate Resilience

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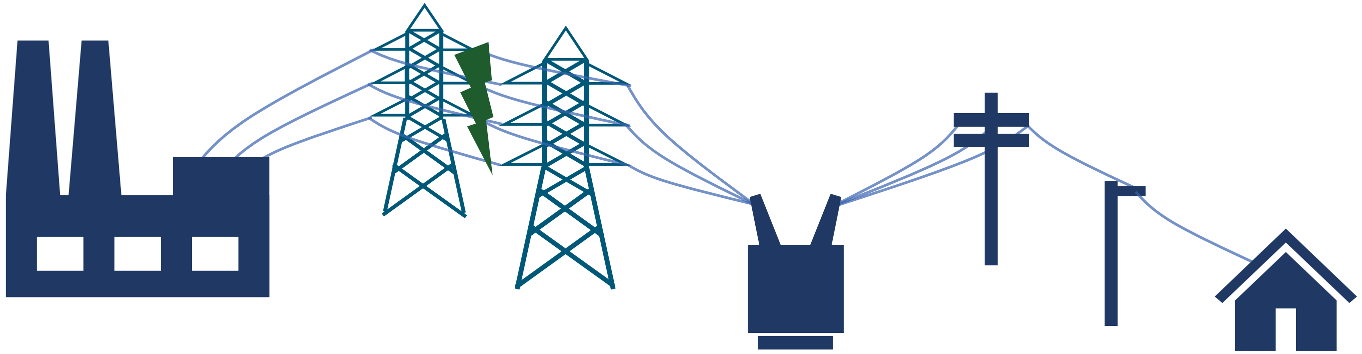
RESILIENCE AND ADAPTATION INITIATIVE

Definition and Terminology Check

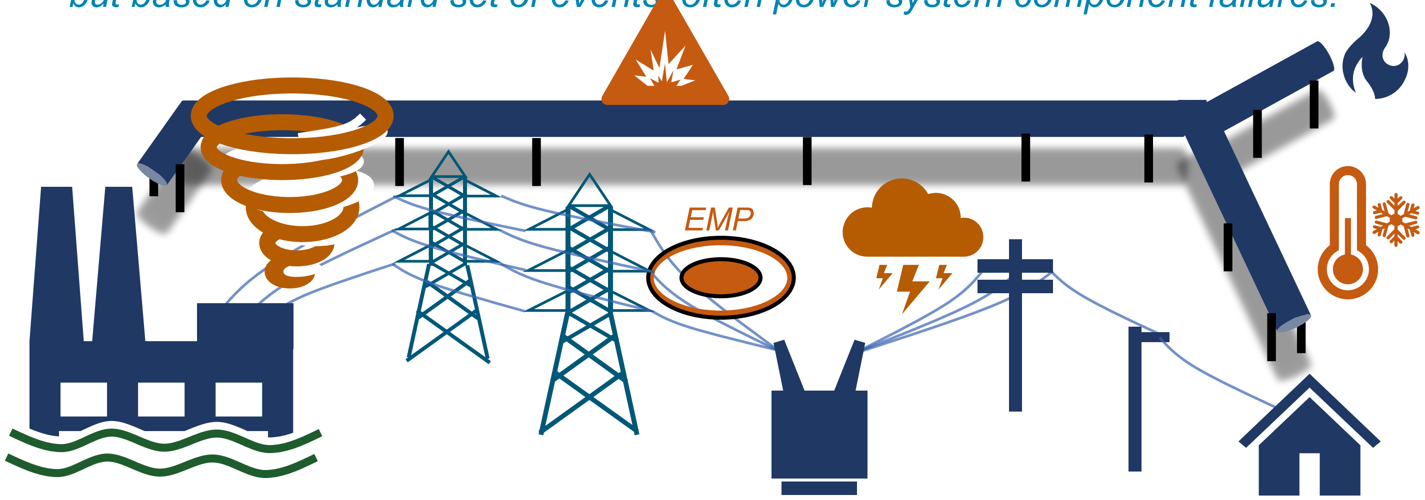
	Reliability	Resilience
Oxford English Dictionary	consistently good in quality or performance; able to be trusted	the capacity to recover quickly from difficulties; toughness
Applied to Power Systems	NERC: **Operating reliability**, the ability of the electric system to **withstand sudden disturbances** such as electric short circuits or unanticipated loss of system components **Adequacy**, the ability of the electric system to supply the **aggregate electric power and energy requirements of electricity consumers at all times**, taking into account scheduled and reasonably expected unscheduled outages of system components.	FERC/NIAC: 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 an event. NIAC's resilience framework: Robustness, resourcefulness, rapid recovery, adaptability

