Strategic Action Plan, Phase 1:

Study Synthesis of Transmission Needs

PREPARED BY
Joe DeLosa III
Kailin Graham
Johannes Pfeifenberger

PREPARED FOR

Northeast States Collaborative on
Interregional Transmission

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Key Takeaways from Review of Studies

Interregional transmission between NYISO and both ISO-NE and PJM is highly valuable in the near- and long-term, and low-regrets expansion opportunities should be pursued

- Cost-effective expansions between these regions are identified in numerous studies
  - Studies consistently demonstrate benefits of added interregional transmission capability: lower production cost and congestion relief; resilience, capacity and ancillary service benefits; and supporting decarbonization policies
  - The near-term need for transmission is evident **even when decarbonization is not a constraint**: low-regrets interregional transmission expansion is **beneficial purely from a reliability and economic perspective**
- We identify a **low-regrets need of 2 GW between NY and PJM and 1.7 GW between NY and New England**
- In the long-term, the exact magnitude of interregional transfer capability needs are still quite uncertain for both interregional seams and depend on progress on decarbonization as well as load growth beyond 2035 needs
- Studies also highlighted the long-term need for expansion between the **Northeast and Canada**
  - **5 GW between Quebec and both New England and New York by 2050 is low-regrets**
- **Realizing the value of interregional transmission identified in these studies requires overcoming key barriers,** particularly introducing intertie optimization (see Appendix slides for further discussion) and fully accounting for the resource adequacy and resiliency value of existing and new intertie capacity

New York – PJM: Significant transmission expansion between is valuable in the near-term

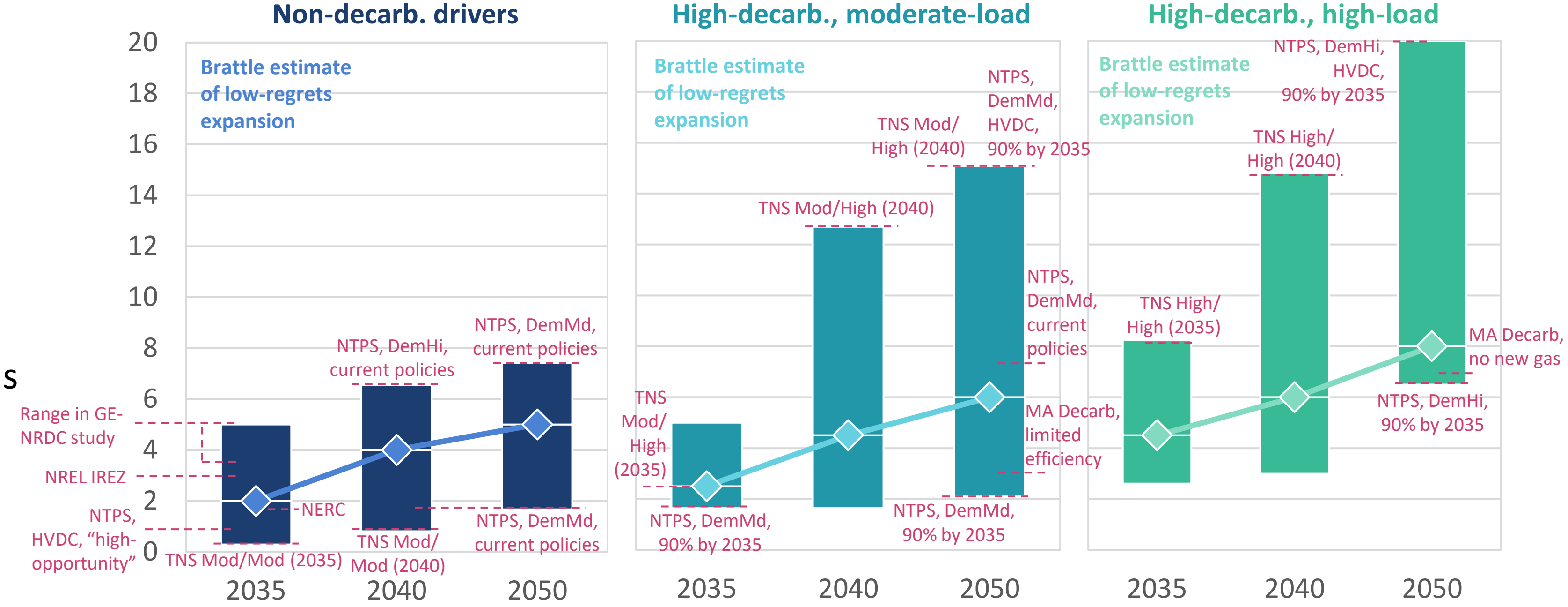
Based on multiple independent studies, we estimate that at least **2 GW** additional transfer capability between **New York and PJM by 2035 is low-regrets**, even without considering the value of transmission for decarbonization

- Represents low end of range from all studies, and central value of studies that did not consider decarbonization as the driver for transmission development

At least **4 GW by 2040 is likely low-regrets**, but needs may be significantly higher in high-decarbonization futures (up to 12–15 GW)

- Building in **flexibility and expandability** is likely efficient given the potential for much larger long-term needs
- Our low-regrets estimates for high-decarb. futures range from **4.5–6 GW in 2040** to **6–8 GW in 2050**
  - Datacenter and electrification demand in PJM makes high-load scenarios more likely

Estimated Range of NY–PJM Transmission Needs (GW)



Notes: Ranges above cover transfer capability needs reported in the DOE 2023 Transmission Needs study (TNS, summarizing multiple studies), DOE National Transmission Planning Study (NTPS), GE-NRDC study, MA Decarbonization Pathways study, LBNL study, NREL IREZ study, and NERC ITCS study. These ranges exclude scenarios deemed unrealistic, such scenarios with zero transmission expansion between NY and PJM in the MA Decarb Study. Annotations indicate noteworthy scenarios from these studies. NTPS results are from "AC" expansion scenarios unless denoted otherwise.

New York – New England: Interregional upgrades across the interface presents low-regrets, near-term opportunities

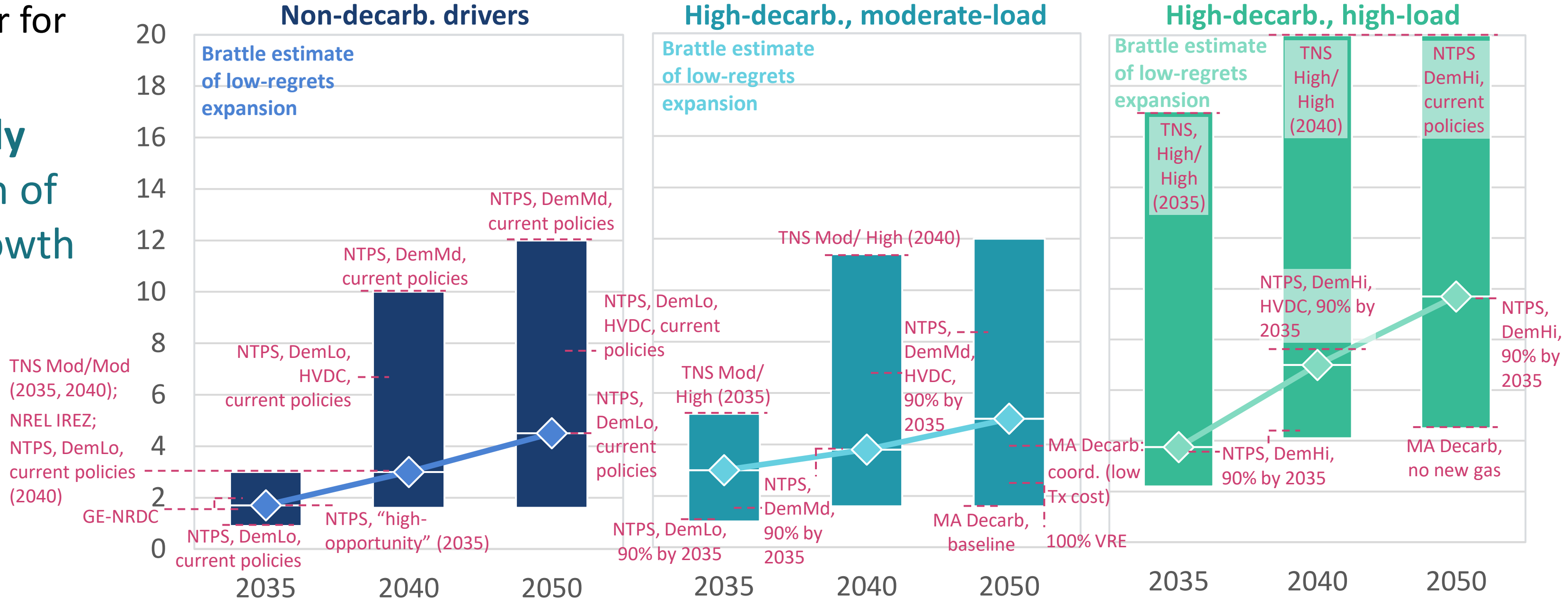
Based on multiple independent studies, we estimate that at least **1.7 GW** additional transfer capability between **NY and New England by 2035 is low-regrets**, even without considering the value of transmission for decarbonization.

