U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2021 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
WIND ENERGY TECHNOLOGIES OFFICE

E04 - Continental-Scale Transmission Modeling Methods for Grid Integration Analysis

Mitigate Market Barriers – Grid Integration
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NREL
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FY21 Peer Review - Project Overview

Project Summary:

- There has been a renewed interest in large-scale, inter-regional, transmission planning in recent years.
- This project finalizes and builds on the Interconnection Seams Study, refining methods and data parameterization for improved modeling of transmission congestion within capacity planning tools and grid operations models.
- The improved characterization of congestion will help model the potential contributions of wind to reliability and resilience in the future grid and help increase stakeholder confidence in the scenarios studied for large-scale grid integration studies.

Project Start Year: End of FY 2019
Expected Completion Year: FY 2022
Total expected duration: 3 years

FY19 - FY20 Budget: $900,000

Key Project Personnel: Greg Brinkman, Josh Novacheck, and Jiazi Zhang, NREL

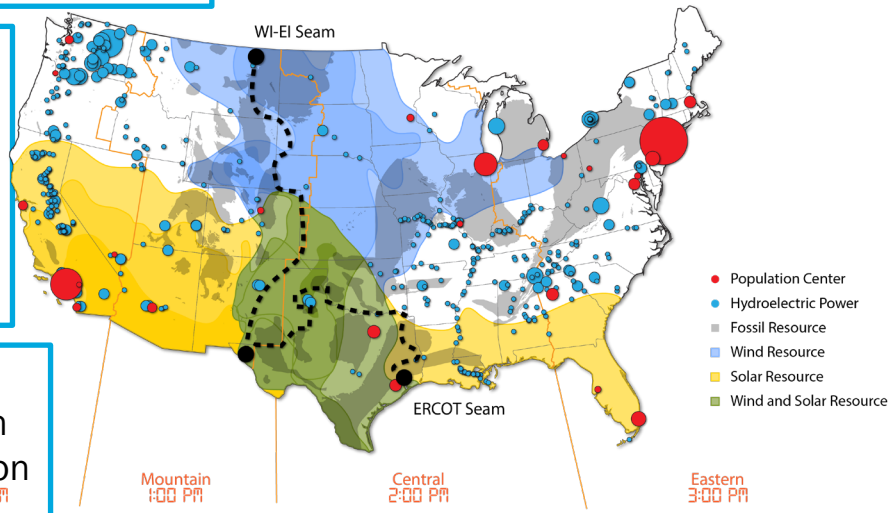
Key DOE Personnel: Jian Fu

Project Objective(s) 2019-2020:

- Complete and publish Interconnection Seams Study, along with visualizations and website
- Initial transmission modeling improvements for capacity expansion modeling, production cost modeling, and the translation between the two.

Overall Project Objectives (life of project):

- Perform analysis with improved transmission representation to understand benefits of continental transmission expansion in more detail



Project Impact

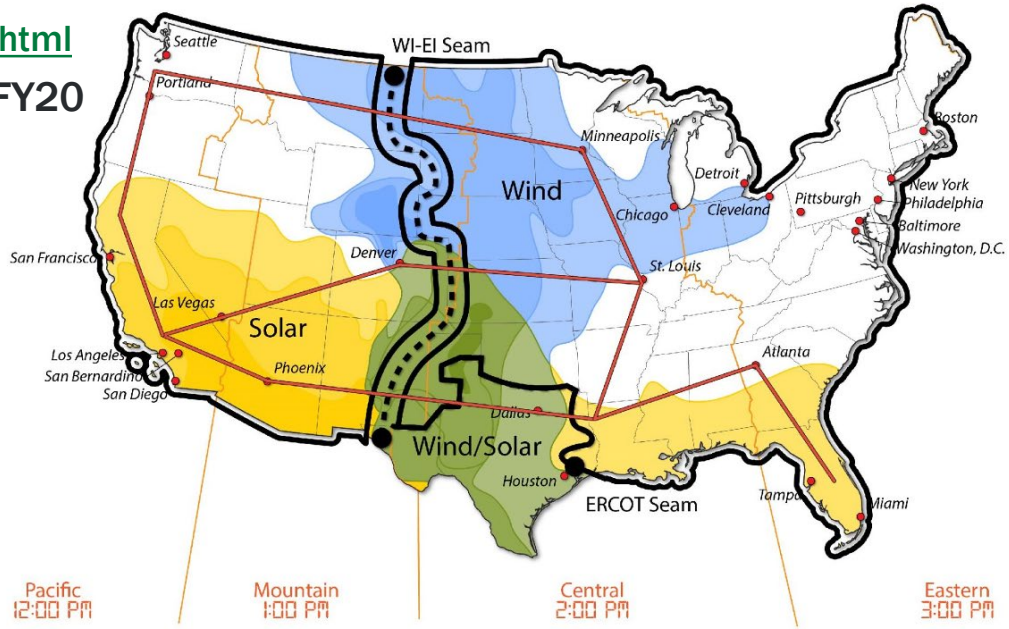
Task	Desired Impacts
Completion and publication of Interconnection Seams Study (mostly FY20)	• Study benefits of inter-regional transmission in wider variety of scenarios • Finalize Seams Study and publish peer-reviewed journal article for citation and details for stakeholders
Improved transmission model representation (FY20 and FY21)	• Improve treatment of transmission in capacity expansion and production cost studies • Open-source improvements for stakeholder use
Analysis of transmission benefits (FY21 and FY22)	• Understand benefits of transmission in more detailed modeling framework

