Design & Valuation of High-Capacity High Voltage DC Transmission to Facilitate High Renewable Growth

The Importance to the Nation's Energy & Climate Future of Interconnecting Western & Eastern Electric Grids

North American HVDC Interconnection Seam Study

- National Renewable Energy Lab (NREL)
- Pacific Northwest National Lab (PNNL)
- Oak Ridge National Lab (ORNL)
- Argonne National Lab (ANL)
- Iowa State University (ISU)
- Southwest Power Pool (SPP)
- Mid-Continent Independent System Operator (MISO)
- Western Area Power Authority (WAPA)
- Western Electric Coordinating Council (WECC)

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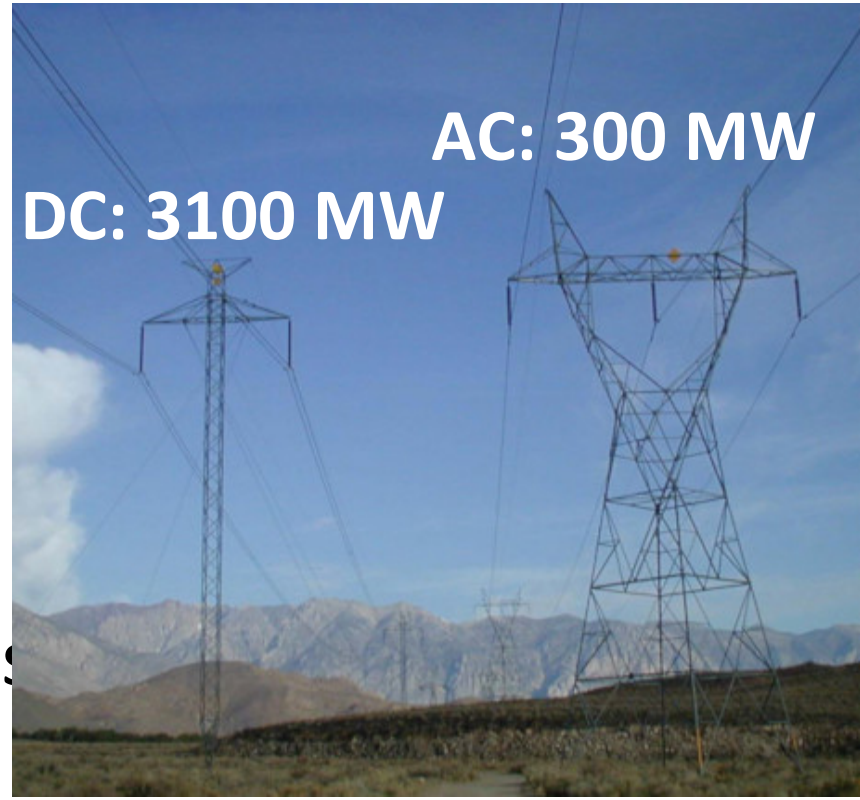
How does HVDC compare to AC Transmission?

- Less expensive for hi-power xfer > 400 mi
- Less losses per MW moved
- Moves power pt to pt w/o affecting parallel circuits
- Better for connecting big asynchronous grids
- Better for cable connections
- Improved cntrl & reliability