Characterizing power system resilience



Existing criteria based on "traditional*" conditions

Traditional events may include high impact low frequency (HILF) events (e.g., n-2), but based on standard set of events, often power system component failures.



Criteria based on "externally driven HILF" events

Externally-driven events are those that are less known and typically events unrelated to the power system but which affect the power system.

Reliability

Limit customer outages

Restoration/ Recovery

Restoring grid components following customer outage

Definitions, metrics, criteria, solutions (influence but can be distinct)

Resilience

Anticipate, absorb, adapt to, and/or rapidly recover

External Events impact many parts of the power system

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Power System Resilience

Supply Resilience	Transmission, Substation and Distribution Infrastructure Resilience	Communications Resilience
Events • Extreme weather (i.e., extreme cold) • Natural disasters (hurricanes, floods)	**Events** • EMP, GMD events • Natural disasters & extreme weather • Manmade threats	**Events** • Cyber attacks • Natural disasters
Strategy • Generator hardening • Fuel supply assurance • Local supply: DER and microgrids	**Strategy** • Line hardening, network redundancy • Strategies for reliable network architecture & communications • Local supply: DER and microgrids	**Strategy** • Enhanced cyber security • Strategies for reliable network architecture & communications
Incentives • Opportunities for market incentives, or products, interdependencies with other infrastructure • Cost based recovery	**Incentives** • Side payments from operators • Cost based recovery through LSE	**Incentives** • Cost based recovery through LSE • New technology and devices (IoT, microgrids)