Program Performance – Scope, Schedule, Execution

Schedule and Execution:

- Project started at the end of FY19: due to the start date, approximately 40% of the total project budget was spent during FY19 and FY20
- All Milestones were met, some delays due to Seams study reviews
- Subcontract executed with Iowa State University for the new scenarios and analysis for the Interconnection Seams Study
- Publication of findings in website, animation videos on YouTube, and publication (submitted for peer review but available)
  - Website and links available at:

  https://www.nrel.gov/analysis/seams.html
- Ongoing methodology work during FY20



Scenarios for Interconnection Seams Study

Scenario	Key Assumption Differences
Base Case	AEO 2017 gas price, existing state RPS laws
Low Gas Price	AEO 2017 High Gas Resource (gas prices regionally and temporally varying around $4/mmbtu)
High Gas Price	AEO 2017 Low Gas Resources (gas prices varying around $6/mmbtu)
High AC Trx Cost (1.5x)	50% higher than base transmission cost. Base transmission cost from [16]
High AC Trx Cost (2x)	Double the base transmission cost
No Retirements	Model does not retire any generating units beyond announced retirements
Low-Cost Renewables	ATB 2017 Low Cost projections for wind and solar
High VG	Least-cost generation mix when using a carbon cost from $3/tonne in 2024 to $45/tonne in 2038**

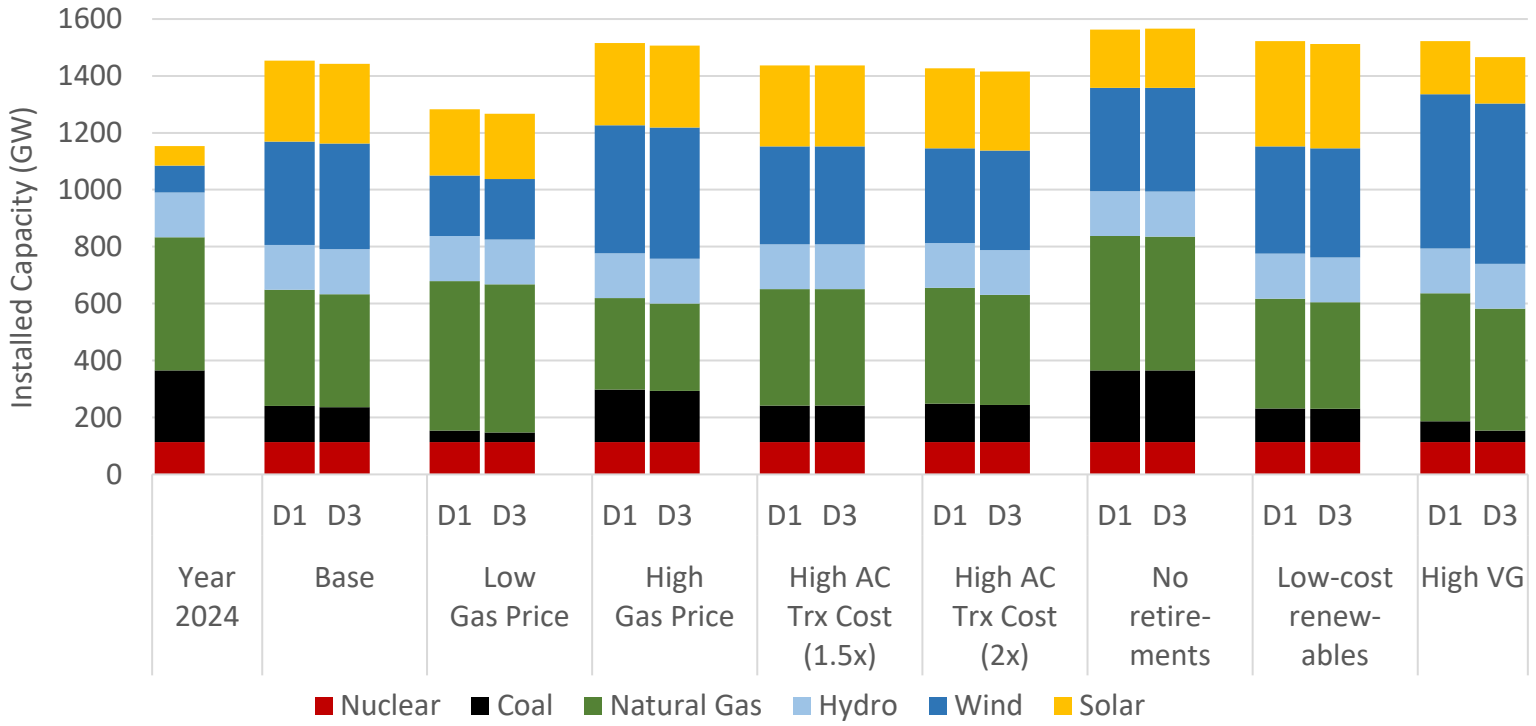
- Four conceptual transmission designs (described on following slides) were studied under eight different grid environments
- A total of 32 total capacity expansion model runs were made by Iowa State University
- Scenarios vary in terms of technology cost, fuel price, and policy assumptions

