National Transmission Planning Study

August 1st, 2023

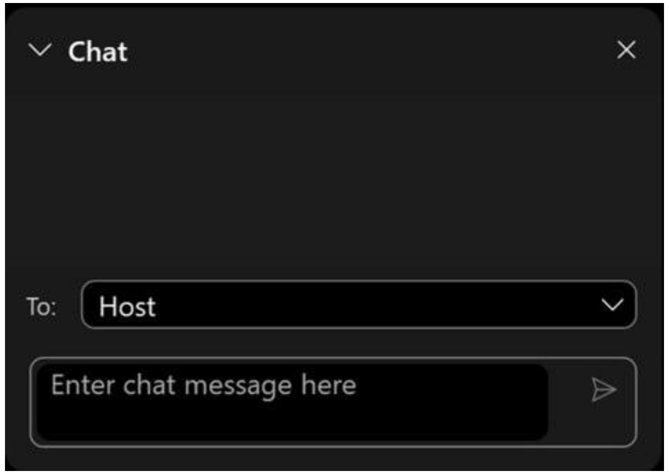
www.energy.gov/gdo/national-transmission-planning-study

Housekeeping

Questions?

Please submit all questions directly through the chat box.

If you have technical questions – please put them in the chat box for the host.



GRID DEPLOYMENT OFFICE

Jeffery Dennis

Deputy Director, Transmission Development,
Grid Deployment Office,
U.S. Department of Energy

DOE’s Grid Deployment Office

Mission Statement: The Grid Deployment Office (GDO) works to provide electricity to everyone, everywhere by maintaining and investing in critical generation facilities to ensure resource adequacy and improving and expanding transmission and distribution systems to ensure all communities have access to reliable, affordable electricity.

Generation Credits Division

The Generation Credits Division works with existing generation facilities to ensure resilience and reliability and works to improve electricity markets at the wholesale and distribution level.

Transmission Division

The Transmission Division supports innovative efforts in transmission reliability and clean energy analysis and programs, and energy infrastructure and risk analysis in support of the Administration’s priorities to enhance grid resilience.

Grid Modernization Division

The Grid Modernization Division oversees activities that prevent outages and enhance the resilience of the electric grid.

U.S. DEPARTMENT OF ENERGY

Building a Better Grid

Engagement and Collaboration

- Federal agencies
- States
- Tribal Nations
- ISOs/RTOs
- Stakeholders

Enhanced Transmission Planning

- National Transmission Needs Study
- ***National Transmission Planning Study***
- Atlantic + West Coast Offshore Wind Transmission Studies

Federal Financing Tools (>$20B)

- Transmission Facilitation Program ($2.5B)
- Transmission Facility Financing ($2B)
- Grid resilience formula grants for states, tribes, and territories ($2.5B)
- Grid Resilience and Innovation Partnerships (GRIP) Program ($10.5B)

Transmission Permitting Process

- Improve federal permitting regimes with federal agency partners
- Designation of national interest electric corridors
- Grants to siting authorities and affected communities ($760m)

Transmission Related R&D

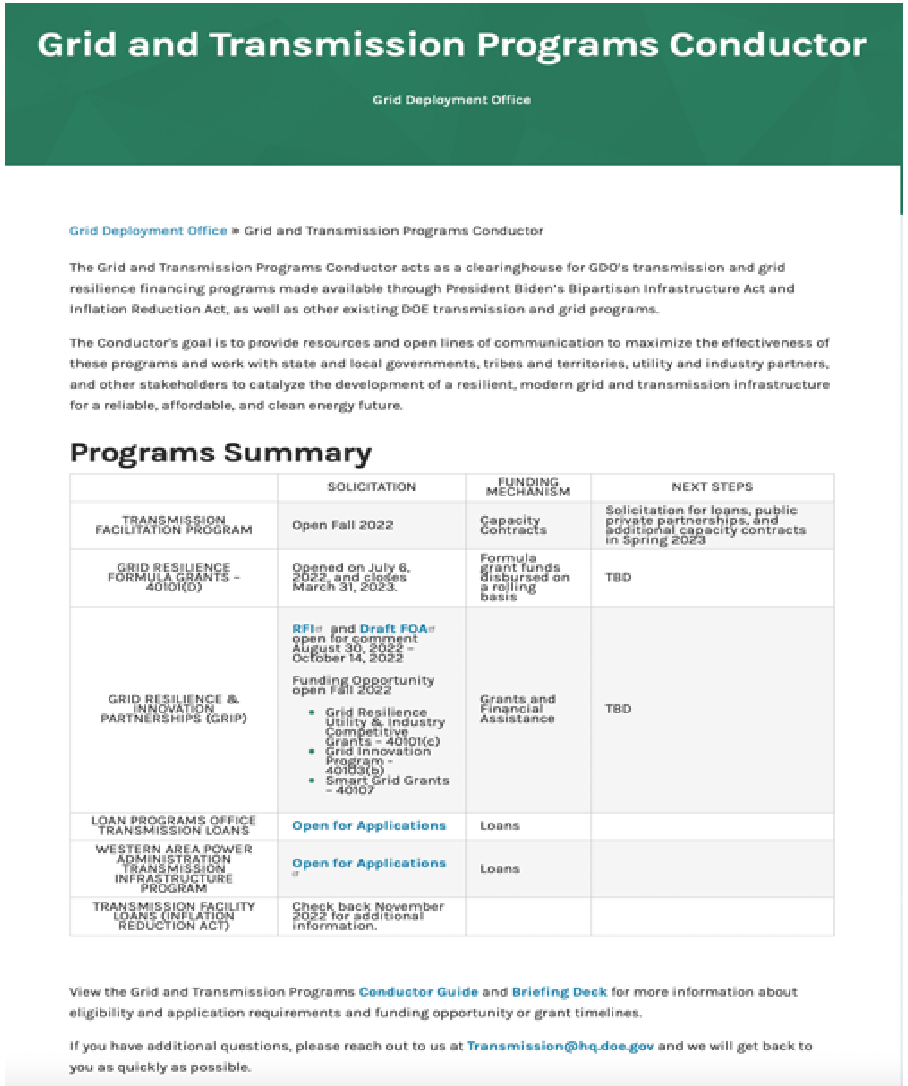
- "Next generation" electricity delivery technologies
- Advanced Conductors/ Reconductoring
- Grid Enhancing Technologies

Learn More about the Grid Deployment Office

The Grid and Transmission Programs Conductor acts as a clearinghouse for GDO's transmission and grid resilience financing programs.

Find information on Grid and Transmission programs within:

- Bipartisan Infrastructure Law
- Inflation Reduction Act
- And other existing DOE transmission and grid programs



Grid and Transmission Programs Conductor

Grid Deployment Office

Grid Deployment Office » Grid and Transmission Programs Conductor

The Grid and Transmission Programs Conductor acts as a clearinghouse for GDO's transmission and grid resilience financing programs made available through President Biden's Bipartisan Infrastructure Act and Inflation Reduction Act, as well as other existing DOE transmission and grid programs.

The Conductor's goal is to provide resources and open lines of communication to maximize the effectiveness of these programs and work with state and local governments, tribes and territories, utility and industry partners, and other stakeholders to catalyze the development of a resilient, modern grid and transmission infrastructure for a reliable, affordable, and clean energy future.

Programs Summary

	SOLICITATION	FUNDING MECHANISM	NEXT STEPS
TRANSMISSION FACILITATION PROGRAM	Open Fall 2022	Capacity Contracts	Solicitation for loans, public private partnerships, and additional capacity contracts in Spring 2023
GRID RESILIENCE FORMULA GRANTS – 40101(D)	Opened on July 6, 2022, and closes March 31, 2023.	Formula grant funds disbursed on a rolling basis	TBD
GRID RESILIENCE & INNOVATION PARTNERSHIPS (GRIP)	RFI and Draft FOA open for comment August 30, 2022 – October 14, 2022 Funding Opportunity open Fall 2022 • Grid Resilience Utility & Industry Competitive Grants – 40101(c) • Grid Innovation Program – 40103(b) • Smart Grid Grants – 40107	Grants and Financial Assistance	TBD
LOAN PROGRAMS OFFICE TRANSMISSION LOANS	Open for Applications	Loans	
WESTERN AREA POWER ADMINISTRATION TRANSMISSION INFRASTRUCTURE PROGRAM	Open for Applications	Loans	
TRANSMISSION FACILITY LOANS (INFLATION REDUCTION ACT)	Check back November 2022 for additional information.		

View the Grid and Transmission Programs Conductor Guide and Briefing Deck for more information about eligibility and application requirements and funding opportunity or grant timelines.

If you have additional questions, please reach out to us at Transmission@hq.doe.gov and we will get back to you as quickly as possible.

www.energy.gov/gdo/conductor

National Transmission Planning Study

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Grid Deployment Office,
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Agenda

- Project Overview
- Progress Update: Multi-Model Approach
- Timeline and Next Steps
- Coordination with Offshore Wind Studies
- Q&A

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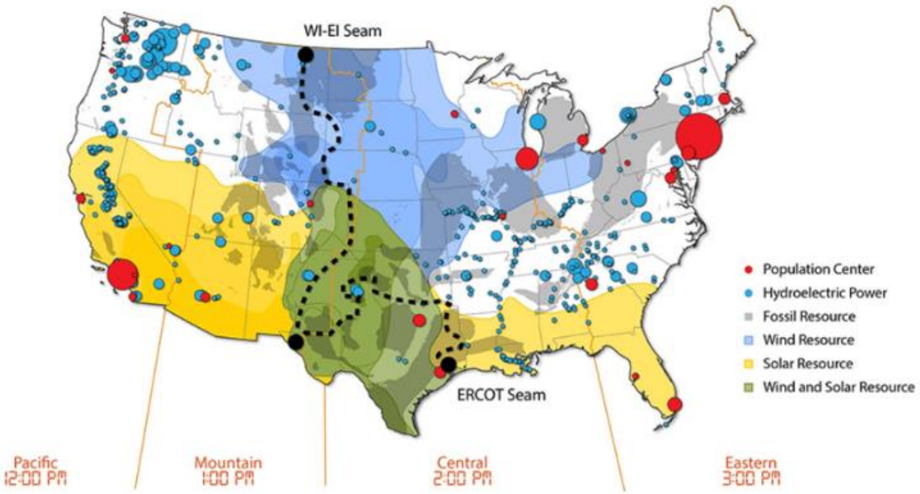
Project Team

- This study is conducted by a joint National Renewable Energy Laboratory (NREL) and Pacific Northwest National Laboratory (PNNL) project team
- This study builds on past projects and expertise at NREL and PNNL with the support and direction of DOE's Office of Electricity and Grid Deployment Office



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Office of Electricity

North American Energy Resilience Model

Objectives of the Study

Identify interregional and national strategies to accelerate cost-effective decarbonization while maintaining system reliability

Inform regional and interregional transmission planning processes, particularly by engaging stakeholders in dialogue

Results help inform future DOE funding for transmission infrastructure support

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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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Themes from Public Engagement

- **Modeling**
  - Recommendations to consider specific reports and other online resources
  - Account for climate change impacts
  - Develop actionable tools, methods and plans; maintain feasible scope
  - Engage with regional planners

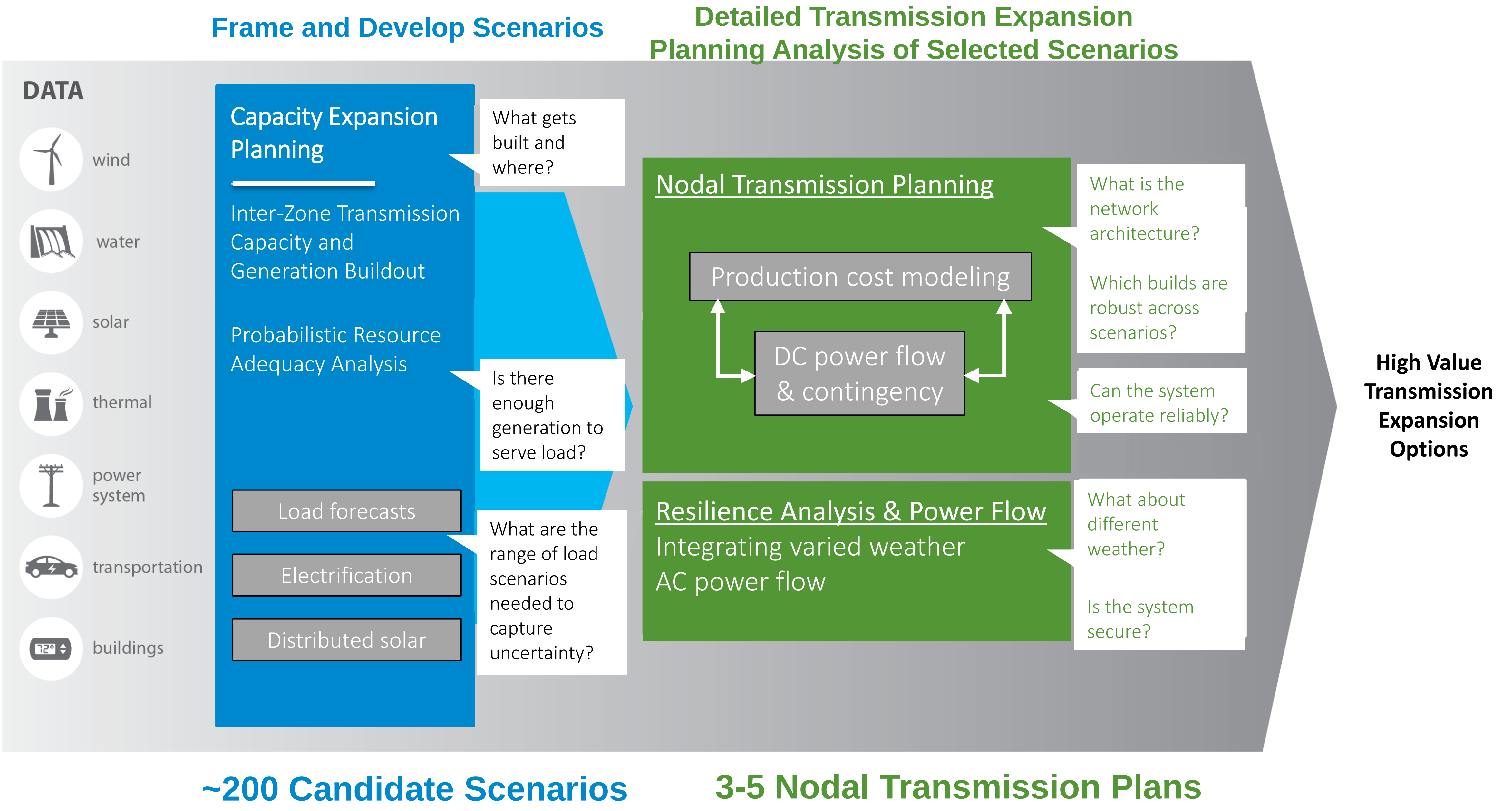
- **Policy**
  - Received information on existing policies and encouraged to work with states to ensure state policies are up to date
  - Incorporate the Inflation Reduction Act to the extent possible
  - Non-binding incentives and goals may influence outcomes