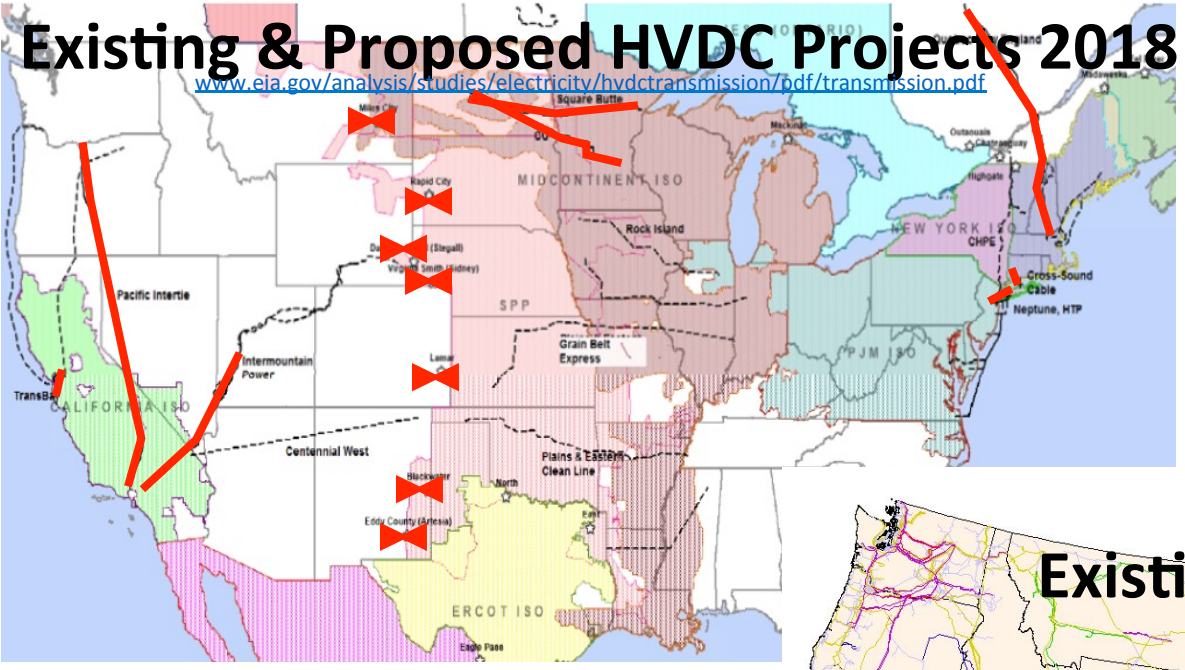


- More expensive for short distances (converters)
- No Xfmrs - expensive to change voltages.
- For networks, DC circuit breakers are expensive

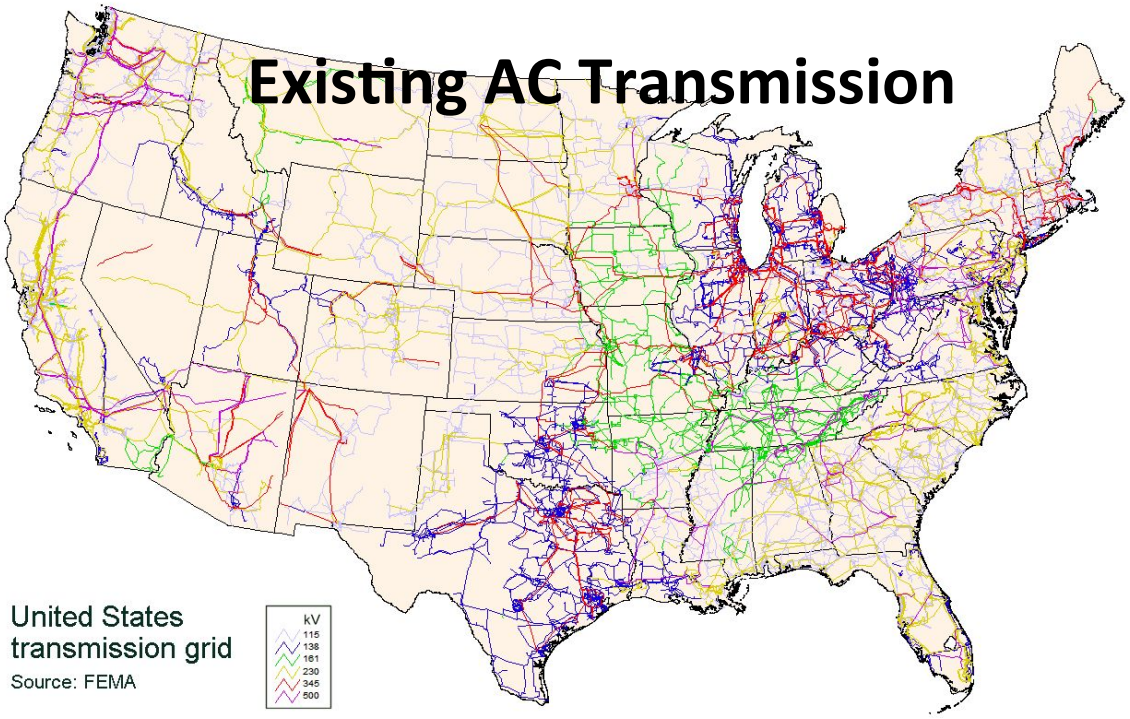
How does HVDC compare to AC Transmission?

