Table of Contents

NATF/EPRI/NERC
Transmission Resilience Summit

Delivering water and power®

PERA Training & Conference Center
Tempe, AZ
May 17, 2023

Open Distribution

Notice – Disclaimer and Trademarks

Agenda Overview

Opening Session	
Welcome and Safety Briefing: *John Coggins (SRP)*	
Opening Remarks: *Tom Galloway (NATF), Andrew Phillips (EPRI), Mark Lauby (NERC)*	
Keynote: *Colette Honorable (Reed Smith and former FERC Commissioner)*	
Session 1 – Resilience is a team sport	
Community Lifelines: *Brock Long (Hagerty Consulting and former FEMA Administrator)*	
Climate Modeling Partnerships: *Tom Wall (Argonne National Lab), Ryan Burg and Nitin Patel (ComEd)*	
Session 2 – Learning from the past	
Winter Preparedness: *Anne-Marie Fournier (Hydro-Québec TransÉnergie)*	
Hurricane Preparedness: *Mike Warr (FP&L)*	
Wildfire Mitigation: *Brian Kelley and Andrew Deemer (Arizona Public Service)*	
Session 3 – Planning for the Future	
DOE National Transmission Planning Study: *Hamody Hindi (DOE)* and *Michael Kintner-Meyer (PNNL)*	
Threat Landscape Panel Moderator: *Kristen Worosz (E-ISAC)*	Panelists: *James Madia (SCE), Travis Moran (SERC), Richard Steeg (DiGioia Gray)*
Transmission NOPRs and Policy Panel Moderator: *Eknath Vittal (EPRI)*	Panelists: *Mark Lauby (NERC), Kamran Ali (AEP), David Wiley (APS)*
Climate READi Panel Moderator: *Anish Gaikwad (EPRI)*	Panelists: *Soo Jin Kim (NERC), Tom Cooper (SRP), Eknath Vittal (EPRI)*

Meeting Reminders

- Format
  - Open meeting
- Guidelines
  - Do not share confidential information
  - Do not share sensitive security information
  - Obey antitrust laws and guidelines
    - Avoid conduct that unreasonably restrains competition

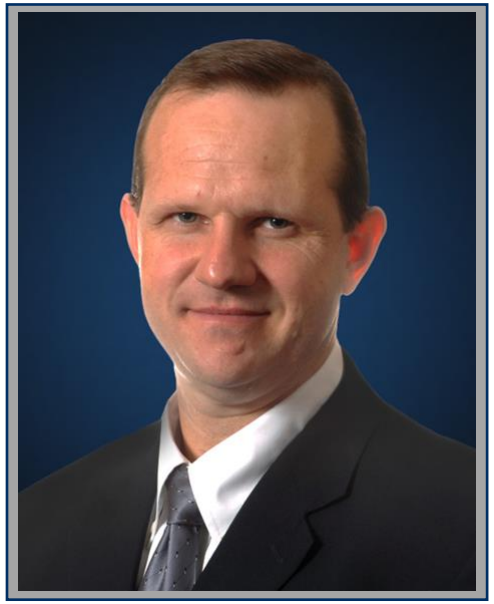
Welcome and Safety Message

John Coggins (Salt River Project)

Opening Remarks

Tom Galloway

President & CEO, NATF



Andrew Phillips

V-President T&D, EPRI

Mark Lauby

SVP and Chief Eng, NERC

Keynote

Colette Honorable

Partner at Reed Smith

SESSION 1

Resilience is a team sport

Community Lifelines

Brock Long (Hagerty Consulting)

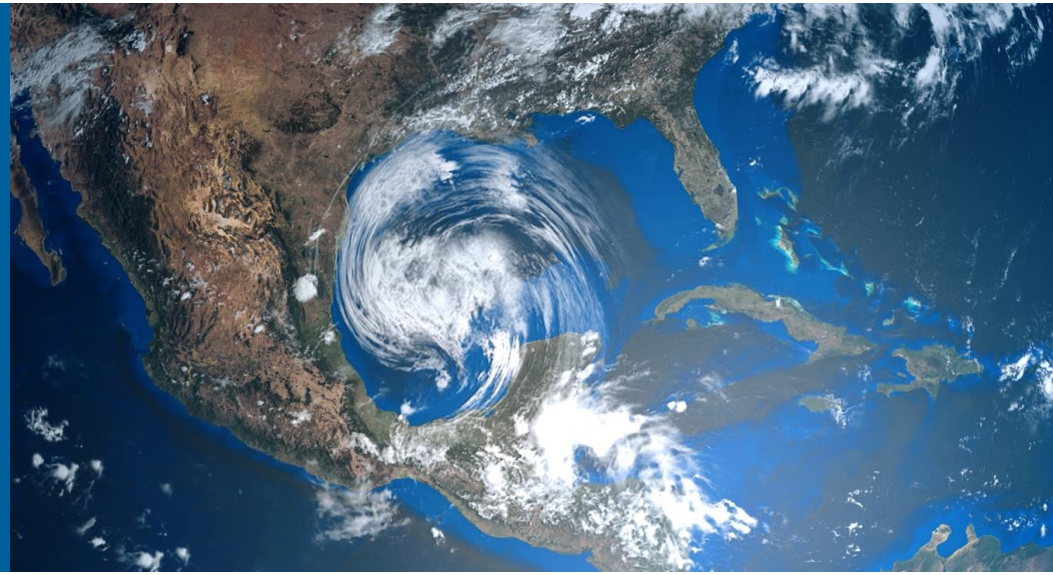
Climate Modeling Partnerships

Tom Wall (Argonne National Labs)

Ryan Burg and Nitin Patel (ComEd)

CENTER FOR
CLIMATE RESILIENCE
AND DECISION SCIENCE
Argonne National Laboratory

BUILDING A CLIMATE RESILIENT FUTURE FOR NORTHERN ILLINOIS



TOM WALL, PH.D.
Program Lead, Engineering & Applied Resilience
Center for Climate Resilience and Decision Science

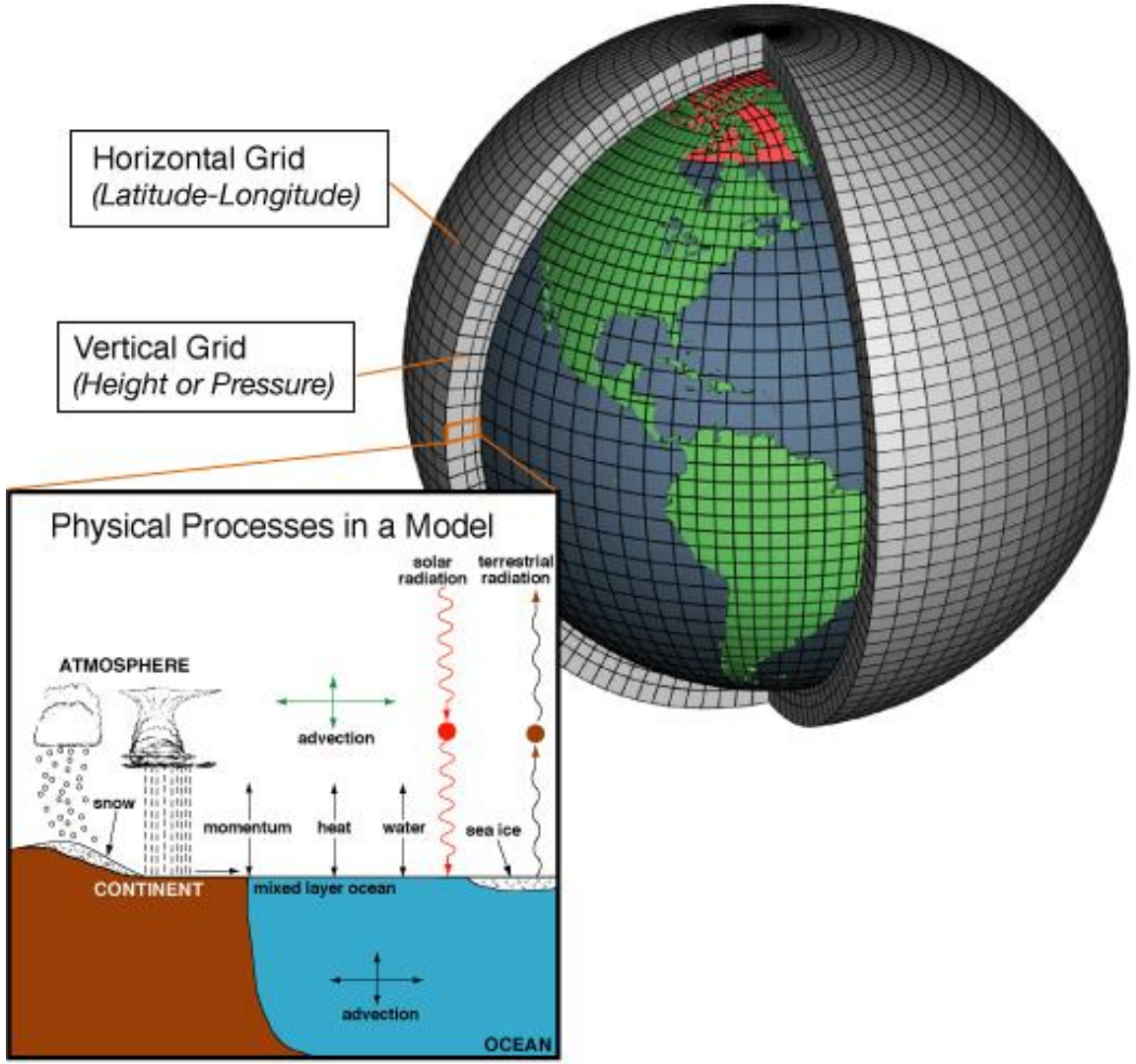
ARGONNE'S ROLE IN CLIMATE RESILIENCE

Center for Climate Resilience and Decision Science

- The Center for Climate Resilience and Decision Science (CCRDS) conducts research and analysis to enable unmatched climate-risk informed decision-making and adaptation planning for public and private stakeholders facing a variety of climate-related challenges around the world.
- The CCRDS is comprised of a multidisciplinary scientific team that collaborates with research partners to ensure that climate risk-informed decision-making is contextualized in socio-economic, infrastructure, environmental, and fiscal realities so that mitigation actions are grounded in science and practicable for immediate implementation.

GLOBAL CLIMATE SYSTEM MODELS

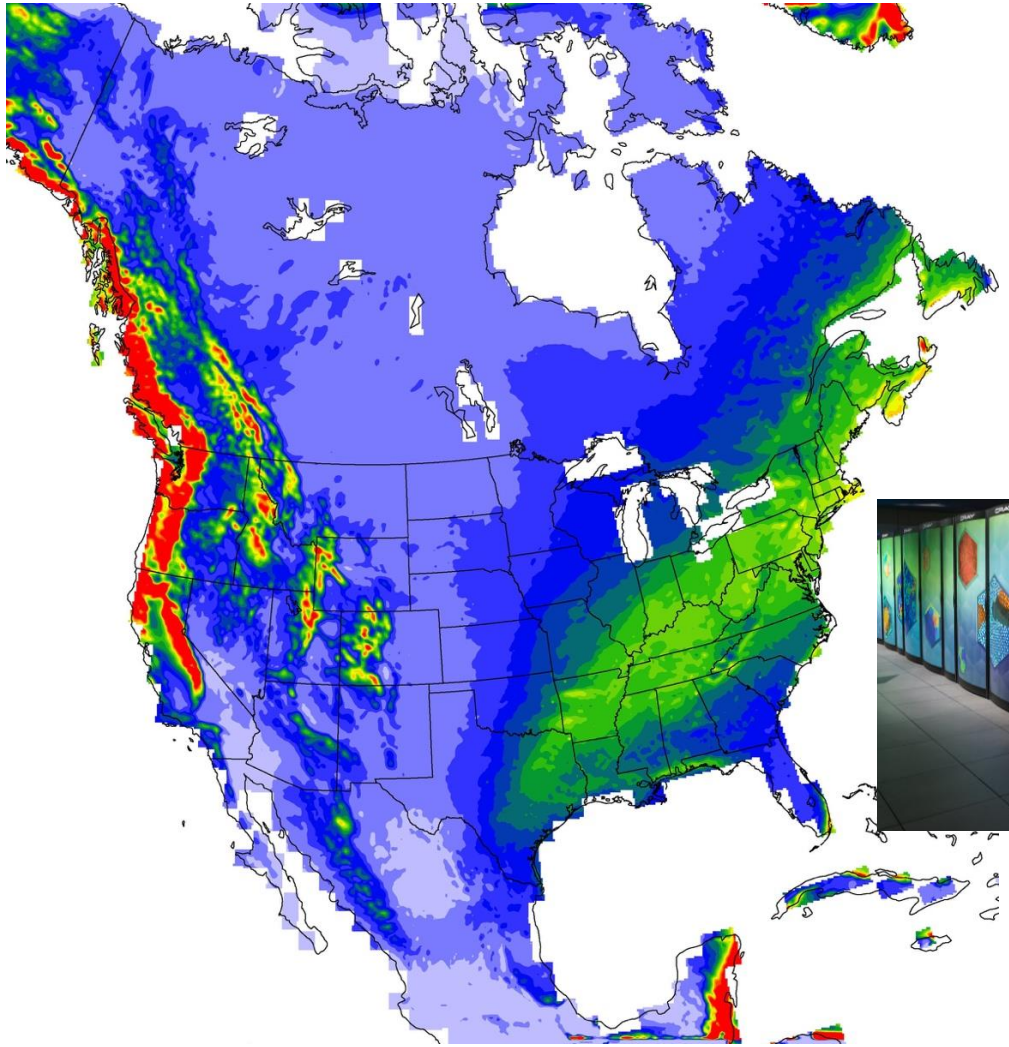
Mathematical representations of the climate system based on physical laws and understanding of processes



DYNAMICAL DOWNSCALING

ARGONNE'S DYNAMICALLY DOWNSCALED, REGIONAL CLIMATE MODELING IS A UNIQUE CLIMATE RESOURCE

- High resolution, neighborhood level (12km)
- Scientific transparency: widely published and scientifically peer reviewed modeling and outcomes
- Dynamical downscaling offers improvements over statistical downscaling
  - Physics-based, addresses non-stationarity
  - Produces 60+ unique climate variables
- RCP8.5 (upper limit) + RCP4.5 (mid-century peak)
  - Useful for infrastructure protection and disaster planning
- Historical, mid-century, end-century timeframes



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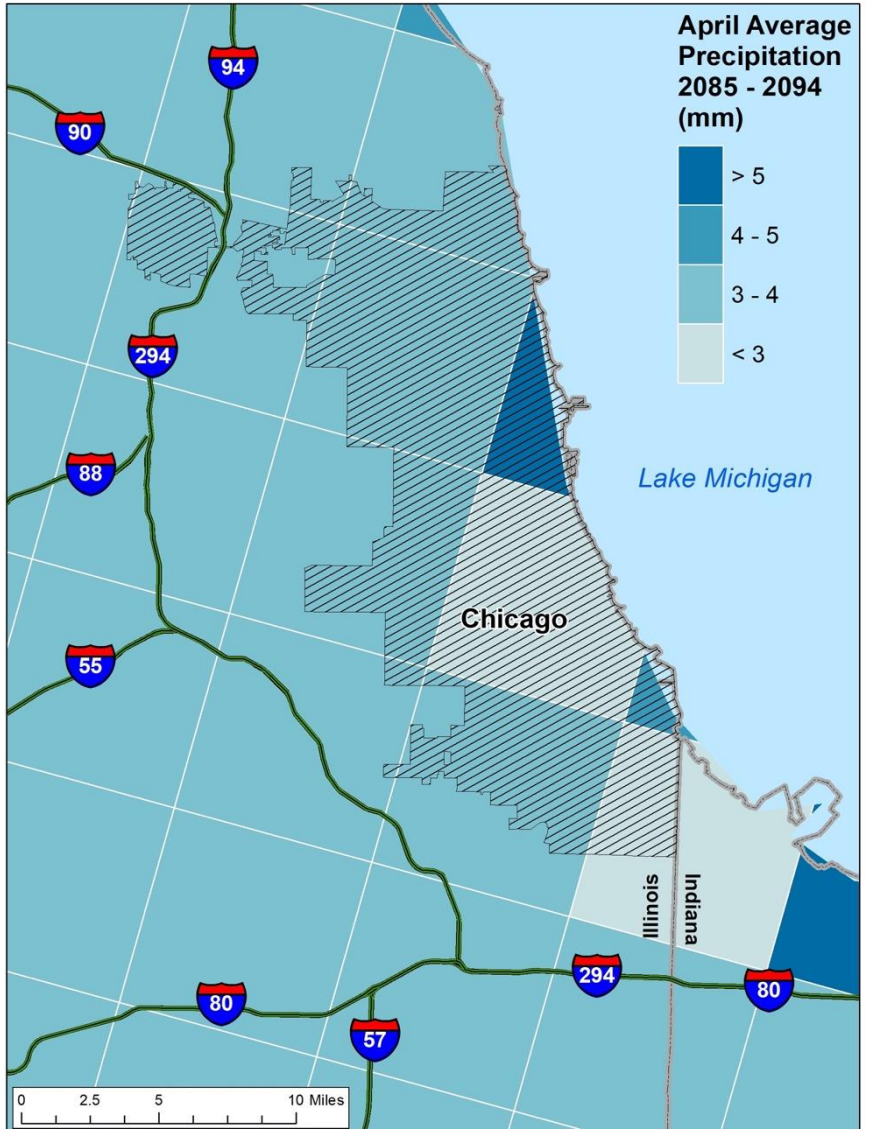

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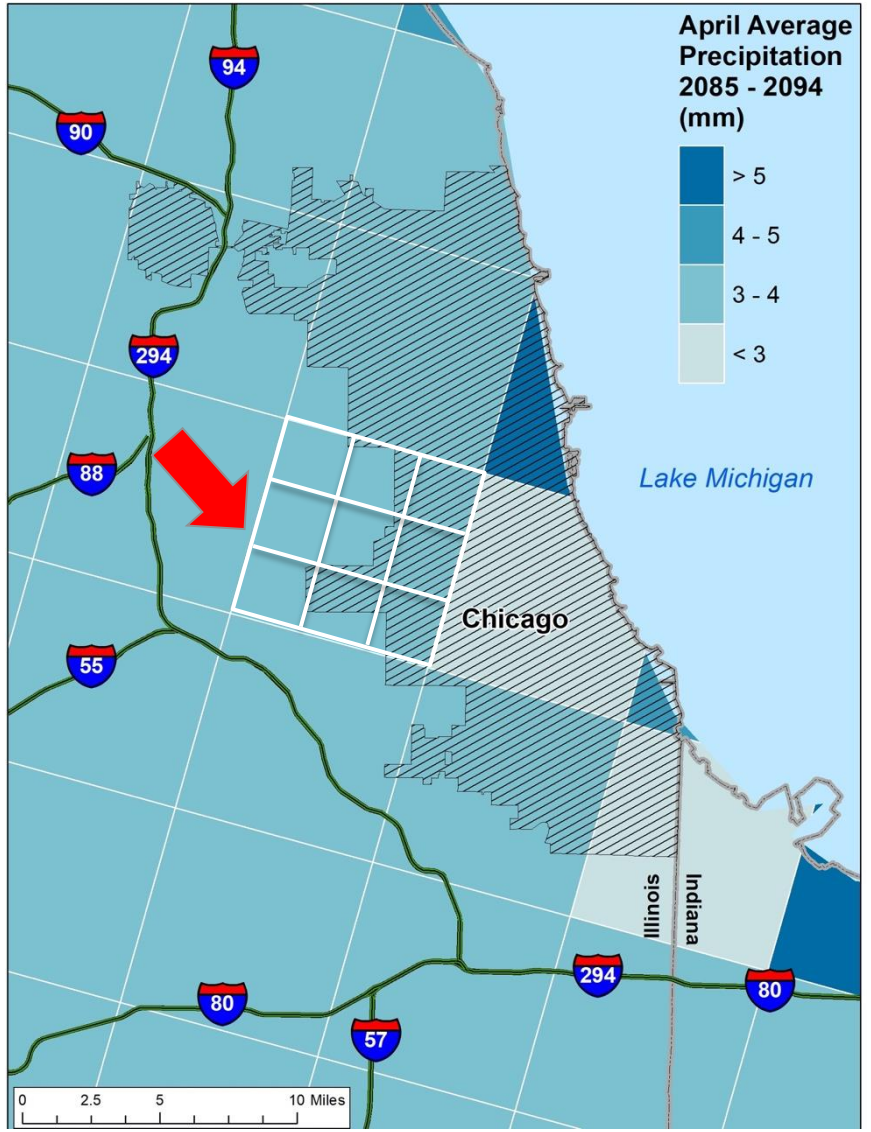
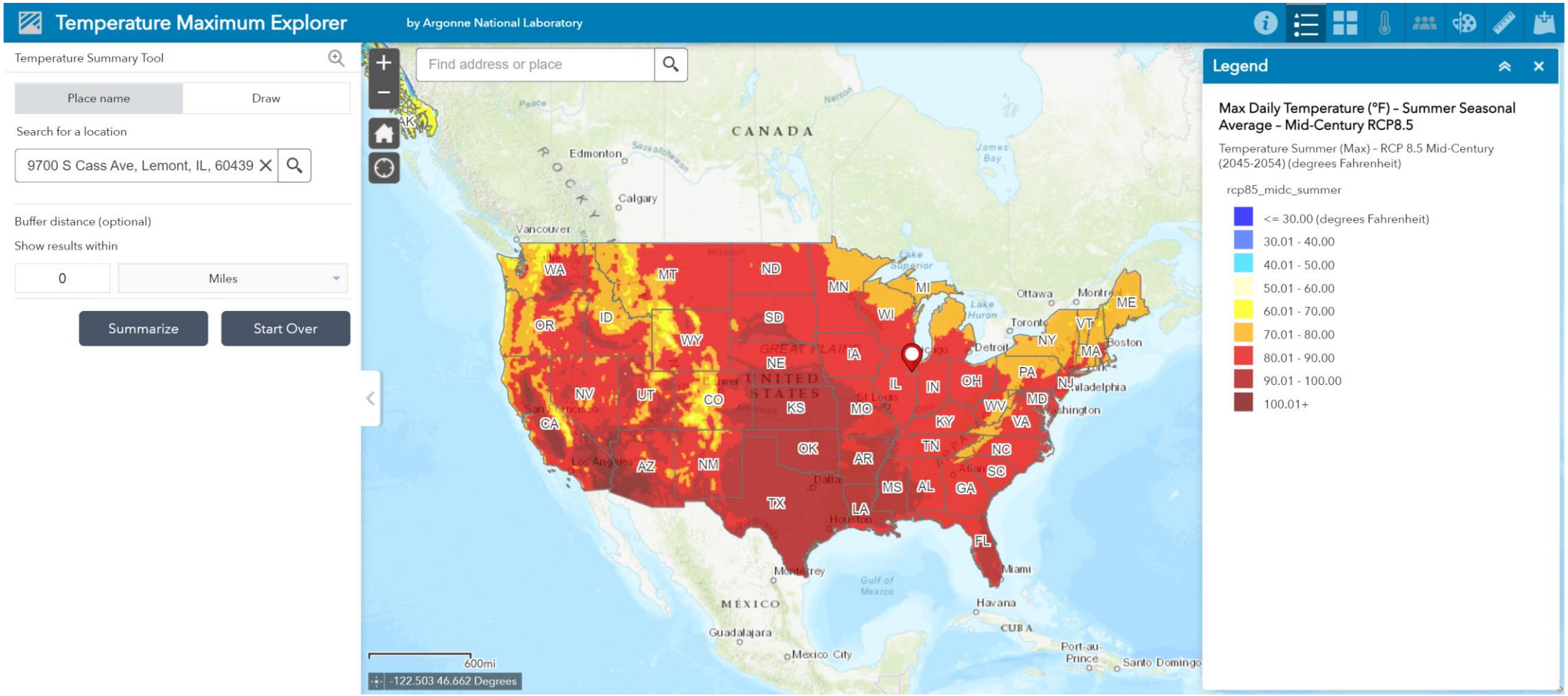


INFORMING DECISIONS

Climate Risk and Resilience Portal (ClimRR)