- **Land Use/Environmental**
  - Permitting and siting challenges (e.g., buried lines and use of existing rights of way will reduce local opposition)
  - Equity considerations

Multi-Model Approach

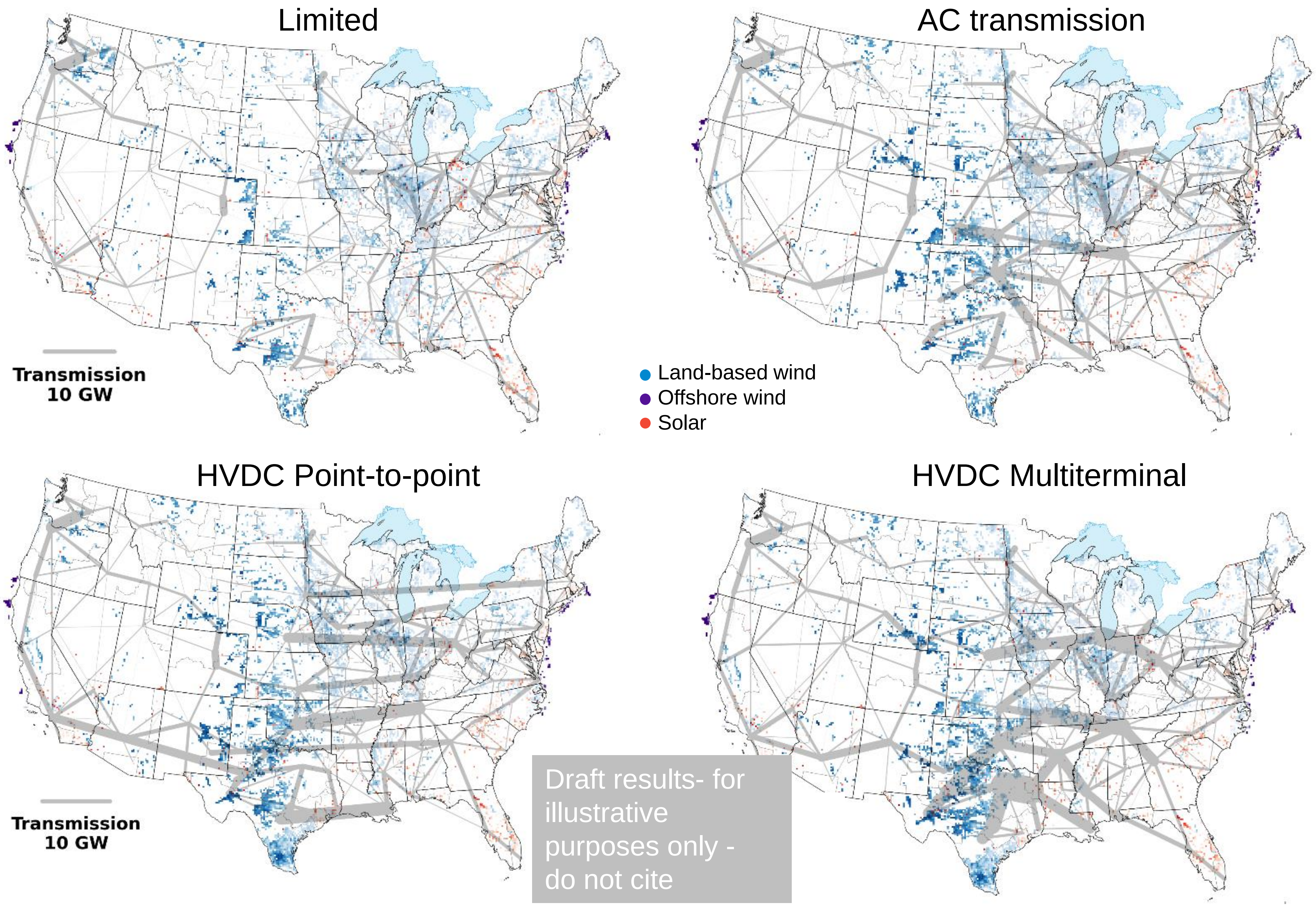
- Capacity Expansion Modeling
- Production Cost Modeling
- Power Flow
- Resource Adequacy
- Stress Analysis
- Economic Analysis

NTPS Scenario Analysis Relies on Multiple Linked Modeling Exercises



Zonal Capacity Expansion Scenario Results (round 1)

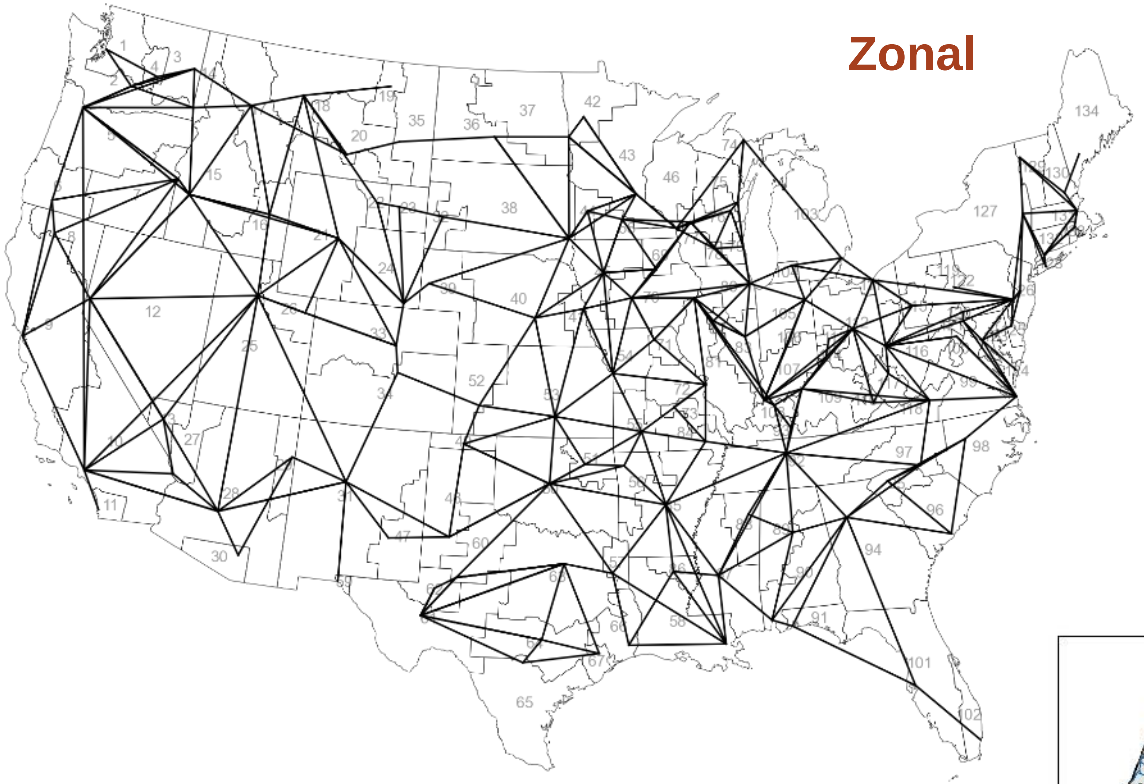
High Demand
90% by 2035
100% by 2050
(2050 shown)



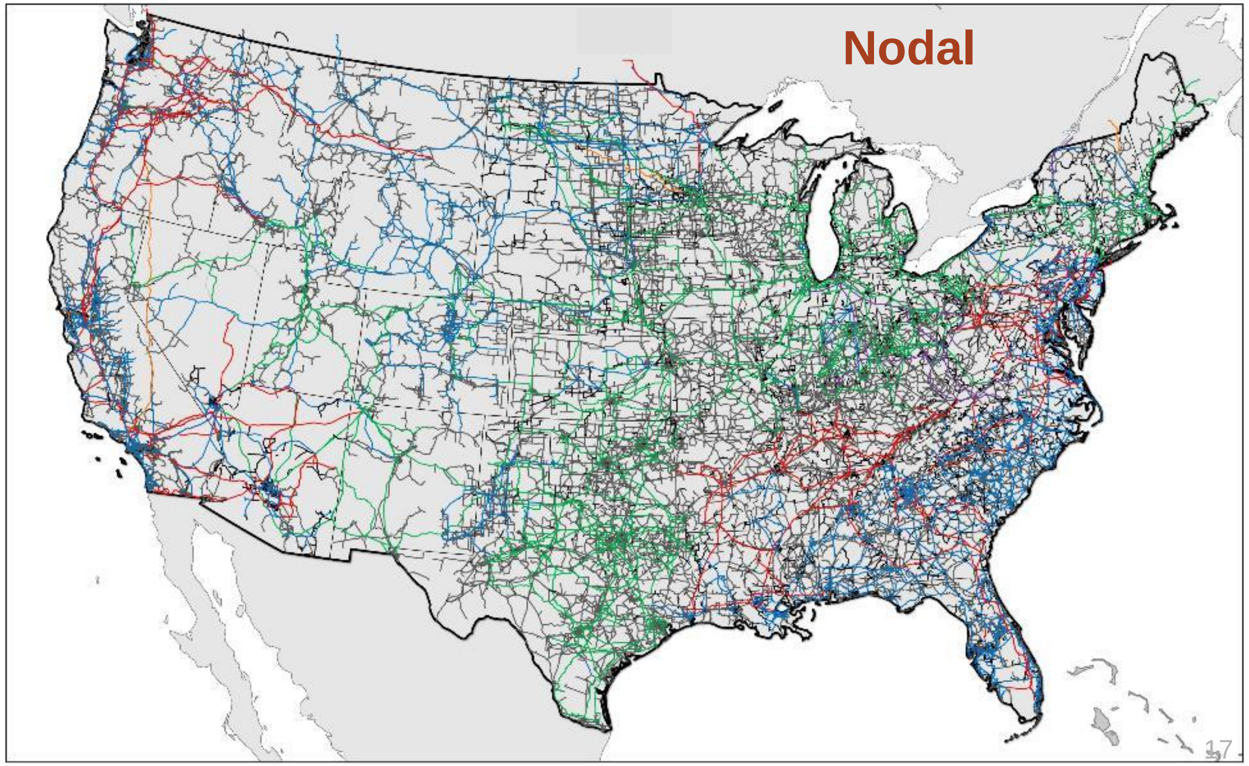
Multi-Model Approach

Production Cost Modeling

Power Flow



Making the Transition to Nodal



What Additional Information do we get from Detailed Nodal Transmission Planning?

✓ Verify the feasibility of future scenarios by adding constraints to match physical realities

✓ Gain grid balancing insights based on more granular spatial and temporal modeling

Verify the Feasibility of Future Scenarios by Adding Constraints to Match Physical Realities

- Physical network model captures power flow distribution and loading patterns across network elements (individual transmission lines and transformers)
- Physical infrastructure limits are represented
- Generators have specific points of interconnection and related system upgrades
- Constraining local transmission flows are captured

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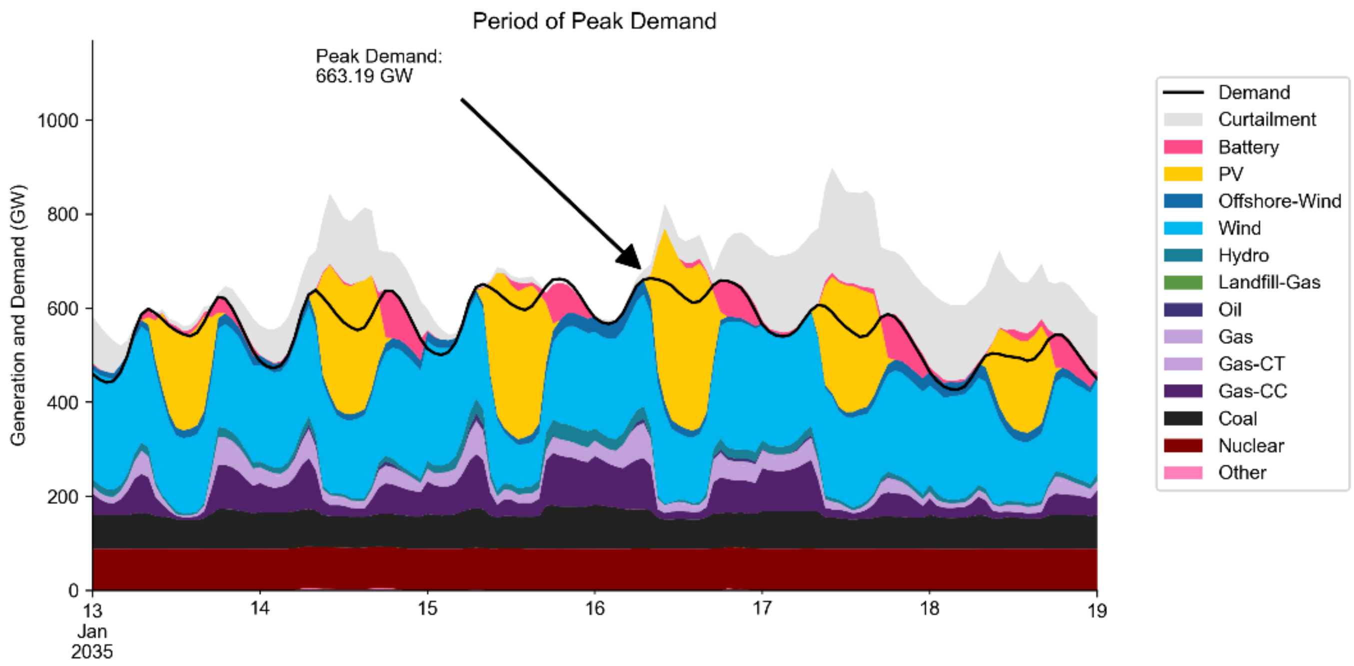
Grid Balancing Insights

- Identify which resources are serving load during stressful periods
- Examine how the transmission system operates during different times of the day and in different seasons
- Analyze utilization of expanded interregional transmission and how that impacts system operation
- Test the flexibility of the system
    - Can the system balance at an hourly resolution?
    - How does energy storage operate to support balancing?
    - What amount and where is wind and solar curtailment happening?