Existing & Proposed HVDC Projects 2018

www.eia.gov/analysis/studies/electricity/hvdctransmission/pdf/transmission.pdf

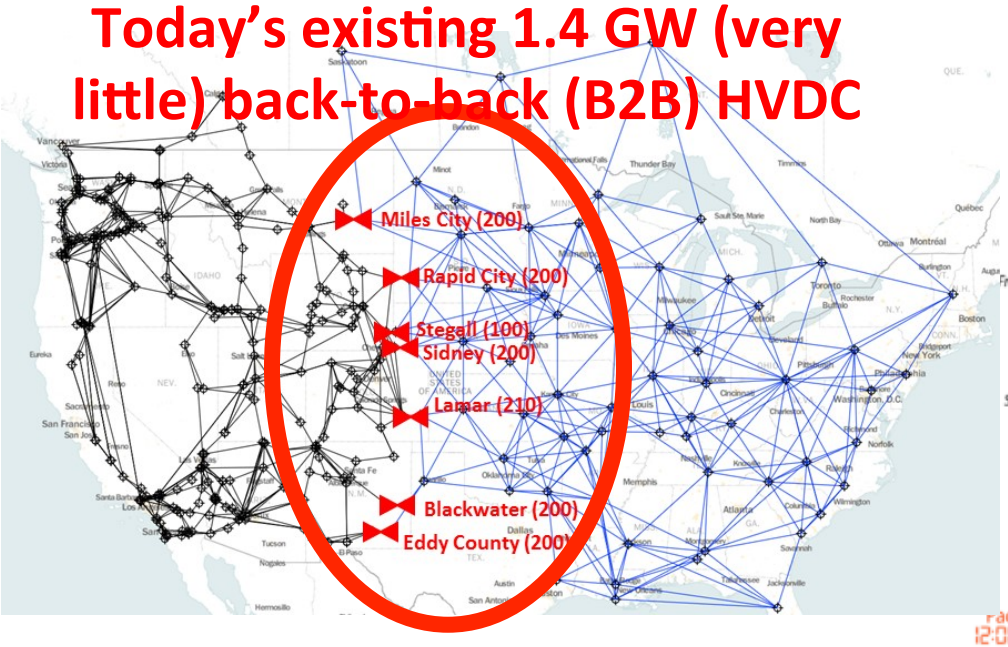


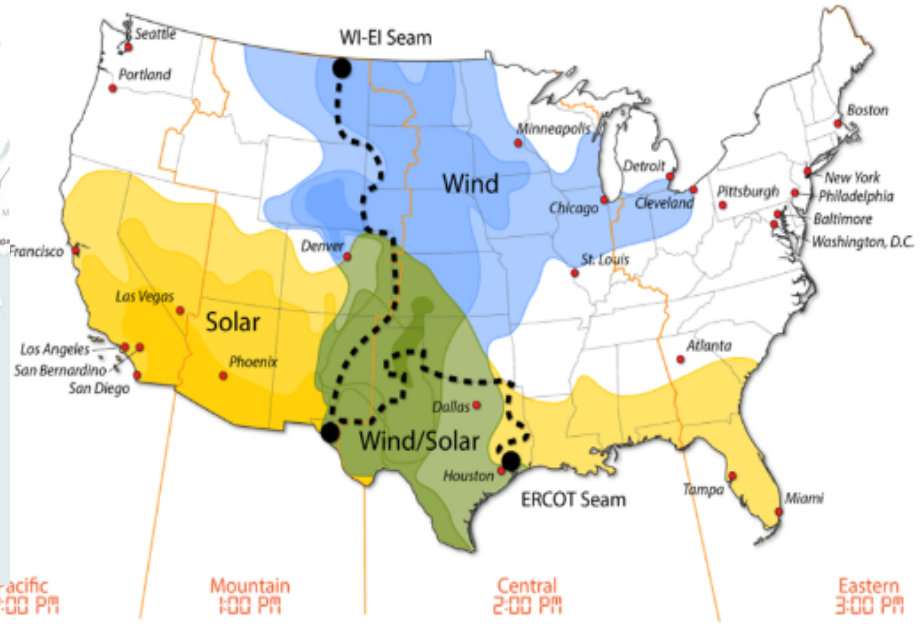
Existing AC Transmission



Interconnection Seam Study: Objective

Given a high-renewable future for electric energy production, what is the economic value of increasing cross-seam transmission over 2024-2038?