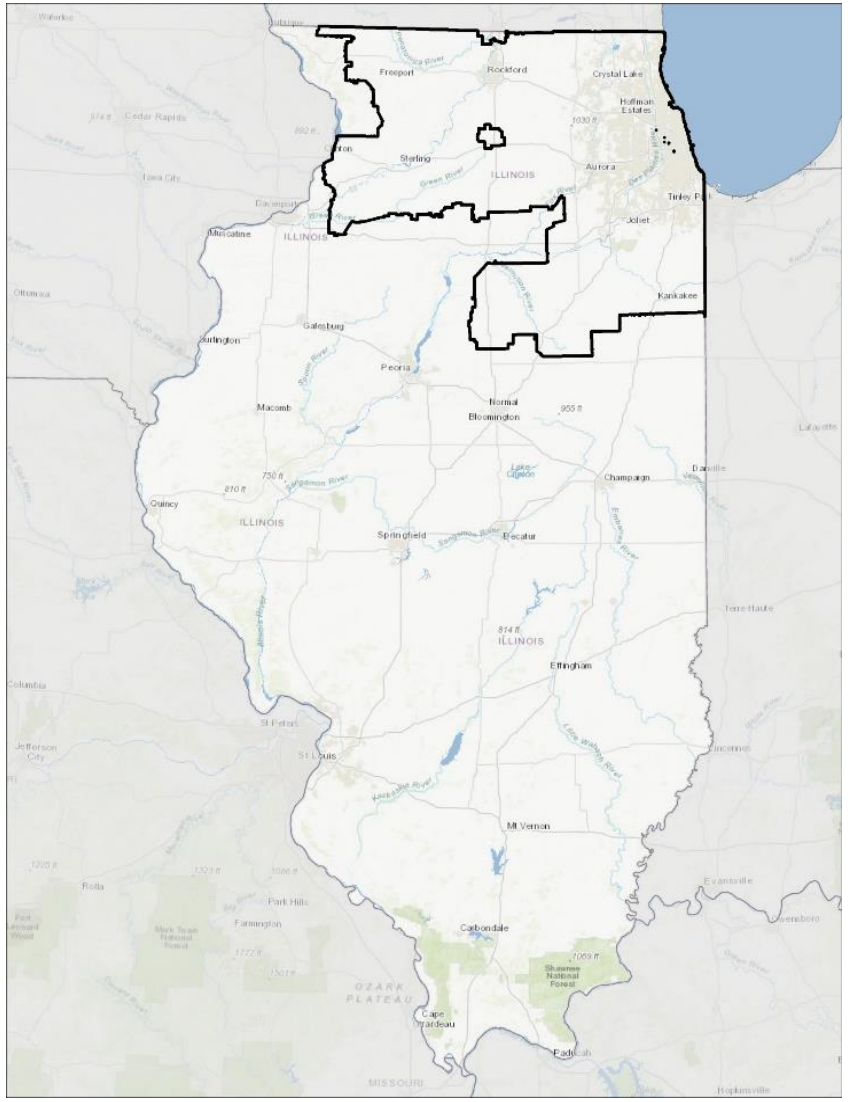


www.anl.gov/ccrds/climrr

SUMMARY OF NORTHERN ILLINOIS CLIMATE

Climate Change in Northern Illinois

- Focus on mid-century climate impacts (2045-2054)
- Emphasis on high-emission, RCP8.5 scenario
- Comparison with historical baseline (1995-2004)
- Northern Illinois mid-century climate:
  - Substantially warmer
  - More humid
  - Wind generally the same, some seasonal differences

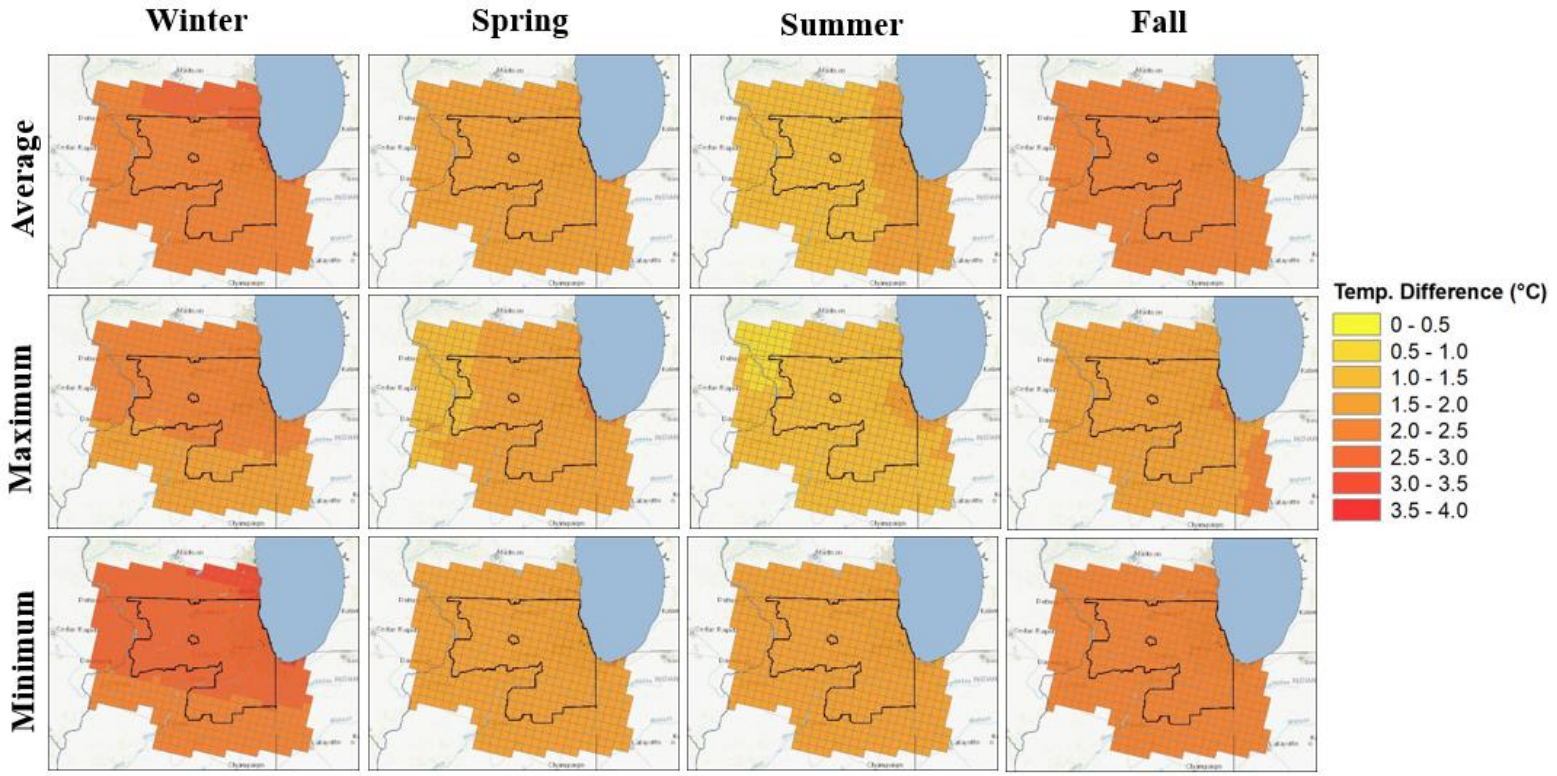


MID-CENTURY TEMPERATURES

Climate Change in Northern Illinois

- **Greater variability in seasonal temperatures, but all increase**
  - Greater increases in Winter and Fall
  - Lesser increases in Spring and Summer

- **Seasonal temperature** increases generally range between 0.5°C and 3.5°C (~0.9°F to 6.3°F)

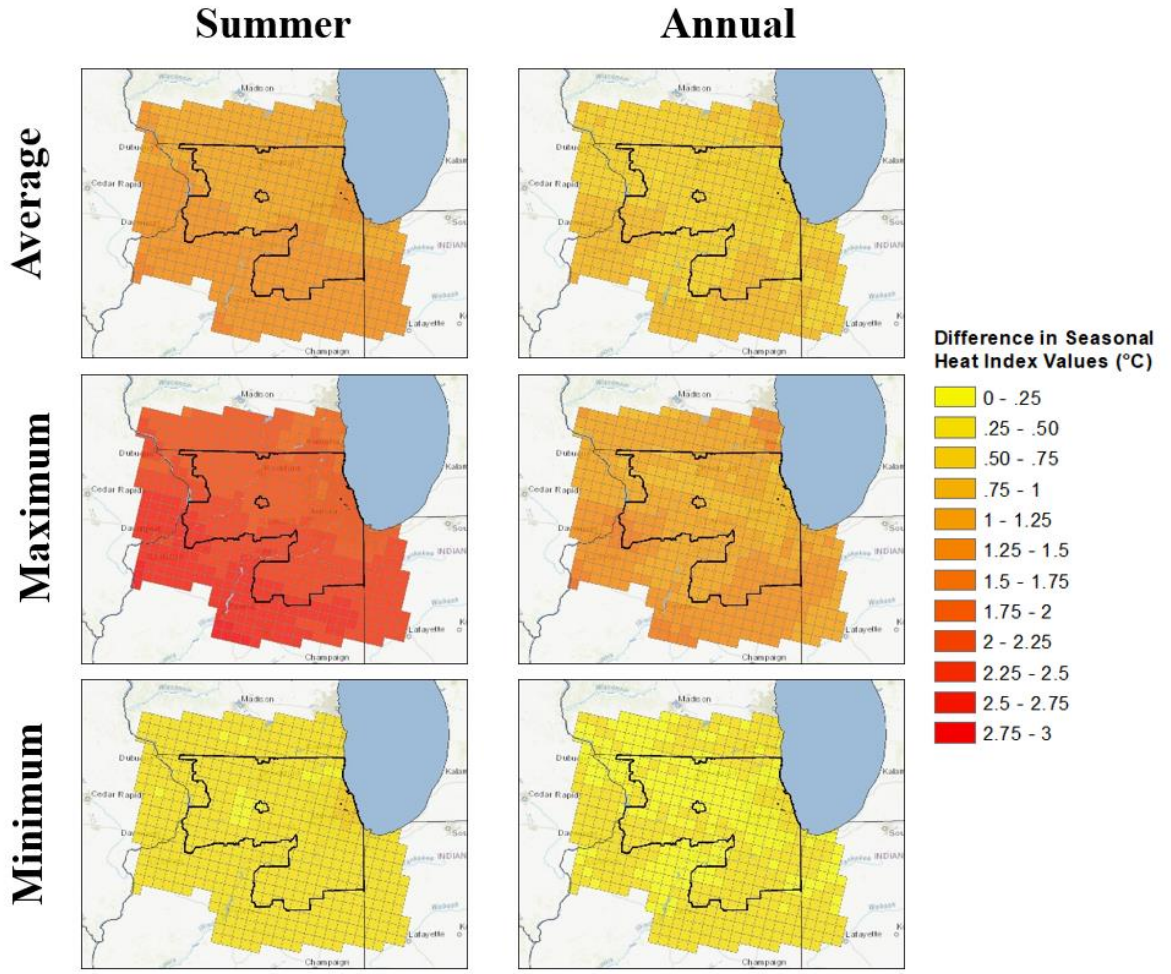


Change in seasonal average, minimum, and maximum temperatures from baseline period to mid-century.

MID-CENTURY HUMIDITY / HEAT INDEX

Climate Change in Northern Illinois

- Consistent increases in humidity (i.e., heat index) across entire service territory, slight trend of greater increases in southern region
- **Average Heat Index**
  - Annual increase of 0.25°C to 1°C
  - Summer increase of 0.5°C to 1.25°C
- **Maximum Heat Index**
  - Annual increase up to 1.25°C
  - Summer increase up to 1.25°C to 2.5°C
- **Minimum Heat Index**
  - Annual increase 0.25°C or stay same
  - Summer increase 0.25°C or stay same

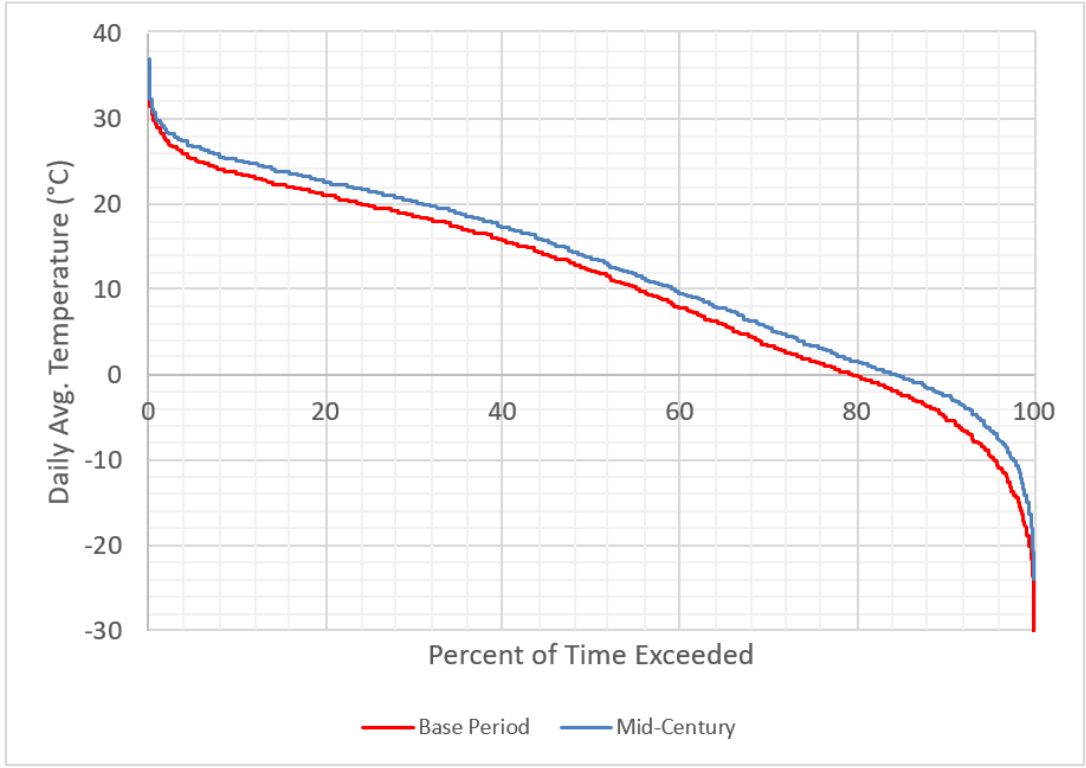


Change in the summer and annual average, maximum, and minimum heat index from the baseline to mid-century periods.

TEMPERATURES ABOVE THRESHOLD

Modeling Utility-Relevant Climate Impacts

- Consistent increase in the frequency by which **daily average** temperature thresholds are exceeded
- Baseline:
  - 30°C (86°F) exceeded 2 days/year
  - 35°C (95°F) exceeded ~1 days/decade
- Mid-century:
  - 30°C (86°F) exceeded 3 days/year
  - 35°C (95°F) exceeded ~4 days/decade



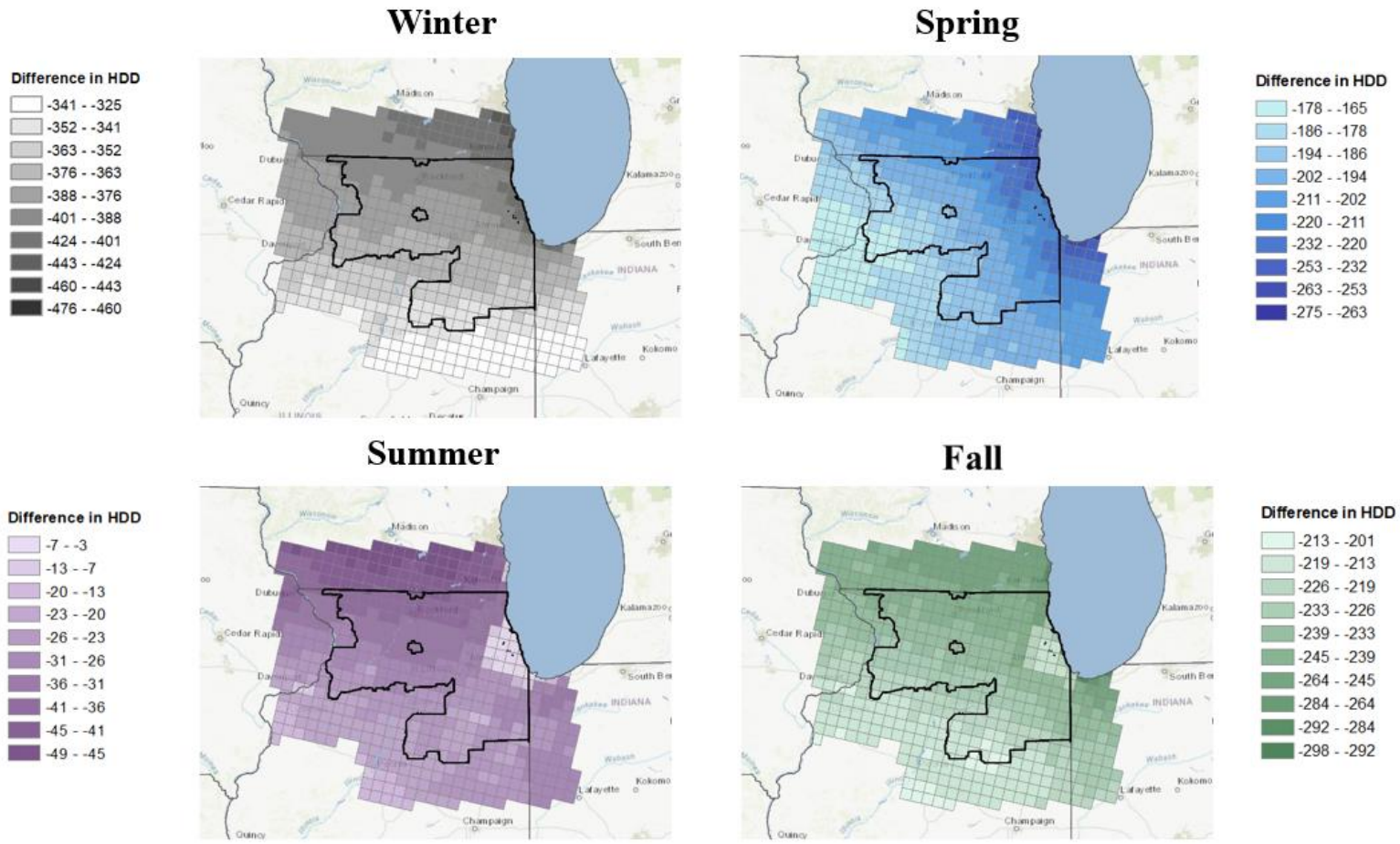
Daily Avg. Temp (°C)	Percent Time Exceeded		Days Exceeded Per Year	
	Base Period	Mid-Century	Base Period	Mid-Century
-30	99.98		365	
-25	99.92		365	
-20	99.51	99.82	363	364
-15	98.24	99.29	359	362
-10	95.44	97.68	348	357
-5	90.03	93.72	329	342
0	79.49	84.37	290	308
5	66.80	71.28	244	260
10	55.30	59.35	202	217
15	42.36	46.73	155	171
20	24.24	31.03	88	113
25	5.75	10.63	21	39
30	0.58	0.95	2	3
35	0.04	0.06	0.15	0.23
40				

Percentage of time (days/year) that daily average temperatures exceed a given threshold for the baseline and mid-century periods

HEATING DEGREE DAYS

Modeling Utility-Relevant Climate Impacts

- **Heating Degree Days** (HDD) calculated using 65°F base temperature
- Annual HDDs decrease between 761 to 1060 across service territory
- Greatest decreases in Fall and Winter
  - Winter: Decrease 341 to 476
  - Spring: Decrease 178 to 275
  - Summer: Decrease 3 to 49
  - Fall: Decrease 213 to 298

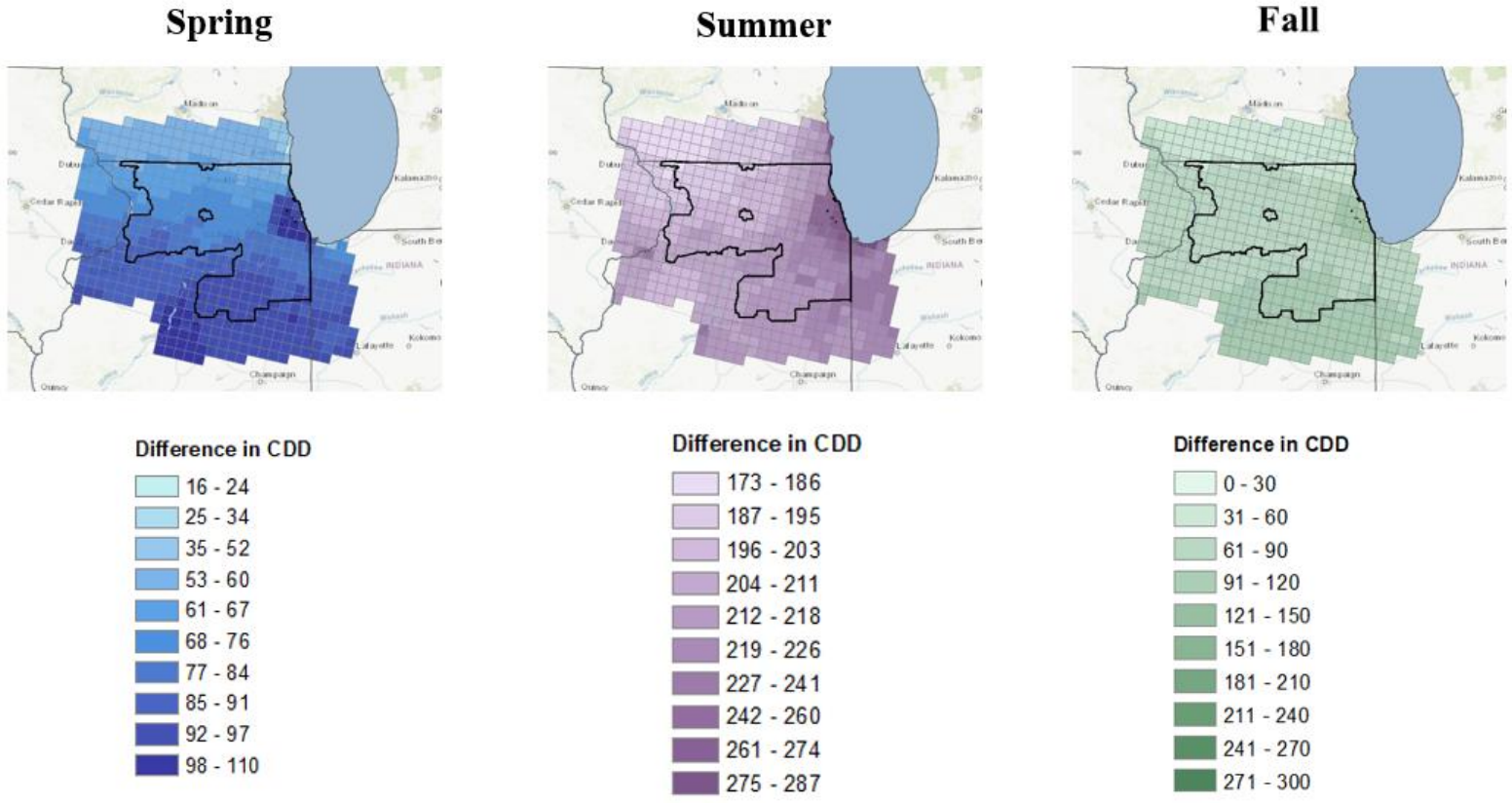


Change in the seasonal count of HDDs between the baseline and mid-century periods

COOLING DEGREE DAYS

Modeling Utility-Relevant Climate Impacts

- **Cooling Degree Days** (CDD) calculated using 65°F base temperature
- Annual CDDs increase between 258 to 399 across service territory
- Greatest increase in Summer and also Fall (Winter not calculated)
  - Spring: Increase 16 to 110
  - Summer: Increase 173 to 287
  - Fall: Increase 0 to 120

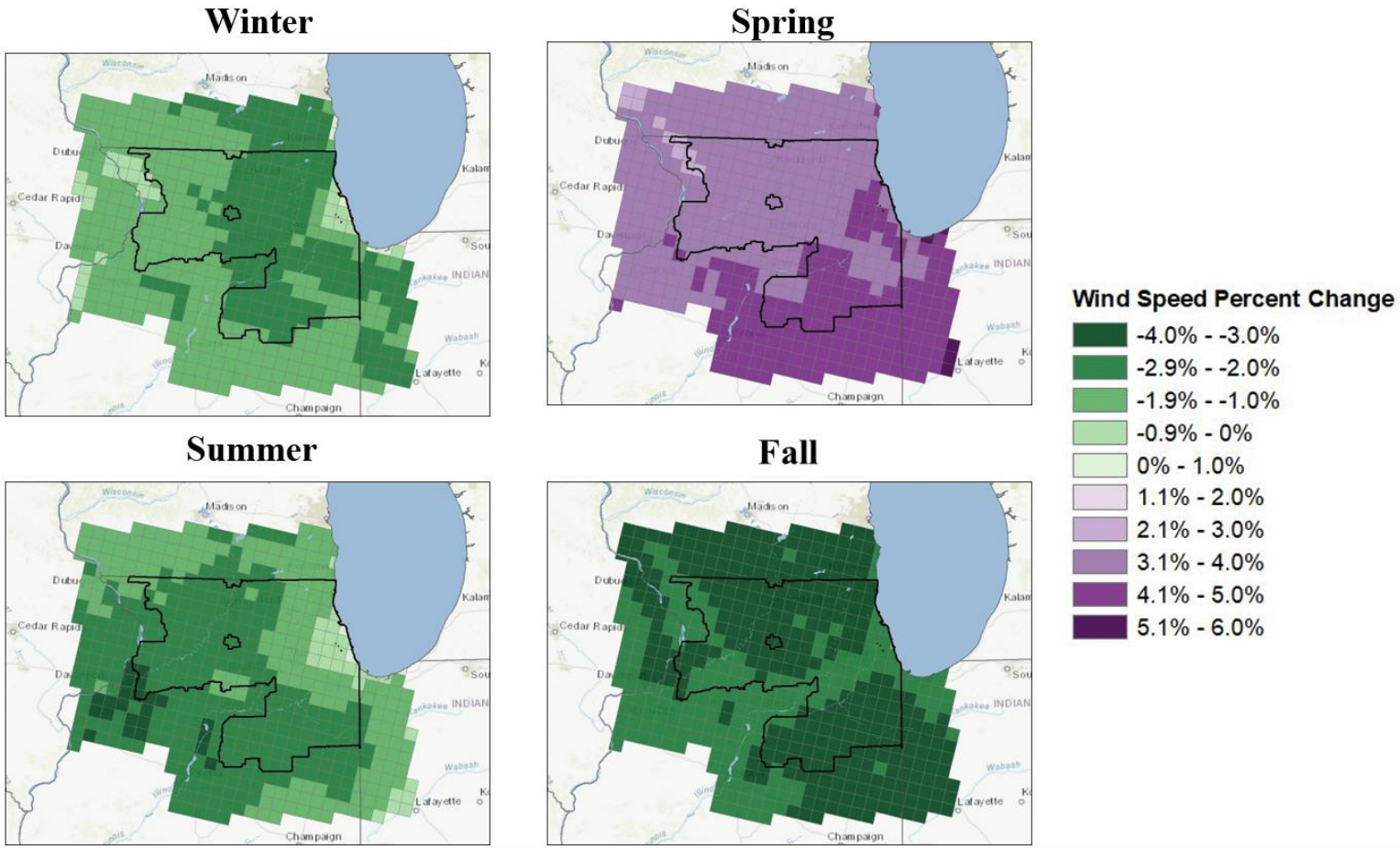


Change in the seasonal count of CDDs between the baseline and mid-century periods