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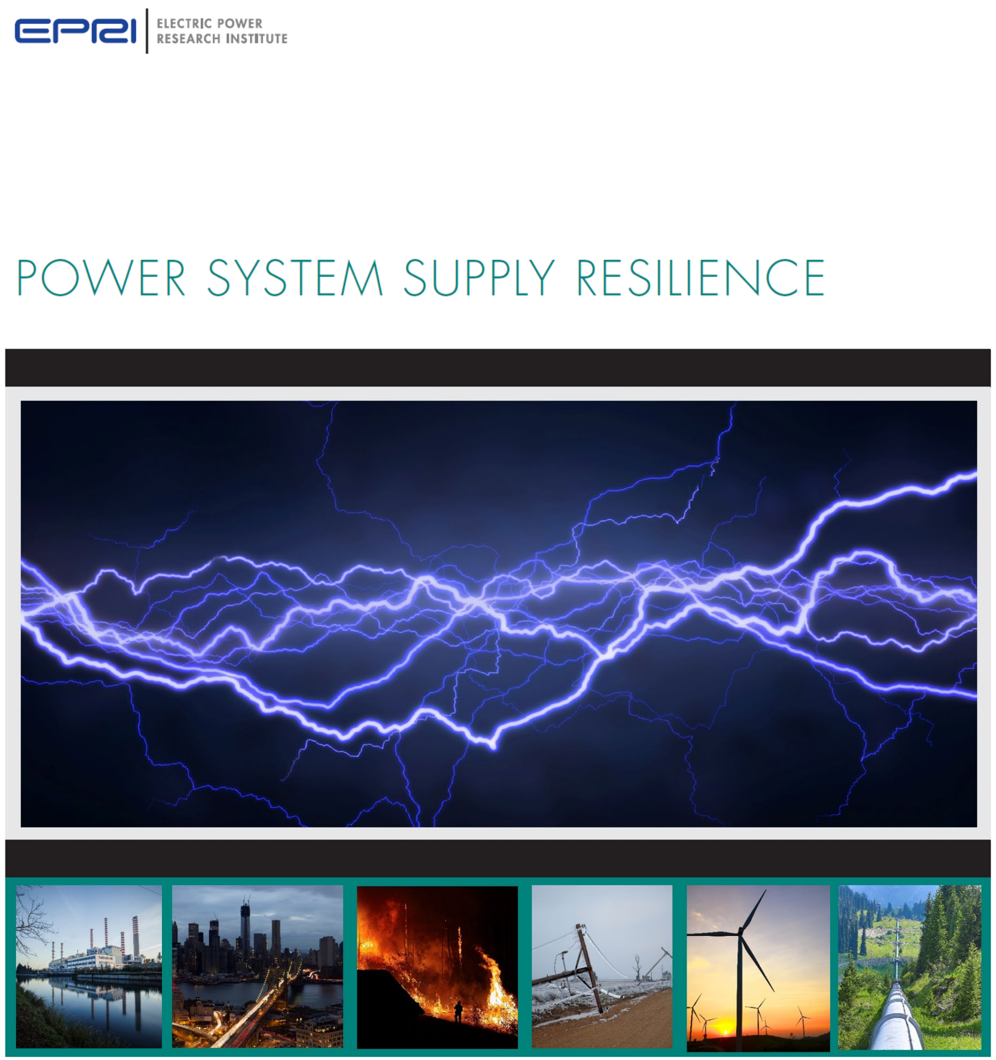
EPRI White Paper: Power system Supply Resilience