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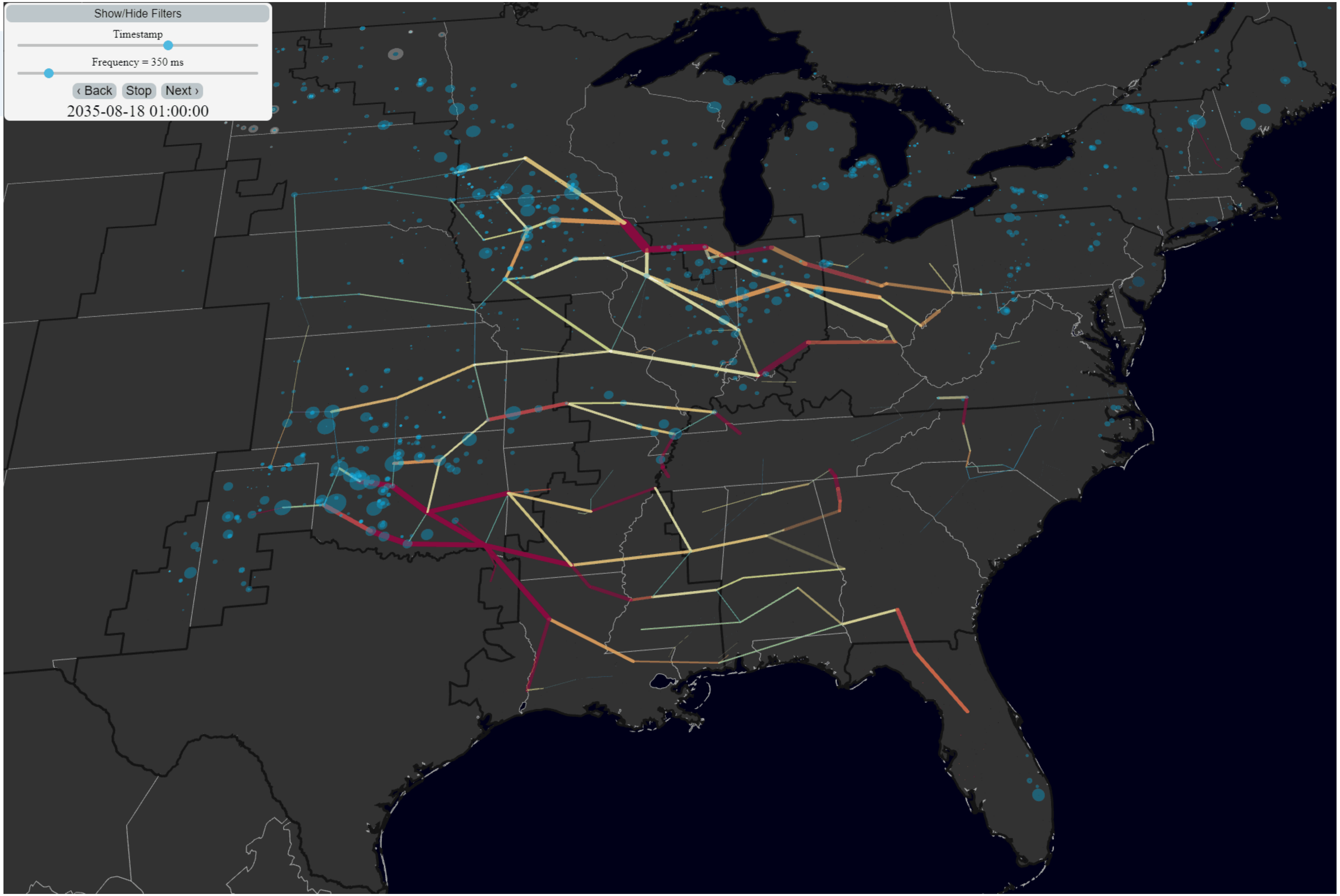

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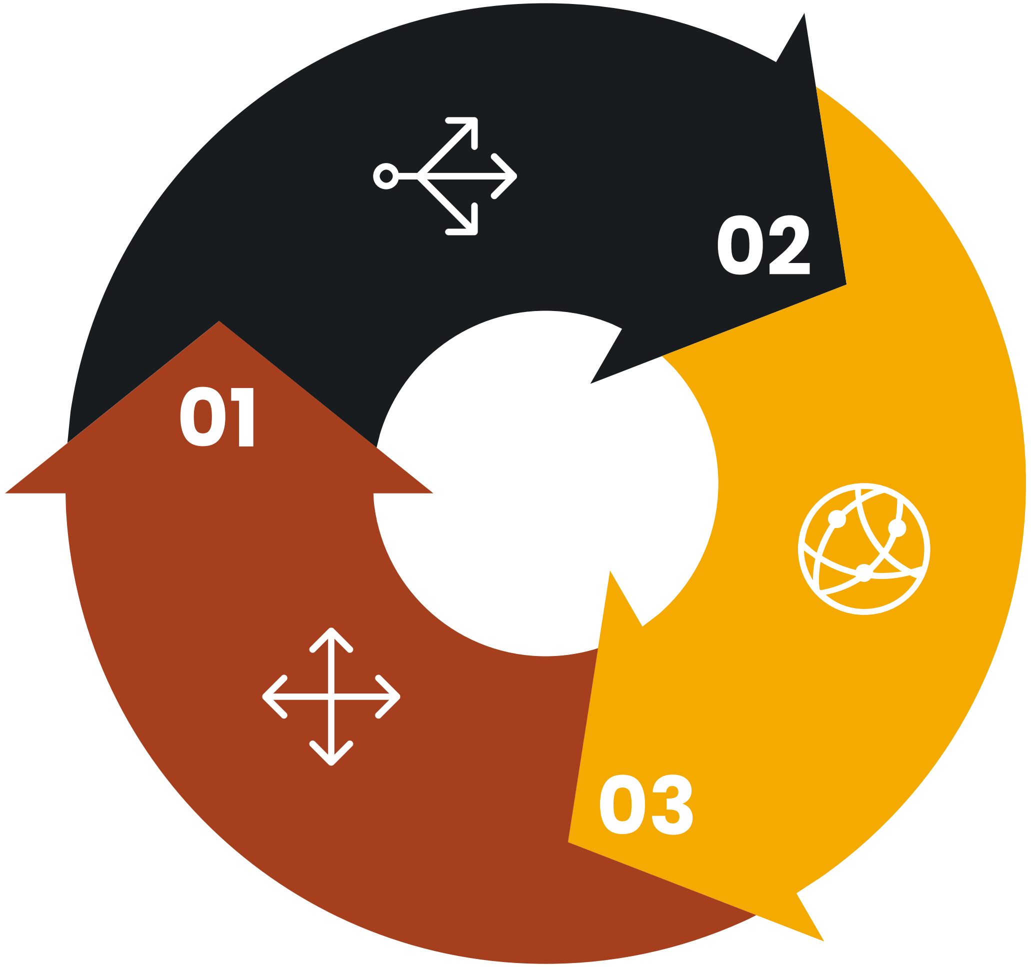
Overview of the Zonal-to-Nodal Translation

DISAGGREGATION

Generation (new builds & retirement), storage, and demand disaggregation to nodal.

CAPACITY EXPANSION

Optimal generation & transmission capacity expansion planning (zonal).



DETAILED TRANSMISSION EXPANSION

Iterative transmission expansion planning informed by CEM zonal transmission buildout (utilizing nodal PCM and DC power flow).

Reliability assessment: ex-post system performance assessment (AC power flow, contingency analysis, and system stability assessment).

Zonal to Nodal Translation – Details

1. Disaggregate generation/storage capacity and demand based on CEM
2. Start running nodal PCM:
   - Unbounded (allow transmission overloads)
   - Semi-bounded (interface limits in selected locations)
   - Constrained (enforce everything at HV)
3. Transfer results to DCPF (snapshots):
   - Iterative transmission expansion with representative snapshots aimed at reducing overloading (with an interregional focus)
   - Use CEM transmission expansion as a guide for scale and general location
4. When overloading is greatly reduced, re-run constrained PCM for feasibility and to check if results are reasonable

DCPF = DC powerflow | CEM = Capacity Expansion Model | PCM = Production cost model

Multi-Stage Nodal Transmission Expansion Planning Approach

STAGE 1

Initial system performance assessment

STAGE 2

Iterative transmission expansion planning under normal condition (N-0 limits)

STAGE 3

Iterative transmission expansion planning checking selected contingencies

01 02 03

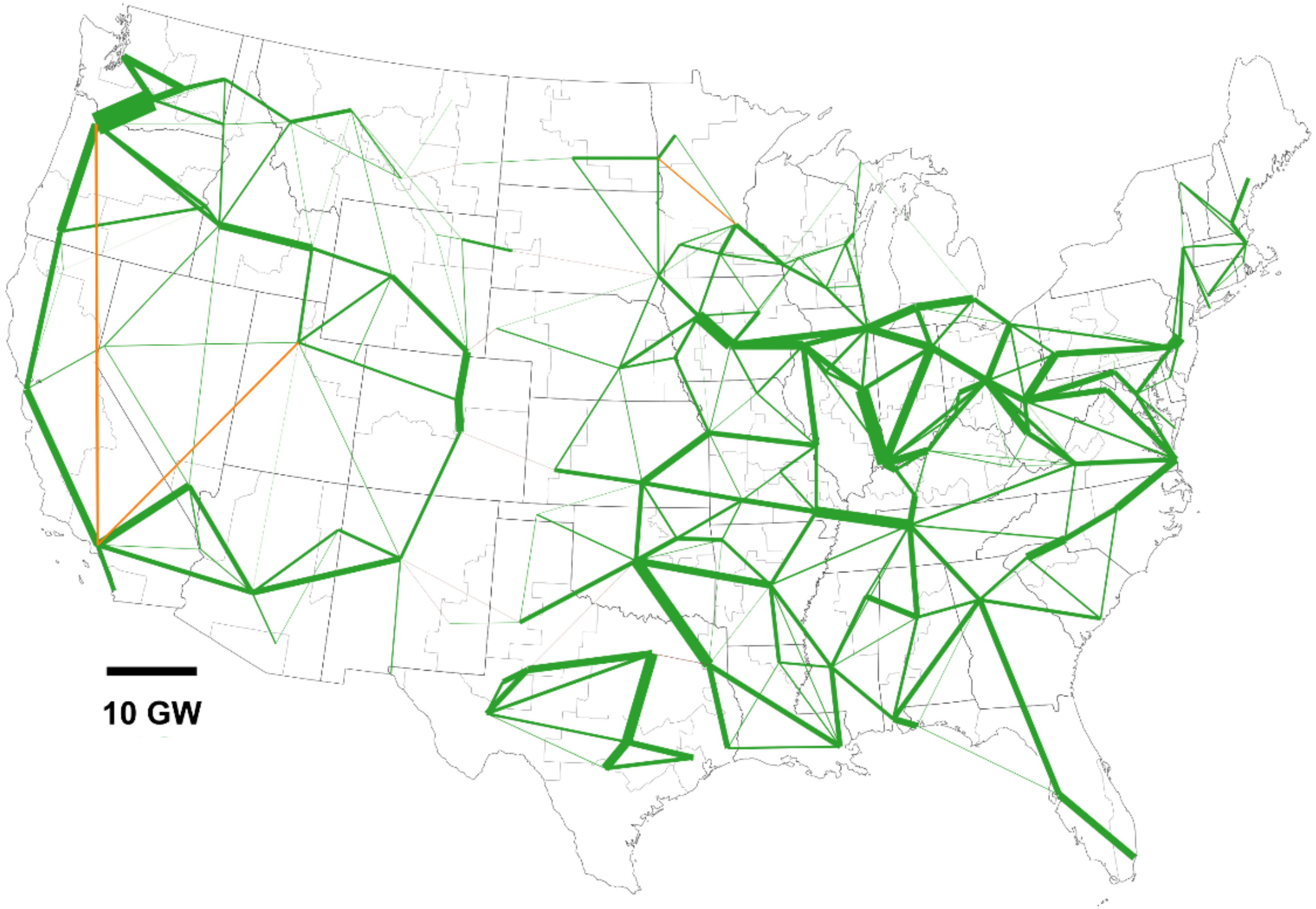
SUPPORTING ANALYTICAL METHODS

- **NODAL PRODUCTION COST MODELING (PCM)**
- **DEFINITION OF TRANSMISSION EXPANSION CANDIDATES**
- **DC POWER FLOW AND CONTINGENCY ANALYSIS**

Sample Nodal Analysis

Definition:

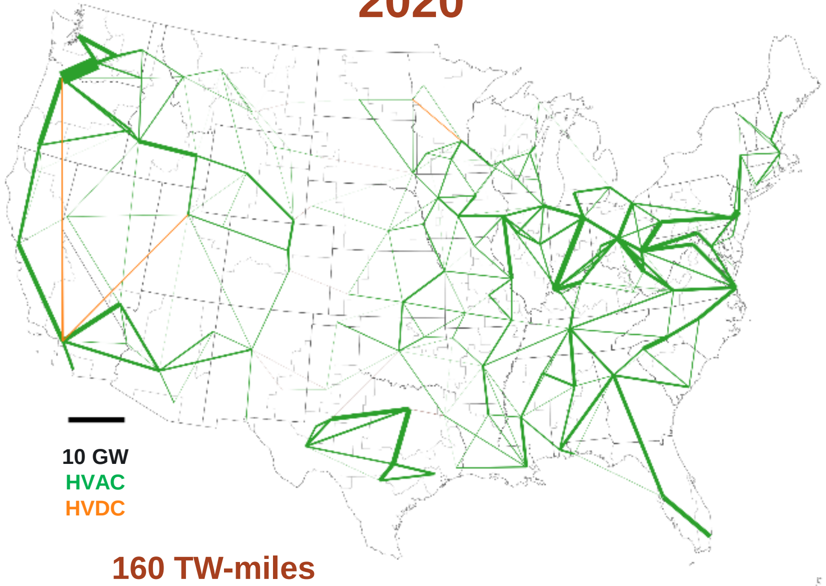
- AC expansion between transmission planning regions
- Year: 2035
- High demand
- 90% decarbonization by 2035



Scenario 1 zonal (CEM) transmission capacity expansion

The Evolution of Installed Capacity and Demand Combined with Transmission in this Scenario are Transformative