MID-CENTURY WIND SPEEDS

Climate Change in Northern Illinois

- Change in annual average wind speed is negligible across service territory (-0.52%)
- Seasonal variation in maximum daily wind speed: decreases in Summer, Fall and Winter; increases in Spring.
- Across entire service territory, average wind speed changes
  - Winter: -1.51%
  - Summer: -1.90%
  - Fall: -2.96%
  - Spring: +3.95%



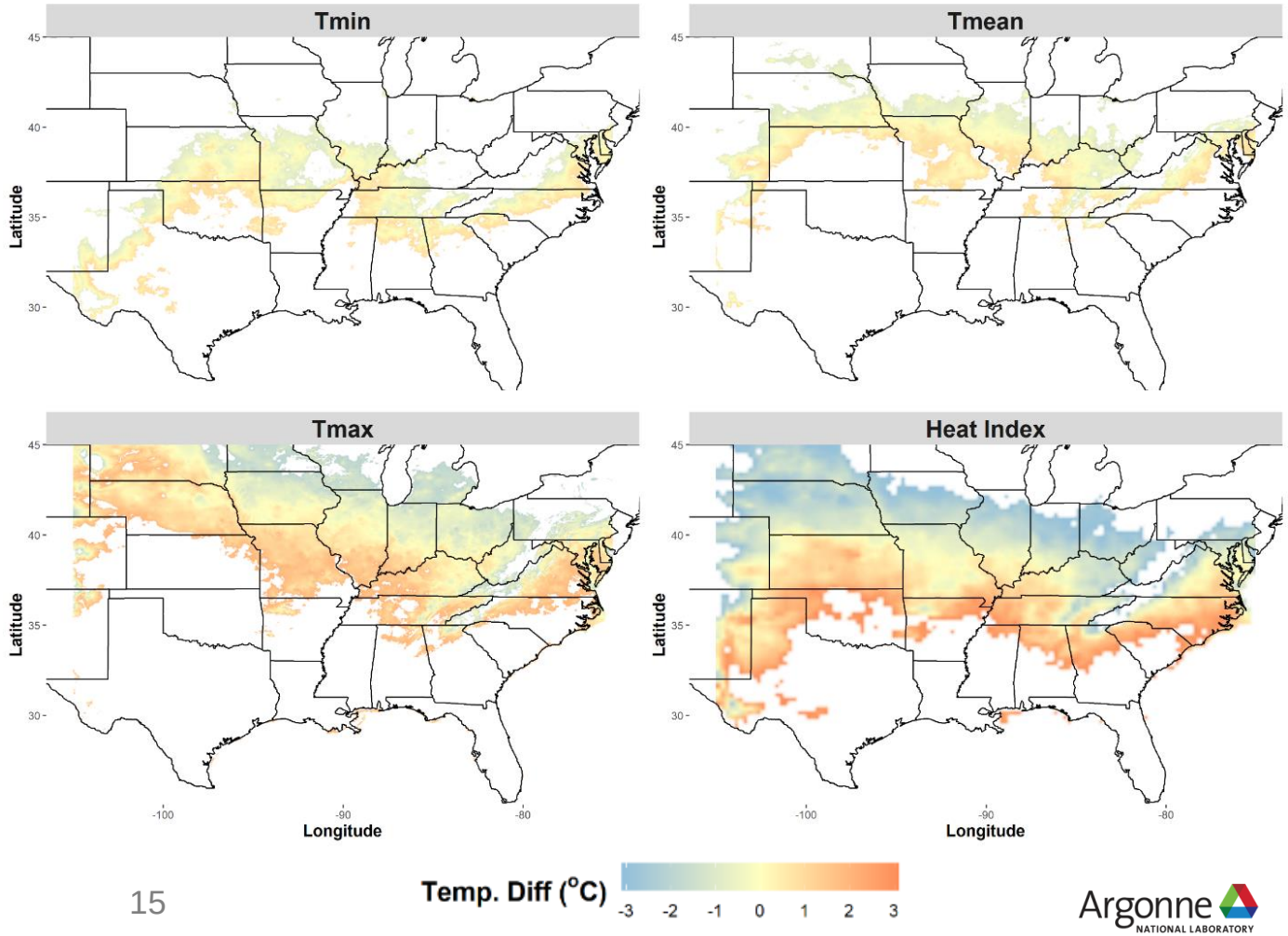
Percentage change in the seasonal averages of daily maximum wind speeds from baseline to mid-century.

REGIONAL ANALOG COMPARISON

Modeling Utility-Relevant Climate Impacts

- Climate analogs compare ComEd's **future** climate at mid-century with other regions that are **currently** experiencing similar climate today

- ComEd's future annual temperatures may feel like today's temperatures in…
  - **Min Temps**: Southern Illinois
  - **Avg Temps**: Springfield, IL
  - **Max Temps**: Champaign, IL
  - **Heat Index**: Central Missouri



QUESTIONS?

CCRDS@ANL.GOV

CENTER FOR
CLIMATE RESILIENCE AND DECISION SCIENCE
Argonne National Laboratory

SESSION 2

Learning from the past

Winter Preparedness

Anne-Marie Fournier (Hydro-Québec)

HYDRO-QUÉBEC

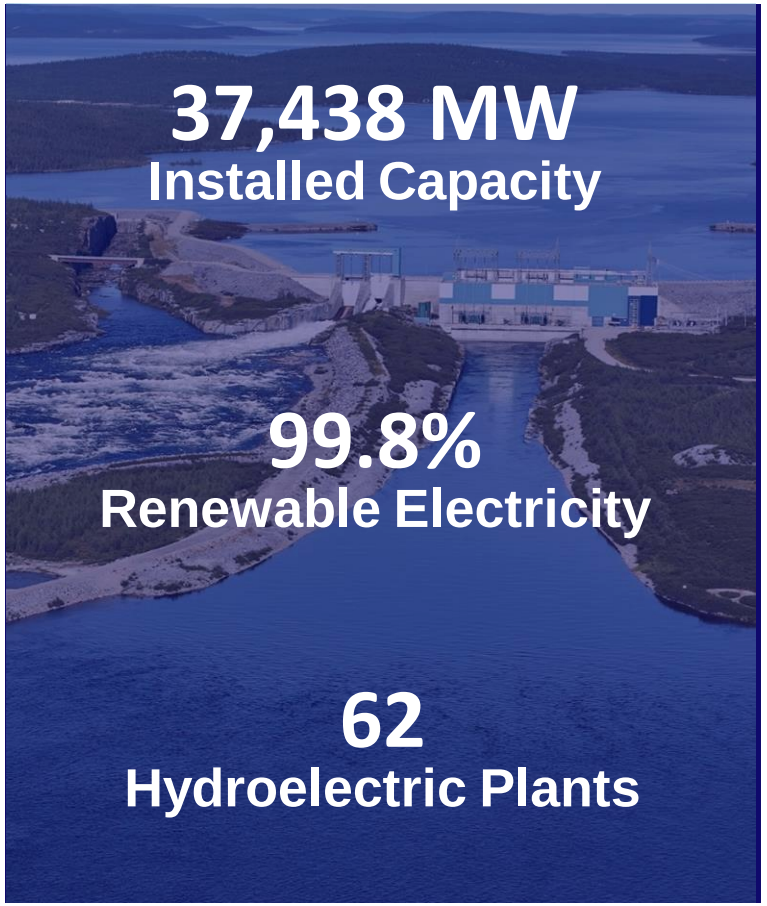
2023 Transmission Resilience Summit

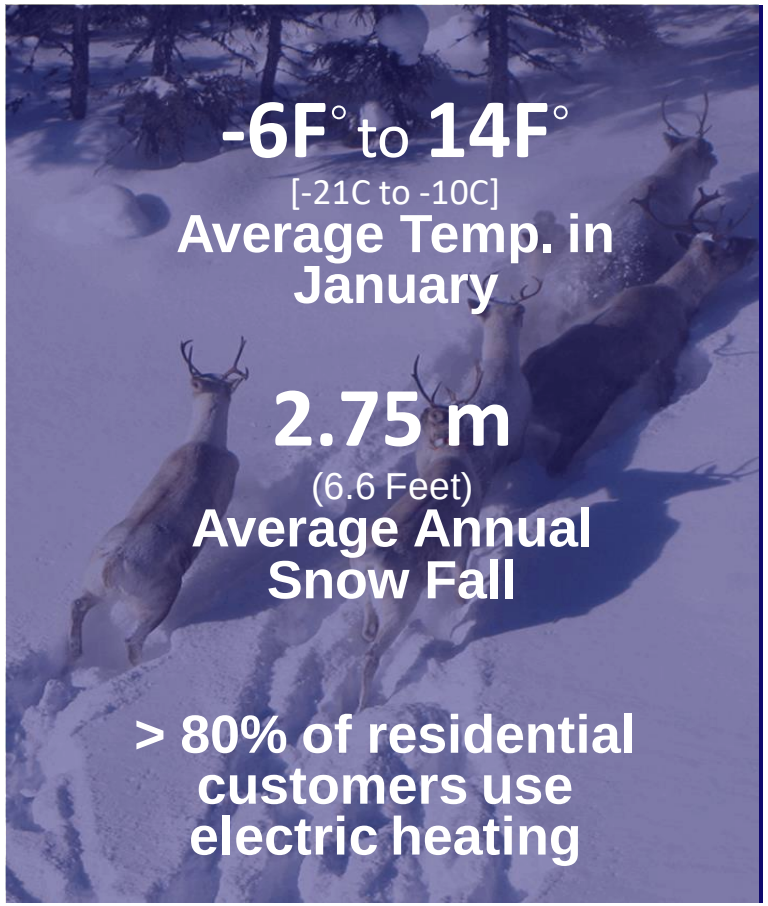
NATF- EPRI & NERC

MAY 17, 2023

Anne-Marie Fournier, M.Sc.
Senior Strategic Advisor, Regulatory Affairs
Reliability Coordinator - Hydro-Québec

Hydro-Québec at a glance

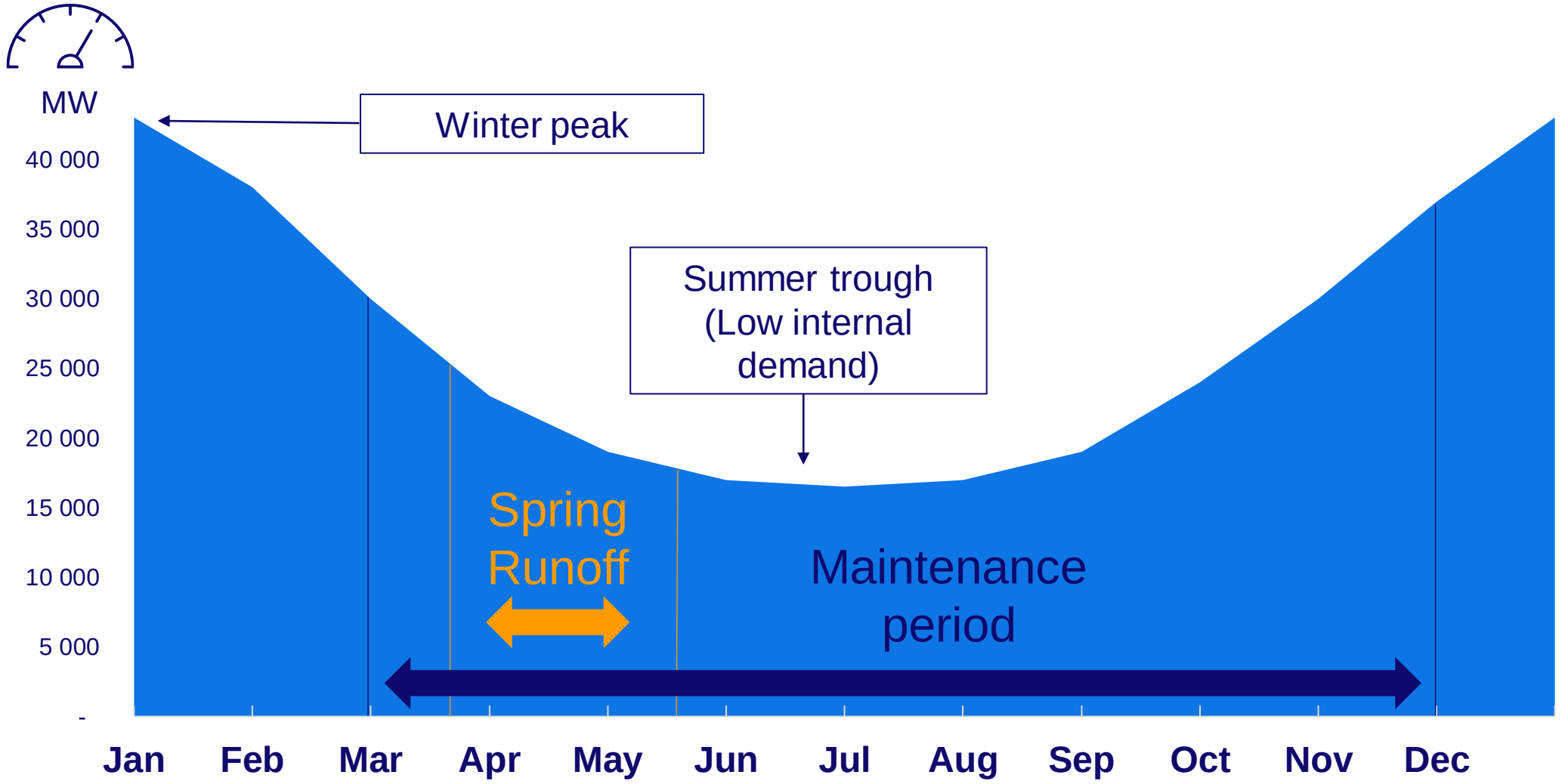




Normal Operating Conditions for Hydro-Québec

2023 NATF - ERPI & NERC RESILIENCE SUMMIT

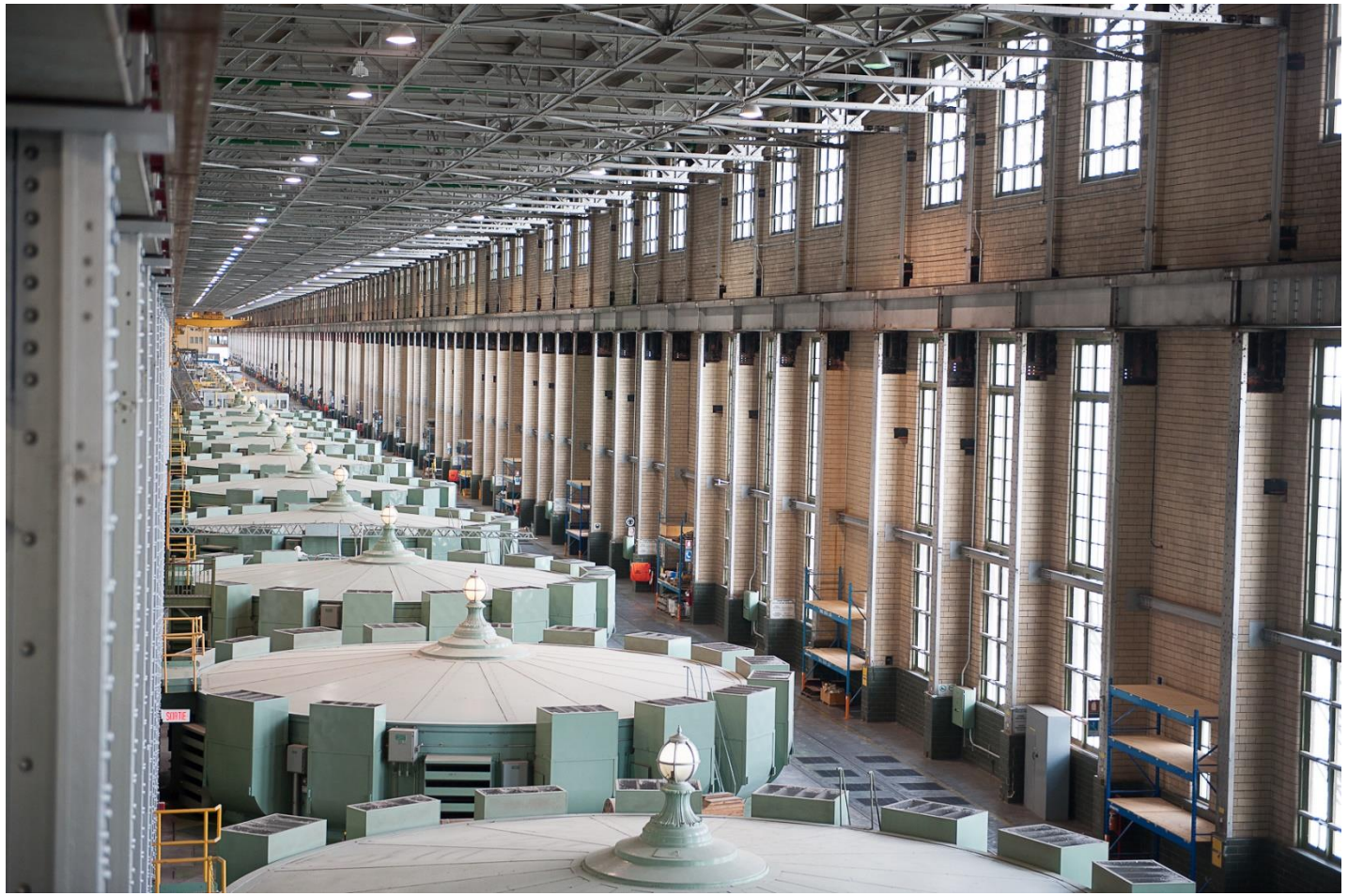
From Warm Summers to Extreme Cold Winters



Features of a Hydroelectric Generating Unit for a Winter Peaking Utility

Equipment design

- Generator units and controls are located indoors
- Auxiliary heating is available in case spinning generators do not provide enough heat
- Spillway gates are heated to keep equipment in good working condition during forced outages
- Dams and penstock are designed to withstand ice and freezing
- All equipment is designed to withstand temperatures as low as -40◦C (-40◦F)



Features of a Hydroelectric Reservoir for a Winter Peaking Utility

Water and ice cover management

- Reservoir levels are at full capacity to maximise available power for winter peak
- Management of ice cover to prevent frazil ice formation on turbines

Winter Preparation at Hydro-Québec

Maintenance (transmission, distribution, generation, IT)
Monthly preparation meetings: cross-functionnal team

May
- Retrospective analysis of previous winter peak period
- Lessons learned and recommendations

July
- Peak forecast update
- Internal resources availability Update

August
- Formal identification of capacity resources available to meet internal demand

September
- Resource adequacy update (all available peak resources & firm exports)
- Peak simulation with several scenarios

October
- Interruptible load subscription
- List of unavailable equipment
- Tests on condensers, de-icer and other equipment

November
- Operational documents updates
- Guidelines to operators
- MW impact of voltage reduction

December – March: Peak Period
- No planned outages
- Peak Monitoring, daily meetings
- Ice storm monitoring
- Call for additional capacity, if needed
- Load-managing resources, if needed

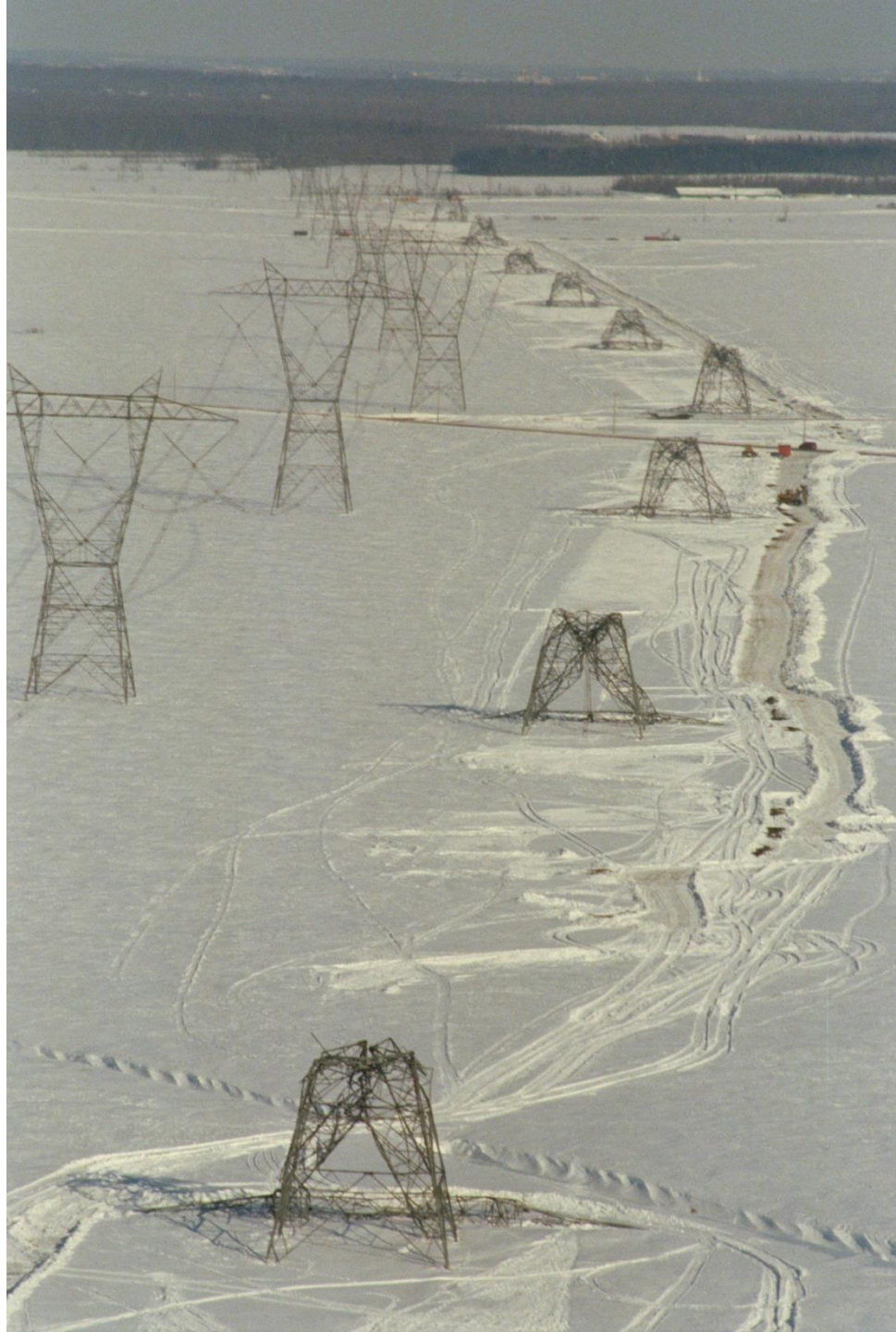
Learning from the previous experiences

The peak retrospective analysis contains:

- Summary of grid condition at peak demand
- Recommendations for next peak season

Example of improvements brought from previous experiences:

- Ice storm monitoring
- Anti-cascading electric tower
- De-icer on strategic transmission lines
- Addition of new lines for reinforcement



What is Climate Resilience for Hydro-Québec?

2023 NATF - EPRI & NERC RESILIENCE SUMMIT

Global warming means warmer winters

More Ice Storms Expected

1998 Ice Storm – Emergency State in the South of Québec

900 steel transmission towers collapsed under 3 inches of freezing rain

December 2022 – Islanding of the Churchill Falls Plant (5000 MW) and Line Damages

Broken conductor wires

Damaged ground wire support

April 2023 – 1,1 M customers without power for up to 6 days in the Montréal area

Distribution network severly damaged

Thank you!