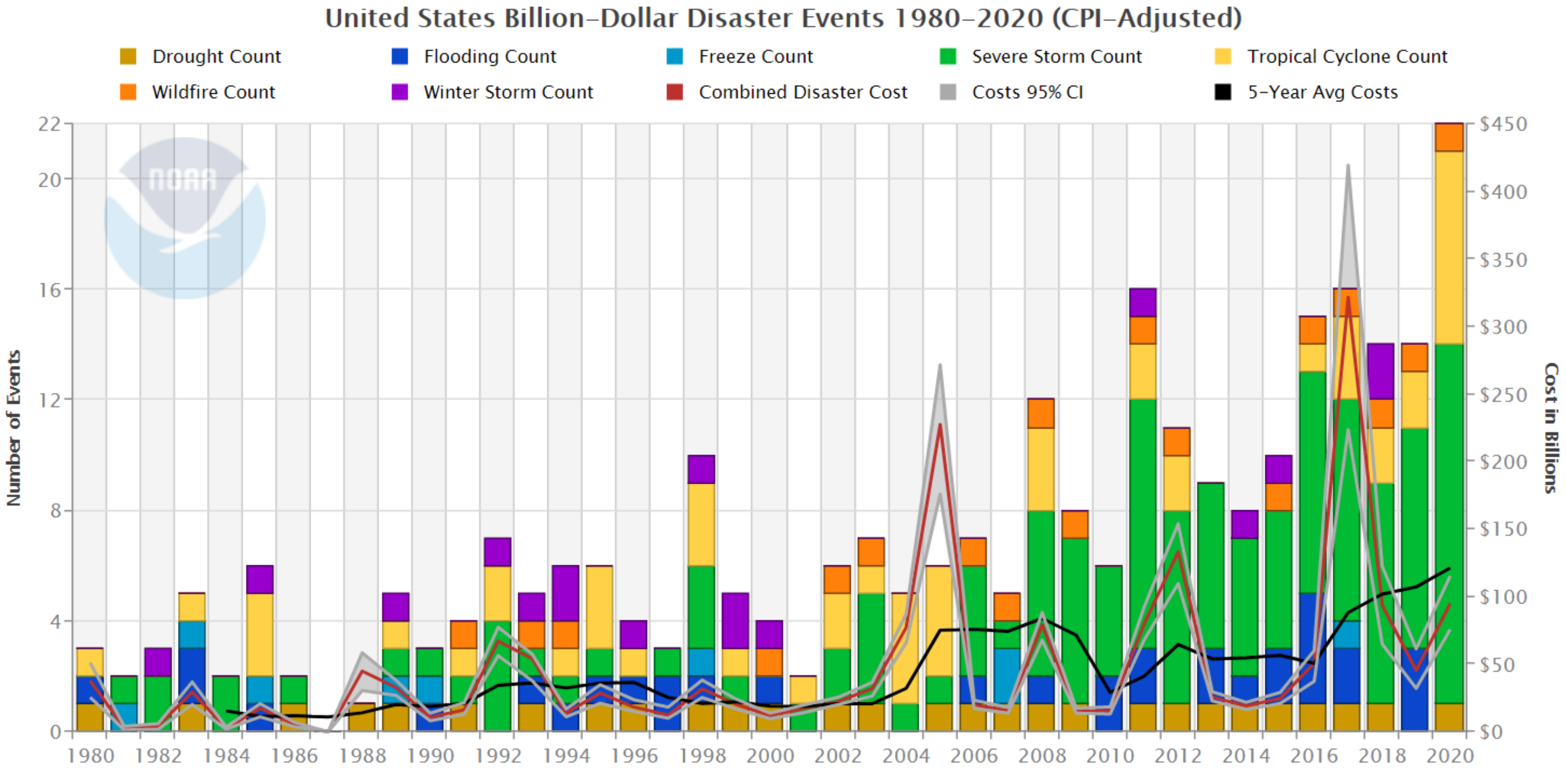
- Framing resilience as it relates to reliability and restoration
- Supply Resilience: the ability to harden supply resources, including associated fuel and all supply components against—and quickly recover from—high impact, low frequency (HILF) events
- Discusses existing reliability metrics and how resilience attributes might be incorporated
- Describes supply resilience and research gaps for
  - Operations
  - Planning
  - Restoration
  - Wholesale market design



https://www.epri.com/research/products/000000003002014963

Costs of extreme events are increasing

- Billion-dollar disasters have increased over time and appear to be on an upward trend.
- Impact of weather events is non-linear and rising much faster than frequency.
- Historical extreme-event statistics underestimate today's probabilities.



Source: NOAA U.S. Billion-dollar Weather and Climate Disasters – 2020

Costs are only a small consequence of increasing extreme events

Climate Challenges we are Confronting

Broad Problem

Climate has many touch points with the energy system and can impact planning, design, operations, and maintenance

Inconsistent & Emerging Methods

We lack consistency and consensus in informed application of climate data in power system applications.
Some applications require novel approaches or methods.

Managing Uncertainty

We know we must act, but future impacts are uncertain.
How do we evaluate, justify, and benchmark proposed responses?

Guidance + consensus is needed on data, assumptions, models, and analysis

How can we better evaluate risk to the power system from extreme weather and a changing climate?

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EPRI Climate REsilience and ADaptation initiative (READi)

- **COMPREHENSIVE:** Develop a *Common Framework* addressing the entirety of the power system, planning through operations
- **CONSISTENT:** Provide an informed approach to climate risk assessment and strategic resilience planning that can be replicated
- **COLLABORATIVE:** Drive stakeholder alignment on adaptation strategies for efficient and effective investment

Workstream 1	Workstream 2	Workstream 3
Physical Climate Data & Guidance	**Energy Asset Exposure & Vulnerability**	**System Planning & Investment Prioritization**
• Identify climate hazards and data required for different applications • Evaluate data availability, suitability, and methods for downscaling & localizing climate information • Address data gaps	• Evaluate vulnerability at the component, system, and market levels from planning to operations • Identify mitigation options from system to customer level • Enhance criteria for planning and operations to account for event probability and uncertainty	• Assess power system and societal impacts: resilience metrics and value measures • Create guidance for optimal investment priorities • Develop cost-benefit analysis, risk mitigation, and adaptation strategies

Deliverables: Common Framework

- Climate data assessment and application guidance
- Vulnerability assessment
- Risk mitigation investment
- Recovery planning
- Hardening technologies
- Adaptation strategies
- Research priorities

What does climate resilience look like for the power system?