- Similarly represents low end of range across studies and central estimate of studies that did not consider decarbonization as the driver for transmission development

Long-term (2040–2050) needs are highly uncertain; depend on scale and location of renewables adoption as well as load growth

- **3 GW by 2040 is low-regrets**, but may be conservative given decarbonization ambitions of both regions
  - Our low-regrets estimates for high-decarbonization scenarios conservatively skew towards the bottom of each range given the uncertainty amongst projects
- Option value for increased transfer capability is particularly valuable, given potentially high interregional needs

Estimated Range of New England–NY Transmission Needs (GW)



Notes: "Non-decarb. drivers" refers to scenarios where decarbonization was not a driver/constraint for the analysis. Ranges above cover transfer capability needs reported in the DOE 2023 Transmission Needs study (TNS, summarizing multiple studies), DOE National Transmission Planning Study (NTPS), GE-NRDC study, MA Decarbonization Pathways study, and NREL IREZ study. These ranges exclude scenarios deemed unrealistic, such as low-electrification and low-offshore wind scenarios in the MA Decarb. study which report low transmission needs due to new nuclear capacity in NY and CT. Annotations indicate noteworthy scenarios from these studies. NTPS results are from "AC" expansion scenarios unless denoted otherwise.

Canada: Significant expansion between the Northeast and Quebec is valuable long-term, and near-term for reliability in New York

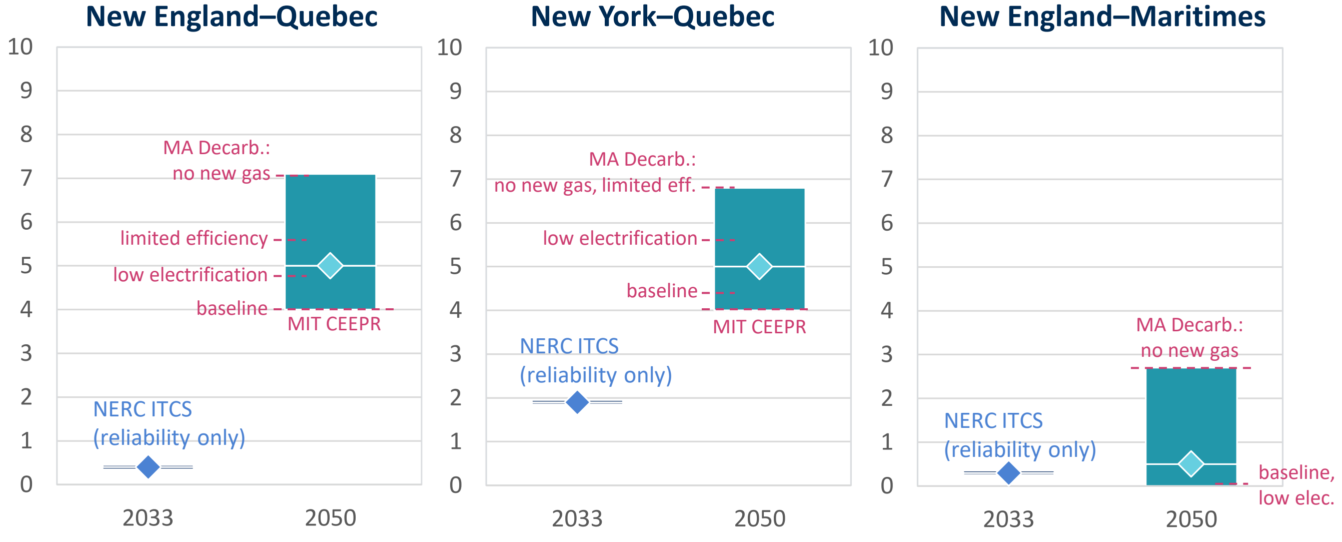
Based on multiple independent studies, we estimate that at least **5 GW** additional transfer capability **by 2050** between both **New England and Quebec** and **New York and Quebec is low-regrets**. When just considering reliability benefits, **1.9 GW between New York and Quebec by 2033 is low-regrets.**

- While fewer studies considered transmission expansion to Canada, long-term (2050) studies show consistent value in significant expansion between Quebec and both New England and New York.
  - Needs are greater (up to 7 GW) in higher renewables/low thermal generation futures.
  - Value is derived from operating lines **bidirectionally** to balance Northeast renewables.
- The MA Decarbonization Pathways study found a moderate need between **New England–New Brunswick** between 0–0.8 GW by 2050, scaling to 2.7 GW in a future with no new gas generation.

NERC study demonstrates near-term reliability need

- **0.4 GW between NE–QC, 1.9 GW between NY–QC, 0.3 GW between NE–Maritimes**
- These figures consider resource adequacy only, and are therefore **conservative estimates that do not consider economic or public policy benefits of further expansion.**

Estimated Range of Northeast–Canada Transmission Needs (GW)



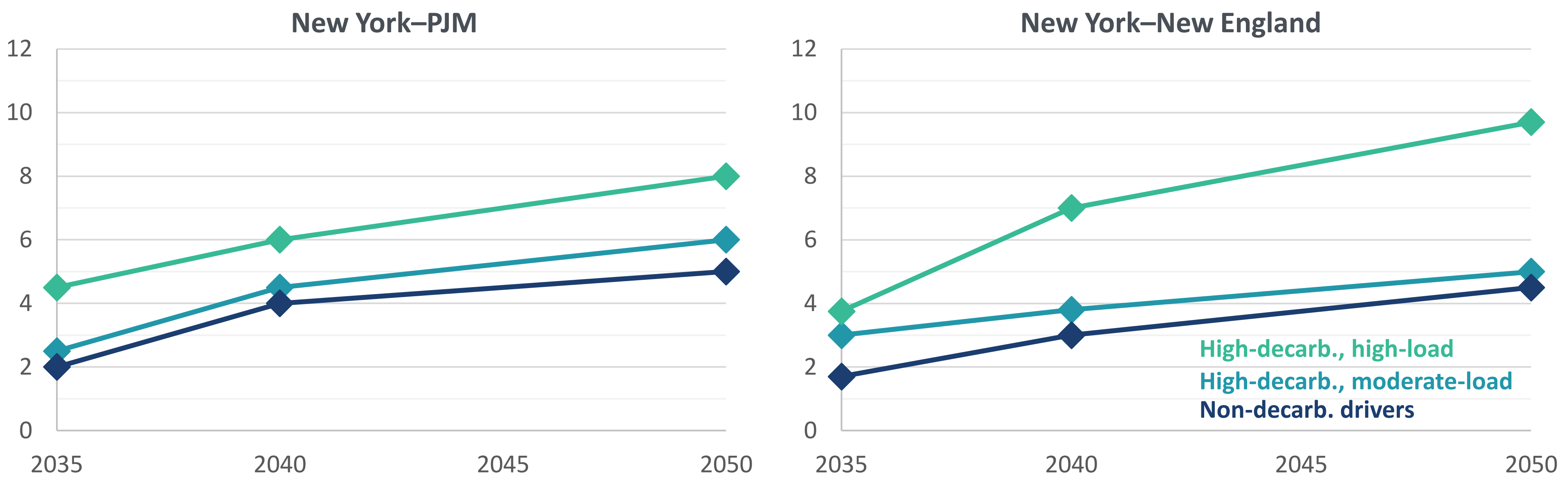
Notes: Ranges above cover transfer capability needs reported in the NERC ITCS (2033 only), the MIT CEEPR study (2050 only) and the MA Decarbonization Pathways study (2050 only). Annotations indicate noteworthy scenarios from these studies.