For questions, please email
Fiabilite@hydroquebec.com

Hurricane Preparedness

Mike Warr (FPL)

Wildfire Mitigation

Brian Kelley (APS)

Andrew Deemer (APS)

APS Fire Mitigation

Andrew Deemer – Fire Mitigation Meteorologist
&
Brian Kelley – Fire Mitigation Specialist

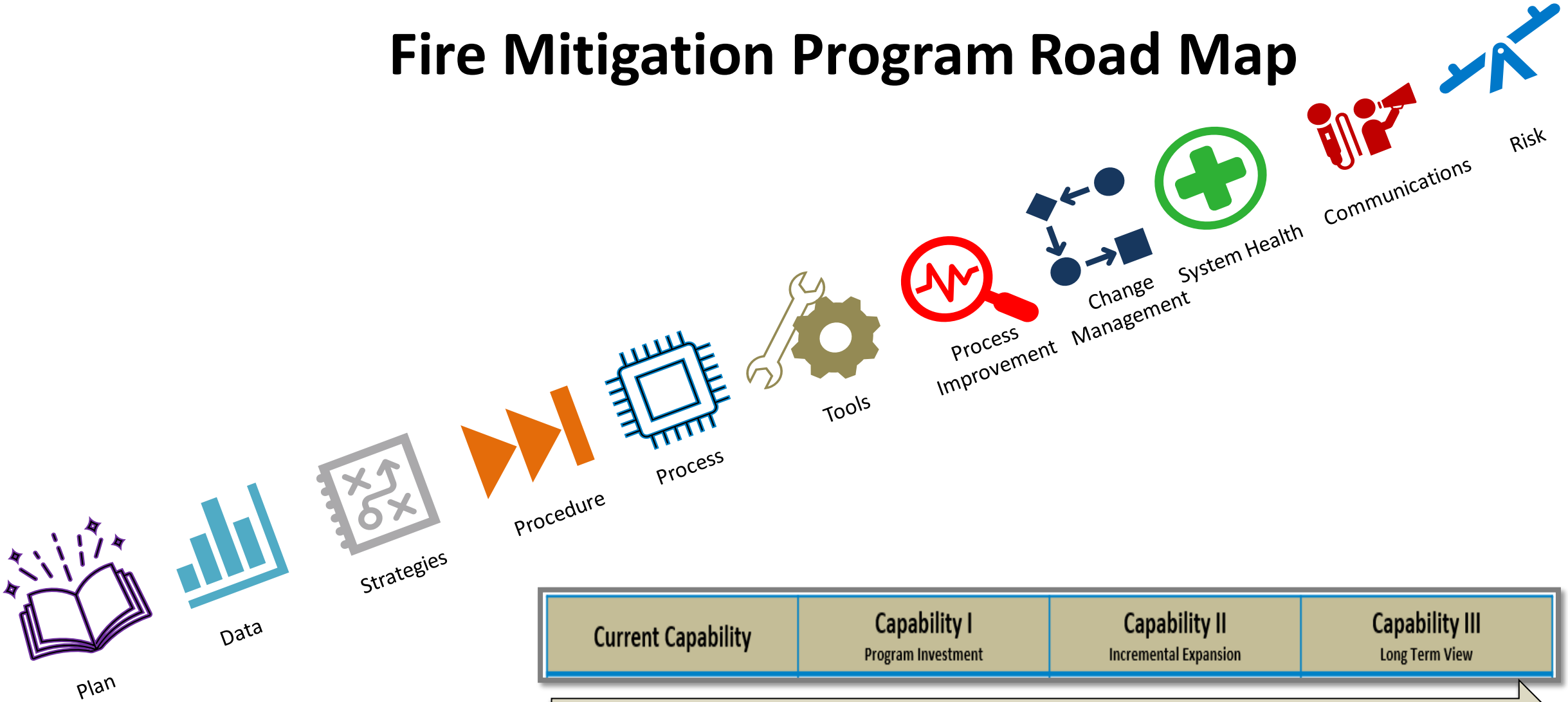
APS Comprehensive Fire Mitigation Plan

Prevention

Mitigation

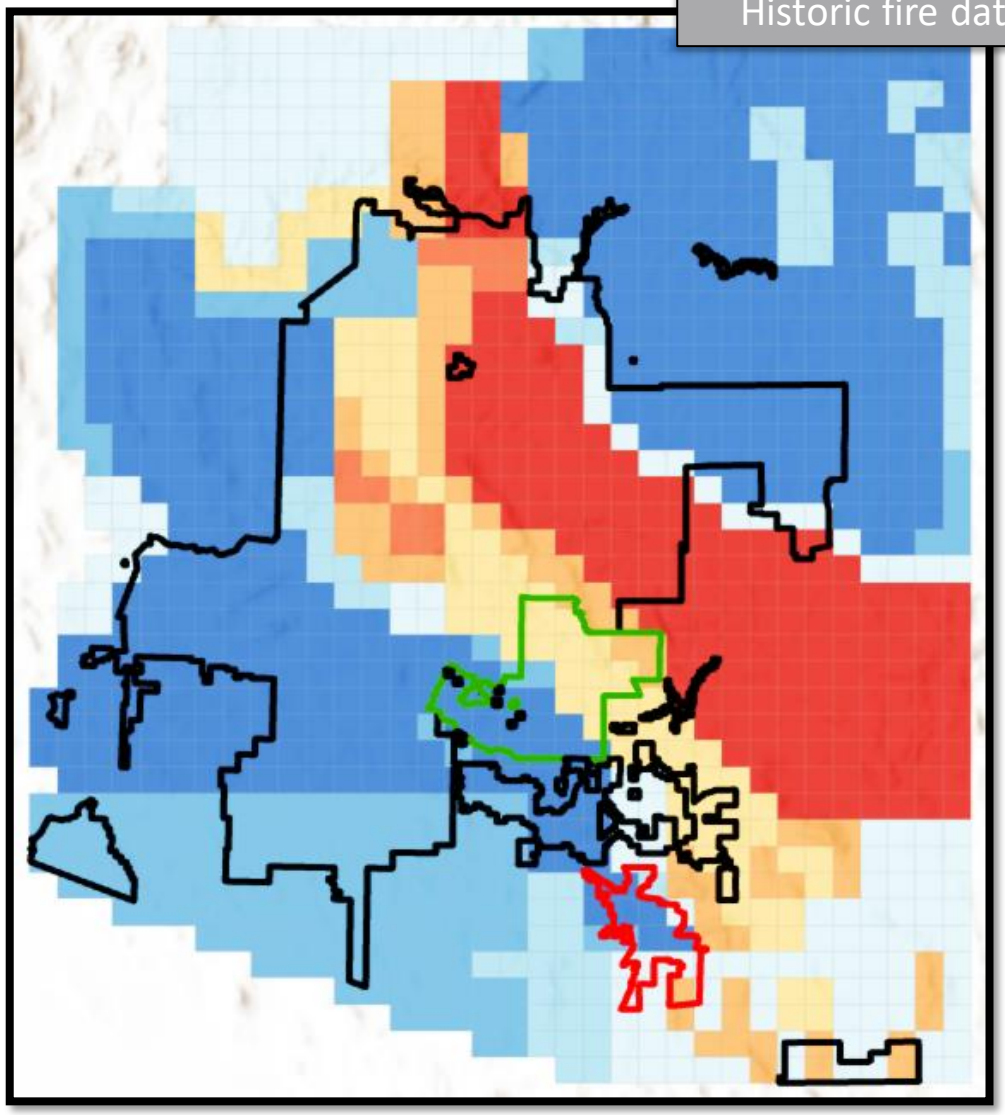
Response

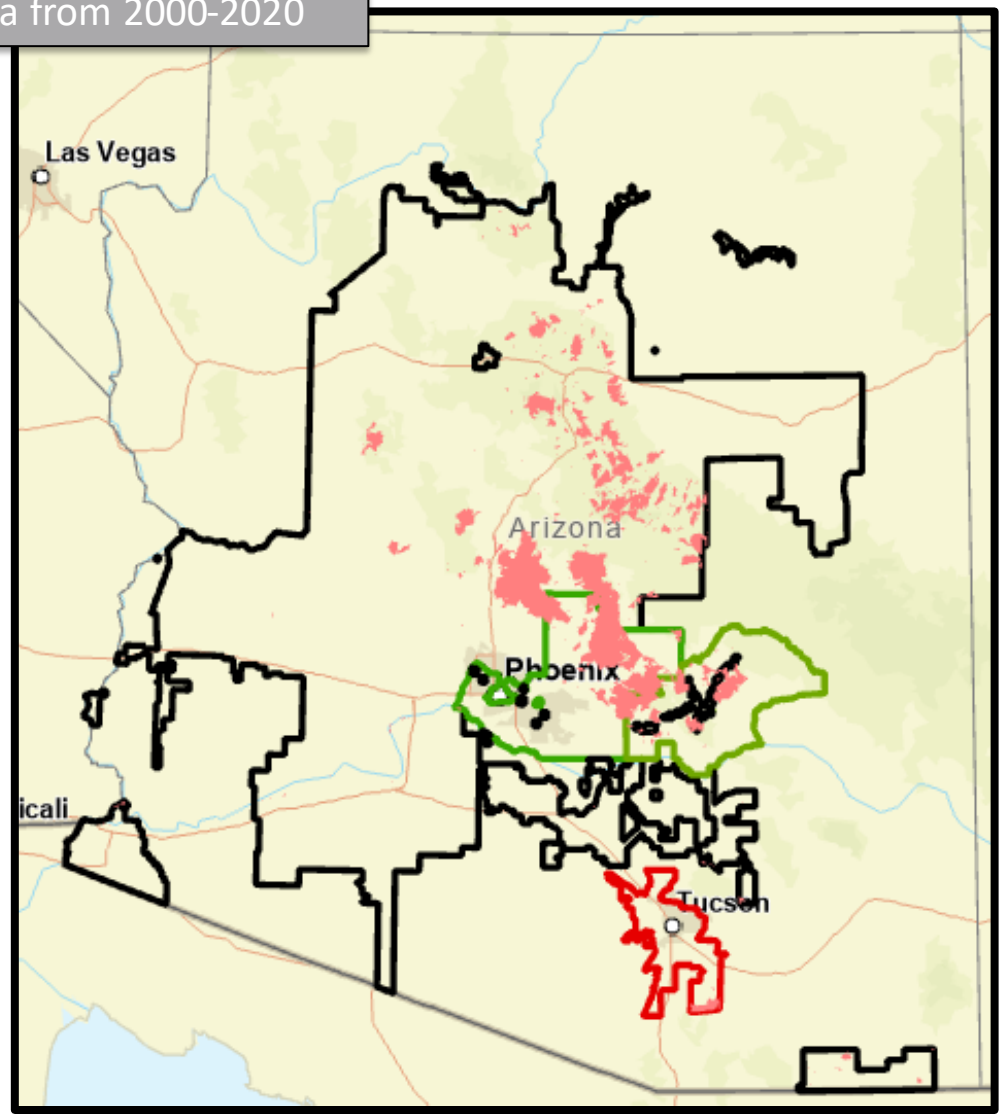
Fire Mitigation Program Road Map



Service Territory Wildfire Threat

Historic fire data from 2000-2020

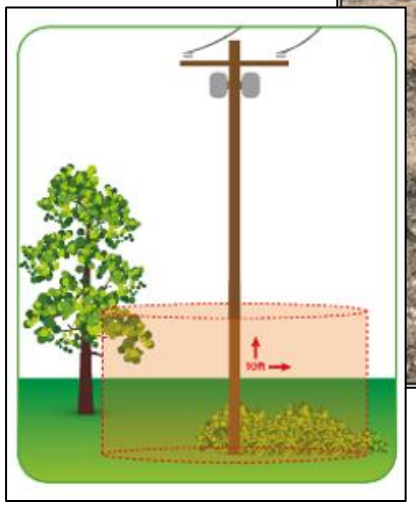




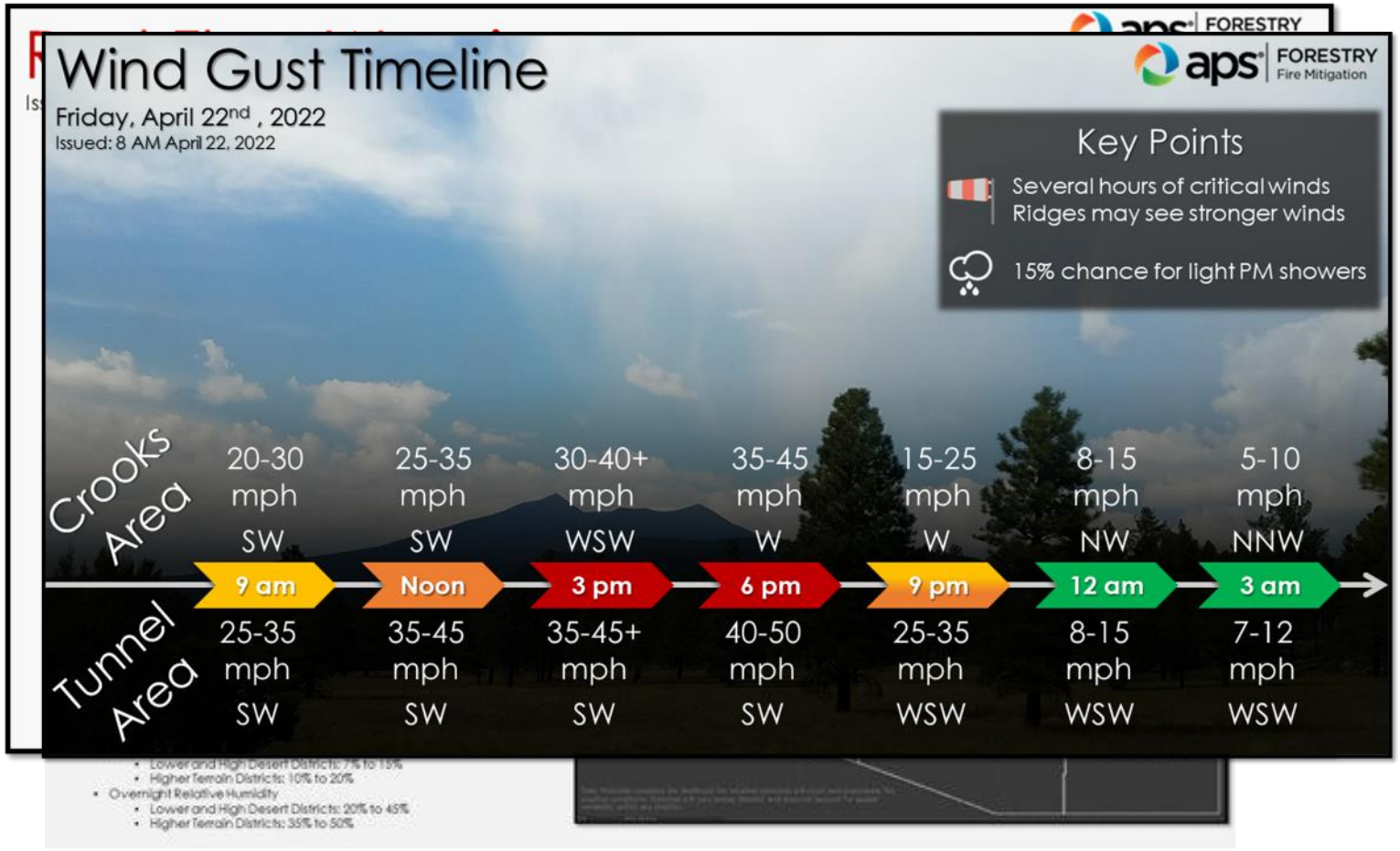
DSAP and Hazard Tree Programs

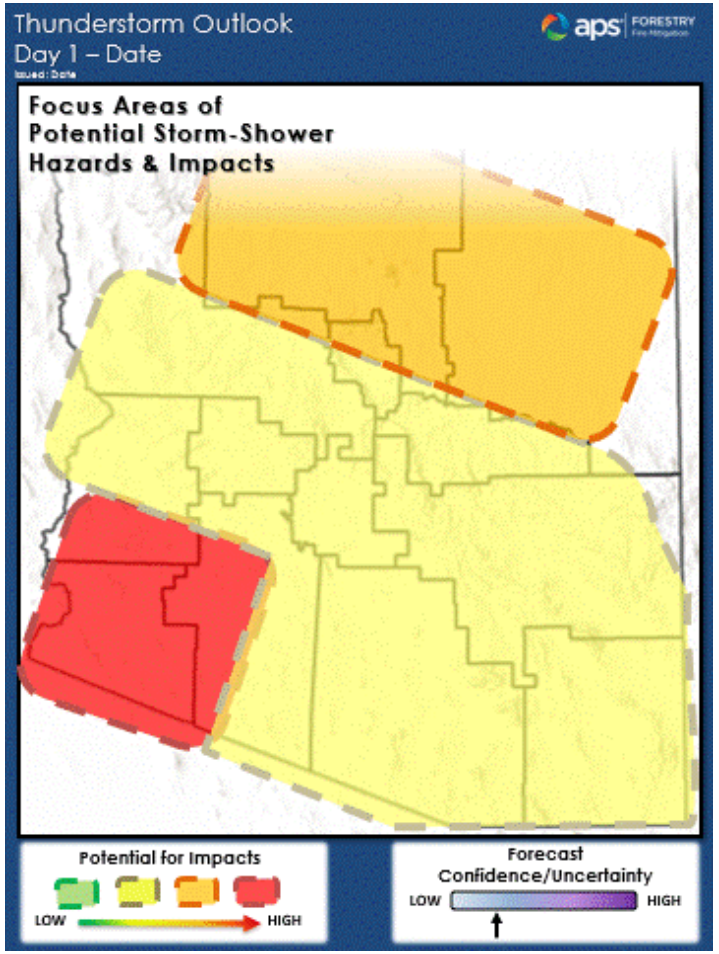
Purpose of the program to proactively create defensible space around poles to prevent wildfire ignitions.

Intent to clear all vegetation 10’ in all directions from equipment poles only.

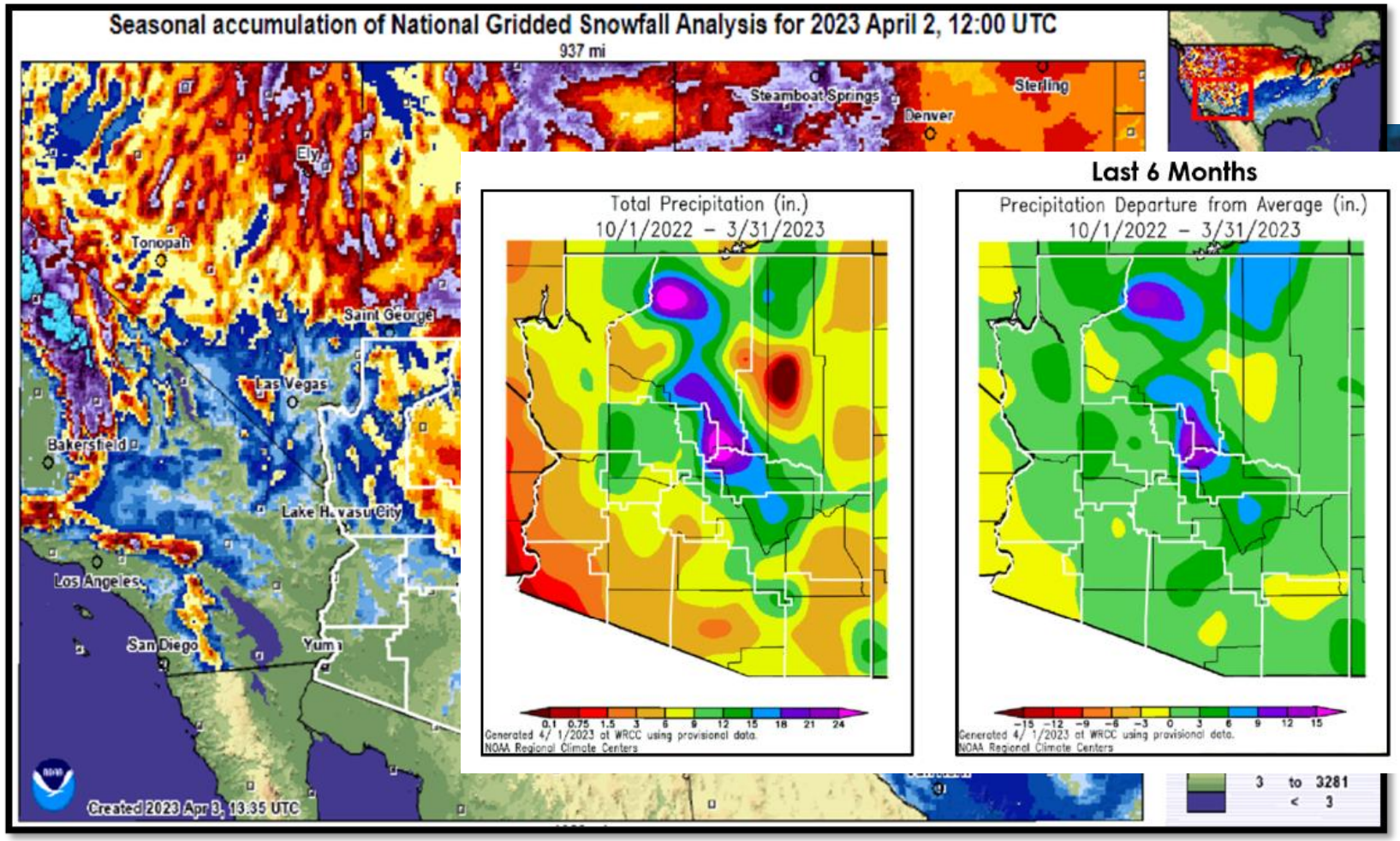


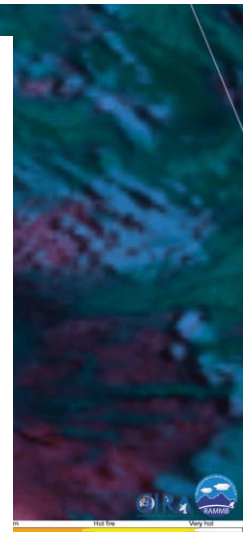
Fire Mitigation Meteorology





Fire Mitigation Meteorology





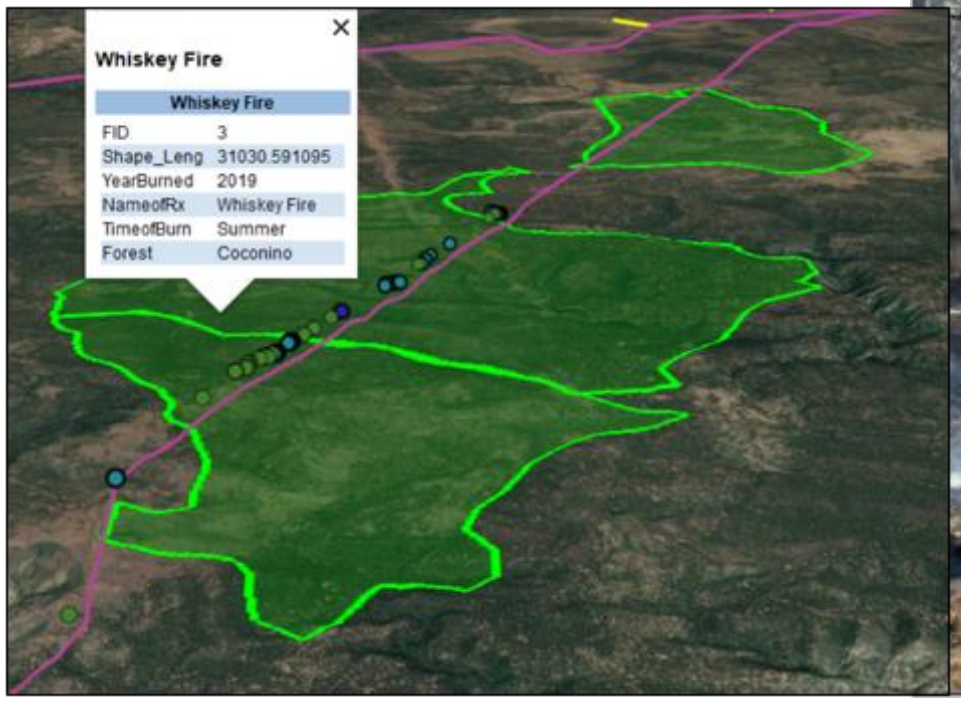
DSAP and HTP Impacts

Increased Wildfire size, severity, and frequency

Prescribed burn efforts

Hazard Tree recruitment

Fine fuel growth



The APS Promise

The APS Promise

Our Purpose
As Arizona stewards, we do what is right for the people and prosperity of our state.

Our Vision
Create a sustainable energy future for Arizona.

Our Mission
Serve our customers with clean, reliable and affordable energy.