Supply	▪ Reduced efficiency in high temperatures ▪ Fuel supply disruptions in extreme low temperatures	▪ Wind and solar droughts ▪ Severe storms damaging assets ▪ Drought limiting hydropower availability
Delivery	▪ Reduced capacity in high temperatures ▪ Wildfire damage	▪ Severe storms damaging assets ▪ Trees falling on lines ▪ Decreased asset life
Demand	▪ Potential for severe increases in demand as temperatures rise ▪ Climate-driven technology adoption will change load shapes	▪ Potential for demand-side resources to contribute to resilience ▪ Electrification increasing criticality of service for many customers

Can we anticipate and plan for these risks?

- Yes! …but the uncertainty space is large
  - What will the grid look like in 10, 20, 30 years?
  - How confident are we of changes in temperature, wind speeds, ice storms?
  - How will current assets respond to changes in climate conditions?
  - How will new technologies respond to changes in climate conditions?
  - How will changes in climate impact demand for electricity?
  - How much will it cost to repair climate damages?
  - How much will the impacts of climate damages cost customers?

Ultimately, we need a standardized approach to determine the best set of adaptation investments to improve resilience

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WORKSTREAM 1

Physical Climate Data & Guidance

WS1: Physical Climate Data and Guidance

The power system is a physical system that is exposed to multiple climate hazards (e.g., extreme heat, wildfire, hurricanes).

\+

The power system is transitioning to greater reliance on weather-dependent resources (e.g., wind and solar).

Multiple types of climate data are needed to assess the potential impacts of climate and climate change on the operation and planning of the electric power system.

WS1's goal is to understand how and where climate data are used in different applications for the electric power system. WS1 seeks to assess the availability and suitability of climate data for different analysis contexts and provide guidance on selecting, interpreting, and applying climate data for various applications.