Summary: “Low-Regrets” Interregional Transmission Expansion

Based on our review of multiple independent transmission studies across several possible decarbonization and load growth scenarios, we believe the following transmission expansions to be low-regrets:

- **New York–PJM:** 2–4.5 GW by 2035, 4–6 GW by 2040, 5–8 GW by 2050
- **New York–New England:** 1.7–3.7 GW by 2035, 3–7 GW by 2040, 4.5–9.7 GW by 2050
- **Northeast–Canada (not pictured):** 1.9 GW NY–QC by 2033; 5 GW NE–QC and 5 GW NY–QC by 2050

Estimated Range of *Low-Regrets* Transmission Expansion Needs (GW)



Summary of Relevant Interregional Transmission Studies

Summary of Studies Reviewed

Study	Years analyzed	Considerations/assumptions	Findings
1. DOE 2023 Transmission Needs Study	2030, 2035, 2040	Review of 300 scenarios and sensitivities from 6 independent national transmission studies. Almost all have decarbonization constraints (in addition to BAU scenarios)	Range of transmission needs: **NY-New England:** 2035: 2.8–17 GW; 2040: 2.9–21.4 GW **NY-PJM:** 2035: 0.29–8.24 GW; 2040: 0.81–12.7 GW Excludes values from the moderate load growth/moderate clean energy cases, which represent business-as-usual scenarios without the IIJA and IRA and are "an unlikely representation of future power sector need."
2. DOE National Transmission Planning Study	2035, 2040, 2050	Conducted zonal capacity expansion & resource adequacy modelling through 2050 under 96 scenarios covering different transmission frameworks (AC, P2P HVDC & meshed HVDC), decarbonization assumptions, load growth assumptions, and 15 sensitivity cases	**NY-New England:** 1.7–2.9 GW by 2035, 3.8–6.7 GW by 2040 in central case **NY-PJM:** ~1 GW by 2040 for AC, but much higher in HVDC futures
3. DOE Atlantic OSW Transmission Study	2050	Optimized offshore transmission cables for five difference transmission topologies, and modeled production cost benefits as well as grid reliability, resource adequacy, power flow, grid strength and contingency analysis.	Interregional topology resulted in a **total of 14 GW of offshore transmission** between Atlantic states, with a **benefit-cost ratio of 2.9** ($2.4 billion/yr in production cost and resource adequacy benefits) [granular results on transfer capability needs between individual regions not provided].
4. GE-NRDC Study	2035	Uses nodal model to optimize transmission buildout by 2035 and estimate resilience benefits under severe weather events as well as production cost and capacity savings.	$12 billion in net present value from 87 GW interregional transmission (2 GW between NY-NE, 5 GW between NY-PJM), including $1 billion in resilience benefits from single 2035 polar vortex event.
5. MA Decarb Pathways Study	2050	Models 8 pathways to net zero for MA, including detailed capacity expansion modeling	**NY-New England:** 0.5–4.5 GW (1.6–4.5 GW when focusing on most realistic scenarios) **NY-PJM:** 1.5–7 GW (Caveat: PJM was not explicitly modeled as its own zone but a boundary condition for New York) **QC-NY:** 3.8–6.8 GW **QC-New England:** 4.1–7.1 GW **New England-Maritimes:** 0–2.7 GW (0–0.8 GW when focusing on most realistic scenarios)

Summary of Studies Reviewed (cont'd)

Study	Years analyzed	Considerations/assumptions	Findings
6. LBNL Analyses	2012–2023	Estimates congestion value (production cost savings) of expanding interregional transmission using historical data (2012-2023) on nodal marginal prices. Does not estimate transfer capability needs in GW.	**NY-New England:** documents historical energy market value of $137–189 million/yr per GW of transmission **NY-PJM:** documents historical energy market value of $149–156 million/yr per GW of transmission
7. NREL IREZ	2022	Models energy cost savings of transmission corridor from Midwest wind to Eastern part of the Interconnection	3 GW expansions from PJM to New York and New York to New England increases energy cost savings of transmission corridor by $118 million/yr and $28 million/yr, respectively (incremental costs: $27 million/yr and $21 million/yr, respectively)
8. MIT CEEPR	2050	Modeled power system cost savings associated with 4 GW transmission expansions for Quebec-New York and Quebec-New England. Analysis was constrained to meet OSW targets.	**QC-New England:** 4 GW provides power system cost savings of $1,121 million/yr (13%) **QC-NY:** 4 GW provides power system cost savings of $913 million/yr (13%) Value is generated by utilizing the transmission bidirectionally to balance Northeast renewables, avoiding firming costs
9. NERC ITCS	2033	Identifies "prudent" interregional transmission additions needed to maintain reliability—does not include any additional transmission justifiable based on economic and public policy benefits	**NY-New England:** 0 GW (this is unlikely once considering economic and public policy benefits) **NY-PJM:** 1.8 GW to alleviate significant resource deficiencies in New York **QC-New England:** 400 MW **QC-NY:** 1.9 GW **New England-Maritimes:** 300 MW

Note on Existing Interregional Transfer Capability

- In additional to transmission expansion needs, **we found that there were a range of values reported across different studies for how much interregional transfer capability exists today**.
- Namely, the DOE Transmission Needs Study, DOE National Transmission Planning Study (NTPS), and NERC Interregional Transfer Capability Study report different existing transfer capabilities at the New York–New England and New York–PJM interfaces.
- Different assumptions on existing capability partially explain differences in additional transfer capability needs.
  - e.g. DOE NTPS assumes greater existing transfer capability between New York and PJM than the Transmission Needs Study, and as a result finds less expansion is needed at that interface.

	DOE Transmission Needs Study	DOE NTPS	NERC ITCS
New York <> New England	2,030 MW	3,500 MW	Summer: >1,303 / <1,660 MW Winter: >2,432 / <1,359 MW
New York <> PJM	2,000 MW	6,600 MW	Summer: >913 / <1,356 MW Winter: >4,019 / <4,814 MW

Sources: DOE NTP Study Team letter, December 17, 2024; NERC ITCS Phase 1 results.