Future Considerations

- Grid Hardening and Resiliency
- Remote Sensing
- Grid Modernization
- Advanced Grid Technology
- Fire Potential Modeling
- Stakeholder Engagement

SESSION 3

Planning for the future

DOE National Transmission Planning Study

Hamody Hindi (DOE)

Michael Kintner-Meyer (PNNL)

GRID DEPLOYMENT OFFICE

National Transmission Planning Study

U.S. Department of Energy

https://www.energy.gov/gdo/national-transmission-planning-study

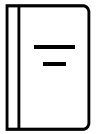
Hamody Hindi & Michael Kintner-Meyer

May 2023

Building a Better Grid Initiative

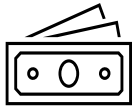
Engagement and collaboration

- States
- Tribal nations
- Stakeholders
- Federal Agencies
- ISO/RTOs
- EROs



Enhanced transmission planning

- Transmission Needs Study
- National Transmission Planning Study
- Atlantic Offshore Wind Transmission Study



Federal financing tools ($20+B)

- Transmission Facilitation Program ($2.5B)
- Smart Grid Investment Matching Grant Program ($3B)
- Grid resilience grants for states, Tribes, and utilities ($10+B)
- Loan guarantee programs
- Transmission Facility Financing ($2B)
- Siting of interstate Electricity Transmission Lines ($760M)

Transmission permitting process

- Streamline permitting with federal agencies
- Public private partnerships
- Designation of National Corridors

Transmission-related R&D

- "Next generation" electricity delivery technologies
- Supporting activities

2 One Stop Shop: [the DOE Grid and Transmission Programs Conductor]

What the Study is and is not doing

What the study will do

- Link several long-term and short-term power system models to test a number of transmission buildout scenarios
- Inform existing planning processes
- Test transmission options that lie outside current planning
- Provide a wide range of economic, reliability, and resilience indicators for each transmission scenario

What the study will not do

- Replace existing regional and utility planning processes
- Site individual transmission line routes
- Address the detailed environmental impacts of potential future transmission lines
- Provide results that are as granular as planning done by utilities
- Develop detailed plans of service

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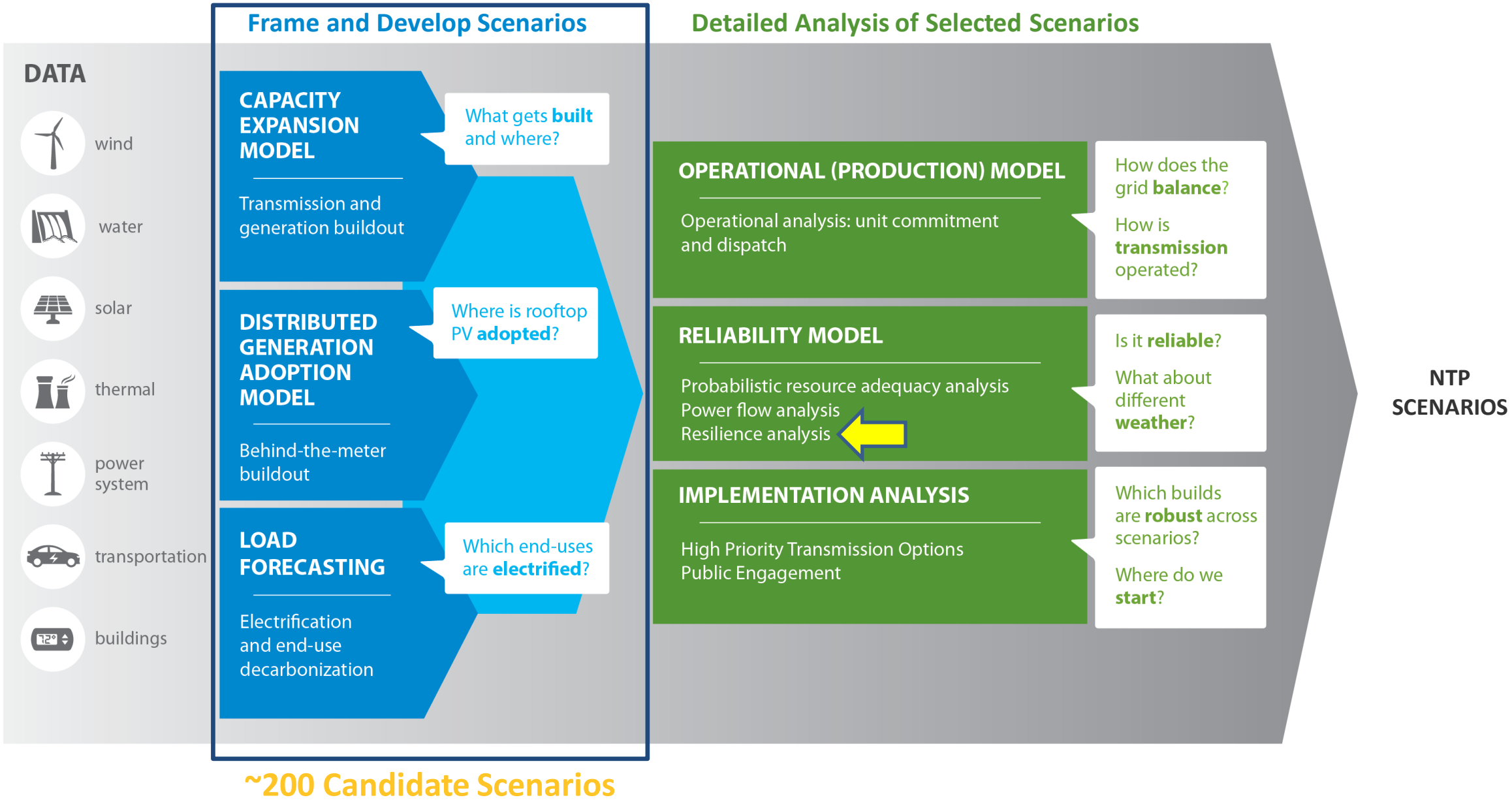
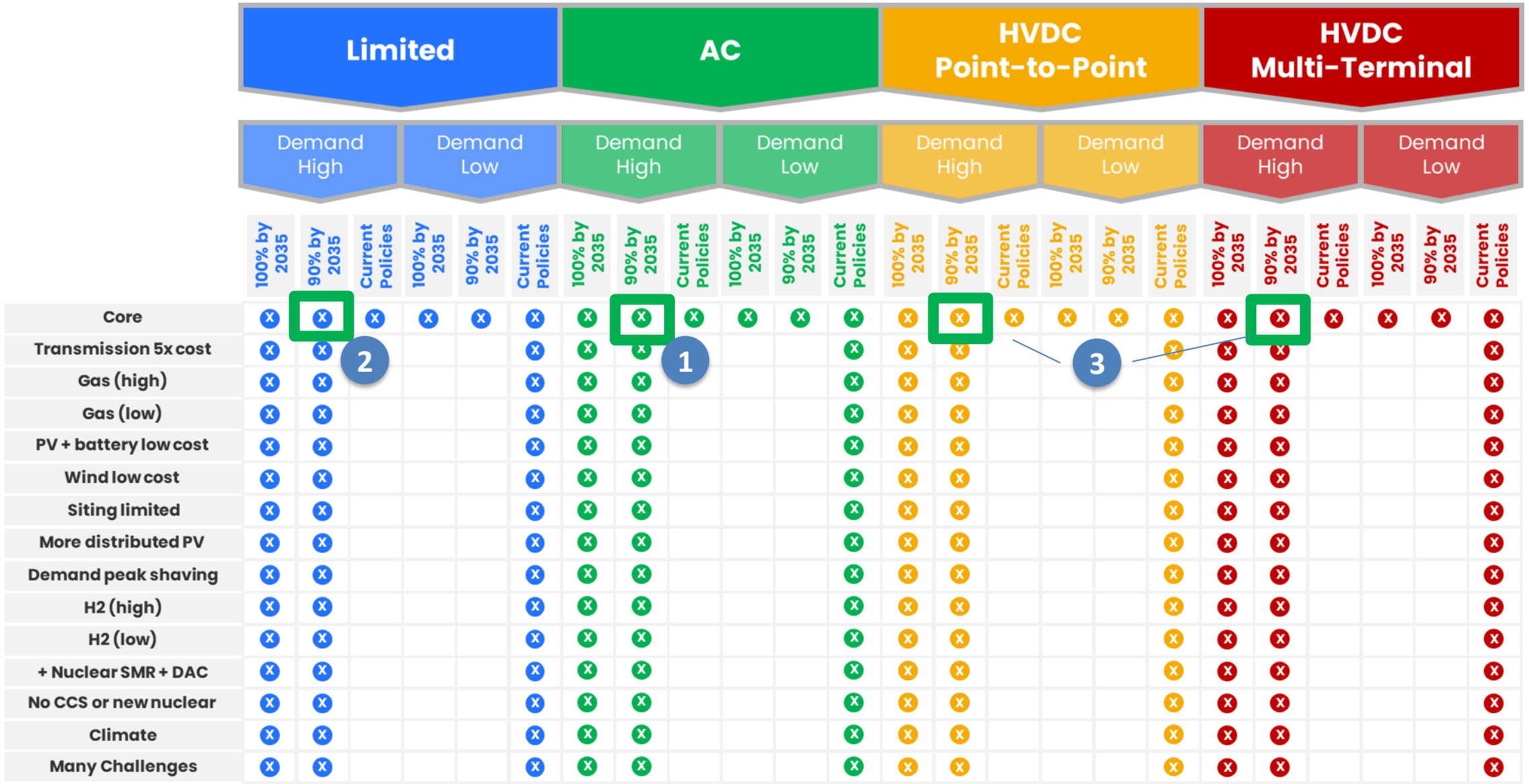
NTP Scenario Analysis Relies on Multiple Linked Modeling Exercises



Team will down-select from ~200 capacity expansion scenarios to 5-7 for translation to nodal

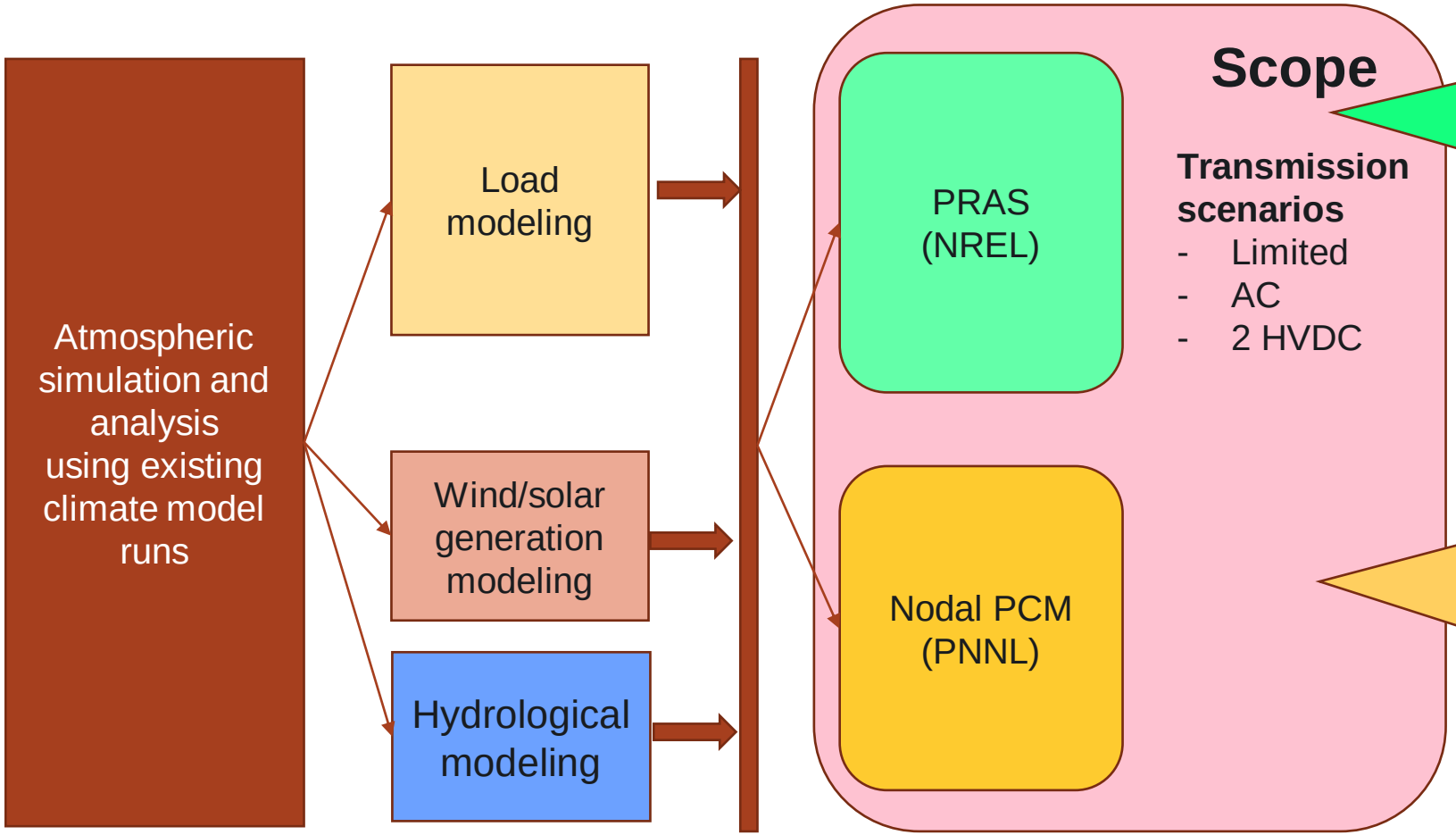


Scope of Stress Cases

- Heat wave impacts
  - Increased loads (buildings AC, additional hotel-loads in electric transportation)
  - Decreased supply
    - ✓ Air-breathing combustion turbines (capacity is density sensitive)
    - ✓ Based on atmospheric condition of stationary high-pressure zone -> decreased wind generation
  - Decreased transmission capabilities
    - ✓ Derated thermal capacity because of hot conductor
- Cold wave impacts
  - Increased loads (e.g., electrified space-heating in buildings, additional hotel-loads in electric transportation)
  - Potentially decreased supply (e.g., PV panels are snow covered; icing, air-density increase, and persistent high-pressure system may slow down wind turbines)
- Drought impacts
  - Decreased hydro-generation

Treatment of Stress Case (Climate)

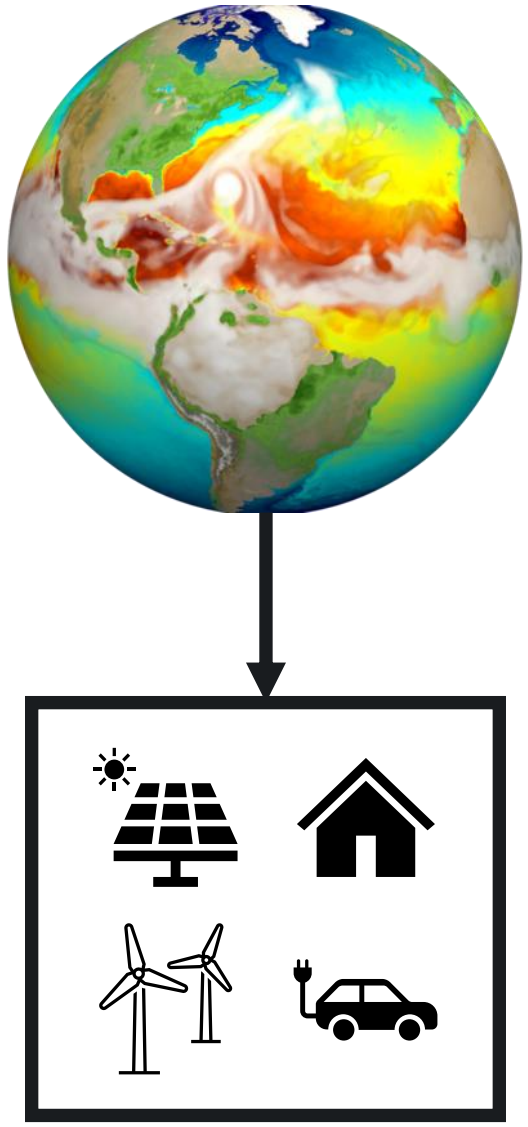
Engineering Analysis



Stress Types

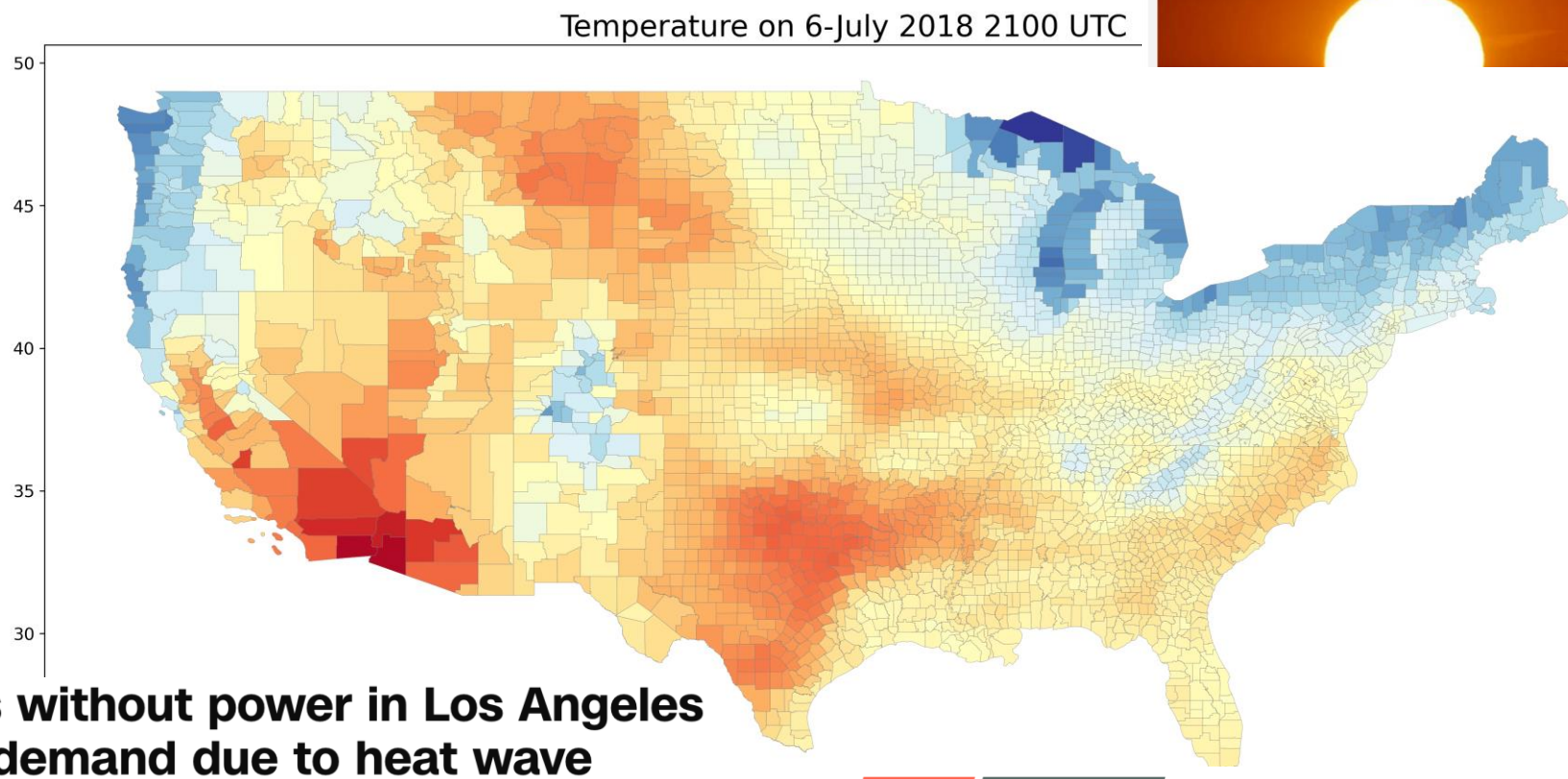
- Type I: Using future climate data and searching for time periods with the largest gaps between projected supply and demand.
  - *Example: Hours when renewable resources are suppressed and demand is unusually high.*
- Type II: Take an event that you know stressed the grid in the past and make it worse.
  - *Example: Studying specific heat wave events that we know will get longer and hotter under climate change.*

NREL's Approach: Type I Stressors



1. Start with one (for now) future climate model simulation:
   - *2050-2060, global, ~100 km grid, daily*
2. ML-based downscaling of future climate:
   - *2050-2060, U.S., 4 km grid, hourly*
3. Run the hourly weather data through NREL's load, solar, and wind models
4. Run the time series through a resource adequacy model and look for largest gaps between supply and demand
5. Pass time series for those periods (days to weeks) to PNNL team for PCM runs

PNNL's Approach: Type II Stressors



Records Broken as Heat Wave Bakes Southern California

• Edited By: Naqshib Nisar • Reuters • Last Updated: JULY 07, 2018, 12:56 IST

High temperatures will exceed 100 degrees Fahrenheit (37 Celsius) in Los Angeles and San Diego on Saturday, the National Weather Service said in a series of excessive heat warnings and advisories.

Thousands without power in Los Angeles after high demand due to heat wave

By Dakin Andone, CNN
Updated 8:19 PM EDT, Sat July 7, 2018

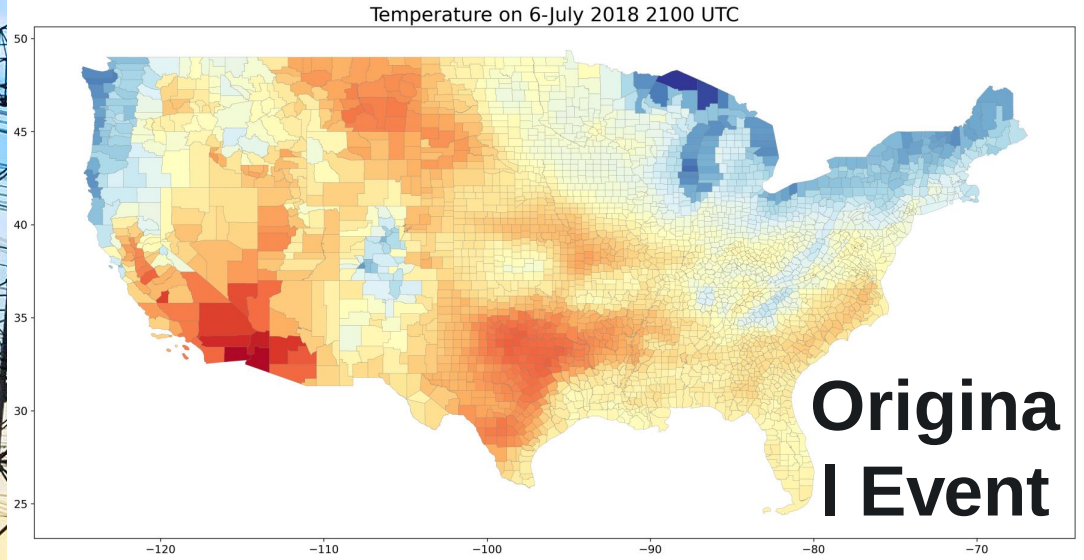
LOS ANGELES | LOS ANGELES WEATHER

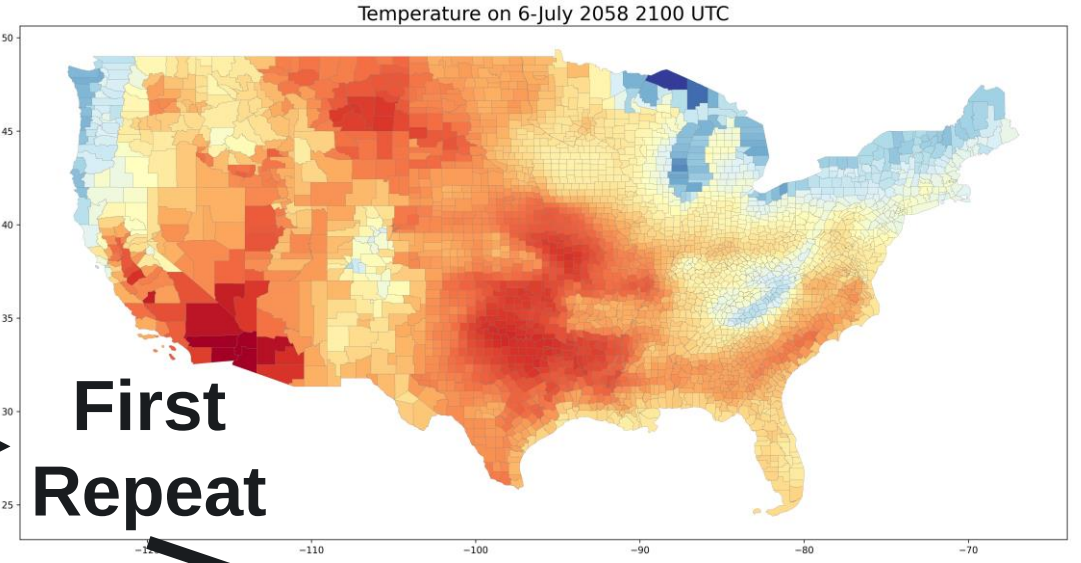
'Unprecedented' heat wave sets new records