Description of the Scenarios*

*Acronyms used here include Energy Information Administration (EIA) Annual Energy Outlook (AEO); Renewable Portfolio Standard (RPS); Annual Technology Baseline (ATB) (atb.nrel.gov); Variable Generation (VG)

**: The study Technical Review Committee recommended this approach (consistent with cost estimates in [17]) as a proxy for potential growth in wind and solar in light of uncertainty in traditional deployment forecasts [18].

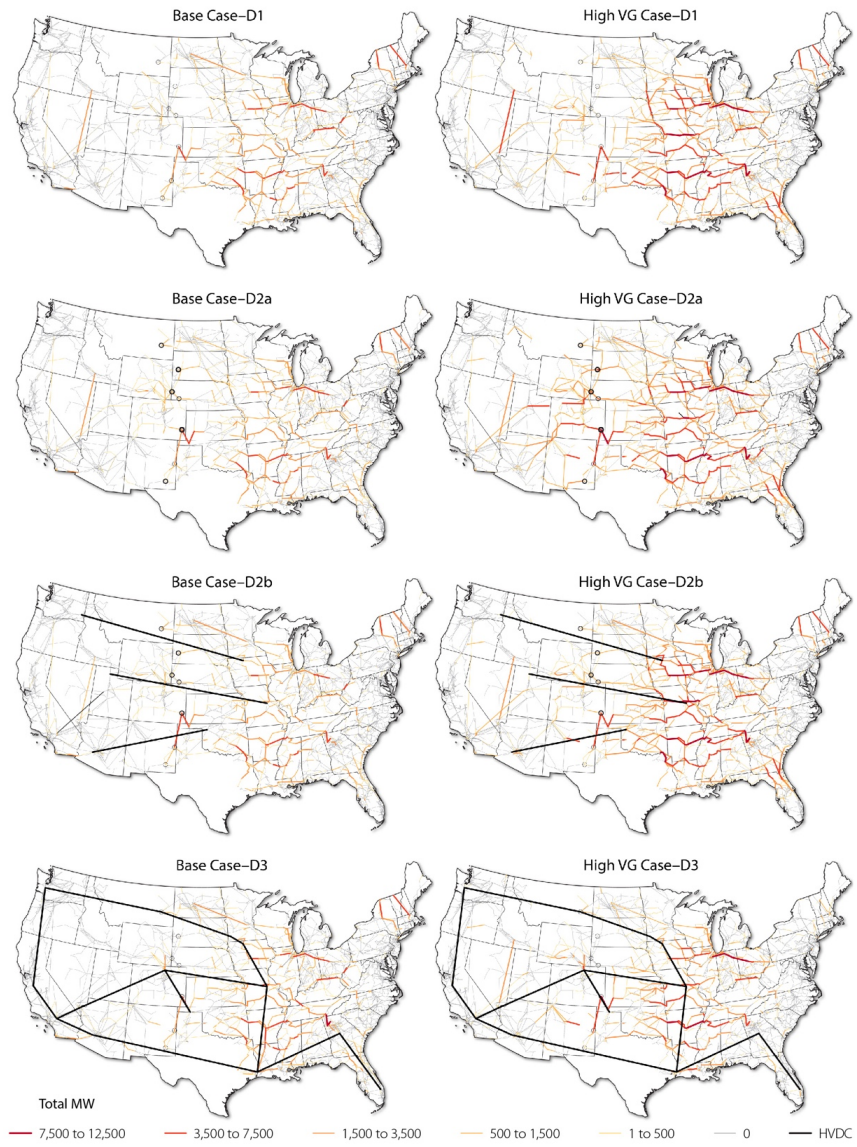
Generation Capacity for Selected Scenarios and Designs



