Transmission Planning for 100% Clean Electricity

Dr. Debra Lew, Associate Director, ESIG
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How can we enable cleaner electricity while maintaining affordability and reliability?
Decarbonization requires action on a transformative scale.

- 28% clean electricity in 2001
- 38% clean electricity in 2019
- 100% clean electricity by 2035
We need transmission to deliver significant resources

- We may need 1000 GW+ of new wind and solar for 100% clean electricity goals.
- Electrification will lead to significantly increased demand.
- Distributed energy resources (DERs) will contribute but are not sufficient on their own.

Source: MISO RIIA Study, Preliminary results from VCE’s ZeroByFifty Study, NREL Electrification Futures Study
A macro grid saves money – especially if you are decarbonizing

- With a 50% renewables goal, this HVDC macro grid has a benefit-to-cost ratio of 2.5
- With a 85% renewables goal, this HVDC macro grid has a benefit-to-cost ratio of 2.9

[Image: HVDC Macro grid]

"Every state for itself" costs twice as much as the nationally optimized and coordinated approach

[NREL Interconnection Seams Study](https://www.nrel.gov/analysis/seams.html)

[MIT Transmission Study](https://doi.org/10.1016/j.joule.2020.11.013)
Transmission costs are tiny compared to other clean resources/infrastructure.
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Transmission costs

Seams Study 50% renewables case

ZeroByFifty 100% clean energy case

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Brown and Botterud, 2020; NREL Interconnection Seams study; Preliminary results from VCE’s ZeroByFifty Study
Transmission is not just about delivering resources to load
Transmission contributes to resource adequacy

Source: Enernex, EWITS, NREL/SR-550-47078, 2010; L. Nickell, SPP, CREPC Spring meeting, 2017

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MISO found that transmission was the key enabler to meet reliability standards at 50% wind/solar.
Can’t we do this with storage?
Or DERs?
Storage-only solutions are more expensive and don’t address all the issues.

If you allow the model to optimize size of storage only, it builds 16GW storage.

If you allow the model to optimize between transmission and storage, it builds 0.5GW storage plus transmission.

DERs are part of the solution. We still need utility-scale wind/PV

- Optimizing G, T&D saves money vs not including distribution in optimization
- Benefits are even bigger if you have clean energy goals - save $473B by optimizing G, T&D
- Optimizing G, T&D builds more DERs and also builds more transmission

ESIG Recommendations

1. Create a national transmission planning authority that conducts ongoing national transmission planning
2. Identify renewable energy zones
3. Design a national macro grid

https://www.esig.energy/transmission-planning-for-100-clean-electricity/
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Extra slides
We evaluated a number of studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Region</th>
<th>Renewable Capacity</th>
<th>Clean Energy Level(s)</th>
<th>Annual Electricity Demand</th>
<th>Target Year</th>
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</thead>
<tbody>
<tr>
<td>Electrification Futures Study</td>
<td>United States and Canada</td>
<td>600 GW (wind)</td>
<td>23% to 75% renewable energy</td>
<td>7,000 TWh</td>
<td>2050</td>
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<tr>
<td></td>
<td></td>
<td>1,000 GW (solar)</td>
<td></td>
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<tr>
<td>Interconnections Seam Study</td>
<td>United States (except Texas) and Canada</td>
<td>600-900 GW (wind and solar)</td>
<td>63% to 95% carbon free electricity</td>
<td>4,900 TWh</td>
<td>2038</td>
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<tr>
<td>MIT study</td>
<td>United States</td>
<td>1,200 GW (wind)</td>
<td>100% clean electricity</td>
<td>5,000 TWh</td>
<td>2040</td>
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<tr>
<td></td>
<td></td>
<td>1,100 GW (solar)</td>
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<tr>
<td>Renewable Integration Impact Assessment</td>
<td>United States - Eastern Interconnection</td>
<td>411 GW (wind)</td>
<td>Up to 100% clean electricity for the eastern interconnection</td>
<td>2018 demand</td>
<td>N/A</td>
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<td>677 GW (solar)</td>
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<td>ZeroByFifty</td>
<td>United States</td>
<td>1,100 GW (wind)</td>
<td>100% clean energy</td>
<td>9,000 TWh</td>
<td>2050</td>
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<tr>
<td></td>
<td></td>
<td>1,000 GW (solar)</td>
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Interconnections Seam Study

• What’s the value of interconnecting the east and west?

• Crossing the seam allows you to build the solar in the west and the wind in the east and share

• 50% renewables case: macro grid adds $19B to transmission costs but saves $48B (generation capacity, O&M and emissions), for a benefit/cost ratio of 2.5

• 85% renewables case (95% clean electricity): macro grid builds 40GW transfers across seam with a benefit/cost ratio of 2.9

<table>
<thead>
<tr>
<th>50% Renewables case</th>
<th>BAU across seams</th>
<th>HVDC Macro grid</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective function</td>
<td>Design 1</td>
<td>Design 3</td>
<td></td>
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<tr>
<td>Line investment (B$)</td>
<td>61.21</td>
<td>80.10</td>
<td>18.89</td>
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<tr>
<td>Generation investment (B$)</td>
<td>704.03</td>
<td>700.51</td>
<td>-3.52</td>
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<td>Operation and maintenance (B$)</td>
<td>1336.36</td>
<td>1300.70</td>
<td>-35.66</td>
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<tr>
<td>Emission cost (B$)</td>
<td>171.10</td>
<td>162.50</td>
<td>-8.60</td>
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<tr>
<td>35-yr B/C ratio</td>
<td>-</td>
<td>-</td>
<td>2.52</td>
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https://www.nrel.gov/analysis/seams.html

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ZeroByFifty

- What is the optimal resource and transmission expansion to decarbonize the whole energy economy including massive electrification?
- Considers widespread DERs, new nuclear, CCS, and hydrogen
- Co-optimize generation (utility-scale and distributed), storage and transmission; combines capacity expansion and production simulation
- Transmission expansion costs are $200B and $350B for 100% clean electricity and energy, respectively
- Transmission depends on scenario: ~38GW between east/west; 30GW between east and ERCOT; 8 GW between west and ERCOT
- Finds that if a macro grid is NOT built, it costs an additional $1 Trillion to get to 100% clean energy by 2050

MIT Study - Value of Transmission for Decarbonization

• What is the value of coordination within regions, between regions and nationally?

• Co-optimized capacity expansion and dispatch model with 7 years of hourly weather

• Least-cost plan results in nearly double today’s transmission system (in MW-miles) with 29 GW transfers between east and west and 74 GW between ERCOT and east

• Finds that an “every state for itself” approach has a levelized capital and O&M cost of $135/MWh and that this cost can be reduced by 46% (to $73/MWh) with inter-regional coordination and transmission expansion

https://doi.org/10.1016/j.joule.2020.11.013
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