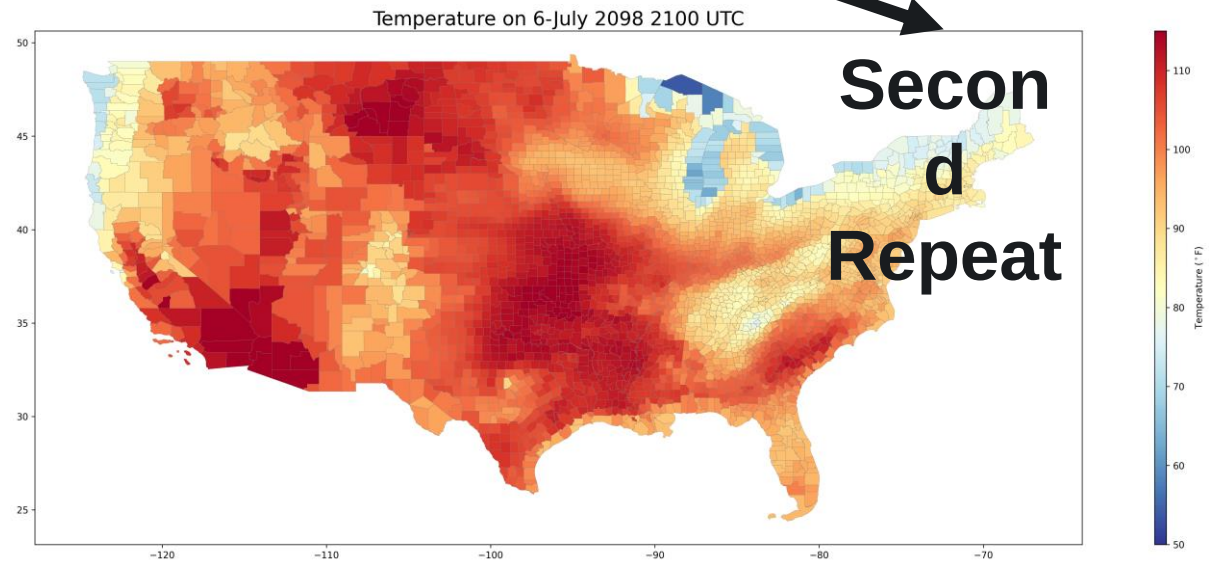
Fire danger is high

By Elijah Chiland | Updated Jul 6, 2018, 5:43pm PDT | 30 comments

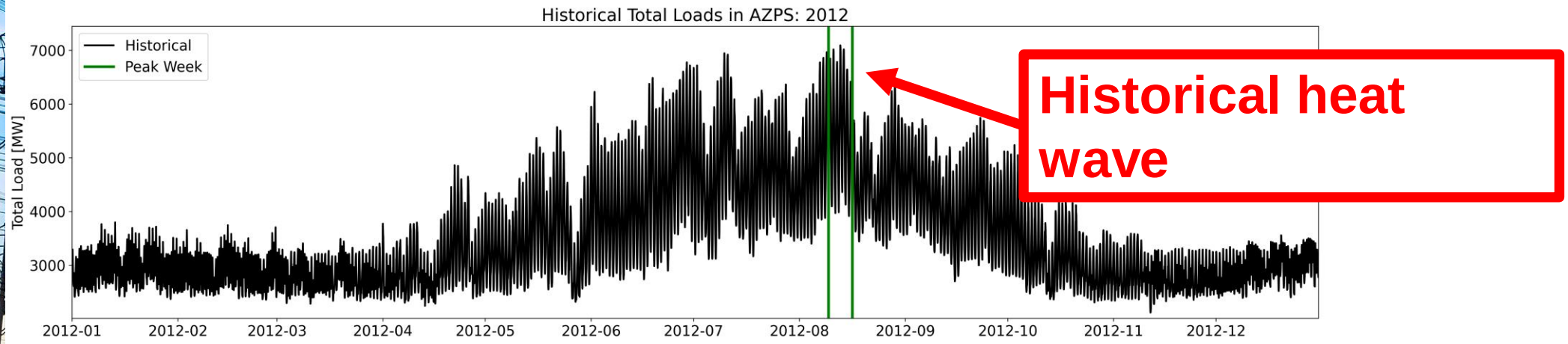
PNNL's Climate Forcing Dataset



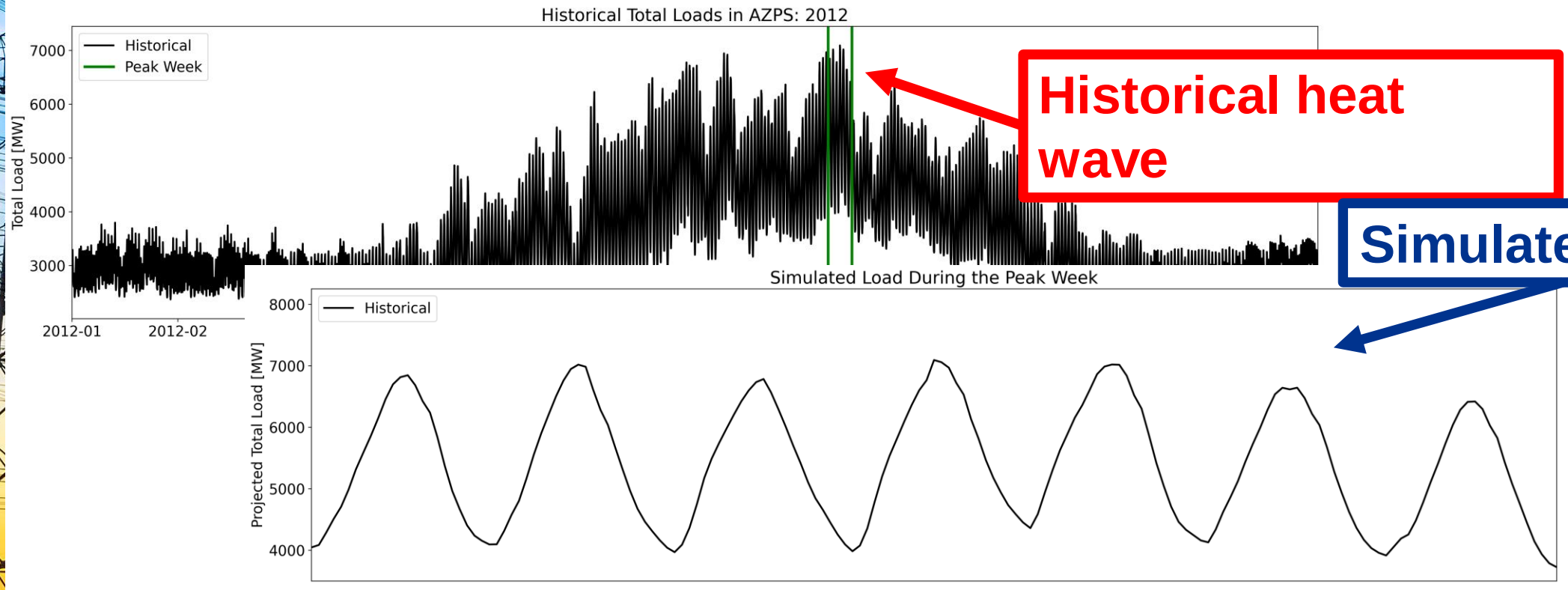




Example Heat Wave: AZPS



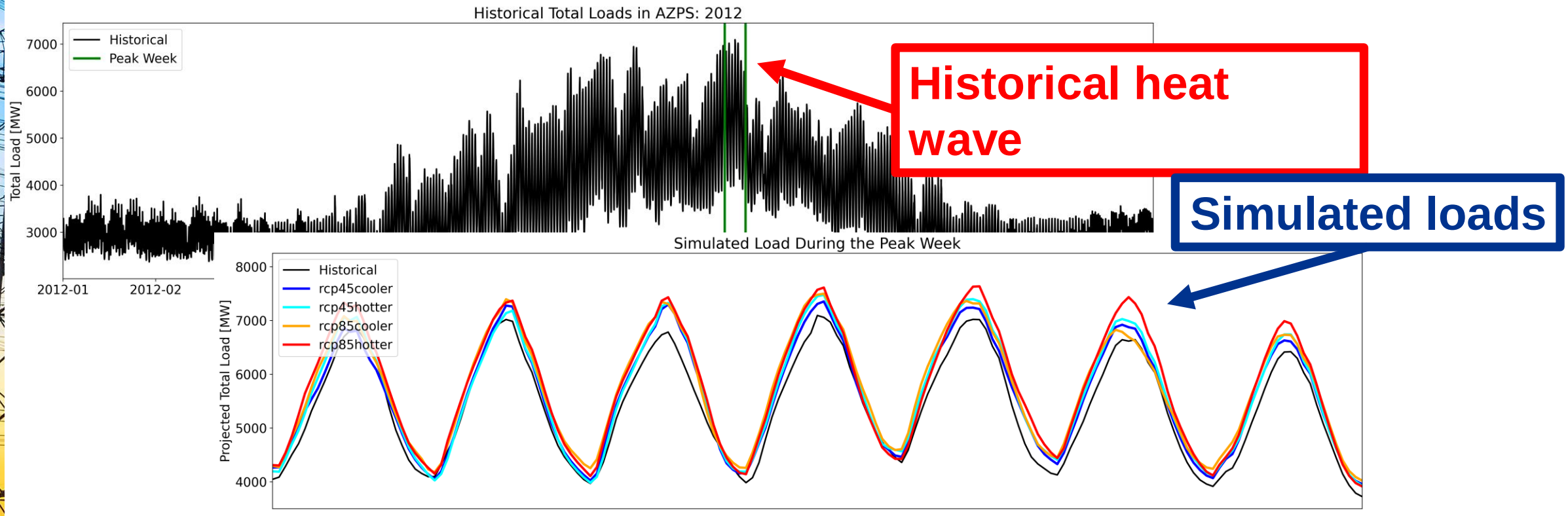
Example Heat Wave: AZPS



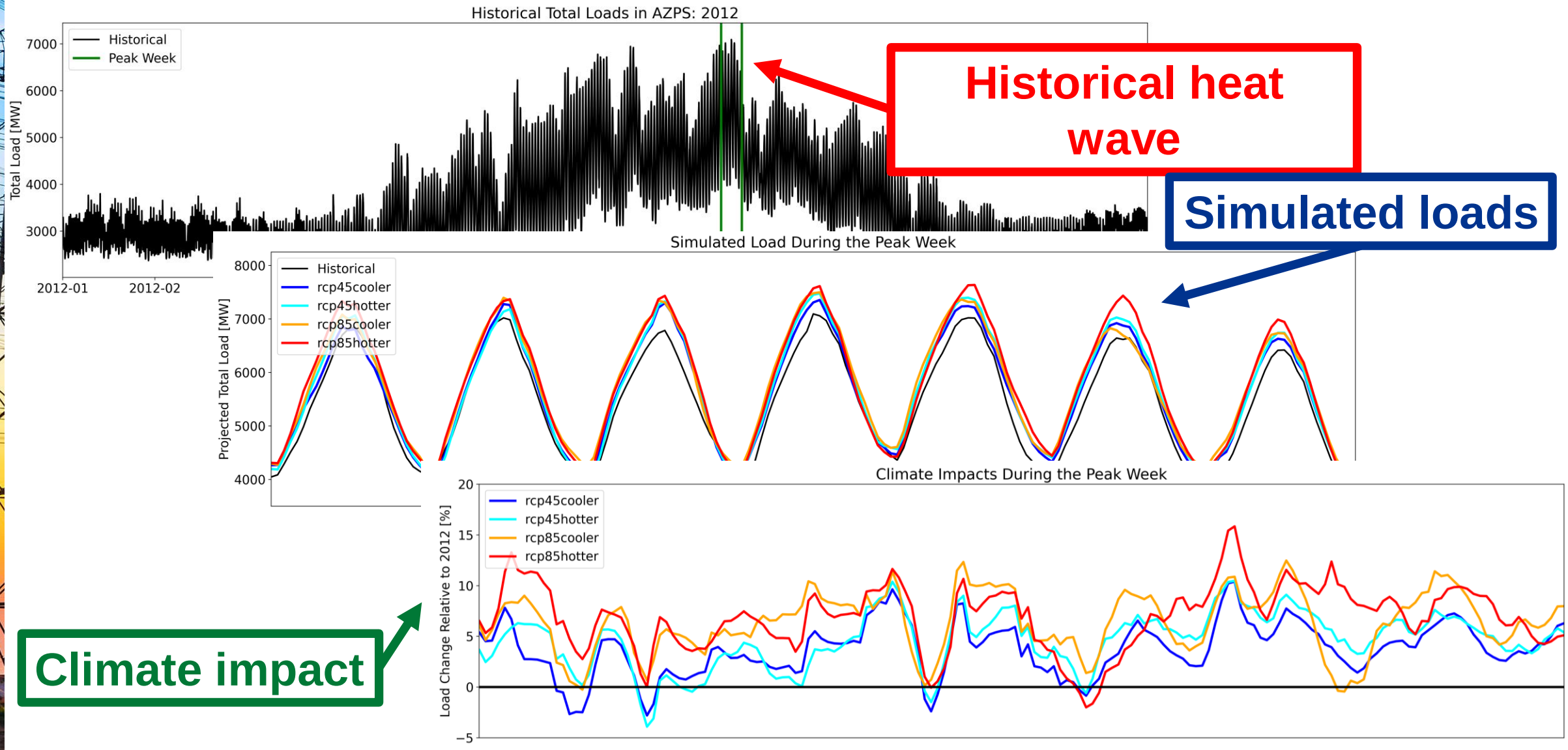
Historical heat wave

Simulated loads

Example Heat Wave: AZPS



Example Heat Wave: AZPS



Spectrum of Stress Cases

				PNNL				NREL	completed by	
				WI		CONUS		CONUS		
Names of scenarios		**Transmission expansions**	**year/% reduction**	**Type II (heat)**	**Type I: "cold"**	**Type II (heat)**	**Type I: "cold"**	**Type I**	CEM (Round 1)	CEM (Round 2)
Scen: 1	AC	inter FERC 1000	2035/90	PCM (nodal)	PCM (nodal)			PRAS (zonal)	15-Aug-23	30-Oct-23
Scen: 2	Limited	Intra FERC 1000	2035/90	PCM (nodal)	PCM (nodal)			PRAS (zonal)	15-Aug-23	30-Oct-23
Scen: 3	DC lines P2P+ multi-terminal	across interconnection	2035/90			PCM (nodal)	PCM (nodal)	PRAS (zonal)	30-Oct-23	10/30/2023 aspirational for PCM feasible for PRAS
Scen: 4	DC lines P2P+ multi-terminal	across interconnection	2050/100			(aspirational) PCM (nodal)	(aspirational) PCM (nodal)	PRAS (zonal)	30-Dec-23	12/30/2023 aspirational for PCM feasible for PRAS

THANK YOU

- Overview of NTP Study goals and objectives
- Project news and milestone results
- Webinar presentations
- NTP Study mailing list
- TRC meeting schedules and presentation materials
- Public comment form

www.energy.gov/gdo/national-transmission-planning-study

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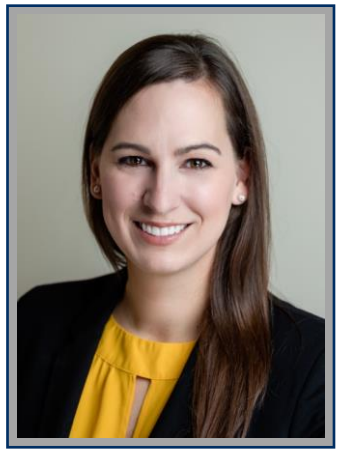
Threat Landscape Panel

Moderator



Kristen Worosz

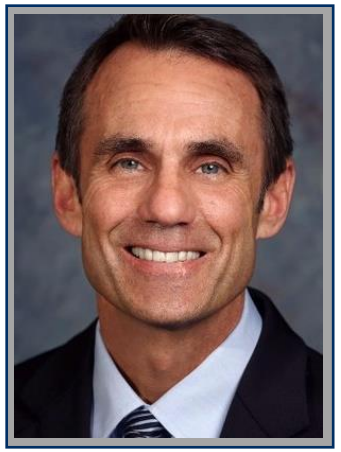
E-ISAC

Panelist

Jim Madia

SCE

Panelist



Travis Moran

SERC

Panelist

Dick Steeg

DiGioia Gray

Unacceptable Consequences

Most life sustaining activities are reliant on BES health

- Securing electric power supply is Grid sustainment
  - Hospitals
  - Other critical infrastructure
  - Fire/EMS/Police Services
  - Water delivery
  - Fuel deliveries

Time, place, weather and other extreme events impact backup power options and life sustaining activities

- Moore County two weeks later
- Buffalo area during & after blizzard (31 deaths)

SERC's Efforts

Information-sharing

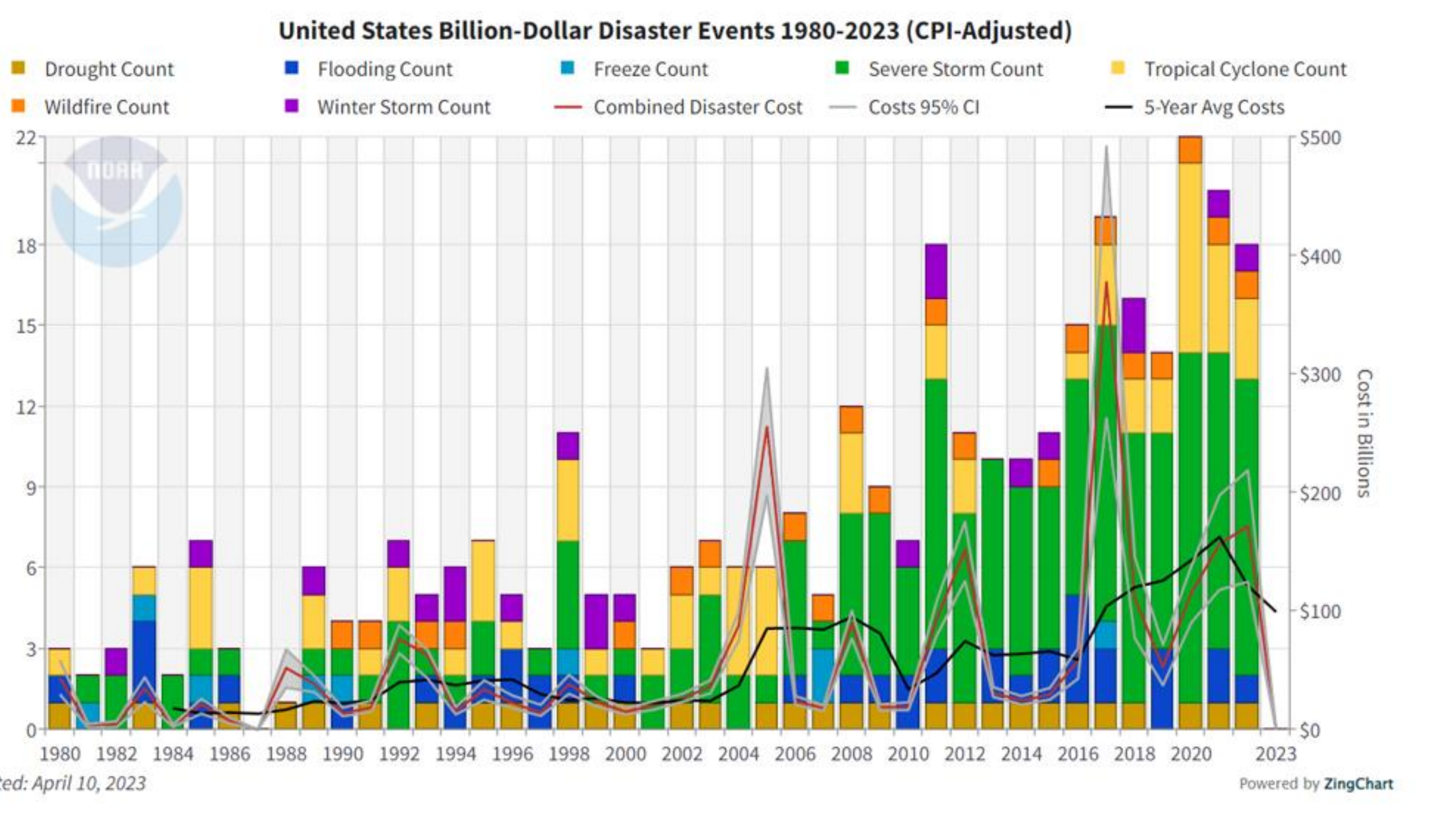
- E-ISAC Partnerships – participation encouragement
- Promoting increased engagement within ERO, Region, ERO Enterprise
- Targeted SERC information on physical security subjects via direct outreach in monthly publications

SERC Assistance, Outreach & Training

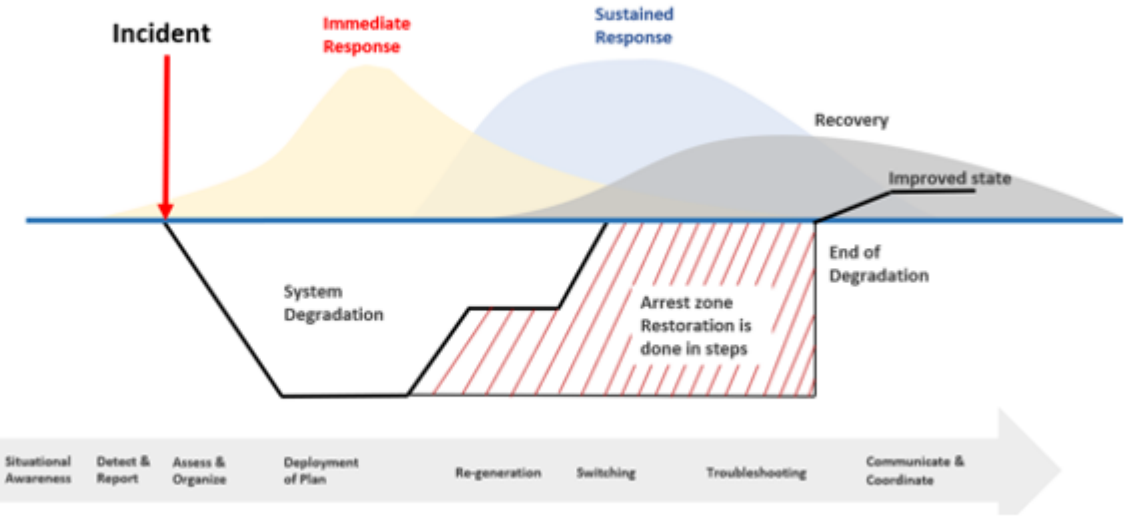
- Physical security SME's
  - Onsite physical security reviews
  - Targeted Physical security training and seminars
  - CIP-006 and CIP-014 assistance

All systems team approach to BES sustainability

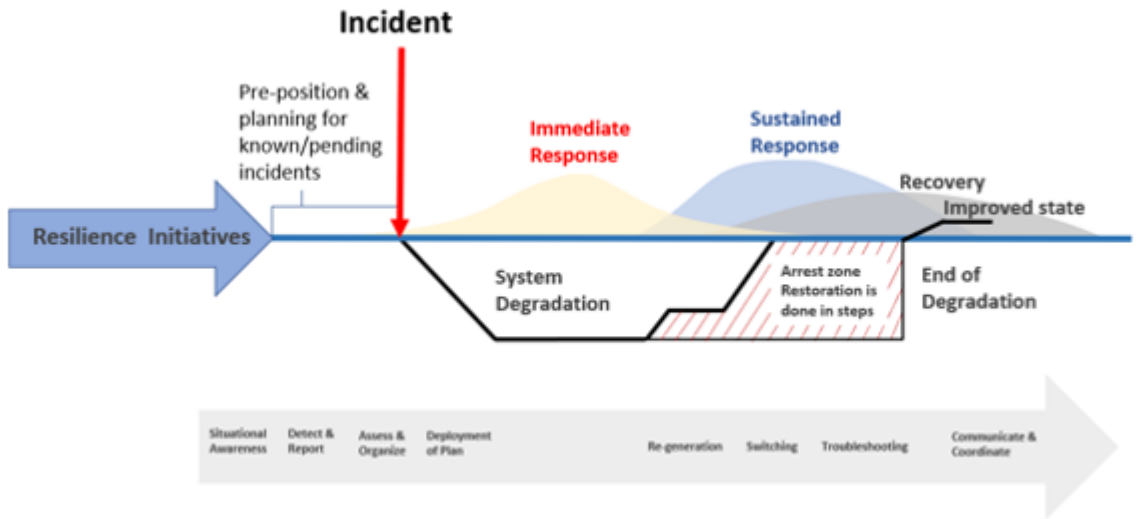
- Initiative drawing on system SMEs in physical security, cybersecurity, Situation Awareness, O&P
  - Systemwide understanding, problem identification, solution recommendations


United States Billion-Dollar Disaster Events 1980-2023 (CPI-Adjusted)
Drought Count
Flooding Count
Freeze Count
Severe Storm Count
Tropical Cyclone Count
Wildfire Count
Winter Storm Count
Combined Disaster Cost
Costs 95% CI
5-Year Avg Costs
22
18
15
12
9
6
3
0
$500
$400
$300
$200
$100
$0
Cost in Billions
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2023
ed: April 10, 2023
Powered by ZingChart

The Prevent/Prepare-Respond-Recover Management Process*



The Prevent/Prepare-Respond-Recover Management Process*



*Idealized Prevent/Prepare-Respond-Restore Process (adapted from Kondziolka 2019)