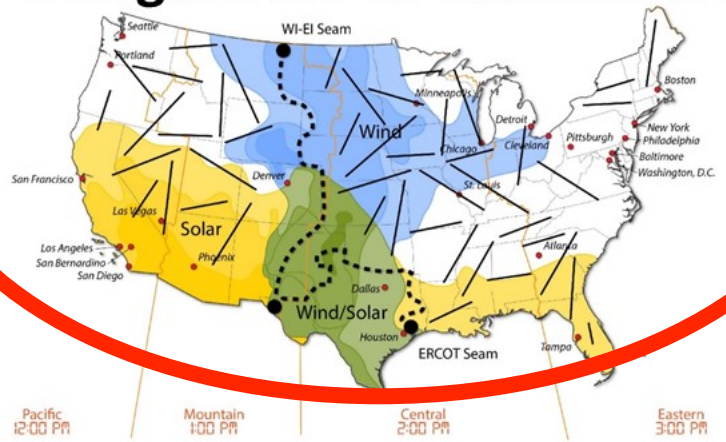


Rationale: Cost of the transmission build is significantly exceeded by **direct economic energy & capacity savings** due to:

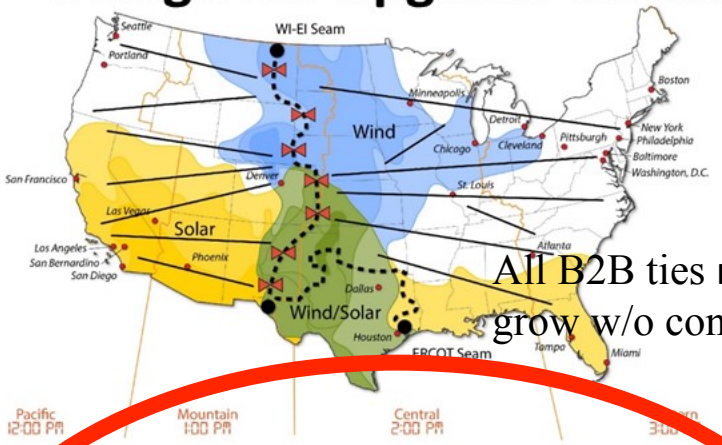
1. **Resource quality**: reduced $/MWhr for wind/solar (accessing high-quality renewables)
2. **Daily energy**: lower cost of daily energy & op. reserves (sharing across time zones)
3. **Peaking capacity**: reduced capacity-build for planning reserves (sharing between regions peaking on different days of the year)

Design concepts

Design 1: No CS Transmission

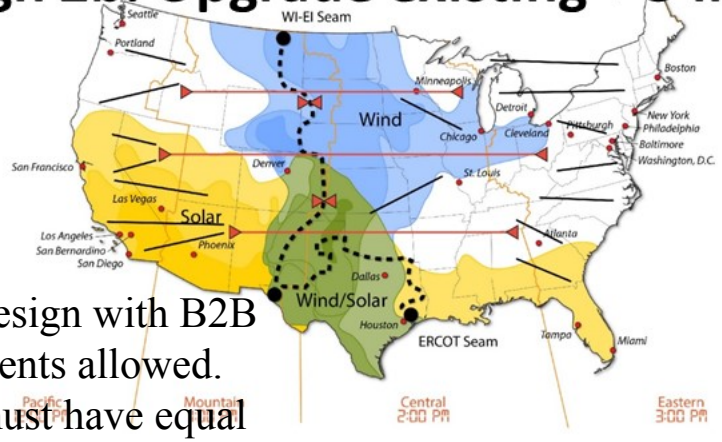


Design 2a: Upgrade existing



All B2B ties may grow w/o constraint.