D1 = No new cross-seam transmission
D2a = Back-to-back intertie expansion only
D2b = Back-to-back intertie expansion + 3 HVDC lines
D3 = HVDC Macrogrid

(see next slide for map of transmission builds comparing the scenarios)

Transmission Builds for Selected Scenarios and Designs



Transmission Investment Summary
Base Scenario

Design→	D1	D2a	D2b	D3
HVDC-B2B (GW)	0	6.7	6.3	0
HVDC-Line (GW-miles)	0	0	14,487	29,062
AC Line (GW-miles)	18,409	19,357	17,778	16,076

High VG Scenario

Design→	D1	D2a	D2b	D3
HVDC-B2B (GW)	0	25.7	7.5	0
HVDC-Line (GW-miles)	0	0	31,335	63,156
AC Line (GW-miles)	52,737	60,141	50,964	43,190

Note: New transmission investments are identified for B2B in terms of GW increased capacity between B2B terminals, and for lines in terms of GW-miles (which is the GW capacity multiplied by the path distance).

Benefit-Cost Ratio

$$\text{Benefit-Cost Ratio} = \frac{\text{Change in Total Non-Transmission Costs}}{\text{Change in Transmission Investment Costs}}$$

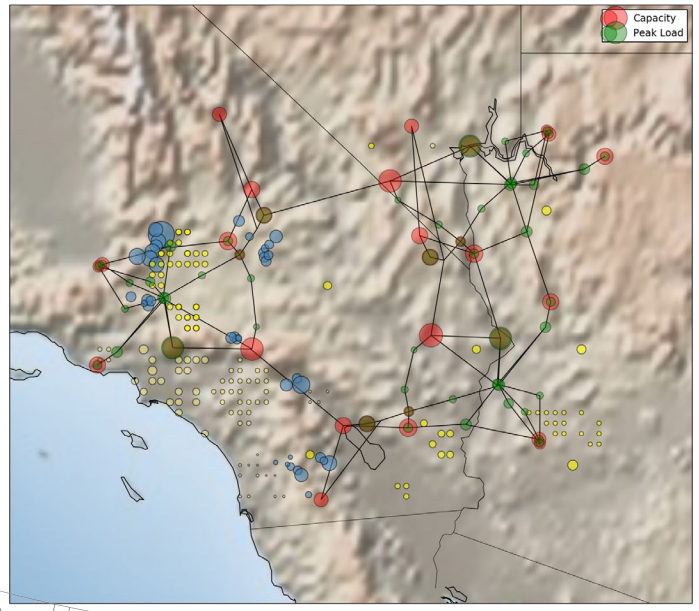
- All benefit-cost ratios except one are larger than 1.25 (a commonly used threshold in industry)
- Largest benefit-cost ratio is in the High VG (wind and solar) scenario
- The best transmission design changes depending on scenario
- There are non-quantified benefits of the HVDC macrogrid (D3)
- Non-Transmission Costs include: Generation Investment, Fuel, Fixed O&M, Variable O&M, Carbon, Regulation Up/Down, and Contingency costs