2020

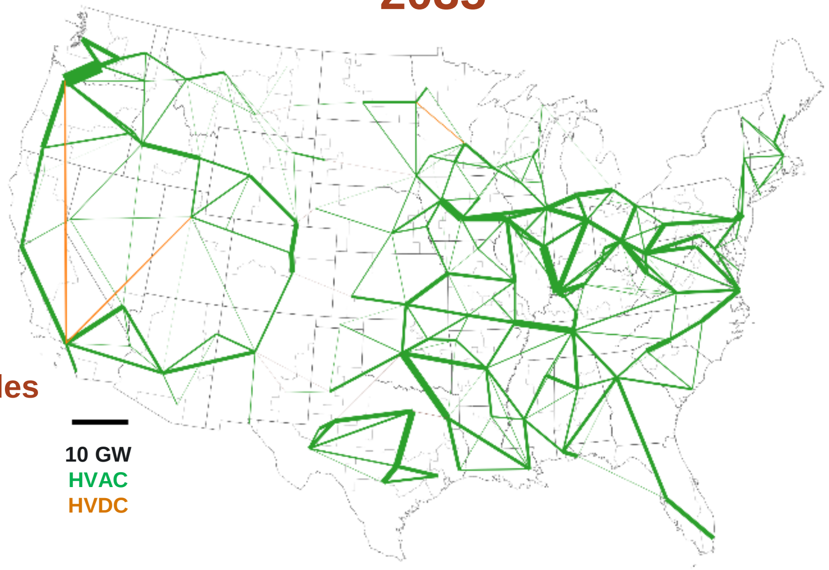


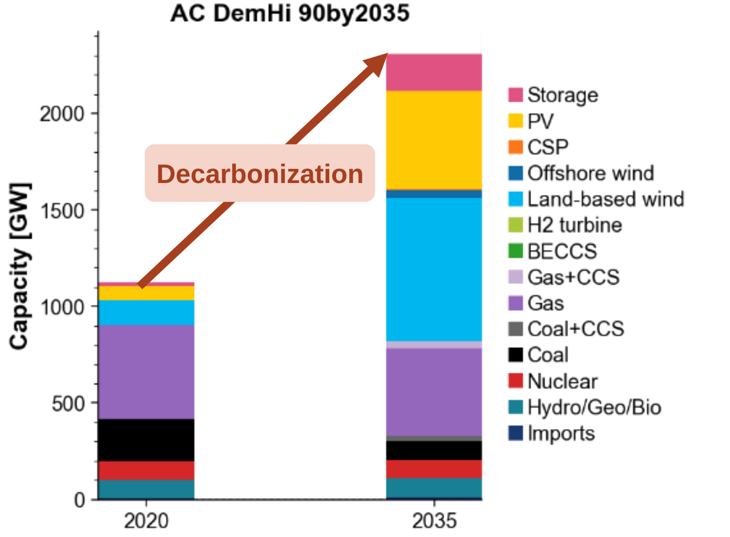
160 TW-miles
(zonal)

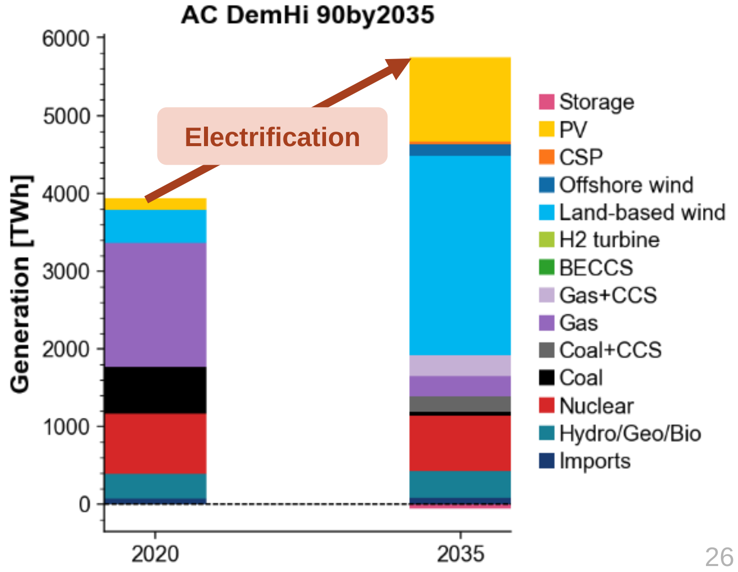
+40%

223 TW-miles
(zonal)

2035

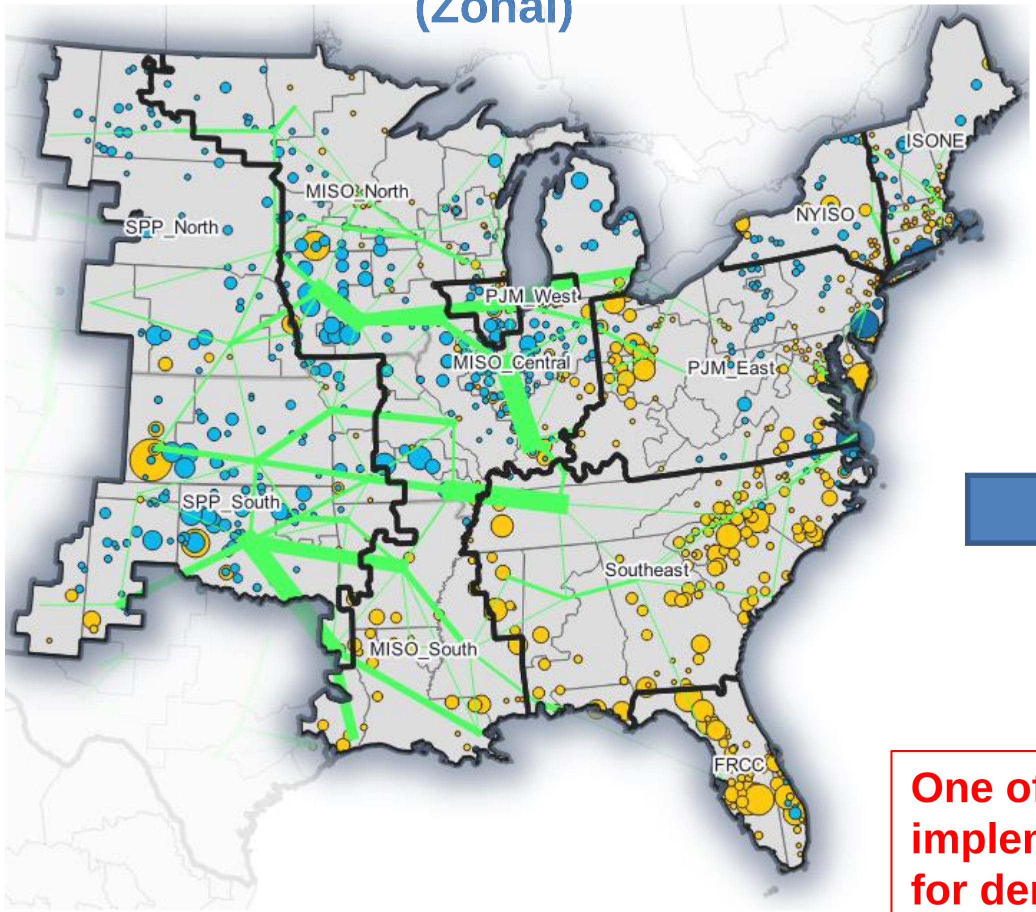




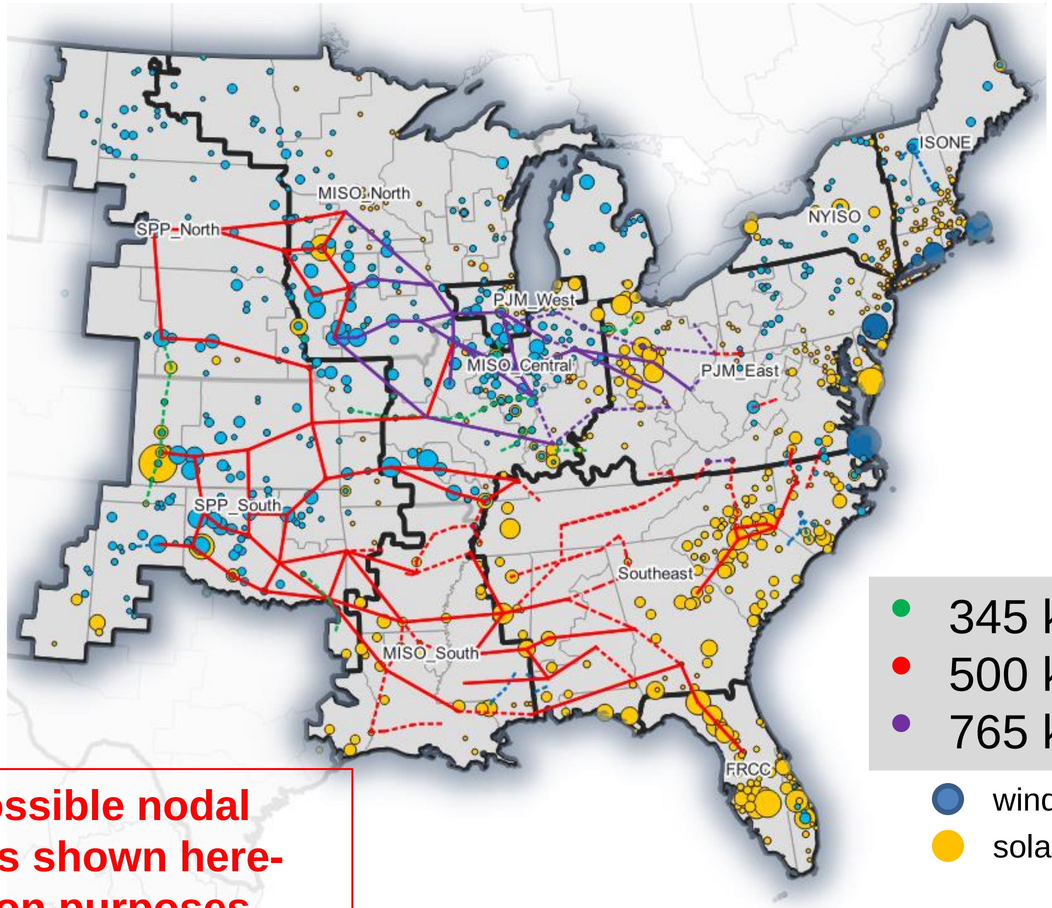


Zonal to Nodal Translation: Eastern Interconnection

Scenario 1 CEM Transmission Expansion (Zonal)



Scenario 1 Nodal Expansion (new only)



345 kV
500 kV
765 kV

wind
solar

One of many possible nodal implementations shown here- for demonstration purposes only – not intended to be a plan of service

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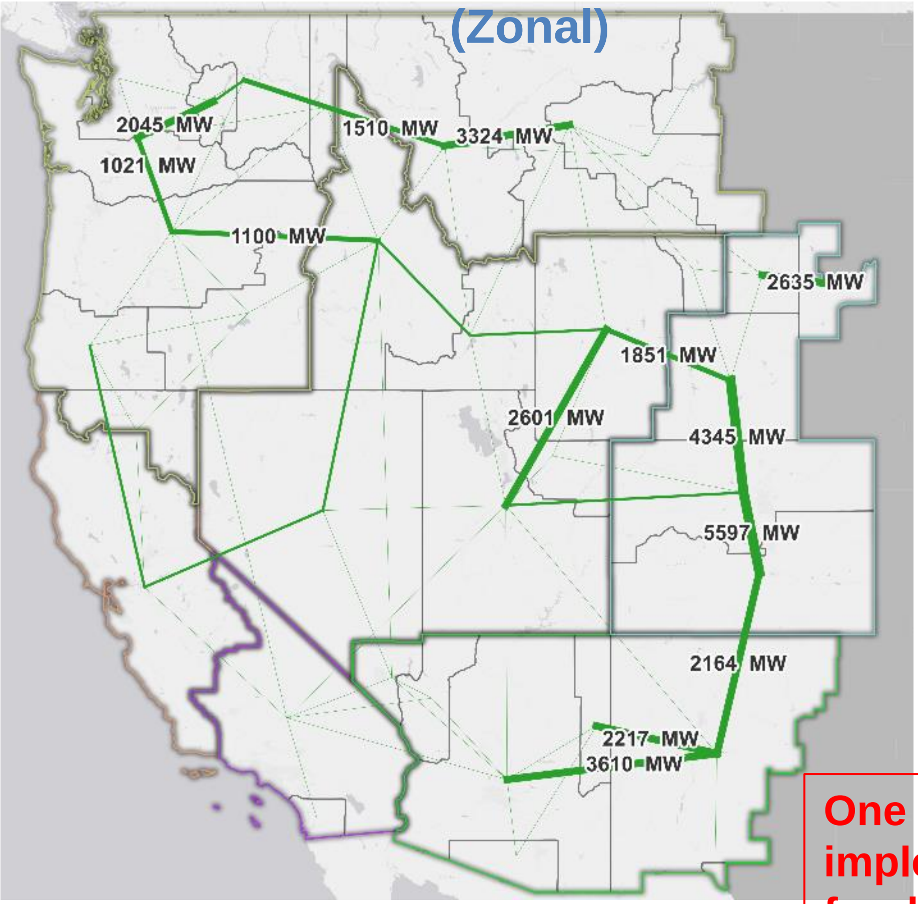
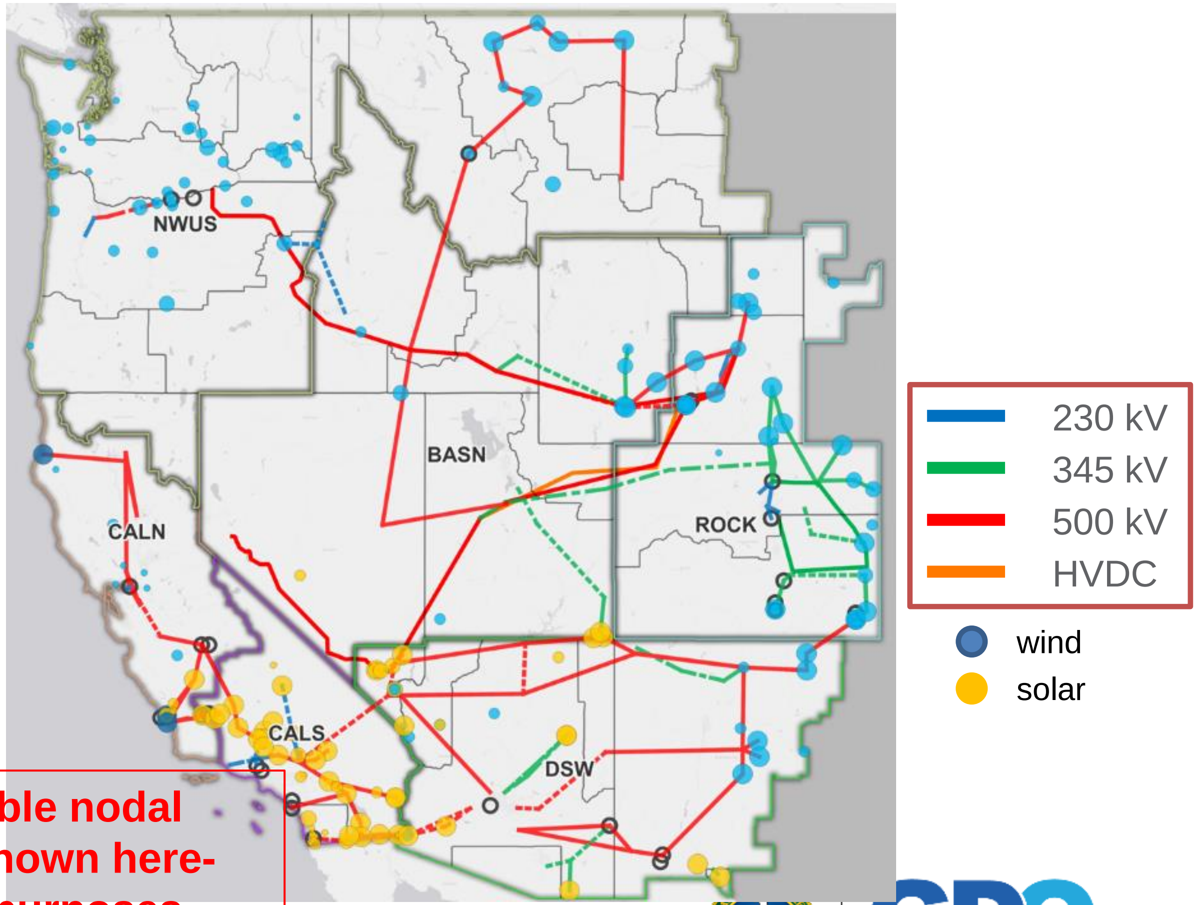
Zonal to Nodal Translation: Western Interconnection