Physical Climate Data 101

Training for operationalizing climate data

Objectives

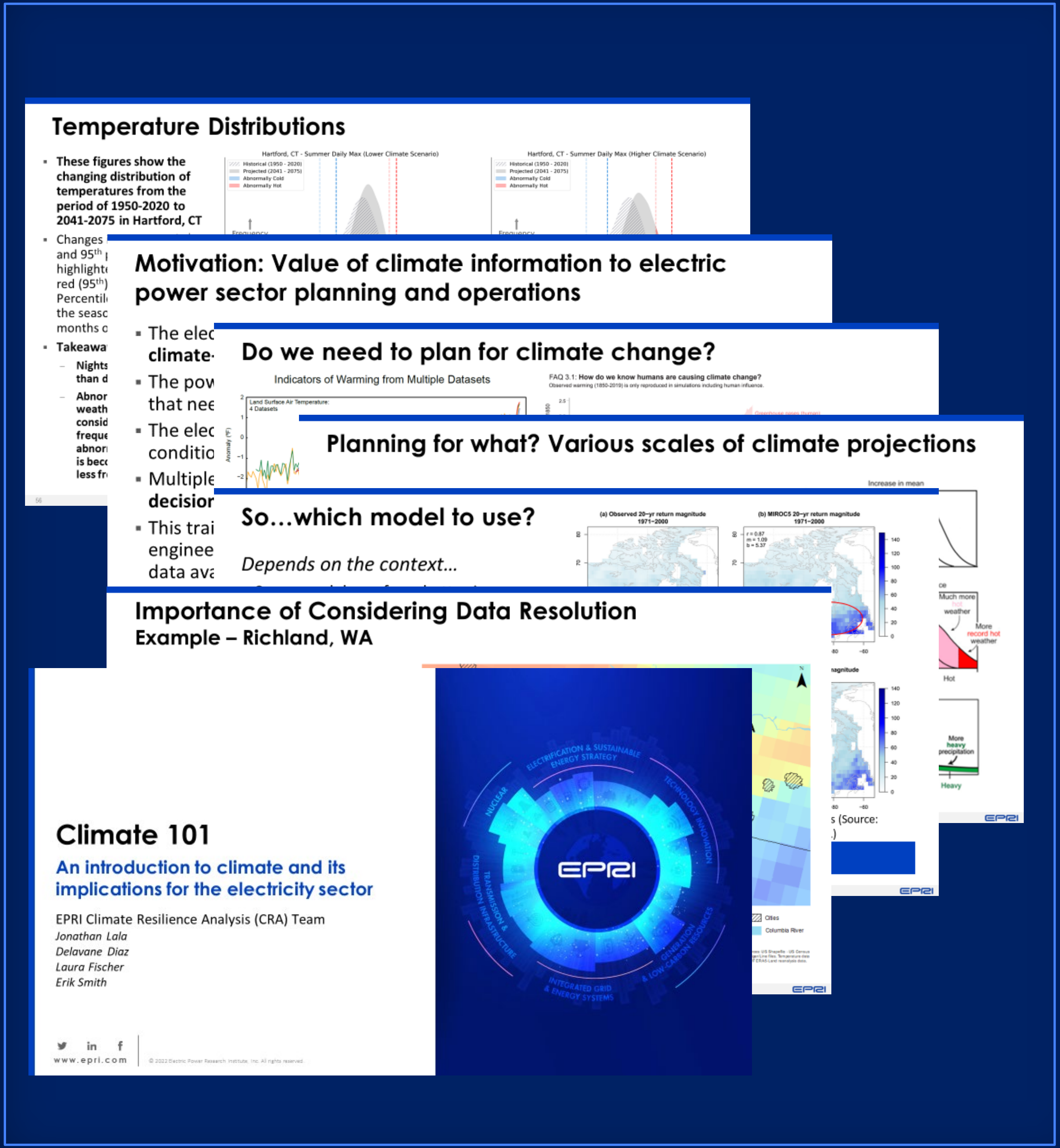
- Level-set terminology, concepts, and structure related to historical and forward-looking climate data
- Resource for initiating collaborations between climate and electricity system subject matter experts

Audience

- Electric company asset managers, engineers, operators, and/or planners
- Anyone who may be working with climate data at your company, but isn't a climate expert

Timeline

- *Physical Climate Data 101* published in early 2023 (3002026223)
- Climate 101, Part II to be released at end of 2023



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WORKSTREAM 2

Energy Asset Exposure & Vulnerability

Climate Risk Assessment – Big Picture

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Climate Change

Hazard

Are local physical conditions changing?

Exposure

What is or will be in harm's way?

Vulnerability and Response

Does it matter? Will assets be impacted?

Risk Management

Is the risk large? Can we adapt to reduce risk?

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Climate Risk Assessment – Big Picture

Climate Change

Hazard

Are local physical conditions changing?

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What is or will be in harm's way?

The realm of WS2

Vulnerability and Response

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Is the risk large? Can we adapt to reduce risk?

For all assets in the power system…

- Thermal Generation (Coal, Gas, CC, Nuclear)
- Renewable Generation (Wind, Solar, Hydropower)
- Transmission & Distribution
- DER and End Use Products
- Cross Cutting Topics
  - Worker Health & Safety
  - Energy Equity
  - Ecological Patterns

How will they respond to, perform in, and withstand changing conditions?