1. DOE National Transmission Needs Study (2023)

Takeaway

By **2035**, interregional transmission needs between New York–New England and New York–Mid-Atlantic will likely exceed **5 GW** and **2.4 GW**, respectively. By **2040**, these needs could grow to **11 GW** and **15 GW**

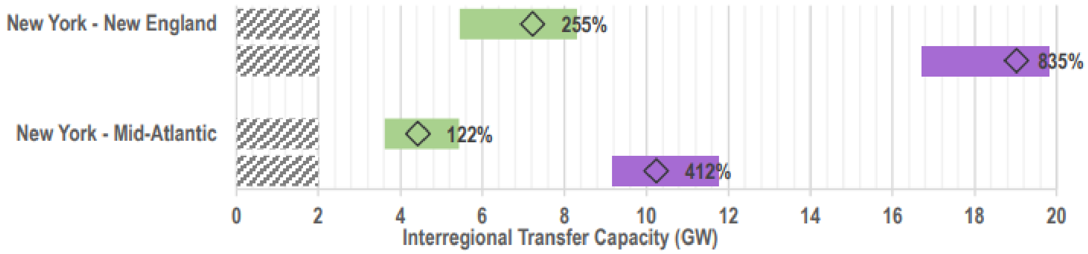
- Summarizes results from six national capacity expansion studies on interregional transmission expansion needs for 2030, 2035 and 2040 to achieve decarbonization
- In **2035** additional transfer capability requirements will be between **5.19–17.0 GW** for New York–New England and **2.43–8.24 GW** for New York–Mid-Atlantic
  - By **2040**, 11.4–21.4 GW and 12.7–14.8 GW, respectively
  - Dependent on load growth and clean energy penetration assumptions
    - We exclude values from the moderate load growth/moderate clean energy cases, which represent business-as-usual scenarios without the IIJA and IRA and are "an unlikely representation of future power sector need."

Gap

Expanding transmission between NY and PJM and New England is **low-regrets**; potential for **"low-hanging" interregional projects** that are cost effective but highly valuable

Within-region transmission and interregional transfer capacity need for New York in 2035

Range of new transmission need for future scenarios with moderate load and high clean energy growth (green, top for each region) and high load and high clean energy growth (purple, bottom). Median % growth compared to 2020 system shown.



Regional Pair	2020 GW	Scenario Group	New in 2030		New in 2035		New in 2040	
			GW	% Growth	GW	% Growth	GW	% Growth
Mid-Atlantic – New York	2.00	Mod/Mod	0.00	0.0%	0.29	14.7%	0.81	40.6%
Mid-Atlantic – New York	2.00	Mod/High	0.00	0.0%	2.43	122%	14.8	742%
Mid-Atlantic – New York	2.00	High/High	2.03	102%	8.24	412%	12.7	634%
New England – New York	2.03	Mod/Mod	1.46	71.7%	2.84	140%	2.90	142%
New England – New York	2.03	Mod/High	1.53	75.1%	5.19	255%	11.4	559%
New England – New York	2.03	High/High	3.96	195%	17.0	835%	21.4	1050%

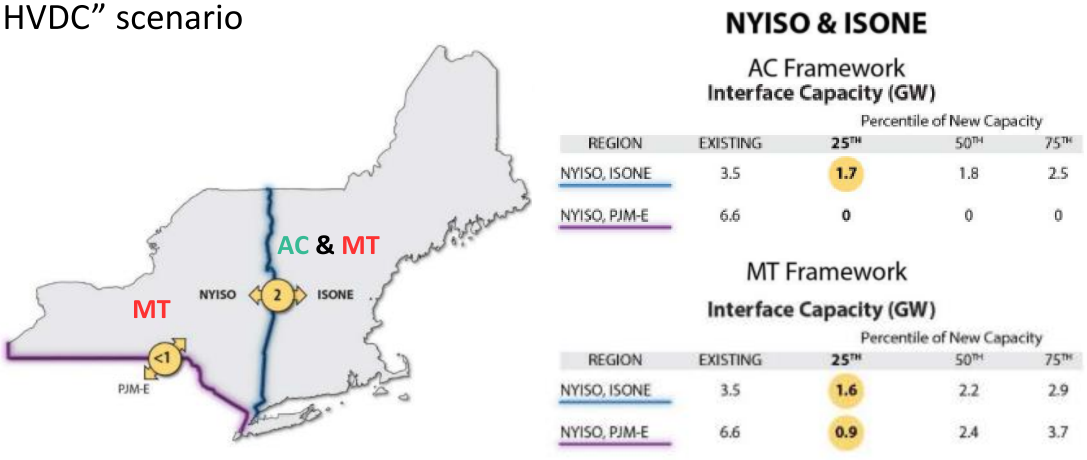
Source: DOE National Transmission Needs Study

2. DOE National Transmission Planning Study (2024)

Takeaway

At least **2 GW** of NY–ISO-NE transmission is likely needed by **2035**, increasing to nearly **5 GW** by **2040**. Significant expansion between NY–PJM and within New England is necessary by 2040. Results in net savings of **$56 billion, $54 billion** and **$33 billion by 2050** for ISO-NE, NYISO and PJM, respectively. HVDC buildout has higher value.

- Conducted zonal capacity expansion & resource adequacy modelling through 2050 under 96 scenarios covering:
  - Transmission frameworks (AC, P2P HVDC & meshed HVDC)
  - Policy assumptions (current policies; 90% power sector decarbonization by 2035; and 100% by 2035 [disregarded in this summary])
  - Low, medium and high demand futures
  - 15 sensitivity cases
  - Does not consider interchange or transmission expansion with Canada (international imports/exports set exogenously)
- "High-opportunity interfaces" for **2035**: Conservative estimates based on central scenario (see figure)
  - **1.7 GW** between **NYISO–ISO-NE**, **0.9 GW** between **NYISO–PJM** in the "meshed HVDC" scenario
  - However, needs increase significantly by 2040, and are sensitive to demand scenarios and transmission framework (see next slide)
- Central expansion scenario generates net cost savings through 2050. HVDC futures increase cost savings
  - ISO-NE: $56 billion (19%), up to $62 billion (21%) with HVDC
  - NYISO: $54 billion (16%), up to $63 billion (19%) with HVDC
  - PJM: $33 billion (2%), up to $75 billion (5%) with HVDC
  - Costs allocated amongst regions using "adjusted production cost" based on zonal marginal prices



NYISO & ISONE

AC Framework

Interface Capacity (GW)

		Percentile of New Capacity		
REGION	EXISTING	**25TH**	50TH	75TH
NYISO, ISONE	3.5	**1.7**	1.8	2.5
NYISO, PJM-E	6.6	**0**	0	0

MT Framework

Interface Capacity (GW)

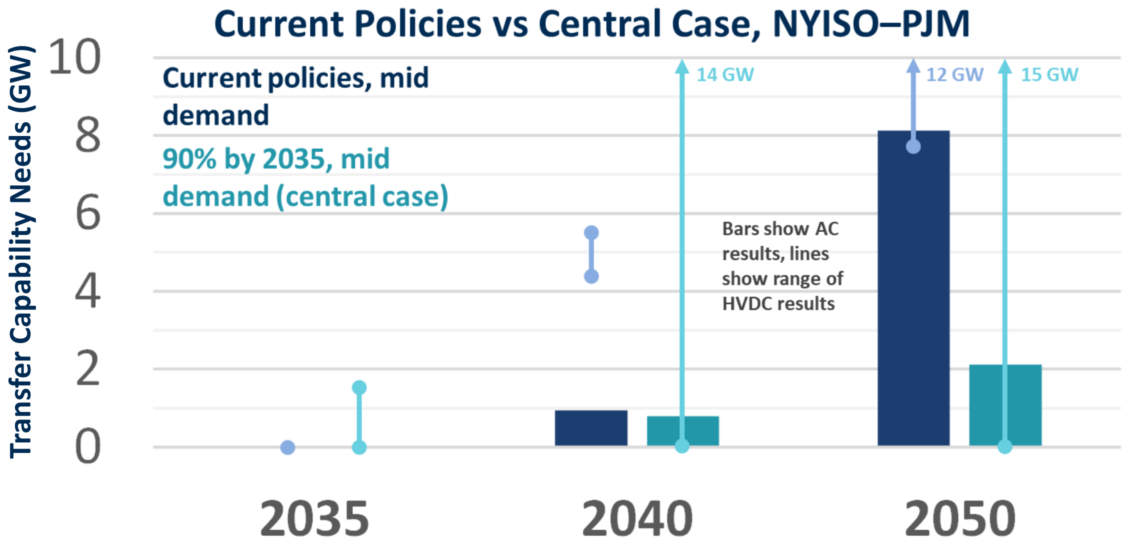
		Percentile of New Capacity		
REGION	EXISTING	**25TH**	50TH	75TH
NYISO, ISONE	3.5	**1.6**	2.2	2.9
NYISO, PJM-E	6.6	**0.9**	2.4	3.7