Transmission NOPRs and Policy Panel

Moderator

Eknath Vittal

EPRI

Panelist

Mark Lauby

NERC

Panelist

Kamran Ali

AEP

Panelist

David Wiley

APS

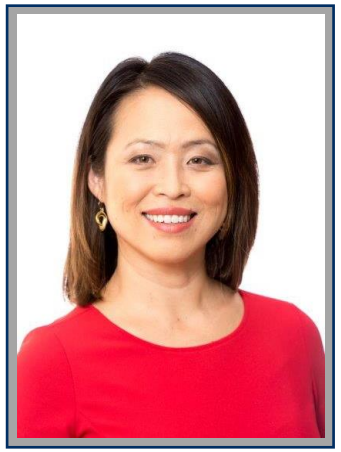
EPRI's Climate READi Program

Moderator

Anish Gaikwad

EPRI

Panelist



Soo Jin Kim

NERC

Panelist

Tom Cooper

SRP

Panelist

Eknath Vittal

EPRI

Climate READi

Initiative Overview

Mr. Anish Gaikwad, EPRI
Dr. Eknath Vittal, EPRI

EPRI-NATF-NERC Resilience Summit
Tempe, AZ
May 18, 2023

CLIMATE READi
RESILIENCE AND ADAPTATION INITIATIVE

Workstream 1	Workstream 2	Workstream 3
Physical Climate Data & Guidance	**Energy System & Asset Vulnerability Assessment**	**Resilience / Adaptation Planning & 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

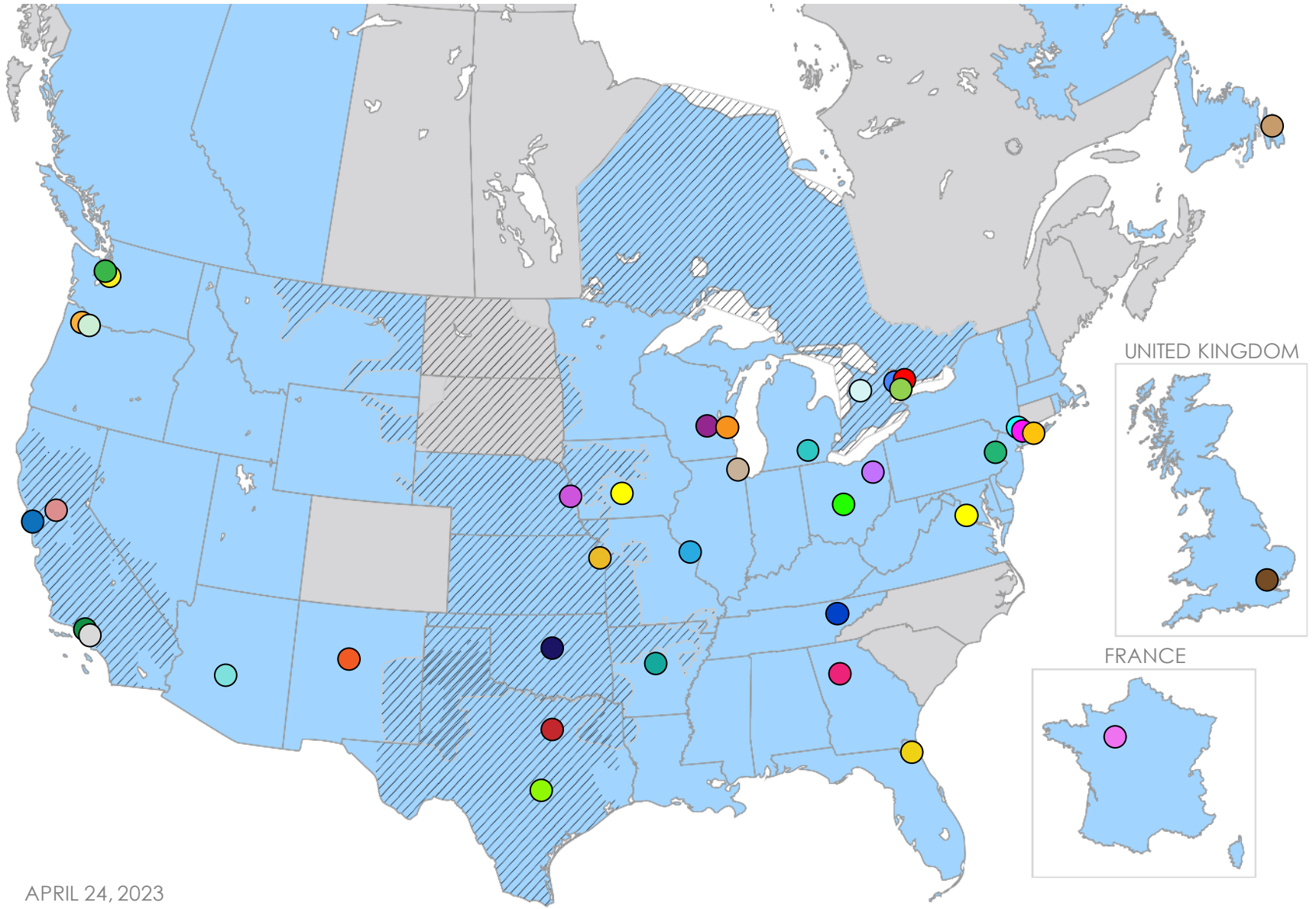
EPRI Climate Resilience and Adaptation Initiative (READi)

- **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

Deliverables: Common Framework "Guidebooks"

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

Climate READi Members

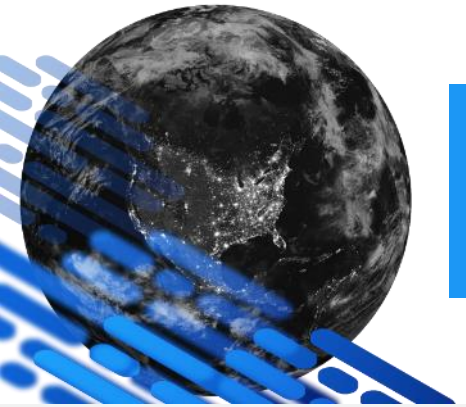


APRIL 24, 2023

○ Member Headquarters ▭ Member Operating States/Provinces ▨ ISO Service Territories *(only HQ location shown for IPPs)*

Climate READi Affinity Group

The Climate READi Affinity Group (CRAG) is comprised of individuals from academia, consulting, finance and insurance institutions, non-governmental organizations, national labs, regulators and government— among others—bringing their expertise to address the critical challenge around resilience and adaptation to the energy sector.



Embracing a 'Big-Tent' Approach to Framework Development

- Accenture
- Alison Silverstein (Consultant)
- Applied Weather Associates
- Australian Bureau of Meteorology
- Battelle
- CarbonPlan
- CDP North America
- Center for Climate and Energy Solutions (C2ES)
- Climate Risk Institute
- Columbia University
- Desert Research Institute
- Disaster Tech
- Eagle Rock Analytics
- Eaton
- Energy Systems Integration Group (ESIG)
- Energy Networks Association (ENA)
- Enline Transmission
- Exponent
- Grid Lab
- Guidehouse
- Houston Advanced Research Center
- ICF
- Imperial College London
- Institute of Nuclear Power Operations
- Jacobs Engineering
- Khalifa University
- King Abdullah University of Science and Technology
- Lawrence Livermore National Laboratory
- Liyang Wang (Consultant)
- Midwest Climate Collaborative
- Model World Consulting
- National Association of Regulatory Utility Commissioners (NARUC)
- North American Transmission Forum (NATF)
- National Center for Atmospheric Research (NCAR/UCAR)
- National Oceanic and Atmospheric Administration (NOAA)
- North American Electric Reliability Corporation (NERC)
- Nuclear Energy Institute (NEI)
- National Renewable Energy Laboratory (NREL)
- Pacific Northwest National Laboratory (PNNL)
- Pacific Northwest Utilities Conference Committee (PNUCC)
- Peter Larsen (Consultant)
- Power Systems Engineering Research Center (PSERC)
- Rand Corporation
- Resources for the Future
- RUNWITHIT Synthetics
- Sharply Focused
- Storm Impact
- Union of Concerned Scientists
- University of Albany
- University of Michigan
- University of Nottingham
- University of Reading
- University of Saskatchewan
- WTW (Willis Towers Watson)

Recent Deliverables

READi Insights: Extreme Heat Events and Impacts to the Electric System

Evaluates severity of recent extreme heat events in the context of historical records and climate change and potential future implications of extreme heat for the power system (300202552)

Costs & Benefits of Proactive Climate Adaptation in the Electric Sector

Outlines how proactively implementing adaptation strategies is expected to result in a more resilient power system, avoided damages, and reduced societal impacts (3002025872)

READi Insights: Extreme Winter Weather Challenges for the Power Systems

Explores how extreme winter weather can pose numerous challenges to power system operations and load forecasting (3002027393)

Climate 101: Physical Climate Data

Over 250 comments from 19 EPRI members and 10 CRAG organizations during review period for the first training in the Climate 101 series (3002026223)

Why the case study approach?

To deliver the WS3 framework, we need to understand how the different areas of power system analysis integrate climate data and their impacts on assets

Ensures:

- That the insights from the WS3 framework are practical and applicable across differing modeling approaches
- The guidelines are grounded computational tractability and model/tool capabilities
- The ability to investigate and identify the main drivers of climate risk through sensitivity analysis
- The generic lessons and linkages from the framework are replicable for differing planning entities

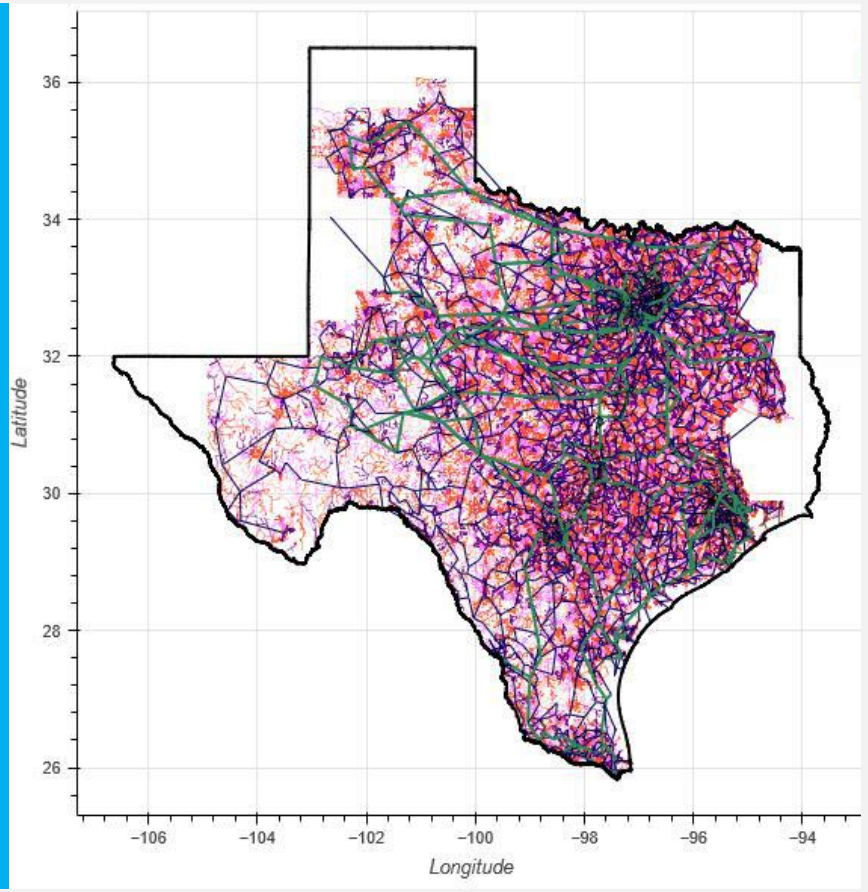
Case study helps us:

- Understand how that information fits into the existing analysis approaches that are used in power system planning today
- Identify specific focus areas that address the current gaps and develop processes to define solutions

As engineers, this approach gives us confidence in the guidance we deliver

Target Case Study I

Synthetic Texas System



A separate smaller case study will explore gas-electric model linkages. Focus on gas model fidelity to capture electric sector impacts

Combined T&D model for Texas

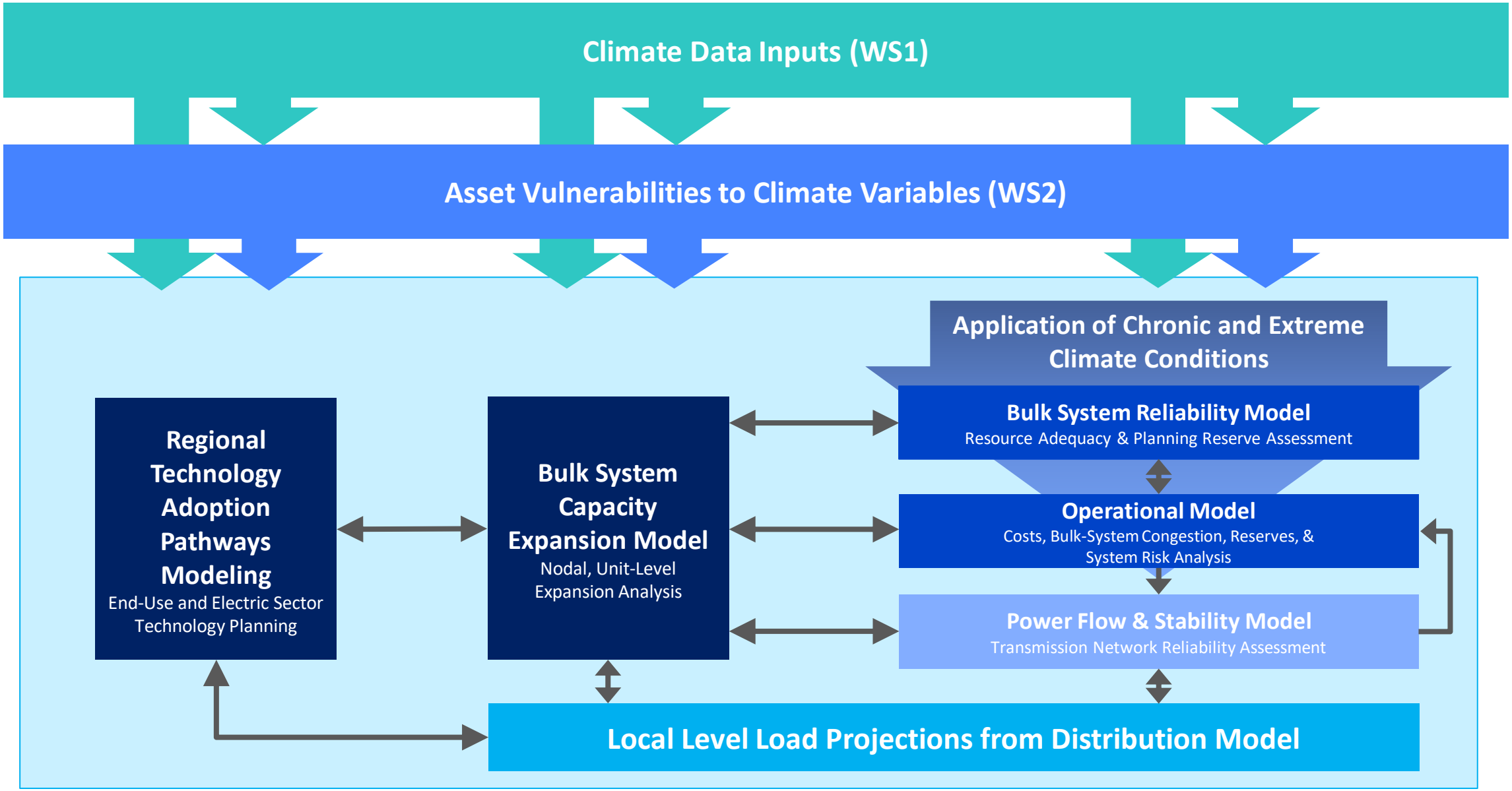
- All of Texas modeled
- Several million nodes modeled down to the zip code level
- Publicly available

Synthetic system allows for:

- Developing assumptions and testing through sensitivity analysis
- Allows for publishing and transparency for all to comment on the results
- Available to us now

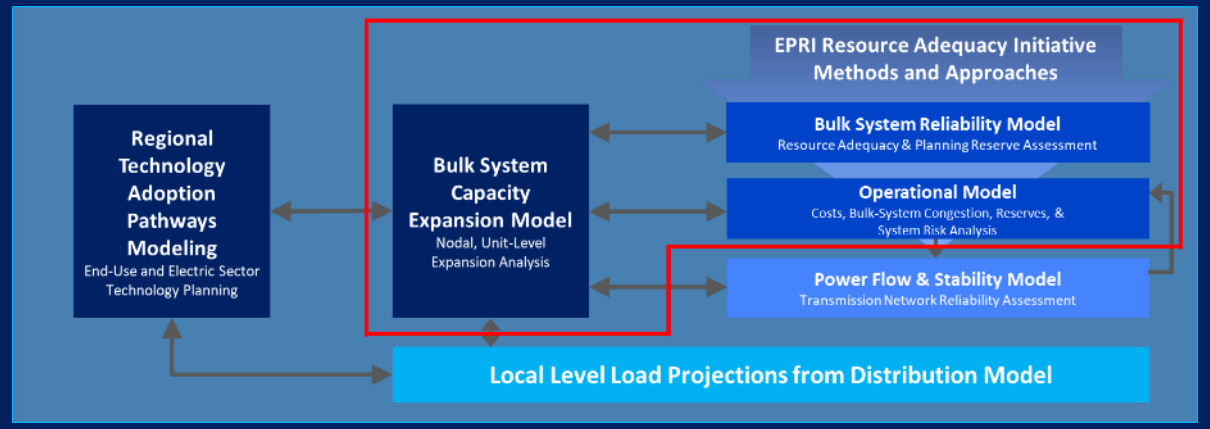
Methods and processes will have to be adapted and modified as we transition to real system models

Draft WS3 Power System Resilience and Investment Framework

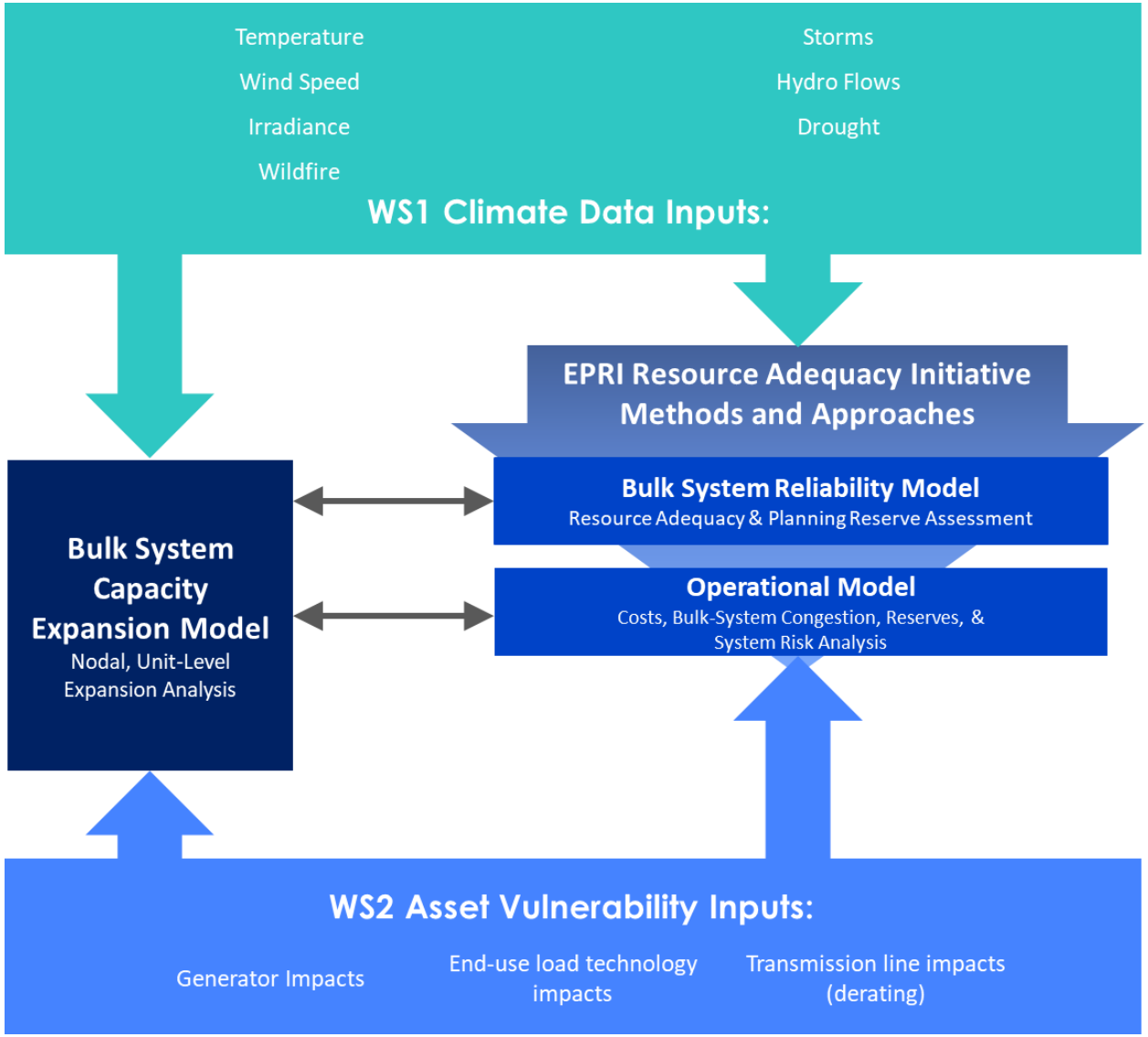


Focus Area II:

Integrating Climate Data into Operational Models



- Dependent on selection of modeling software
  - Need to map PERFORMS data to software dependent database
- Climate data needs to be 8760 hourly
- Need sufficient weather years to capture extreme
- Need to understand modeling detailed required (nodal vs. reduced)
- dc representation of transmission network will be required



FA II: Climate Informed RA Risk Assessment

WS1 Climate Data Inputs:
Temperature, wind speed, irradiance, wildfire, storms, hydro flows, drought

WS2 Asset Vulnerability Inputs:
Generator impacts, transmission line impacts (de-rating), end-use load technology impacts

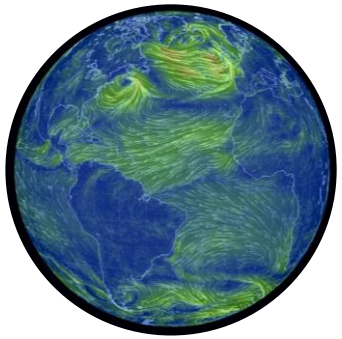
Power System Information
e.g. generators, demand

Weather Data
Historical & Climate Model

Asset Risk Profiles
e.g. normal operating ranges

Project Future Weather

Develop hourly synthetic weather profiles for future periods



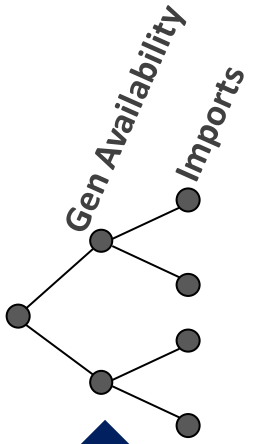
Identify High Risk Events

Screen weather for periods of potential high risk

- Cold Snap
- Severe Storm
- Heatwave

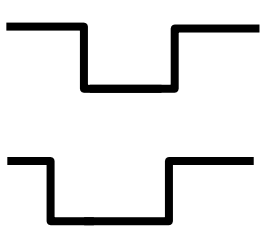
Event Scenarios

Identify potential non-weather scenarios



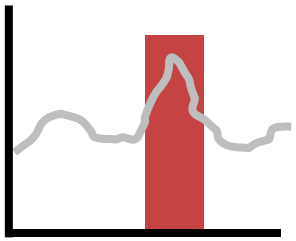
Weather Dependent Outages

Simulate outages of thermal plant



Operational Simulation

Simulate how the system operates through events

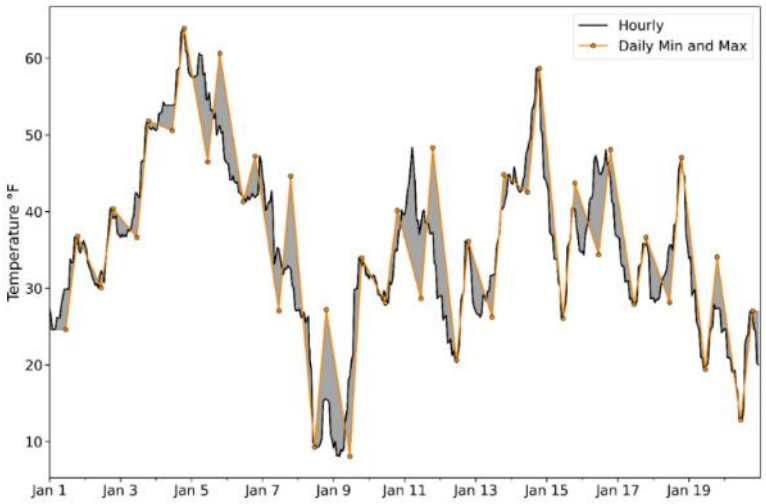


WS3 Load and DER Projections

Source: https://qcaptain.com/earth-weather-visualized/

Background on future synthetic hourly profiles

Motivation: Global climate model (GCM) projections typically have daily resolution, whereas most power system applications require hourly data