Air Density
Air Humidity
Air Quality
Air Temperature
Barometric Pressure
Cloud Cover
Concurrent Effects
Drought
Hydrology: Discharge
Hydrology: Flooding
Hydrology: Water Quality
Hydrology: Water Temperature
Hydrology: Waterbody Elevation
Lightning
Precipitation
Sea Level Rise
Severe Storms: Hurricanes/Tropical Storms/Typhoons
Severe Storms: Tornadoes & Derechos
Soil Characteristics
Solar Irradiance
Wildfires
Wind

Asset-Climate Metrics Matrices

Impact ID	Application	Climate Variable Category	System/Facility Type	Sub-System	Impact	Specific impact measure (e.g., threshold, exposure-response function)
6.1	Operations	Air Temperature	Coal, CCGT, and Nuclear	Cooling Tower	Cold air temperatures can lead to low water temperature which can damage hardware or cause **freezing in cooling tower**, restricting flow	Derate depends on the loss of cooling capacity; structural damage can force out unit <32F
6.2	Operations	Water Temperature	Coal, CCGT, and Nuclear	Cooling Tower	Cold air temperatures can lead to low water temperature which can damage hardware or cause **freezing in cooling tower**, restricting flow	Derate depends on the loss of cooling capacity; structural damage can force out unit <32F
8.2	Operations/Infrastructure	Precipitation	Overhead Lines, Structures, and Components	Lines; poles; towers	Flooding and high soil moisture can affect geotechnical conditions; flooding may directly impact poles and towers through additional force from fast moving waters	Amount of precipitation needed to raise soil moisture content such that pole instability occurs
8.3	Operations/Infrastructure	Soil Moisture	Overhead Lines, Structures, and Components	Lines; poles; towers	Flooding and high soil moisture can affect geotechnical conditions; flooding may directly impact poles and towers through additional force from fast moving waters	What % soil moisture begins to become a threat for pole instability
8.4	Operations/Infrastructure	Hurricanes/Typhoons/Tropical Storms	Overhead Lines, Structures, and Components	Lines; poles; towers	Flooding and high soil moisture can affect geotechnical conditions; flooding may directly impact poles and towers through additional force from fast moving waters	What level of hurricane can be concern for pole stability?
8.5	Operations/Infrastructure	Sea Level Rise	Overhead Lines, Structures, and Components	Lines; poles; towers	Flooding and high soil moisture can affect geotechnical conditions; flooding may directly impact poles and towers through additional force from fast moving waters	