Source: DOE National Transmission Planning Study

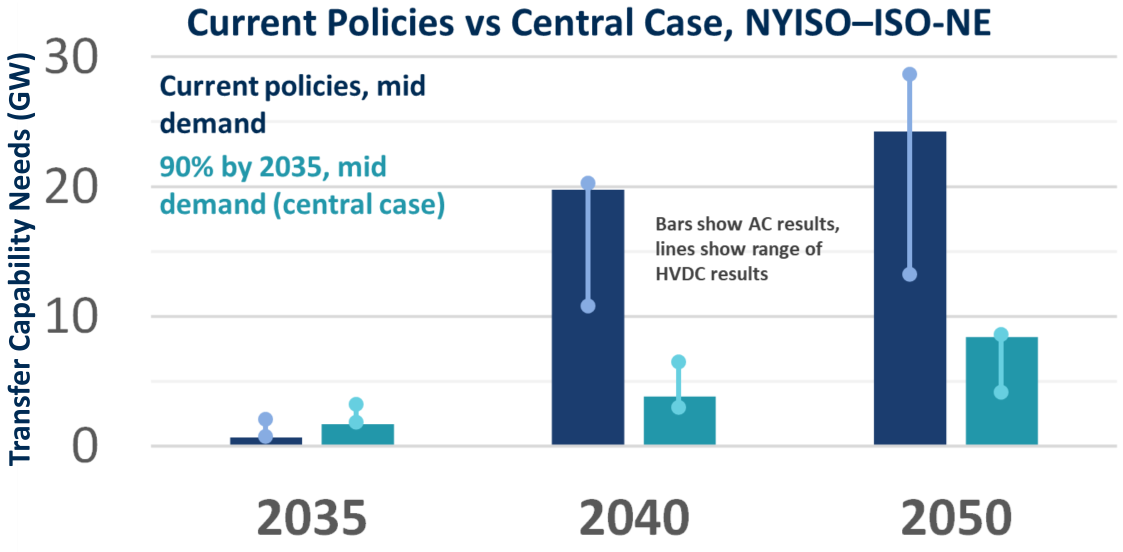
2. DOE National Transmission Planning Study (2024) (cont'd)

Transmission needs increase by 2040, but vary greatly

- **NYISO–ISO-NE**: from 1.7–2.9 GW by 2035 to **3.8–6.7 GW by 2040** in central case
  - Under current policies, 2040 needs are much higher (11–21 GW)
- **NYISO–PJM: to ~1 GW by 2040** for AC scenario, but much higher in HVDC scenario
  - Low end of HVDC range represents point-to-point HVDC, whereas high end reflects multiterminal future



Bars show AC results, lines show range of HVDC results



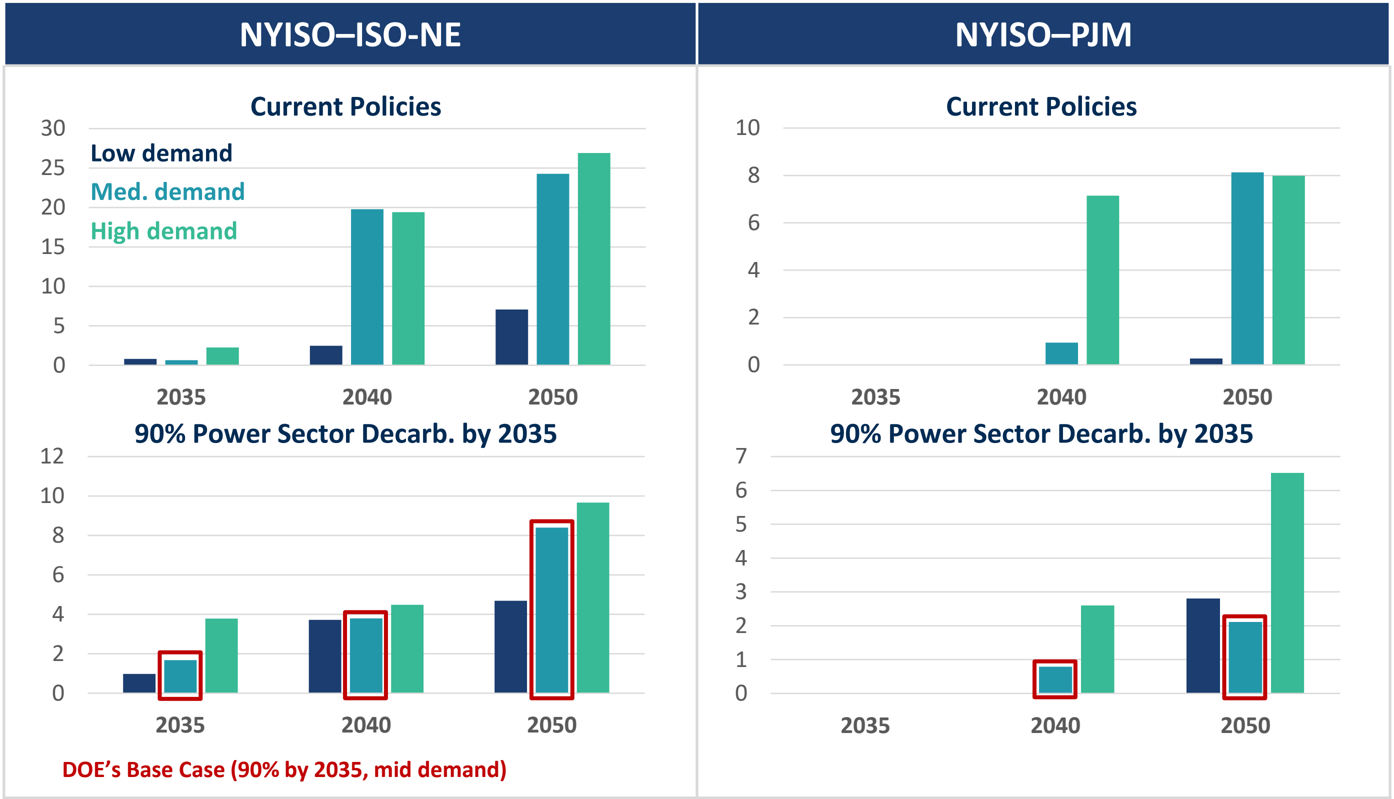
Bars show AC results, lines show range of HVDC results

2. DOE National Transmission Planning Study (2024) (cont'd)

Load Assumptions Significantly Affect Interregional Transfer Capability Additions

- High demand increases transmission needs, particularly between NYISO–PJM (1 GW to 7 GW from mid to high demand)
- Even under low load and moderate decarbonization assumptions, nearly 4 GW is needed between NYISO–ISO-NE by 2040