Example: Hourly vs Daily Temperature

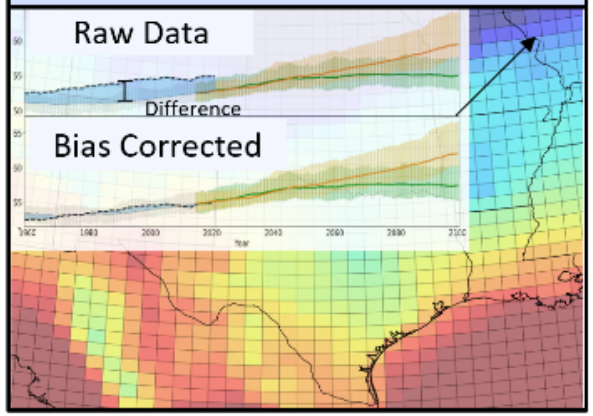
- Interpolating between daily values can miss important patterns (see figure)
- Customized dynamical downscaling can offer hourly resolution (but expensive, computationally and $$)
- Historical weather records capture real-world variability and preserve physical link between meteorological variables
- We present an innovative approach that leverages “best” of both historical and projection datasets to create 720 realistic synthetic hourly weather profiles

Relevance: Various utility functions could utilize this type of future hourly data, such as resource adequacy or other risk analysis, system planning, load projections, line ratings, asset/engineering design standards, among others

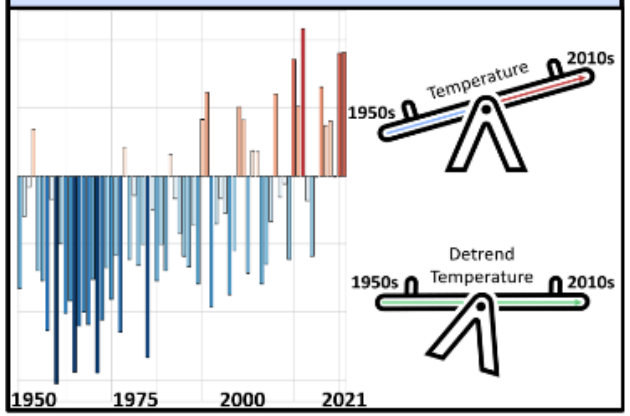
Overview of Data & Methods

- Historical data: ERA5
  - 1950 – 2021 (72 years)
- Projected Data: 5 CMIP6 models from Inter-Sectoral Impact Model Intercomparison Project (ISI–MIP)
  - SP1-2.6 (lower emission scenario) and SSP3-7.0 (higher emission scenario)
  - 5 models x 2 scenarios x 72 years of historical data = 720 synthetic profiles

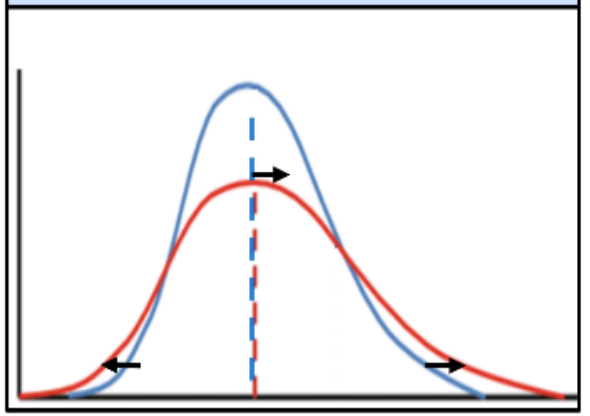
Step 1: Spatial bias-correction to localize climate projections (standard practice)



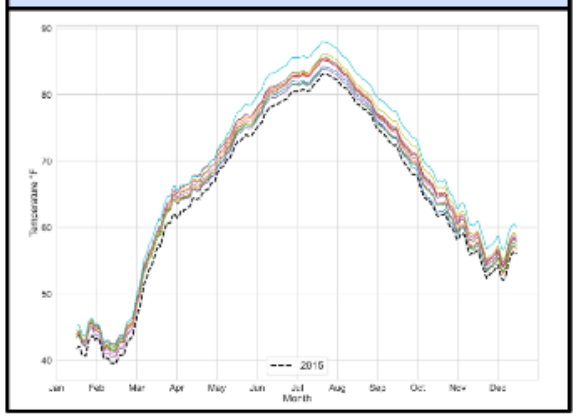
Step 2: Detrend historical data using representative years with natural variability



Step 3: Calculate **distributional shift** from GCM historical simulation to projection period



Step 4: Apply temperature delta for monthly quantile to historical data

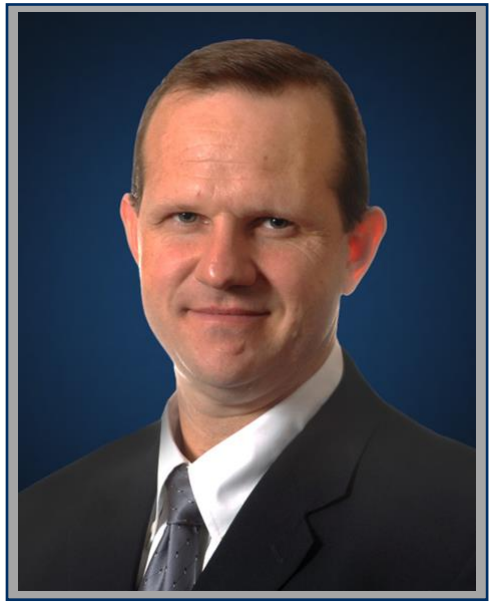


Together...Shaping the Future of Energy®

Closing Remarks

Tom Galloway

President & CEO, NATF



Andrew Phillips

V-President T&D, EPRI

Mark Lauby

SVP and Chief Eng, NERC

North American Transmission FORUM

EPRI

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

THANK YOU

Feedback Survey

SRP Delivering water and power®

NATF/EPRI/NERC Resilience Summit: Speaker Bios

May 17, 2023

Ali, Kamran

Kamran Ali is Vice President of the Transmission & Telecom Planning organization at American Electric Power (AEP).

Kamran holds a BS in Electrical Engineering from University of Alabama, an MS in Electrical Engineering from Kansas State University, and an MBA from Ohio University. Kamran is a registered professional engineer in the state of Ohio.

Burg, Ryan

Ryan Burg is a Principal Business Analyst on the smart grid programs team at Commonwealth Edison. Ryan manages engineering strategy on energy storage and leads academic partnerships on air quality, quantum computing, and climate risk adaptation.

Coggins, John

John Coggins is part of Salt River Project's Executive Management Team, serving as Associate General Manager & Chief Power System Executive.

John is responsible for the operation of SRP's power system including renewable, hydro, nuclear and fossil generation, a high voltage transmission system, and an extensive electrical distribution network. John has over 35 years of experience in the energy industry. He currently serves on the board of RMEL and is a member of the Research Advisory Committee for the Electric Power Research Institute. He is also Vice Chair of the Large Public Power Council Operating Executive Work Group. John is active in the local community and serves on the Board of Trustees for the Heard Museum in Phoenix and is also a board member for the O'Connor Institute for American Democracy.

Cooper, Tom

Tom Cooper is SRP's Director of Corporate Strategy, Sustainability, and Economic Services. He has been in the electric utility industry for over 22 years with experience in finance, wholesale electric and gas markets, operations, resource planning and development, load forecasting, strategy, sustainability, and economic development.

Deemer, Andrew

Andrew Deemer is a meteorologist at Arizona Public Service, a new position within APS designed to provide internal weather and climate support for various goals. His position is embedded within the Fire Mitigation team whose overarching goal is to mitigate wildfire risk to the company in order to best serve APS customers. Prior to joining APS, Andrew worked several years at NOAA/NWS in Phoenix.

Fournier, Anne-Marie

Anne-Marie Fournier has been working in the energy sector in Québec for the past 20 years in different roles: load forecasting, energy procurement, system condition analysis for Northeast electricity markets and, most recently, on the regulatory affairs team at the Québec Reliability Coordinator. Anne-Marie works on different committees with other Canadian partners, dealing with technical, commercial, and legal matters.

Gaikwad, Anish

Anish Gaikwad is currently the Senior Program Manager, Transmission Planning Program at Electric Power Research Institute, Inc. (EPRI) and is a long-time EPRI employee with over 20 years of experience.

Anish has published several journal papers and frequently presents at industry conferences and other research forums. He is an active member in the IEEE Power and Energy Society, Power Engineering Society.

Galloway, Tom

Thomas J. Galloway, Sr. serves as the president, CEO, and a board member director for the North American Transmission Forum (NATF). As CEO, Mr. Galloway formulates strategy, leads staff, and facilitates member activities to advance NATF's mission: to promote excellence in the reliable, secure, resilient, and safe operation of the electric transmission system. Under Mr. Galloway's direction, NATF operates rigorous programs used to confidentially share superior practices among members and promote continuous improvement. These program areas include peer reviews, assistance, training, practices, initiatives, operating experience, surveys, metrics, and RESTORE. Mr. Galloway has promoted NATF's increasing leadership role on key industry topics including grid transformation, methods to quantify and advance system resilience, supply chain cyber security, and risk-informed approaches to reliability and compliance.

Mr. Galloway began his professional career in 1981 with Northeast Utilities, holding a variety of engineering and managerial roles. Mr. Galloway continued his career with the Institute of Nuclear Power Operations (INPO) for the next 10 years, gaining valuable experience and skills related to human performance, organizational effectiveness, operational excellence, and performance improvement. Mr. Galloway subsequently served as SERC Reliability Corporation's vice president and director of compliance. In this role, Mr. Galloway implemented the mandatory NERC Compliance Monitoring and Enforcement Program (CMEP) within the SERC region. Immediately prior to joining NATF, Mr. Galloway was NERC's chief reliability officer and the senior vice president for the Reliability Performance organization. During Mr. Galloway's 11 plus years as NATF's CEO, the membership has grown significantly and has made increasingly positive impacts on transmission reliability,

security, resilience, and safety. Mr. Galloway continues to be driven by his passion for electric system reliability and the recognition of the critical role electricity plays in everyday life.

Hindi, Hamody

Hamody Hindi is a Transmission Planning Engineer with the DOE Office of Electricity leading a National Transmission Planning Study to inform grid needs for the Administration's clean electricity by 2035 goal. He came from the Bonneville Power Administration, where he led engineering teams to develop transmission expansion plans to meet NERC reliability requirements, generation interconnection requirements, and commercial requests for long term firm service. He also has experience working in cross-disciplinary teams that include transmission planning, transmission operations, commercial, policy, legal and generation groups. He has participated in a number of WECC and NERC working groups, including chairing the WECC Load Modeling Task Force from 2015-2017. Hamody holds a B.A. in Physics from U.C. Berkeley and an M.S.E.E. from University of Washington, Seattle. He is a registered Professional Engineer in the state of Washington.

Honorable, Colette

Colette Honorable is Partner at Reed Smith and currently leads their Energy Regulatory group. Colette recently served as Commissioner at the Federal Energy Regulatory Commission (FERC) from January 2015 until her term expired in June 2017. At FERC, Colette focused on reliability oversight of the bulk power system, cyber and physical security, gas-electric coordination, ratemaking, and infrastructure development just to name a few.

Kelley, Brian

Brian Kelley is a fire mitigation specialist at Arizona Public Service in which he supports fire mitigation efforts throughout the company. He oversees the APS comprehensive fire mitigation plan and assists in all aspects of fire mitigation including serving as a fire liaison during wildfires near APS assets. Prior to joining APS Brian worked as a wildland firefighter in northern Arizona.

Kim, Soo Jin

Soo Jin Kim is the vice president of Engineering and Standards. In this role, she is responsible for providing engineering analysis and support for NERC activities and directing all aspects of NERC's continent-wide standards development process by providing oversight, guidance, coordination, and industry education of the development of Reliability Standards.

Throughout her time at NERC, Ms. Kim has worked on numerous initiatives involving Standards, Compliance, and coordination across the ERO Enterprise. She joined NERC in 2012 as a standards developer and has since served as reliability manager and senior manager of Standards. From 2020–2023, she served as director of Power Risk Issues and Strategic Management (PRISM) where she transformed the group into a cross-cutting department that serves as technical advisors to other NERC functions. Under her leadership, PRISM initiated several projects to tackle energy assurance risks, particularly those to address extreme weather challenges. Most notably, her team was instrumental in the formation of the Energy Reliability Assessment Task Force and the efforts to provide the technical support for registering new inverter-based resources. She also

works with the Reliability Issues Steering Committee, and she was an integral leader in planning and executing the 2023 NERC Leadership Summit.

Prior to joining NERC, Ms. Kim was an associate at Troutman Sanders LLP in Washington, D.C. in their Energy Practice. At Troutman Sanders, she worked on a variety of Federal Energy Regulatory Commission compliance matters. Prior to attending law school, she was a consultant/business analyst with various consulting firms focused on energy and commodity trading.

Ms. Kim has a bachelor's degree in Economics and English from the University of Georgia and her juris doctor degree from American University, Washington College of Law. She is licensed to practice law in Georgia and Washington, D.C. She also served for five years on the board of the Women's Energy Network where she served as co-president for two of those years.

Kintner-Meyer, Michael

Dr. Michael Kintner-Meyer is a research engineer and systems analyst with more than 25 years in the area of energy/economy and multi-sector simulation and analysis for national and international clients. Educated in Germany with a Diplom Ingenieur Degree from RWTH Aachen in Mechanical Engineering and a Ph.D. from the University of Washington, Seattle, he worked on European Union funded Energy/Economic research and on the U.S. Energy Information Administration's National Energy Modeling System (NEMS). He is currently leading the mobility and electrification of transportation research area as well as PNNL's energy policy research and institutional support for the Grid Modernization Initiative of the U.S. Department of Energy.

For the past few years, Dr. Kintner-Meyer has been at the forefront of modernizing the nation's power grid, leading key projects for the U.S. Department of Energy's Grid Modernization Laboratory Consortium. One project focuses on foundational metrics analysis. Here, Kintner-Meyer and his team developed a comprehensive compendium of grid metrics that include (1) reliability, (2) resilience, (3) flexibility, (4) sustainability, (5) affordability, and (6) physical security.

He has led several major national assessments for energy storage, Hyperloop technology impacts on the US Grid, EV grid impacts and valuation of EVs for renewables integration.

Additionally, Dr. Kintner-Meyer most recently headed a study (Offsite link) that evaluated how an influx of electric vehicles (EVs) could impact the power grid in 2028. The team ran scenarios that included the evolution of the grid and its capacity at state and regional levels. The team focused on scenarios with the greatest potential for grid impacts. They found that bottlenecks due to new EV charging appeared the most in areas of California, including Los Angeles, which plans to go all-electric with its city fleet by 2030. In a follow-on study, the team will take a closer look at ways to integrate EVs into local and regional power distribution systems across the nation.

"We have the data and the method to run what-if scenarios," said Kintner-Meyer. "With data from utilities about feeders and infrastructure, we can build out the models then hand it off so that cities can get ahead of the curve."

Currently, Dr. Kintner-Meyer leads for PNNL the research activities in mobility research focusing on transitioning the transportation sector to meet the nation's 21st century mobility needs under sustainability objectives. This

includes decarbonization strategies, large scale traffic simulations of urban centers, connected vehicle controls research, as well as EV charging controls technology development.

Dr. Kintner-Meyer holds 9 patents on EV charge management, grid-friendly appliances, and energy storage controls technologies.

Lauby, Mark

Mark G. Lauby is senior vice president and chief engineer at the North American Electric Reliability Corporation (NERC). Mr. Lauby joined NERC in January 2007 and has held a number of positions, including vice president and director of Standards and vice president and director of Reliability Assessments and Performance Analysis.

In 2012, Mr. Lauby was elected to the North American Energy Standards Board and was appointed to the Department of Energy's Electric Advisory Committee by the Secretary of Energy in 2014. Mr. Lauby has served as chair and is a life member of the International Electricity Research Exchange, and served as chair of a number of IEEE working groups. From 1999 to 2007, Mr. Lauby was appointed as a member of the Board of Excellent Energy International Co., LTD, an energy service company based in Thailand. He has been recognized for his technical achievements in many technical associations, including the 1992 IEEE Walter Fee Young Engineer of the Year Award. He was named a Fellow by IEEE in November 2011 for "leadership in the development and application of techniques for bulk power system reliability," and in 2014, Mr. Lauby was awarded the IEEE Power and Energy Society's Roy Billinton Power System Reliability Award. In 2020, the National Academy of Engineering (NAE) elected Mr. Lauby as a member, citing his development and application of techniques for electric grid reliability analysis.

Prior to joining NERC, Mr. Lauby worked for the Electric Power Research Institute (EPRI) for 20 years, holding a number of senior positions, including: director, Power Delivery and Markets; managing director, Asia, EPRI International; and manager, Power System Engineering in the Power System Planning and Operations Program. Mr. Lauby began his electric industry career in 1979 at the Mid-Continent Area Power Pool in Minneapolis, Minnesota. His responsibilities included transmission planning, power system reliability assessment and probabilistic evaluation.

Mr. Lauby is the author of more than 100 technical papers on the subjects of power system reliability, expert systems, transmission system planning, and power system numerical analysis techniques. Mr. Lauby served as chair and is a life member of the International Electricity Research Exchange and served as chair of a number of IEEE working groups. He earned his bachelor's and master's degrees in Electrical Engineering from the University of Minnesota. In addition, Mr. Lauby attended the London Business School Accelerated Development Program as well as the Executive Leadership Program at Harvard Business School

Long, Brock

Mr. William “Brock” Long, former Administrator of the Federal Emergency Management Agency (FEMA), and Hagerty Consulting’s Executive Chairman has more than 18 years of experience assisting and supporting local, state, and federal governments to build robust emergency management and public health preparedness programs nationwide. He specializes in strategic planning, Homeland Security Exercise and Evaluation Program (HSEEP) exercises, evacuation, public safety, recovery management, and response logistics. Mr. Long provides strategic direction and leadership to Hagerty’s full complement of emergency management programs and professionals. He offers subject matter expertise for select projects and contributes to the growing body of knowledge in the emergency management community.

Madia, James

Dr. James D. Madia is a senior energy security and risk management professional with 37 years of experience in the emergency response community. He is currently the Manager of Business Operations, infrastructure Security and Compliance at Southern California Edison, and an independent consultant to government and business.

James has a law enforcement background, spanning almost 30 years, and is a subject matter expert in homeland security, including critical incident response, infrastructure protection, and emergency management.

James holds a Doctor of Policy, Planning & Development degree from the University of Southern California and a Master of Arts in Security Studies from the United States Naval Postgraduate School, Center for Homeland Defense and Security. He also holds executive certificates from the California Institute of Technology and the National Counter-Terrorism Academy.

James has experience in Security Management & Operations, Public Information/Media Relations, Crisis Communications, Crisis Negotiations, Forensic and Scientific Investigations, and Organizational Management.

Moran, Travis

Travis Moran is a retired law enforcement professional with over 30 years of enforcement, security, and intelligence experience with the U.S. National Central Bureau – Interpol, the U.S. Department of State and U.S. Department of Justice, Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) where he spent his last 15 years.

Upon retirement from federal service, Travis became a Senior Investigator with one of the nation's largest electric utilities to conduct counter terrorism security risk assessments on the utility’s critical assets - to include those of national importance regarding the operation of the United States' Bulk Power System. He has also served as the Senior Physical Security Specialist for NERC’s Electricity Information Sharing and Analysis Center (E-ISAC), whereby he helped lead the utility sector's Physical Security Advisory Group (PSAG) and is a current member.

Travis holds a Master of Arts in Criminology, Law, and Society from George Mason University, a Master of Science in Criminology from Indiana State University, and a Bachelor of Business Administration from James Madison University.

Patel, Nitin

Nitin Patel is a Transmission and Substation Equipment Group Manager for ComEd (part of Exelon Corporation utilities located in Chicago, Illinois.) Nitin has been working for ComEd for 34 years in various positions including distribution engineer, capacity planner, Operations Control Manager, and Substation Engineering Manager. Prior to ComEd, Nitin worked for G&W company in their research and development group. Nitin has a bachelor's degree in electrical engineering from NC State University and an MBA from Graham School of Management.

Phillips, Andrew

Andrew Phillips is Vice President of Transmission and Distribution Infrastructure. He provides executive oversight and direction for research, development and demonstration programs addressing asset management, information communication technology and cyber security, including issues and opportunities in diverse areas such as data analytics, reliability, robotics, and sensors. During his career at EPRI, Dr. Phillips has led the industry in developing advanced approaches and technologies to manage a range of T&D assets.

Since joining EPRI in 1998, he has led various research programs and initiatives covering transmission and distribution infrastructure and systems. From 2005 to 2017, he was Director of EPRI Transmission and Substations research where he led the team investigating all aspects of transmission asset management. Dr. Phillips has been integral to the development of advanced inspection techniques and technologies including radio frequency sensors, robotics, and data analytics.

Prior to EPRI he managed research programs focused on insulators, equipment aging and lightning for J.A. Jones Power Delivery. Prior to that, at the University of Witwatersrand, he conducted research for South Africa's electric power industry.

Dr. Phillips earned a Bachelor of Science, Master of Science, and Doctor of Philosophy in Electrical and Electronics Engineering from University of the Witwatersrand, in Johannesburg, South Africa.

He holds over 20 U.S. patents and is the author of more than 60 journal and conference publications. He is a member of IEEE and CIGRE.

Steeg, Richard

Richard Steeg, P.E., retired from Exelon / Pepco Holdings electric utility in 2019 as Manager of Transmission and Civil Engineering for Atlantic City Electric, Delmarva Power, and Pepco. Steeg's career spans 50 years in the electric and gas utility, DOT transportation, and civil engineering sectors. In addition to ExelonPepco Holdings Steeg has worked for Baltimore Gas and Electric, and Florida Power Corporation (now Duke Power) in distribution. He has held numerous technical and key line management positions in both transmission and distribution including engineering, construction, operations, and maintenance. His DOT experience as

Director of Operations was focused on highway operations and intelligent transportation systems. He has extensive emergency operations experience in managing extreme weather and other significant events on the utility electric power system and highway transportation networks.

Steeg is also the co-inventor of 'Utility Pole with Energy Absorbing Layer,' US Patent No. 10,435,911 B2 leveraging his DOT experience with utility pole location roadside safety. Pepco Holdings LLC is the patent assignee.

He is currently working on electric system grid resiliency initiatives associated with significant changes in the electric utility industry due to the increasing frequency and severity of weather and natural disasters as well as resiliency challenges associated with the emerging modern electric grid.

Steeg is a Principal Consultant, Applied Research with DiGioia Gray and Associates. He holds a Bachelor's and Master's Degree in Civil Engineering from the University of Maryland. He is a graduate of the Baltimore Polytechnic Institute

Vittal, Eknath

Eknath Vittal is a Principal Technical Leader at the Electric Power Research Institute (EPRI) in the Transmissions Operations and Planning Group of the Power Delivery and Utilization Sector.

His work is in the area of reliability and resilience assessment of power systems at the bulk transmission level. At EPRI, Dr. Vittal is responsible for managing research projects focused on advanced reliability analysis of power systems for planning studies. He is also responsible for developing methods to evaluate the risk associated with extreme contingency events driven by natural disasters, climate change and other significant impacts to evaluate the resilience of power systems. He is a co-lead of Workstream 3 in Climate READi. Before joining EPRI, Dr. Vittal was at General Electric Energy Consulting from 2013-2015. While there his work was focused on the industrial application of power systems analysis, facilitating the interconnection and design of power system apparatus and equipment.

He completed a post-doctoral fellowship and his Ph.D. in Electrical Engineering at University College Dublin in Ireland focused on the integration of wind generation and the reactive power stability impacts associated with the resource. He finished his M.Sc. in Electrical Engineering at Iowa State University and his B.Sc. in Electrical Engineering at the University of Illinois at Urbana-Champaign. He has been a visiting scholar at the National Renewable Energy Laboratory (NREL) in Colorado. He is an active member in the IEEE Power and Energy Society and CIGRE and participates in activities throughout the power industry. He is a Senior Member of the IEEE.

Wall, Tom

Tom Wall is Argonne's Program Lead for the Center for Climate Resilience and Decision Science (CCRDS) that aims to leverage their capabilities in climate science and modeling to provide actionable climate impact information to industry and government for the benefit of all.

Warr, Mike

Michael Warr, P.E., is the Senior Director of Transmission & Substation (T&S) Field Operations with Florida Power & Light Company, a NextEra Energy company. He is responsible for the Transmission & Substation system

operations, compliance, reliability, construction, maintenance, and restoration of service for all of FPL's service territory, which covers about 5.8 million customers throughout Florida. Mike oversees an organization of more than 400 employees, which includes high voltage line specialists, substation electricians, protection and control field engineers and support groups.

Mike joined FPL in 1992 and has served in a variety of positions, primarily in the Transmission & Substation Business Unit, including Engineering, Area Operations Lead, Technical Service Manager and Area Operations Manager.

Mike has a Bachelor's degree in Mechanical Engineering from Georgia Institute of Technology. He is also a Registered Professional Engineer in the State of Florida.

Worosz, Kristen

Kristen Worosz currently serves as the Policy and Partnerships Advisor for the E-ISAC. Kristen has more than 15 years of experience in both the federal government and private sector. In her previous positions, Kristen was a senior analyst and a production manager, focusing on threats posed by domestic campaign groups and producing analytical products on the cyber and physical threats facing the electricity industry. Worosz also worked as a counterterrorism intelligence analyst for the FBI and as an analyst in the Investigations Division for the U.S. Department of Justice's Office of the Inspector General.

Wiley, David

David Wiley, P.E., is the Supervisor of Transmission Planning and Engineering at Arizona Public Service. After graduating with bachelor's and master's degrees in engineering, electric power and energy systems, David joined APS and now has almost ten years of experience.