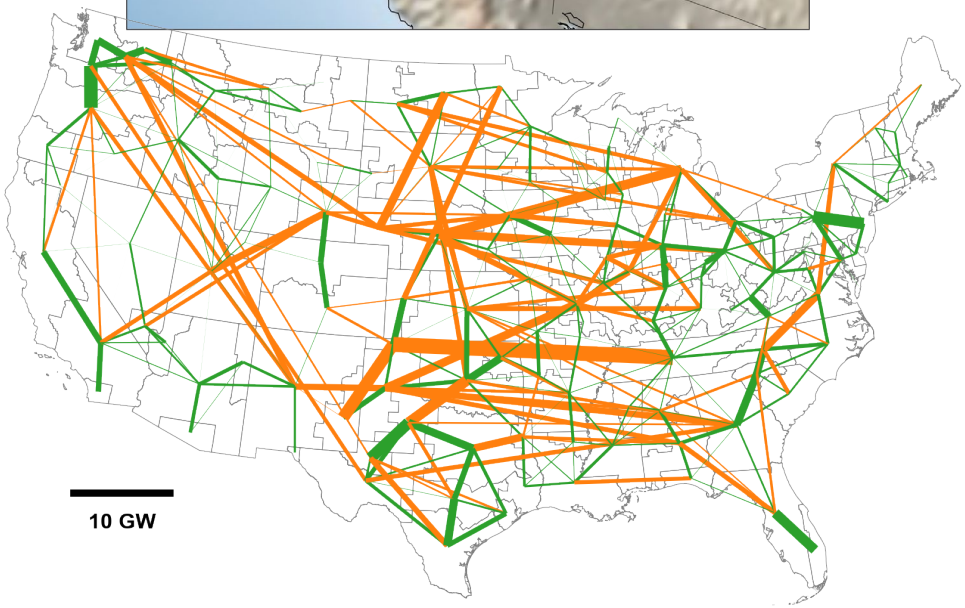
Scenario	ΔD2a	ΔD2b	ΔD3
Base Case	2.02	1.66	1.36
Low Gas Price	1.81	1.52	1.22
High Gas Price	1.76	1.84	1.46
High AC Trx Cost (1.5x)	1.87	1.45	1.29
High AC Trx Cost (2x)	2.26	1.52	1.37
No retirements	1.98	1.72	1.33
Low-cost renewables	2.53	1.77	1.56
High VG	2.09	2.89	1.80

Note: D2a, D2b, and D3 results are shown as savings relative to D1. Emission costs included in the High VG scenario are not included in Net Costs.

Project Performance - Upcoming Activities

- Testing automated N-1 tool on RTS-GMLC (map to the right) and North American Renewable Integration Study (NARIS) datasets (FY21)
- Improving ReEDS inter-regional modeling methods for developing scenarios (FY21)
- Analysis using newly-developed tools (FY22), focused on comparing offshore wind scenarios and comparing with transmission scenarios

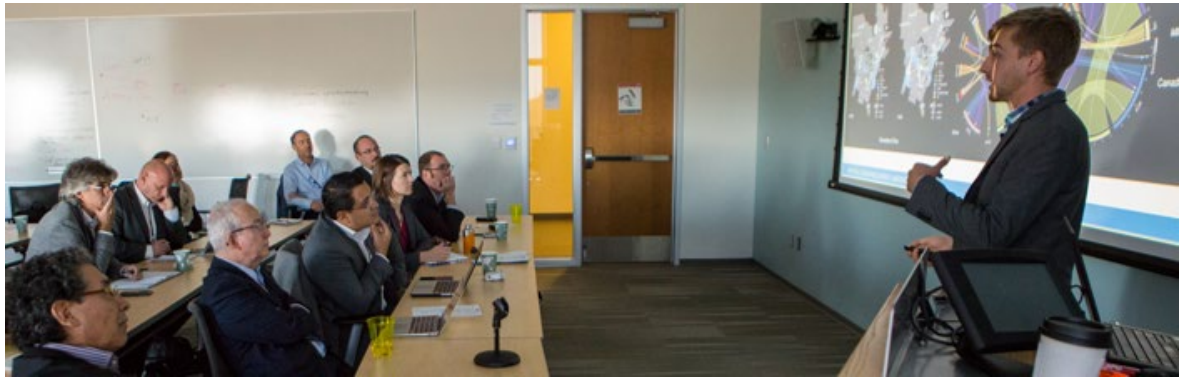




Stakeholder Engagement & Information Sharing

Technical Review Committee and project partners for Interconnection Seams Study:

- Over 30 organizations throughout North America
- Worked with stakeholders to refine assumptions and methods (including FY20 updates with key partners)
- Website for animations, videos, and publication: **https://www.nrel.gov/analysis/seams.html**



Plans for upcoming method development and analysis

- All ReEDS capacity expansion model improvements will be open-source
- Methodology improvements will be written in either a separate document or as part of the larger analysis work
- Similar dissemination to the Seams study is planned (data, animations, webinars, and report)