Scenario 1 CEM Transmission Expansion (Zonal)



Scenario 1 Nodal Expansion (new only)



One of many possible nodal implementations shown here- for demonstration purposes only – not intended to be a plan of service

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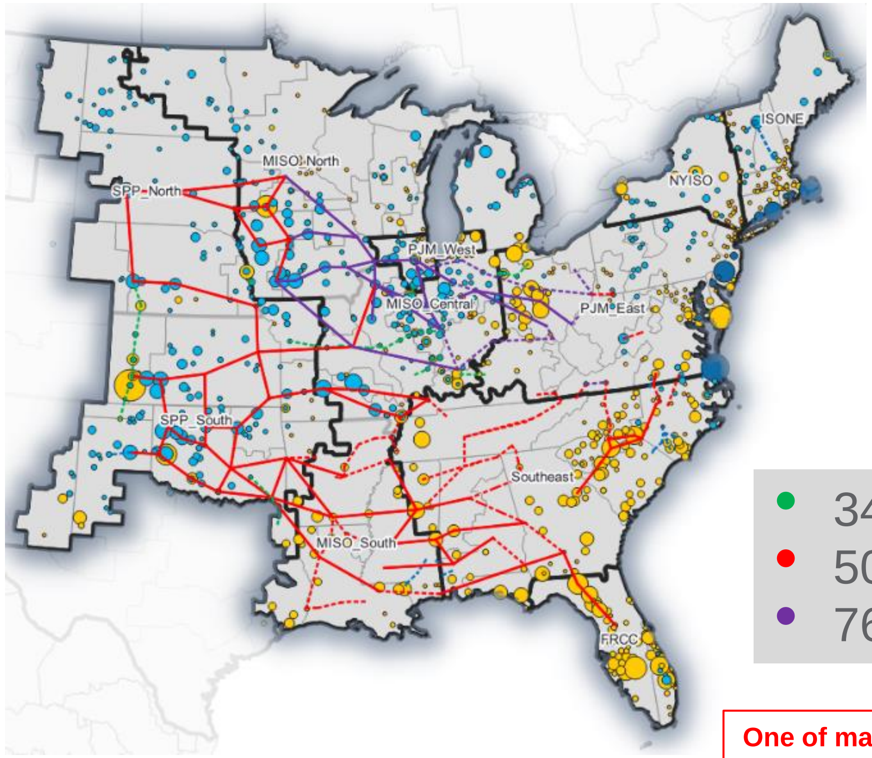
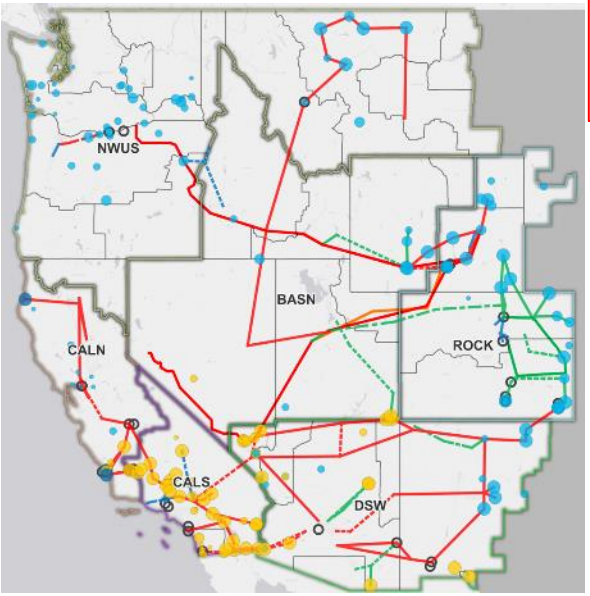
Key Takeaways So Far

- A given future power system scenario can be represented by many possible nodal implementations- here we show one possibility. This implementation does not represent a final plan of service. These are a set of buildouts that can be used for comparison across scenarios to help identify high value inter-regional transmission.
- Robust trends in resource mixes and transmission expansions are observed across a broad range of future scenarios, showing that many investment decisions can withstand changes in policy, economics, and technology evolution.
- Transformative scenarios of the future grid can be represented with detailed industry-grade network models.
- Expanding the purview of planning decisions beyond single regions could have substantial impacts to the resulting needs of the regional power system.



- 345 kV
- 500 kV
- 765 kV

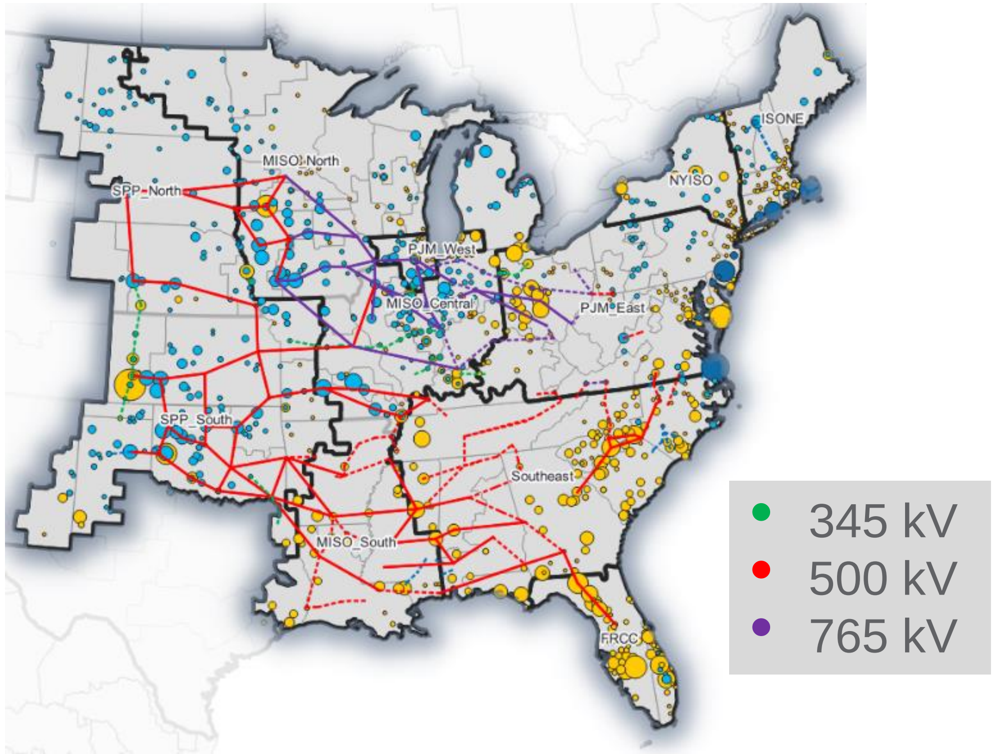
One of many possible nodal implementations shown here- for demonstration purposes only – not intended to be a plan of service

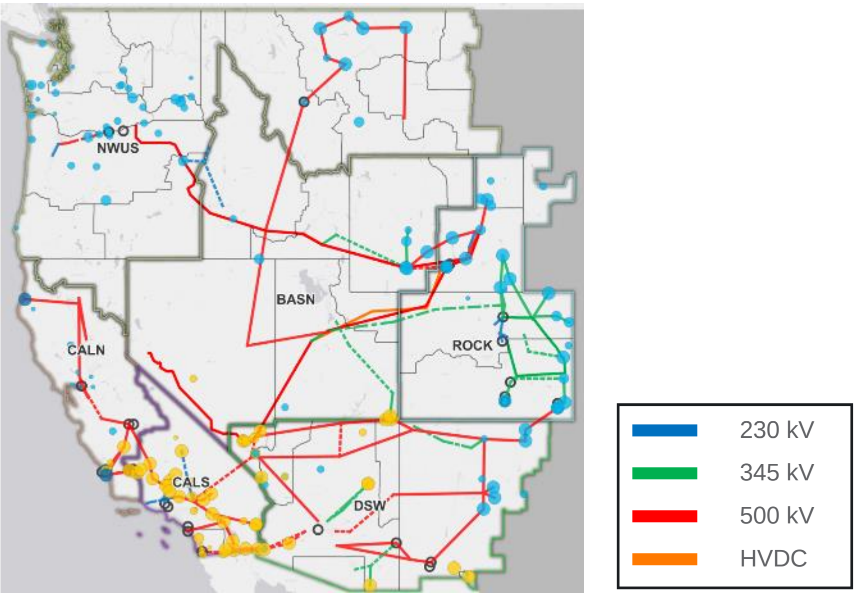


- 230 kV
- 345 kV
- 500 kV
- HVDC

Key Takeaways so Far

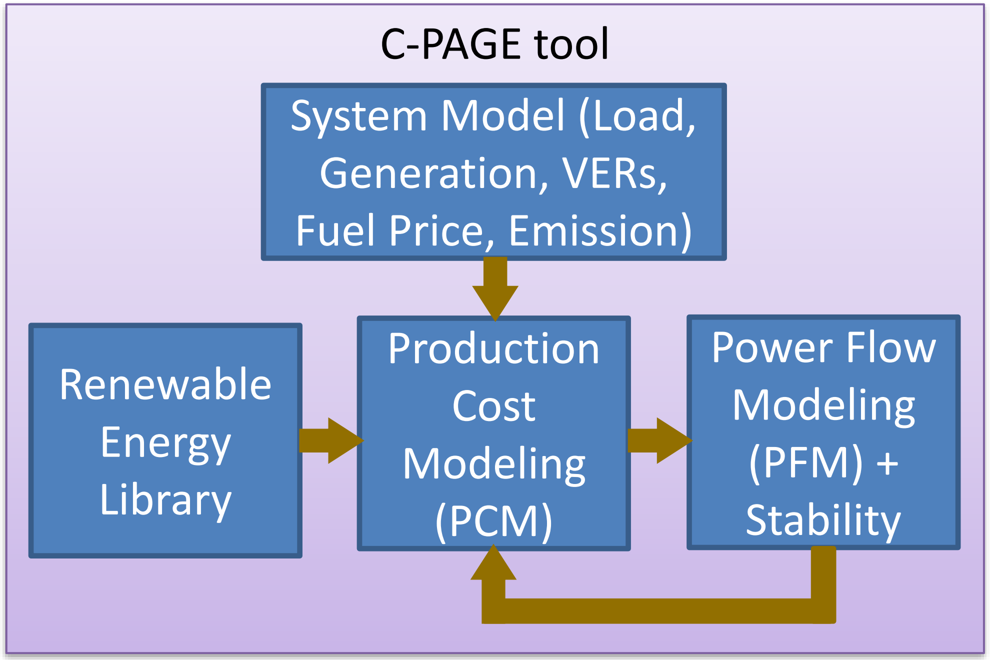
- Effective inter-regional transmission buildouts require coordination with intra-regional buildouts to avoid curtailment of variable renewable energy due to localized congestion
- A collector backbone is frequently required to interconnect very large pockets of variable renewable energy in weak parts of the system
- Nodal modeling work done to date has helped inform adjustments for zonal models going forward
- New insights on value and technical feasibility of transmission expansions are being gained by using multiple models.
  - Nodal models have increased spatial and temporal granularity to better understand utilization and physical limitations of both generation and transmission for different seasons and times of day.
- We are building tools and data sets that can be leveraged by industry

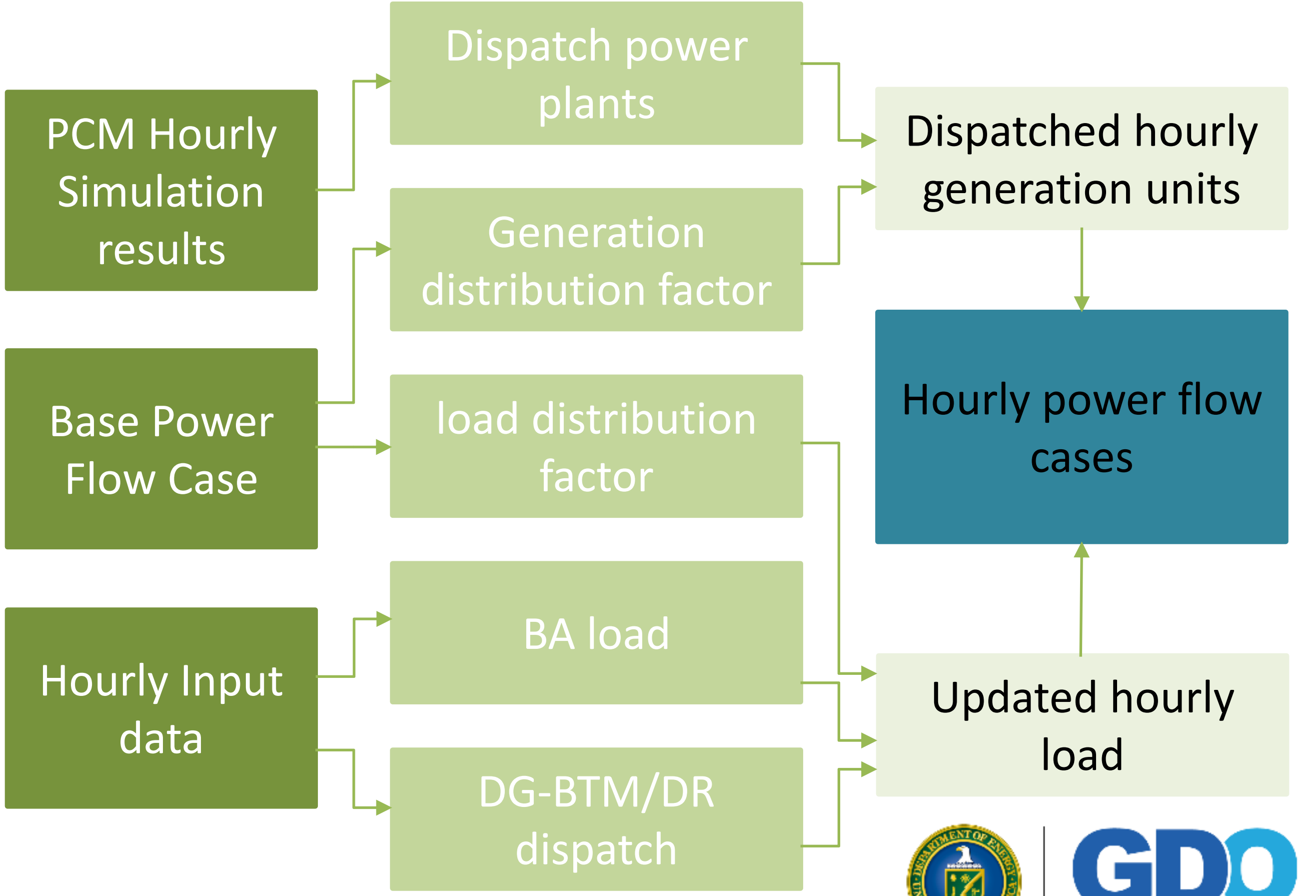




AC Power Flow

Chronological AC **P**ower Flow **A**utomated **Ge**neration Tool **(C-PAGE)**





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Multi-Model Approach

Capacity Expansion Modeling (Round 2)