Design 2b: Upgrade existing + 3 lines



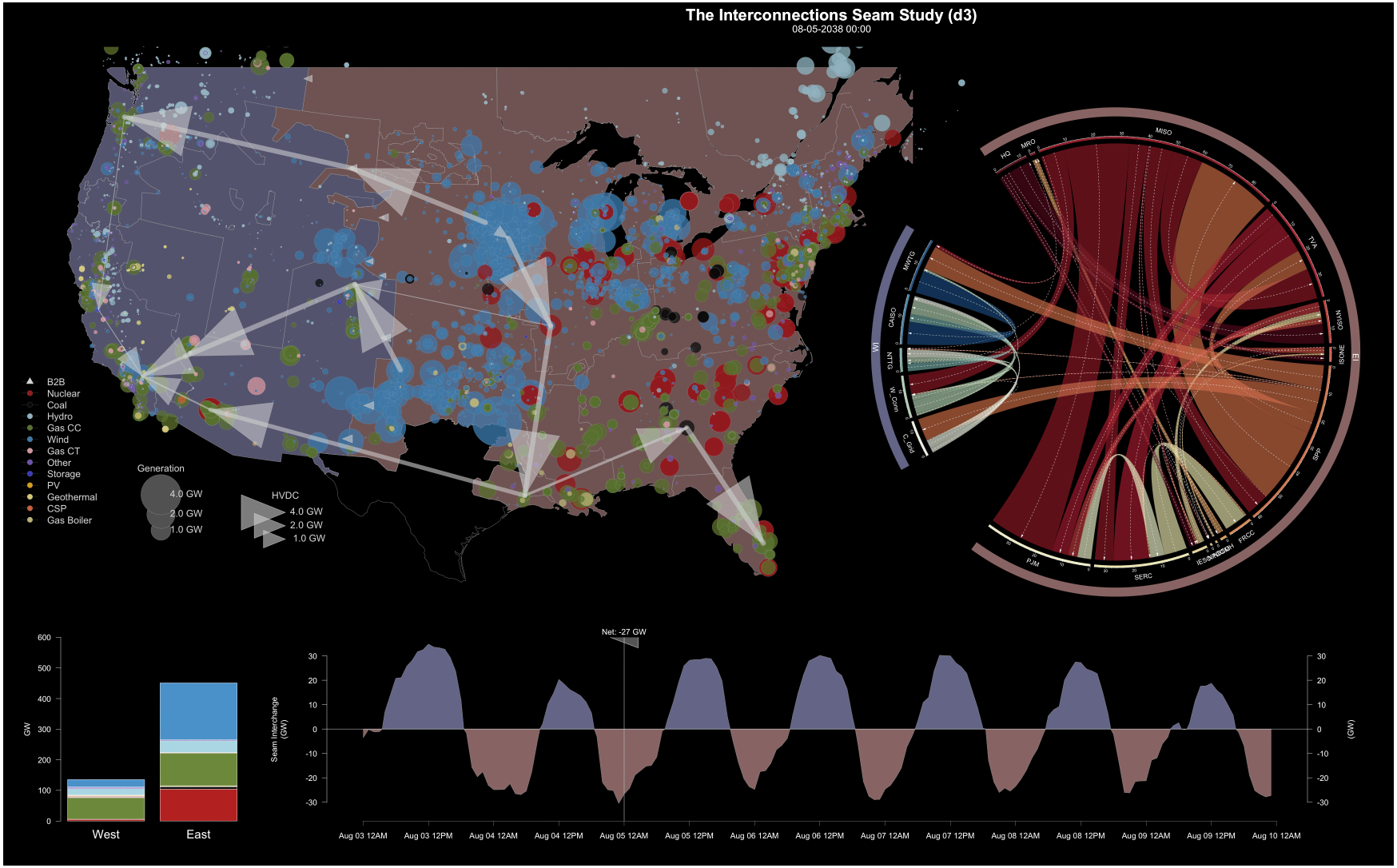
- 3 line design with B2B investments allowed.
- Lines must have equal capacity.