Transfer Capability Needs (GW), AC Framework



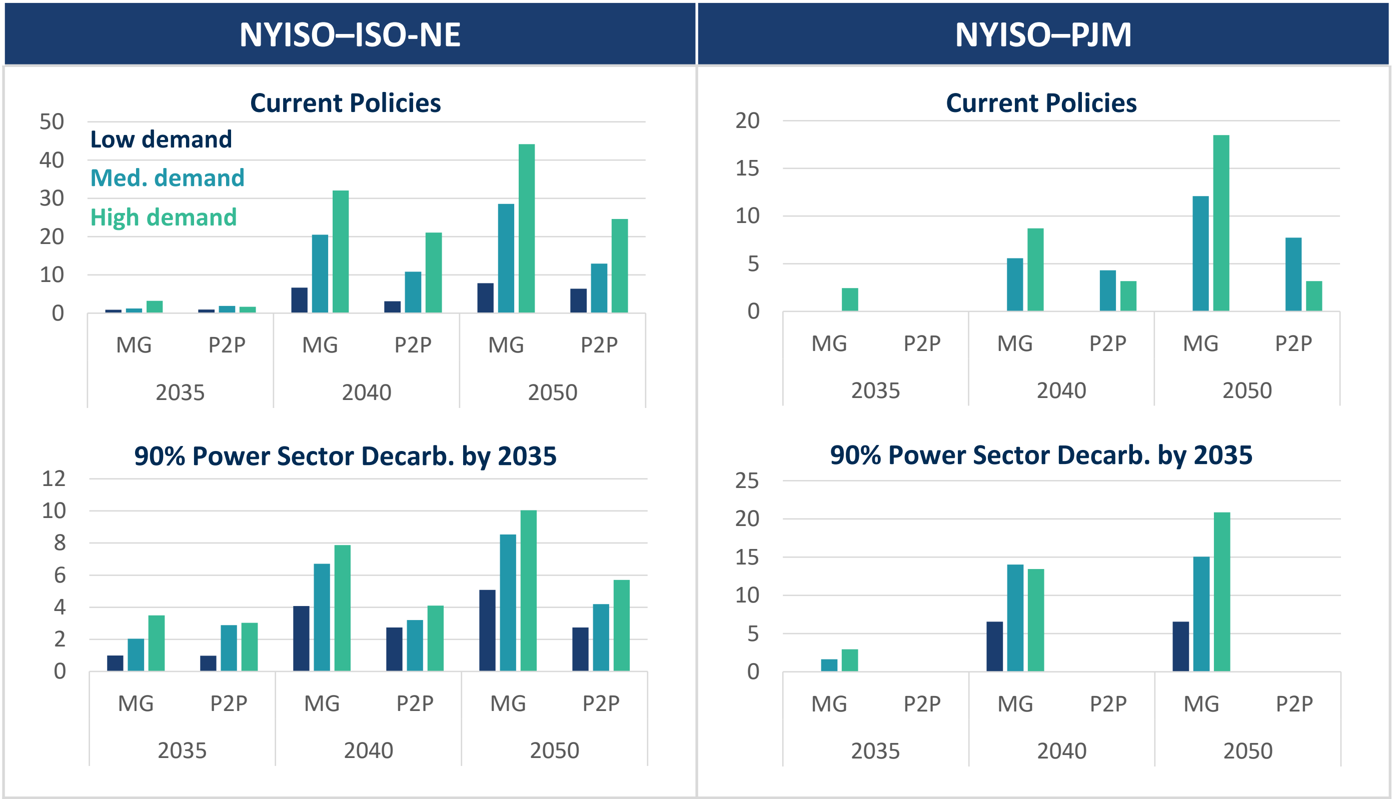
Note: All results assume an early phaseout of IRA tax credits in 2032.

2. DOE National Transmission Planning Study (2024) (cont'd)

HVDC Futures See Greater Variation in Transfer Capability Needs

- While NYISO–ISO-NE needs are similar to AC case, large differences in NYISO–PJM buildout
- Multiterminal HVDC sees significant buildout between NYISO–PJM by 2040, even under low load growth

Transfer Capability Needs (GW), HVDC Frameworks



Note: MG = multiterminal, P2P = point-to-point. All results assume an early phaseout of IRA tax credits in 2032.

3. DOE Atlantic Offshore Wind Transmission Study (2024)

Takeaway

Proactive, coordinated interregional transmission planning is urgently needed to integrate Atlantic OSW, and networking offshore transmission generates that benefits significantly outweigh the costs

- Considered several transmission configurations to integrate **85 GW** of OSW: radial (reference case, directly from onshore to offshore), intraregional, interregional, inter-intra, and backbone
- **By 2050, benefits of interlinking offshore transmission outweigh costs by more than 2 to 1** across all configurations, with **interregional configurations offering the highest value-to-cost ratio**
  - Arise from reduced curtailment and generation costs, and increased reliability

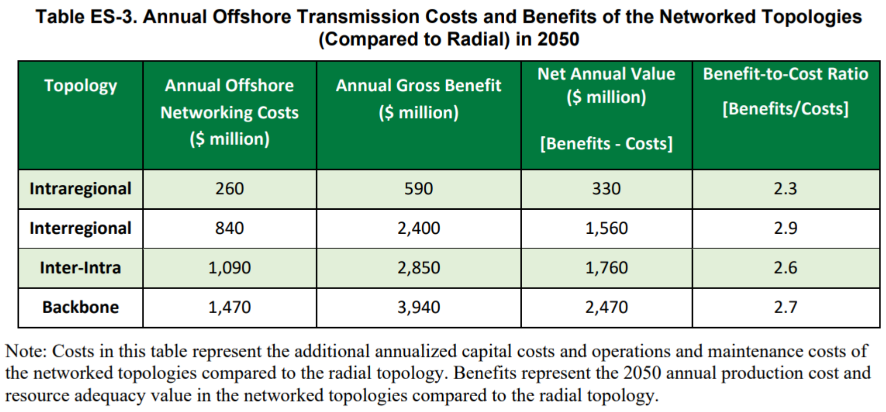
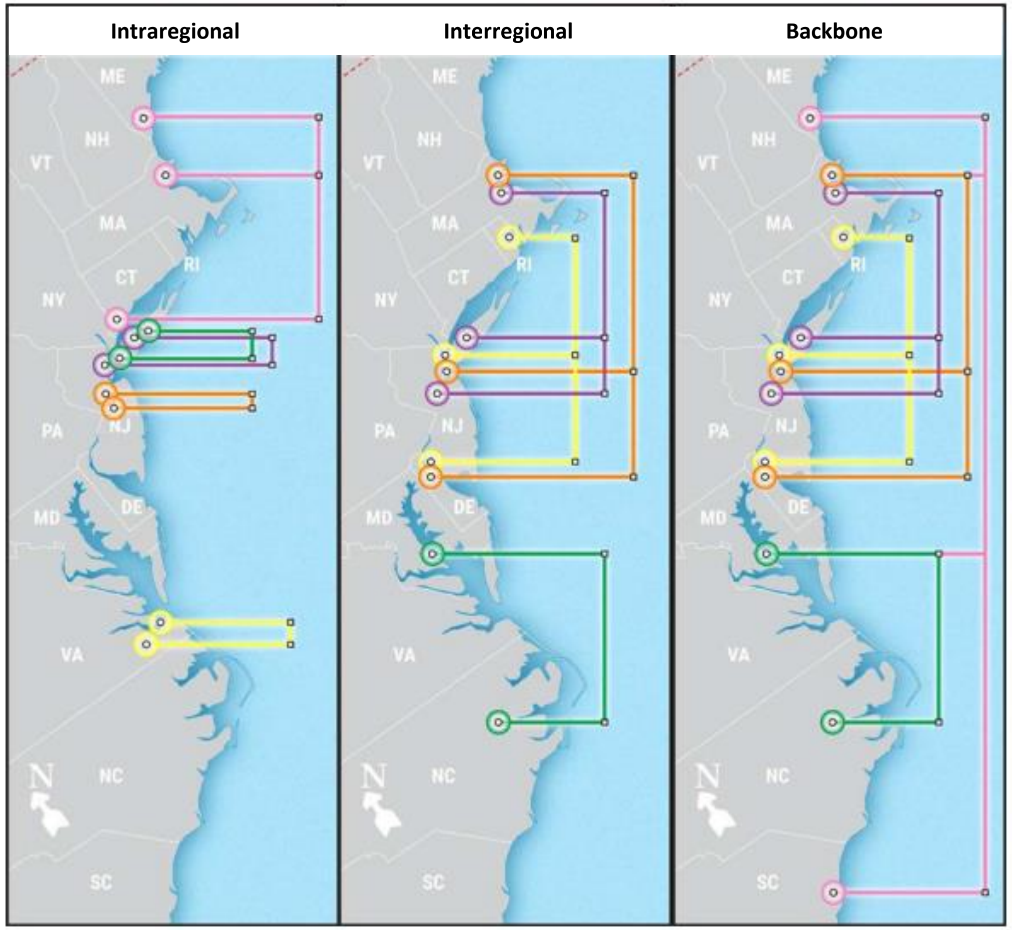


Table ES-3. Annual Offshore Transmission Costs and Benefits of the Networked Topologies (Compared to Radial) in 2050

Topology	Annual Offshore Networking Costs ($ million)	Annual Gross Benefit ($ million)	Net Annual Value ($ million) [Benefits - Costs]	Benefit-to-Cost Ratio [Benefits/Costs]
Intraregional	260	590	330	2.3
Interregional	840	2,400	1,560	2.9
Inter-Intra	1,090	2,850	1,760	2.6
Backbone	1,470	3,940	2,470	2.7

Note: Costs in this table represent the additional annualized capital costs and operations and maintenance costs of the networked topologies compared to the radial topology. Benefits represent the 2050 annual production cost and resource adequacy value in the networked topologies compared to the radial topology.