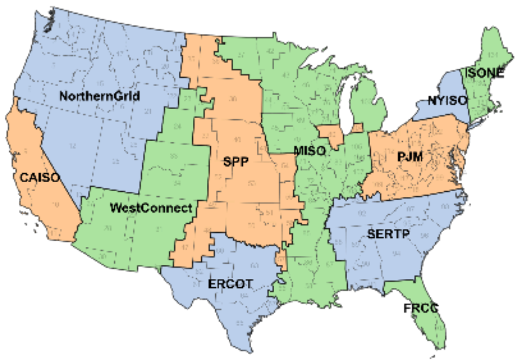
Capacity Expansion Modeling: Two Rounds

Model Feature	Round 1	Round 2
Temporal resolution	17 time slices/yr	33 representative days and 30 stress period days at 4-hr resolution: 378 time slices/yr
Resource adequacy	Seasonal capacity credit	Stress-period dispatch
Hydrogen	Exogenous prices for a clean fuel	Endogenous H2 supply and demand modeling
RE availability	Existing (2022) supply curves	Updated siting exclusions and higher resolution wind turbine modeling
Transmission network reinforcement costs	Uniform $120/kW network reinforcement costs for RE	Spatially-varying reinforcement costs
Demand projections	Existing (2022) projections	Improved state and sector calibration and with stakeholder data, and includes new projection with the IRA
Technology cost and policy updates	ATB* 2022 costs	ATB 2023 costs; RPS and CES updates, west coast OSW, improved IRA representation for H2 and CCS

ATB= NREL's Annual Technology Baseline | RPS = Renewable Portfolio Standard | CES = Clean Energy Standard | OSW = Offshore Wind

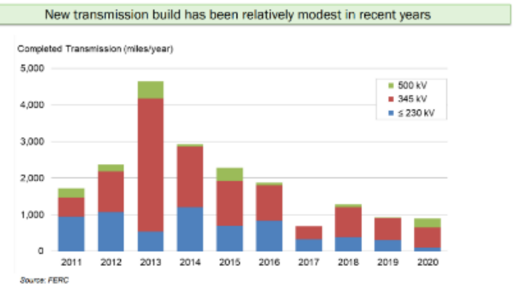
Transmission Paradigms

Limited

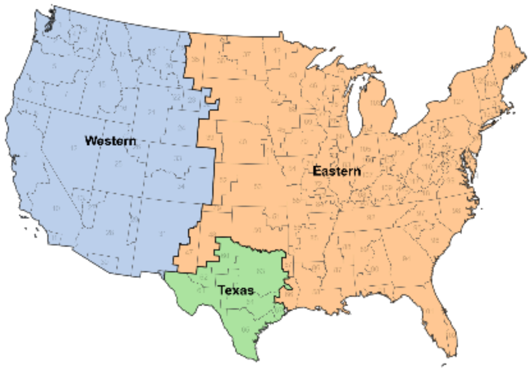


- **Intra-regional** transmission expansion within planning regions only
- Annual transmission additions <1.1 TW-miles per year based on recent (since 2009) development of ≥345 kV lines

LBNL 2021



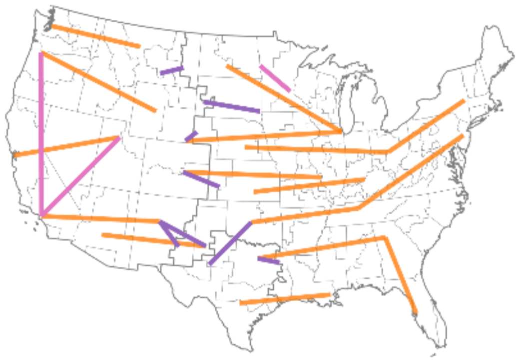
AC



- **Intra-interconnection** transmission expansion between 134 zones (no new back-back DC ties across seams)
- Transmission cost and losses based on AC transmission (500 kV).

HVDC-P2P

HVDC "point-to-point"



Illustrative of one potential scenario. Scenarios will vary.

- **Inter-interconnection** transmission expansion
- Expansion of back-to-back interties, existing HVDC, and select new connections allowed
- ~200 candidate interregional connections (≤1000 miles) between high-wind resource and high-demand regions; capacities optimized by the model
- Costs of HVDC are based on line-commutated-converter technologies

HVDC-MT

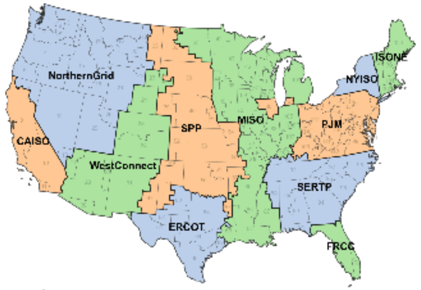
HVDC "multi-terminal"

Illustrative of one potential scenario. Scenarios will vary.

- **Multiterminal HVDC** network designed by the model and specific to the scenario
- Costs and characteristics are based on voltage-source-converter technologies
- Transmission lines converter capacities are decided separately
- MT expansion is not allowed until after 2030

Scenario Framework: 36 Core Scenarios

4 transmission paradigms X 3 demand cases X 3 emissions targets



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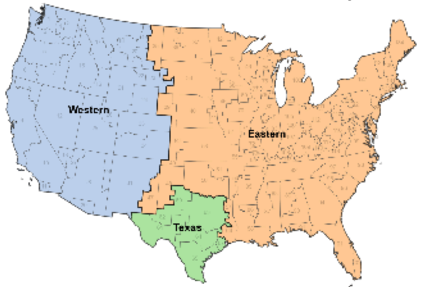

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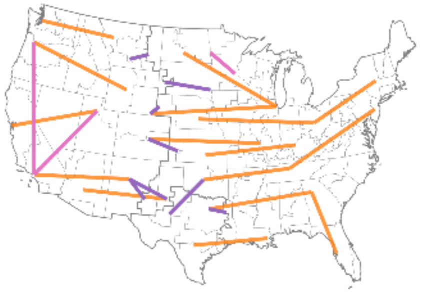
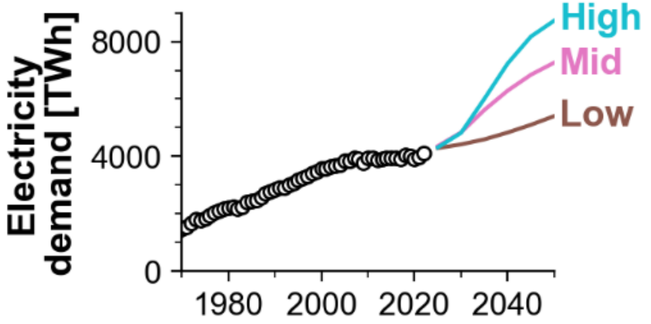


P2P

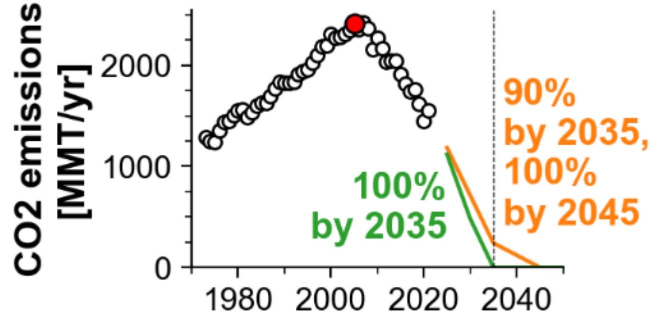
MT

Demand Growth ⟷ (columns); *Emissions Target* ⟷ (rows)

Current Policies Low Demand	Current Policies Medium Demand	Current Policies High Demand
90-by-2035 Low Demand	90-by-2035 Medium Demand	90-by-2035 High Demand
100-by-2035 Low Demand	100-by-2035 Medium Demand	100-by-2035 High Demand



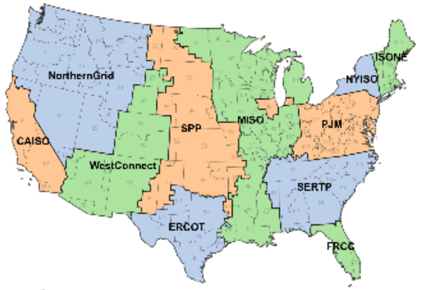
Electrolytic H2 production would increase this demand



Current policies include the IRA and state policies as of 2023

Scenario Framework: 144 Sensitivities

4 transmission paradigms X 3 emissions-demand combinations X 12 sensitivities



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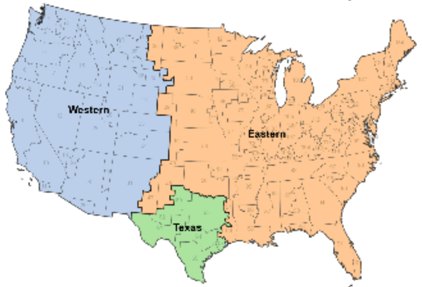

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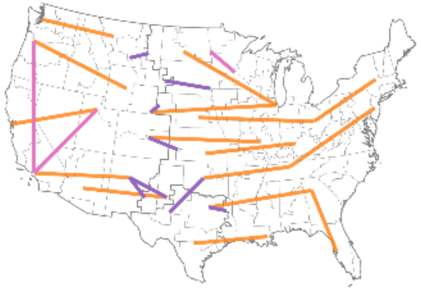


P2P

VSC

Demand Growth (columns) / *Emissions Target* (rows)

Current Policies Low Demand	Current Policies Medium Demand	Current Policies High Demand
90-by-2035 Low Demand	90-by-2035 Medium Demand	90-by-2035 High Demand
100-by-2035 Low Demand	100-by-2035 Medium Demand	100-by-2035 High Demand

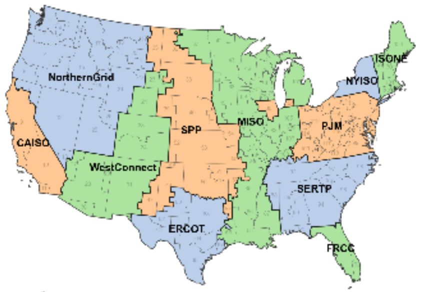
Sensitivity
Lower wind costs
Lower PV and battery costs
Lower CCS cost
Expanded technologies (nuclear-SMR and DAC)
Higher (2x) transmission costs
Limited wind and PV siting
No CCS
No H2
No CCS, H2
No new nuclear, CCS, H2
Climate change heuristics
Many challenges

more optimistic

Less optimistic

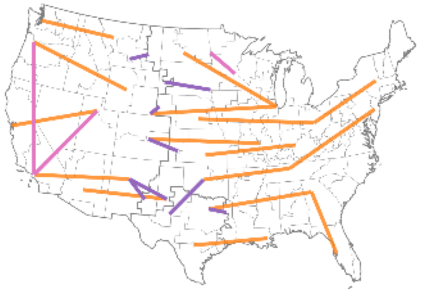
Scenario Framework: 144 Sensitivities

4 transmission paradigms X 3 emissions-demand combinations X 12 sensitivities



Limited

AC



P2P

VSC

Demand Growth →

Emissions Target ↓

Current Policies Low Demand	Current Policies Medium Demand	Current Policies High Demand
90-by-2035 Low Demand	90-by-2035 Medium Demand	90-by-2035 High Demand
100-by-2035 Low Demand	100-by-2035 Medium Demand	100-by-2035 High Demand

Sensitivity
Lower wind costs
Lower PV and battery costs
Lower CCS cost
Expanded technologies (nuclear-SMR and DAC)
Higher (2x) transmission costs
→ Limited wind and PV siting
No CCS
No H2
No CCS, H2
→ No new nuclear, CCS, H2
→ Climate change heuristics
→ Many challenges

more optimistic

Less optimistic

Multi-Model Approach

Resource Adequacy

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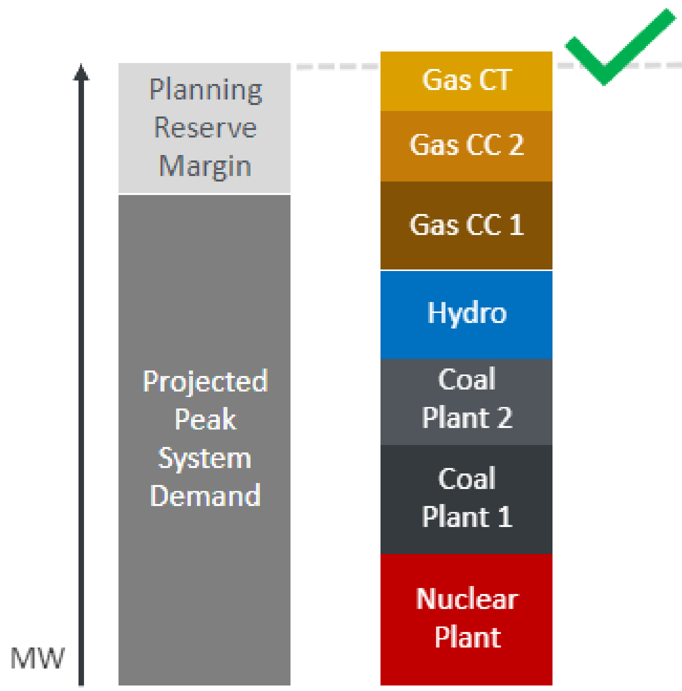
What is Resource Adequacy (RA)?

“The ability of the electric system to supply the aggregate electrical demand and energy requirements of the end-use customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.”