Informs asset adaptation options & Informs WS3 system modeling

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WORKSTREAM 3

System Planning and Investment Prioritization

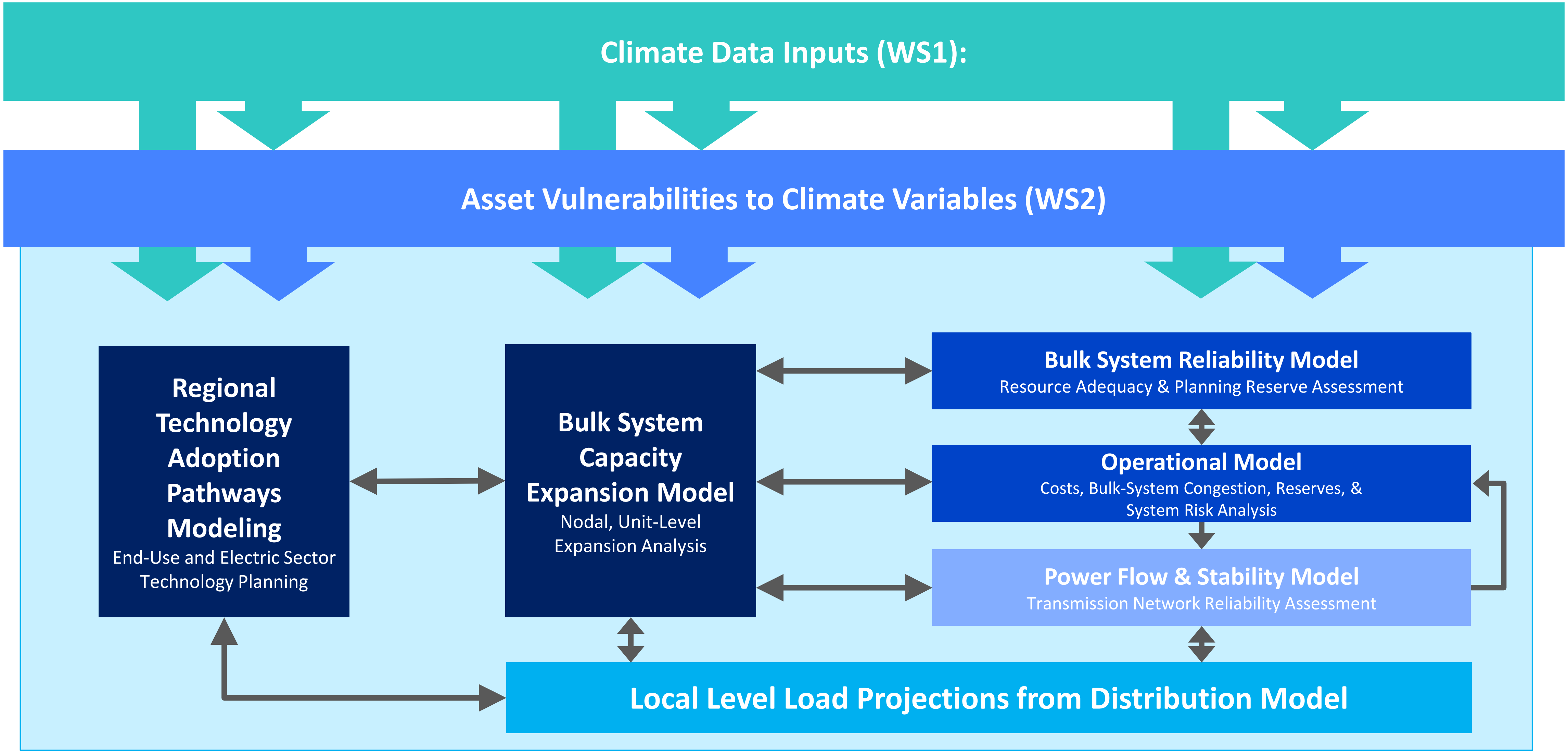
Workstream 3 Objective

Investment prioritization for resilience that accounts for climate risks, asset vulnerability, and impacts on society and communities

To identify and prioritize investments, we need to:

- **Account for what the system might look like in response to climate and technology development**
- **Understand how existing assets and infrastructure will be vulnerable to climate**
- **Identify what are the new adaptations that we want to invest in to ensure resilience**
- **How these adaptations impact communities, equity, and justice**

Power System Resilience and Investment Framework



Incentivizing Asset Owners to provide Resilience Attributes

Ancillary Service Markets	Shortage Pricing	Emergency Pricing Procedures
Capacity Performance	Dual Fuel Constraints and Recovery	Explicit Event Contingency Models and Pricing

Market design to incentivize resilience already exists. Potential for improvement possible, particularly for growing list of non-traditional events

Thank you!

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Recent Deliverables Across all Workstreams

- A Starting Point for Physical Climate Risk Assessment and Mitigation: Future Resilience and Adaptation Planning
- READi Insights: Extreme Heat Events and Impacts to the Electric System
- Costs and Benefits of Proactive Climate Adaptation in the Electric Sector
- 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
- READi Insights: Extreme Winter Weather Challenges for the Power System
- Climate-Informed Planning and Adaptation for Power Sector Resilience
- 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: Physical Climate Data 101 Course Overview
- Climate Vulnerability Considerations for the Power Sector: 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
- Climate Vulnerability Considerations for the Power Sector: Non-Nuclear Generation Assets

Find all this and more at www.epri.com/READi