Design 3: Macrogrid

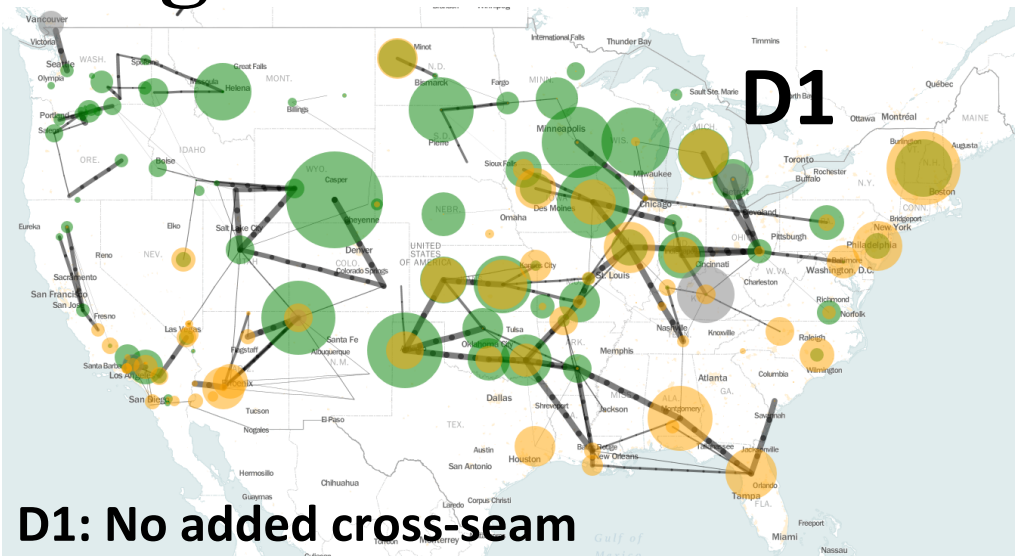
All segments have equal capacity

2038 renewables by energy	State RPS	CO_2 cost
50%	Not enforced	Increases at $3/mton/yr

Design concepts



HighVG results: 2024-38 (pays for itself!)

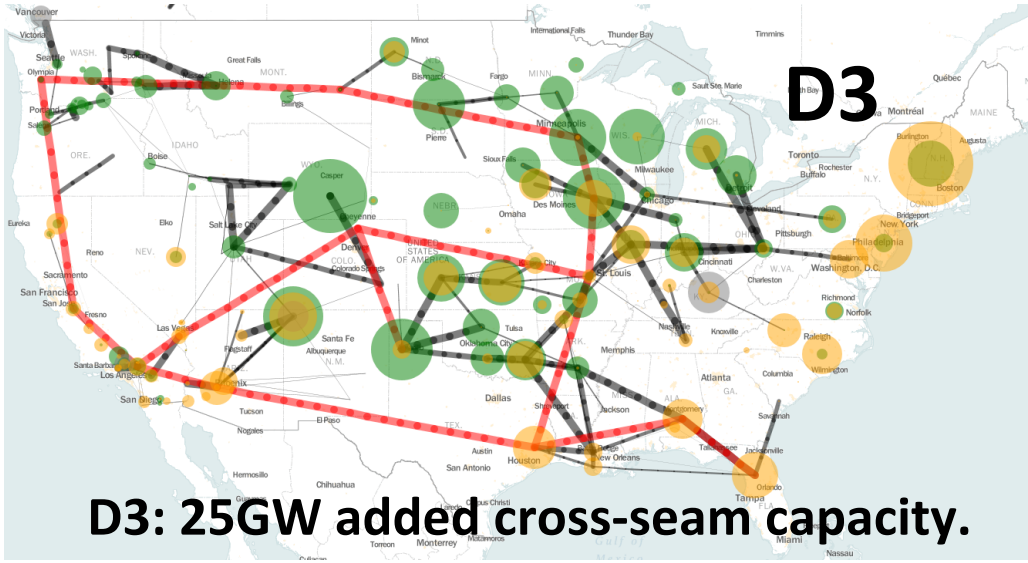


D1: No added cross-seam capacity. Benchmark.

<u>Both D1 and D3 added 600GW of generation capacity</u>

- 392GW wind
- 170GW solar
- 38GW gas

and retired 250-300GW of coal.