– North American Electric Reliability Corporation (NERC) Version 0 Reliability Standard

- Traditional method to ensure adequacy
  1. Forecast peak system demand
  2. Calculate a Planning Reserve Margin (PRM), which represents the common reliability standard of 1 day in 10 years of lost load expectation (LOLE)
  3. Build enough resources to ensure demand + the planning reserve margin are met

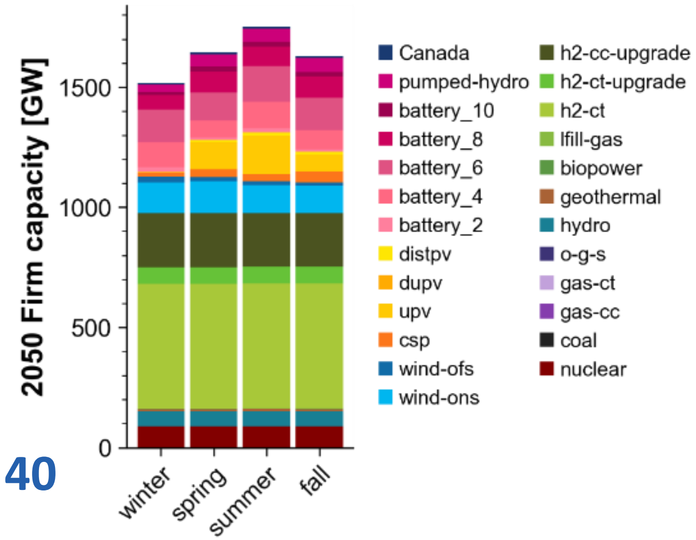


Ensuring Resource Adequate Systems in NTP Study

Capacity Expansion Model (ReEDS Round 1)

- Enforces constraints in line with RA method described above

Firm Capacity Built ≥ Peak Demand + NERC Planning Reserve Margin



Additional verification and stress testing

Probabilistic Resource Adequacy Suite (PRAS)

- Simulation-based resource adequacy assessment
- Captures uncertainty due to forced outages, load, variable generator profiles

Production Cost Models (Sienna, PLEXOS, GridView)

- Unit commitment and dispatch model
- Captures detailed operating considerations

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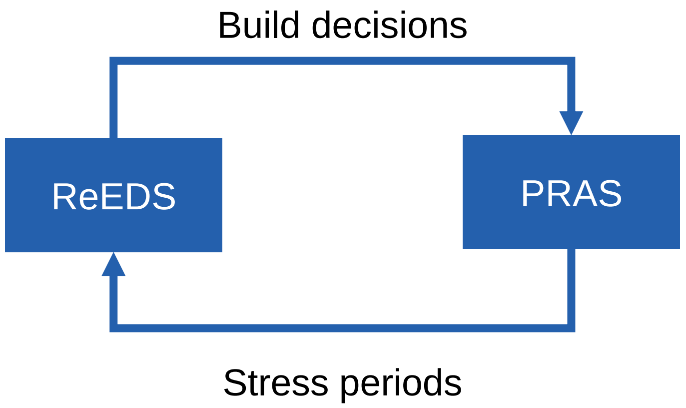
Resource Adequacy Improvements: ReEDS-PRAS Integration

Goal: Improve representation of resource adequacy in the capacity expansion model to achieve more reliable and cost-efficient solutions

Improvements (ReEDS Round 2)

- Stressful periods identified via chronological, probabilistic, full year, hourly dispatch model (PRAS)
- Directly models network flows and storage operation during stress periods
- Can identify periods of inadequacy due to energy limitations (in addition to capacity)
- Directly estimate adequacy metrics (EUE, LOLP, LOLE) that can inform feedback to build decisions



Multi-Model Approach

Stress Analysis

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)

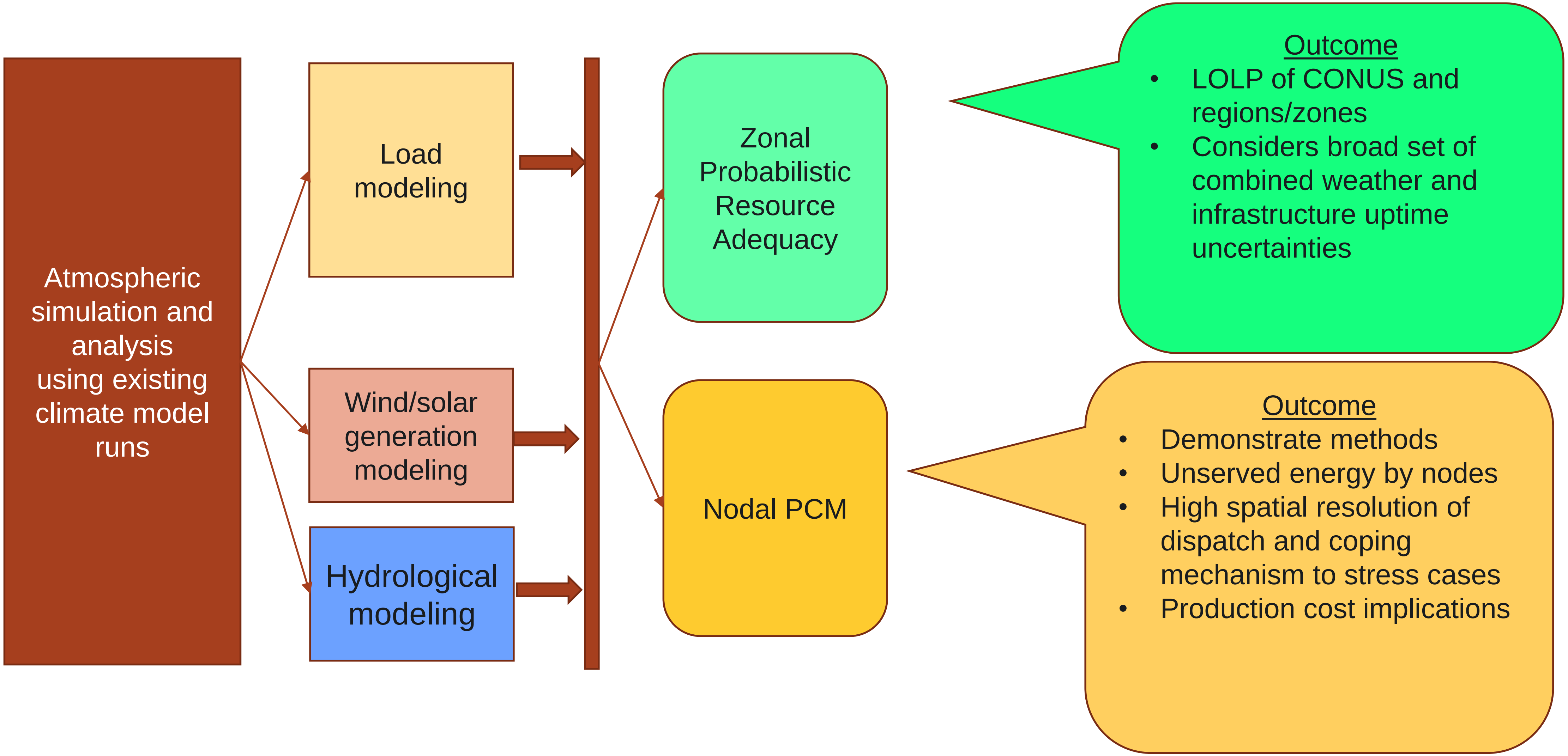
Potentially decreased supply (e.g., PV panels are snow covered; icing, air-density increase, and persistent high-pressure system may slow down wind turbines)