Source: Atlantic Offshore Wind Transmission Study

3. DOE Atlantic Offshore Wind Transmission Study (2024) (cont'd)

Takeaway

Proactive, coordinated **interregional transmission planning is urgently needed** to integrate Atlantic OSW, and **networking offshore transmission generates that benefits significantly outweigh the costs**

- Interregional offshore transmission generates **significant resource adequacy value** by displacing generation investment
  - This contributes substantially to total value of offshore transmission
  - Accrues in winter-peaking conditions in colder, electrified regions like PJM, NYISO, and ISO-NE
- AOSWTS did not answer the question of <u>when</u> building offshore transmission is cost-effective (benefits were only evaluated for 2050)

Gap

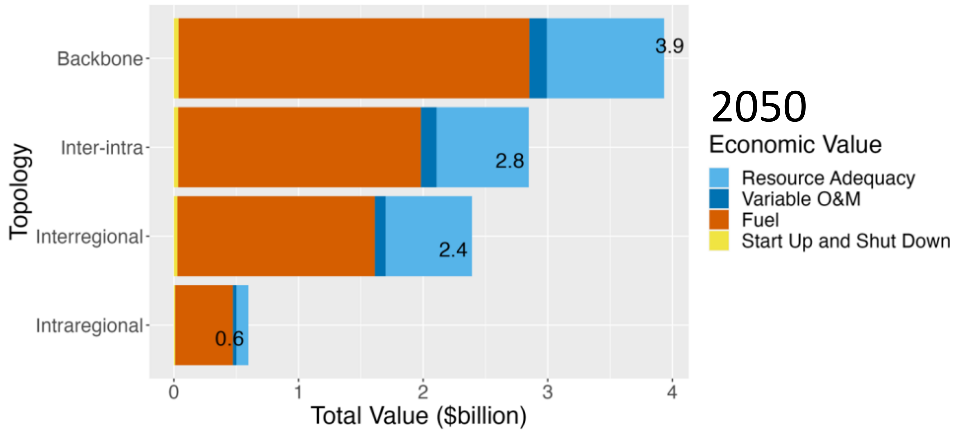
Resource adequacy value must be appropriately captured within **benefit assessment methodologies**

Gap

HVDC technology standards will be required to enable a phased rollout of interregional offshore transmission

Gap

Standards to for design of meshed offshore facilities **("mesh-ready standards")** required to overcome barriers to offshore networking



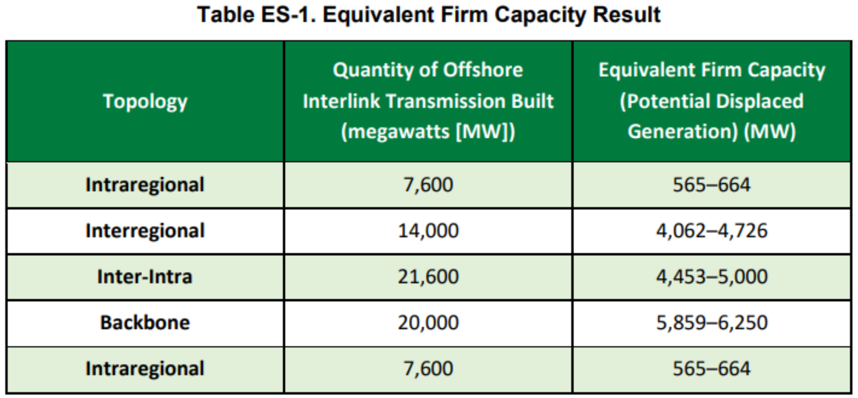


Table ES-1. Equivalent Firm Capacity Result

Topology	Quantity of Offshore Interlink Transmission Built (megawatts [MW])	Equivalent Firm Capacity (Potential Displaced Generation) (MW)
Intraregional	7,600	565–664
Interregional	14,000	4,062–4,726
Inter-Intra	21,600	4,453–5,000
Backbone	20,000	5,859–6,250
Intraregional	7,600	565–664

Source: Atlantic Offshore Wind Transmission Study

4. GE & NRDC: Benefits of Interregional Transmission Capacity (2022)

Takeaway

Expanding interregional transfer capability on Eastern Interconnect provides **significant resilience benefits** against major weather events, in addition to capacity and production cost savings

Resilience benefits

- **76 GW** of additional interregional transmission on Eastern Interconnect (~**1.3 GW** between ISO-NE and NYISO and **~5 GW** between NYISO and PJM) protects against simulated major weather events in **2035**, with **resilience benefits of $0.875–1 billion**
  - Summer heat wave: 27 GW (~0.7 GW ISO-NE to NYISO, ~5 GW NYISO to PJM) avoids loss of load equivalent to **$875 million**
  - Winter polar vortex: 65 GW (~1.3 GW ISO-NE to NYISO) avoids loss of load to ~2 million customers, equivalent to **$1 billion** of resilience benefits
- Assumes 28 GW of OSW by 2035 and 39 GW by 2040

Production cost and capacity savings

- Buildout would result in 20 GW of **capacity savings worth $2 billion/yr** and **ancillary service savings of $50 million/yr**
- Optimizing buildout to enable access to lower cost generation would build 54 GW of new interregional transmission (**~2 GW** ISO-NE–NYISO, **~3.5 GW** NYISO–PJM) and generate production cost savings of **$3 billion/yr in 2035** and **$4 billion/yr in 2040**

Altogether, 87 GW of additional interregional transmission (**~2 GW** ISO-NE–NYISO, **~5 GW** NYISO–PJM) would generate **$12 billion in net benefits**

Gap

Consistent benefit assessment frameworks are necessary for resilience benefits of interregional transmission to be correctly valued

Source: Economic, Reliability, and Resiliency Benefits of Interregional Transmission Capacity

5. MA Decarbonization Pathways Roadmap (2020)

Takeaway

Significant interregional transmission expansion, particularly New England–New York and both New England and New York to Quebec, is **required to integrate OSW** and reach **net-zero** economy-wide by **2050** at lowest cost

Offshore wind is pivotal to MA's decarbonization roadmap

- At least 15 GW installed in MA across all scenarios where OSW isn't limited

Integration of OSW requires significant new transmission capacity

  - **1.7–4.5 GW** between New England and New York (excluding low OSW and low load growth cases)
  - **1.5–7 GW** between NY–PJM in aggressive decarb., high load scenarios
    - Caveat: PJM was not explicitly modeled as its own zone but a boundary condition for New York
  - **4.1–7.1 GW** and **3.8–6.8 GW** between QC–New England and QC–NY, respectively
    - Operated **bidirectionally** in all cases
  - **0–2.7 GW** between New England and New Brunswick.
- Enhancing interregional coordination on transmission planning was found to reduce overall system costs and result in greater interregional buildout
  - However, study did not evaluate processes required to achieve improved interregional coordination, but rather simply represented it through a lower transmission cost