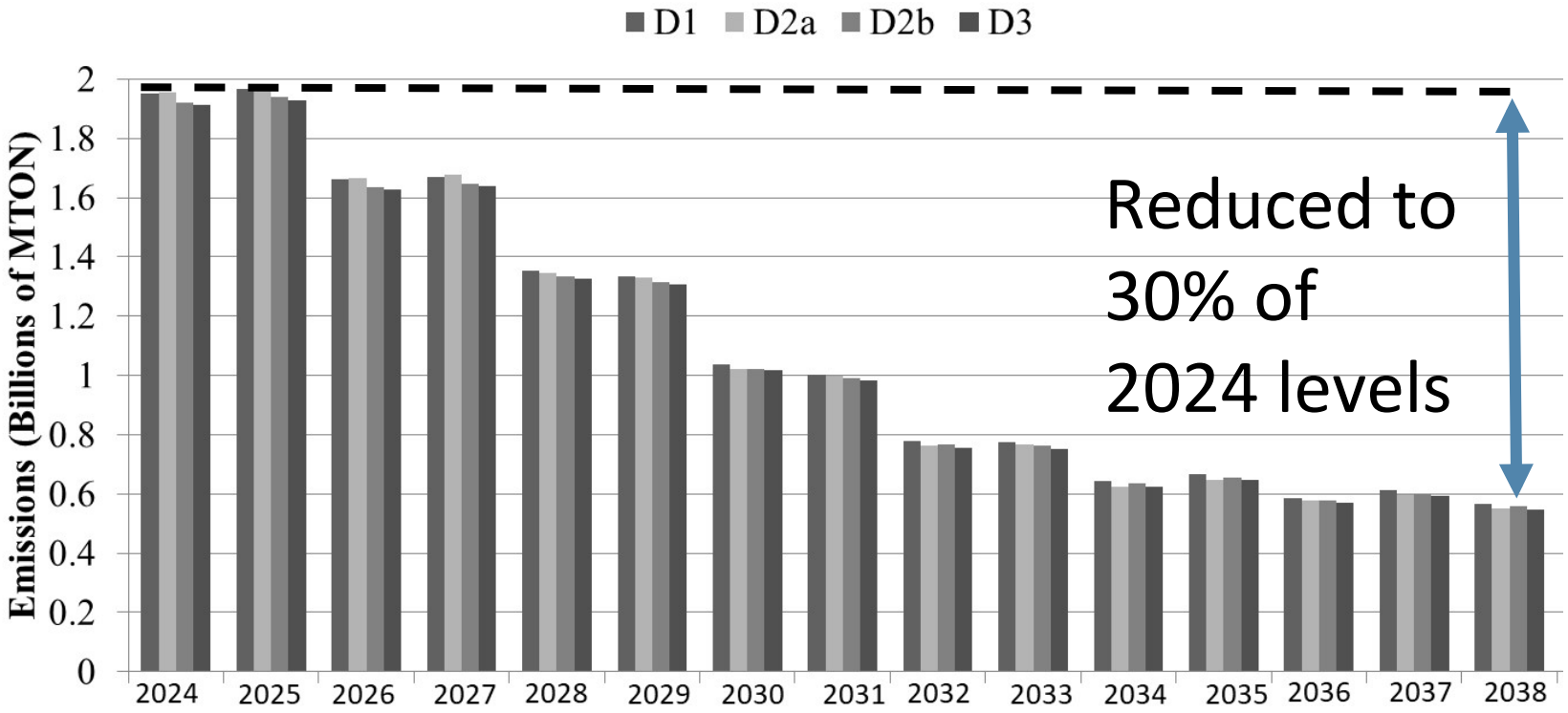


D3: 25GW added cross-seam capacity.

Solar
Wind
Gas
HVDC B2B
HVDC Line
AC Line

- 37 GW wind moves eastward
- 26 GW solar moves westward

Electricity Sector CO2 Reduction



Some characterizing numbers

Relative to reference case:

- Additional transmission cost: $19B
- Savings (gen cap, prod cost, O&M): $47.8B
- B/C Ratio of HVDC Macrogrid: 2.51
- Annualized savings, 2024-2038: $2.9B/y
- Annualized savings, 2024-2059: $4.2B/y
- Total CO_2 abatement: 12.9 BMT

Summary comments

- Direct economic savings (previous slide)
- Non-quantified benefits (NQBs):
  - Additional reliability improvements via HVDC
  - Efficient on/off-ramps nation wide making least-cost resources available at load centers, providing great flexibility for large changes in regional gen capacity
  - Increased resilience via interregional sharing in extreme events
  - Increased adaptability for changes in future policy
- Requires two new oversight bodies to get it started:
  - Technical studies/design: RTOs and utilities
  - Regulatory issues: FERC and states