Drought impacts

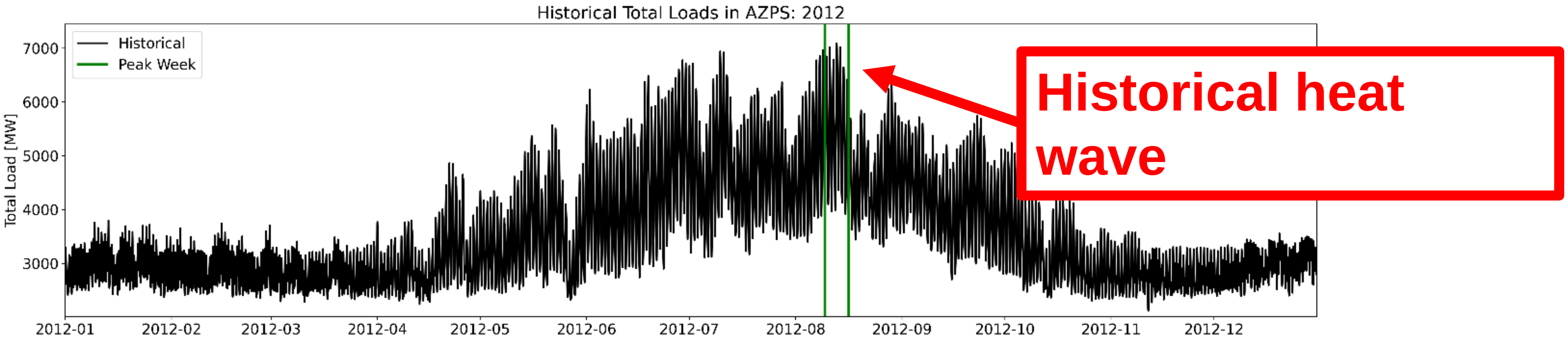
Decreased hydro-generation

Treatment of Stress Case

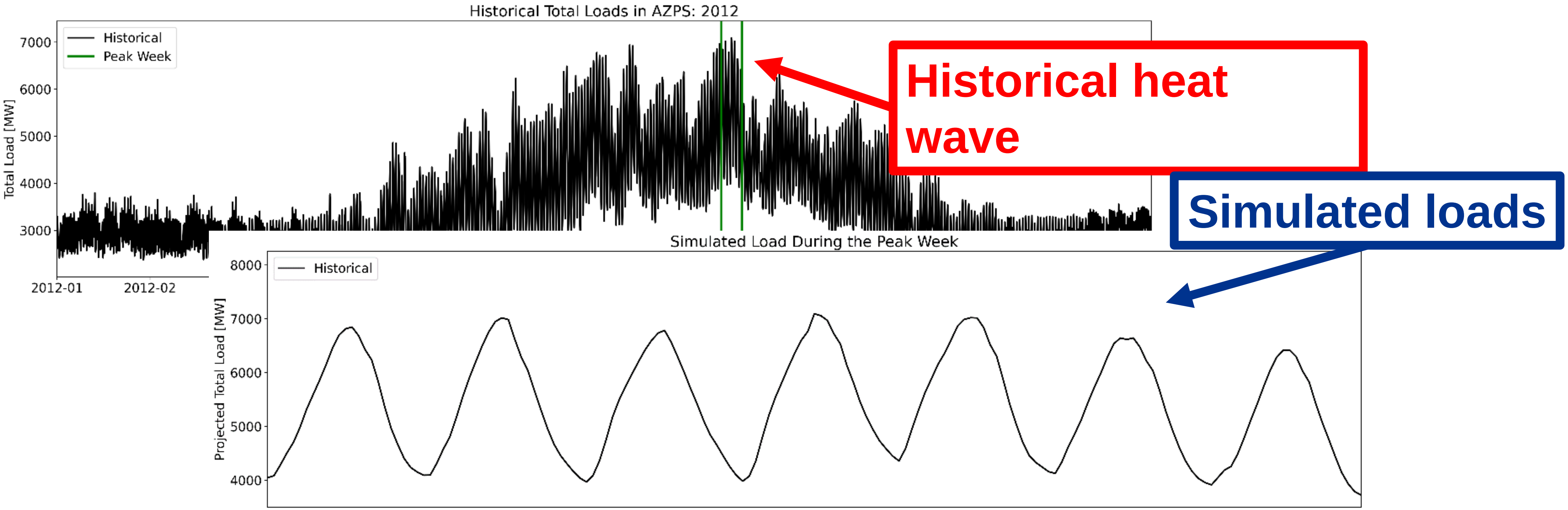
Engineering Analysis



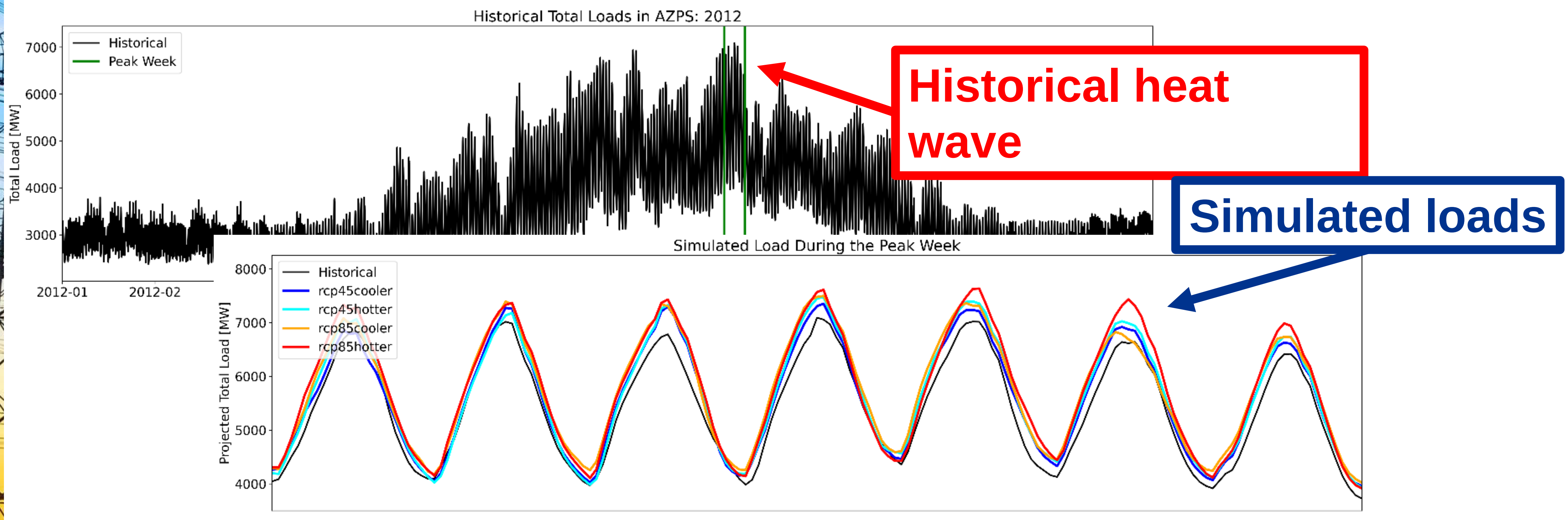
Example Heat Wave: AZPS



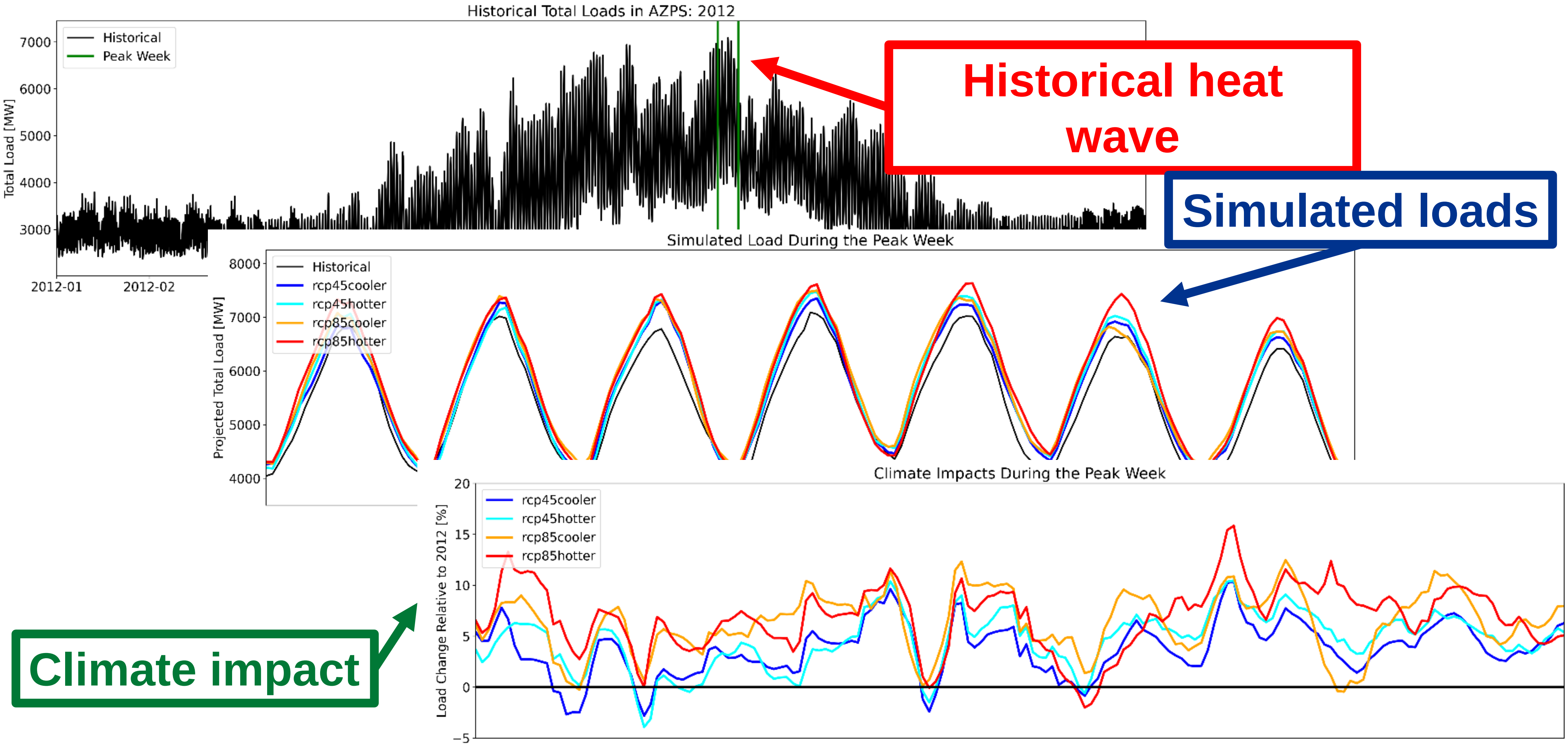
Example Heat Wave: AZPS



Example Heat Wave: AZPS



Example Heat Wave: AZPS



Multi-Model Approach

Economic Analysis

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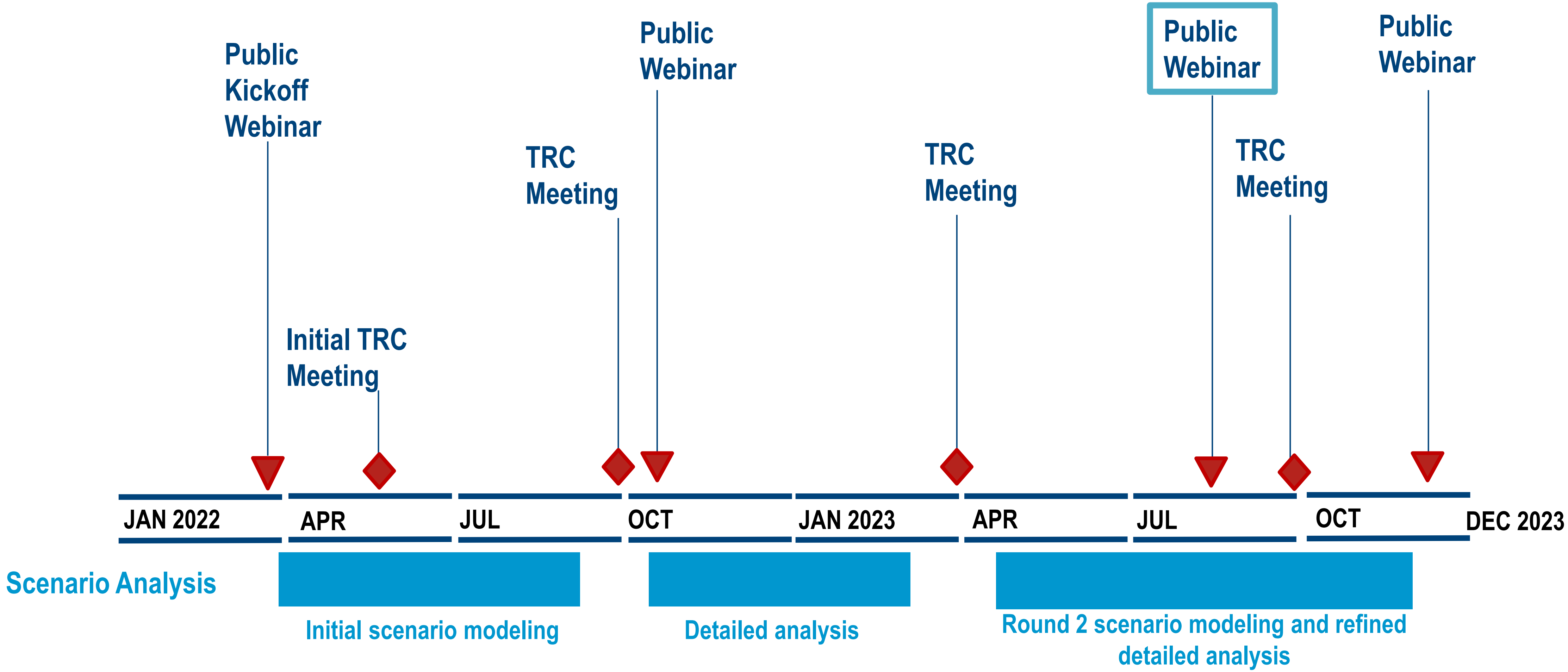
Economic Analysis is using a Suite of NTP Modeling Tools

	Capacity Expansion	Zonal Production Cost	Resource Adequacy
Capital Costs	Avoided generation and transmission investments Access to lower cost generation sites Access to policy incentives for RE investments		
Operating Costs	Avoided costs for fuel and other variable costs Access to policy incentives for RE generation	Avoided costs for unit cycling	
Reliability	Reduced cost of ancillary service and resource adequacy requirements		Reduced loss of load probability
Resiliency		Reduced severity and duration of outages	Reduced outages during extreme events Mitigation of weather and load uncertainty

NTPS Timeline



TRC = Technical Review Committee

Coordination with Offshore Wind Studies

Alissa Baker

Grid Deployment Office,

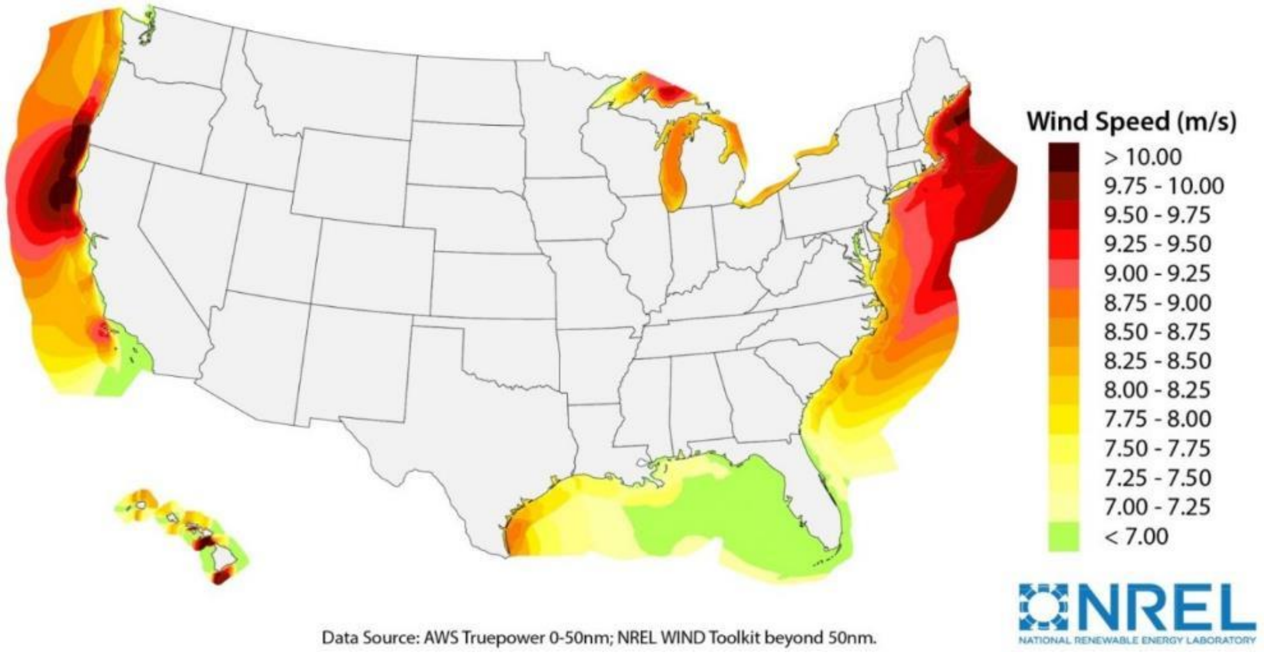
U.S. Department of Energy

DOE & BOEM Efforts on OSW Transmission

Convening Workshops: DOE and BOEM conducted a series of convening workshops, in consultation with FERC and other federal agencies, to develop a set of recommendations for OSW transmission development, planning policy, and permitting for the Atlantic Coast.

Transmission Analysis: DOE is completing the Atlantic OSW Transmission (AOSWT) Study ,which is a comprehensive transmission analysis that compares costs and benefits of transmission buildout scenarios while considering grid operability; reliability and resilience; and environmental and ocean co-use siting considerations.

Action Plan & Recommendations Report: These recommendations and a time-bound action plan are being documented in a report for publication this summer.



U.S. DEPARTMENT OF ENERGY Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

LPO LOAN PROGRAMS OFFICE

U.S. DEPARTMENT OF THE INTERIOR BOEM Bureau of Ocean Energy Management

NREL Transforming ENERGY

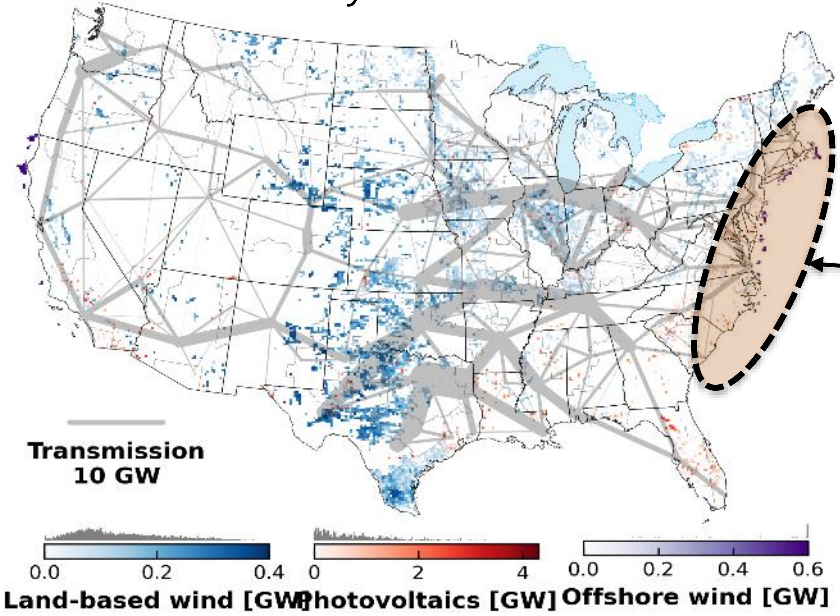
Pacific Northwest NATIONAL LABORATORY

Study Coordination: NTP Study and OSW Tx

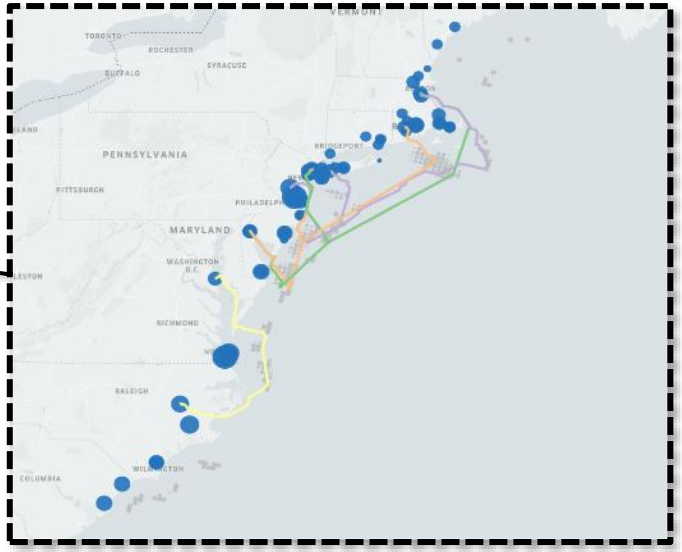
Coordination between the National Transmission Planning Study and Atlantic Offshore Wind Transmission Study:

- Overlapping technical review committees and lab (NREL and PNNL) study teams
- Scenario creation relies on the same model (e.g., ReEDS capacity expansion) and key assumptions for both studies
- Economic analysis applies a common multi-value approach developed for both studies
- NTP Study will use AOWTS POI data for offshore wind nodal modeling
- <u>Proposal</u> to adopt the AOWTS 2050 `interregional topology' for one of nodal scenarios for production cost analysis under NTPS (see conceptual figure)

Ex. NTP Study multi-terminal HVDC scenario



Ex. AOWTS interregional topology



Preliminary and illustrative results only

▸Questions?

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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