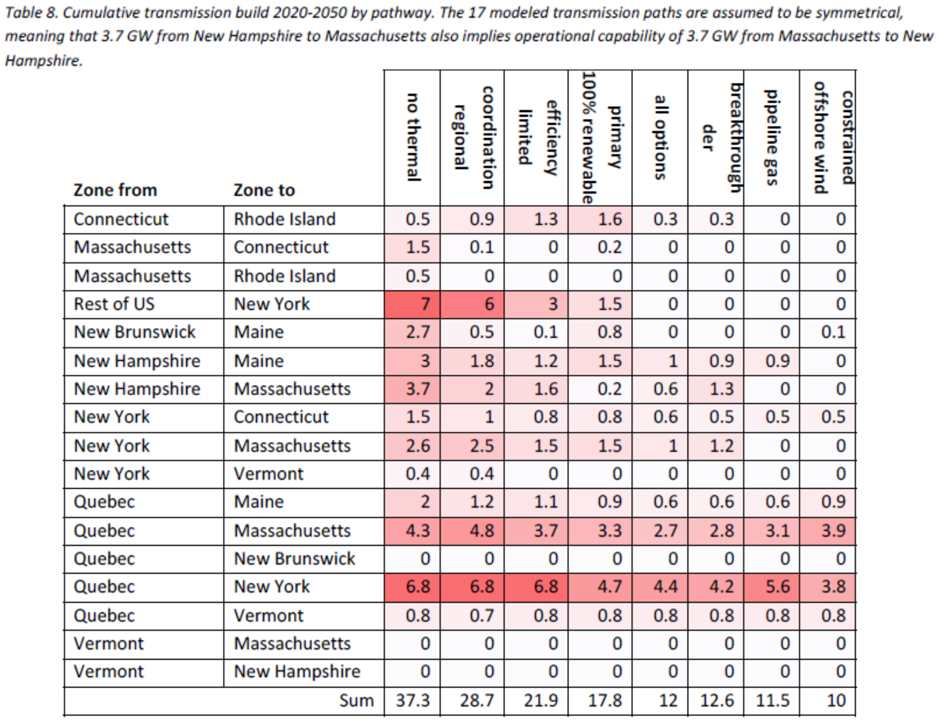


Table 8. Cumulative transmission build 2020-2050 by pathway. The 17 modeled transmission paths are assumed to be symmetrical, meaning that 3.7 GW from New Hampshire to Massachusetts also implies operational capability of 3.7 GW from Massachusetts to New Hampshire.

Zone from	Zone to	no thermal	regional coordination	efficiency limited	primary 100% renewable	all options	der breakthrough	pipeline gas	offshore wind constrained
Connecticut	Rhode Island	0.5	0.9	1.3	1.6	0.3	0.3	0	0
Massachusetts	Connecticut	1.5	0.1	0	0.2	0	0	0	0
Massachusetts	Rhode Island	0.5	0	0	0	0	0	0	0
Rest of US	New York	7	6	3	1.5	0	0	0	0
New Brunswick	Maine	2.7	0.5	0.1	0.8	0	0	0	0.1
New Hampshire	Maine	3	1.8	1.2	1.5	1	0.9	0.9	0
New Hampshire	Massachusetts	3.7	2	1.6	0.2	0.6	1.3	0	0
New York	Connecticut	1.5	1	0.8	0.8	0.6	0.5	0.5	0.5
New York	Massachusetts	2.6	2.5	1.5	1.5	1	1.2	0	0
New York	Vermont	0.4	0.4	0	0	0	0	0	0
Quebec	Maine	2	1.2	1.1	0.9	0.6	0.6	0.6	0.9
Quebec	Massachusetts	4.3	4.8	3.7	3.3	2.7	2.8	3.1	3.9
Quebec	New Brunswick	0	0	0	0	0	0	0	0
Quebec	New York	6.8	6.8	6.8	4.7	4.4	4.2	5.6	3.8
Quebec	Vermont	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8
Vermont	Massachusetts	0	0	0	0	0	0	0	0
Vermont	New Hampshire	0	0	0	0	0	0	0	0
	Sum	37.3	28.7	21.9	17.8	12	12.6	11.5	10

Gap

Expanding transmission **between New England and New York is low-regrets**; indicates potential for **"low-hanging" interregional projects** that are cost effective but highly valuable

Source: Energy Pathways to Deep Decarbonization – A Technical Report of the Massachusetts 2050 Decarbonization Roadmap Study

6. LBNL: Empirical Estimates of Transmission Value (2022)

Takeaway

Expanding **New England–New York** and **New York–PJM** transfer capability could generate **$137–400 million per GW of transfer capability** and **$149–313 million per GW**, respectively, in energy trading value alone

Energy trading value / production cost savings:

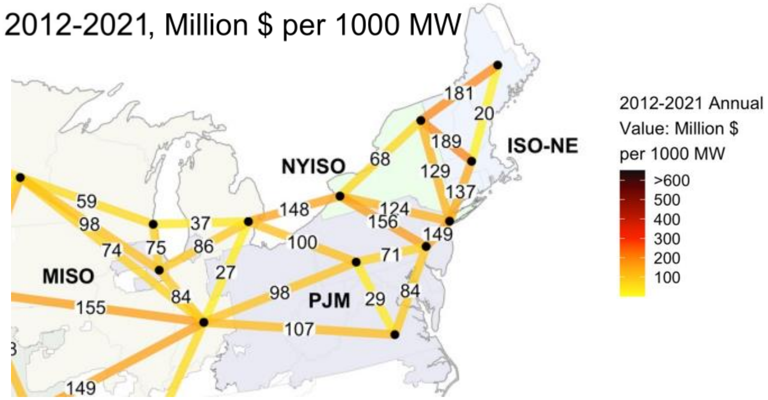
- Expanding interregional transmission capacity between ISO-NE–NYISO and NYISO–PJM would have generated **$137–189 million/yr per GW** and **$149–156 million/yr per GW** of trading value alone on average, respectively, between 2012 and 2021
- 2022 Update: ISO-NE–NYISO $211–400 million/yr, NYISO–PJM $219-313 million/yr
- Interregional transmission is more valuable than regional

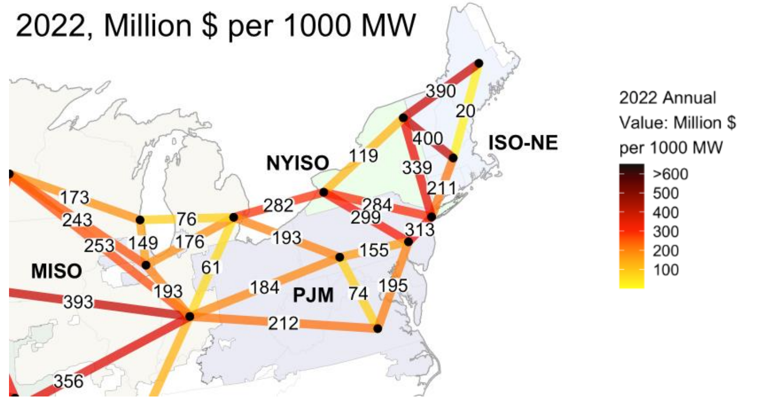
Resilience benefits:

- Not explicitly modelled, but **40–80%** of congestion value arises from **top 5%** of hours due to extreme conditions
- Winter storm Elliott (Dec 22–31 2022, ~2.5% of the year) made up **8–10%** and **12–13%** of the total 2022 value of expanding transmission between **ISO-NE–NYISO** and **NYISO–PJM**, respectively

Gap

Realizing congestion value of interregional transmission requires RTOs to implement effective **intertie optimization**


2012-2021, Million $ per 1000 MW


2022, Million $ per 1000 MW

Source: Empirical Estimates of Transmission Value using Locational Marginal Prices
The Latest Market Data Show that the Potential Savings of New Electric Transmission was Higher Last Year than at Any Point in the Last Decade
Transmission Value in 2023

7. NREL Interregional Renewable Energy Zones Study (2024)

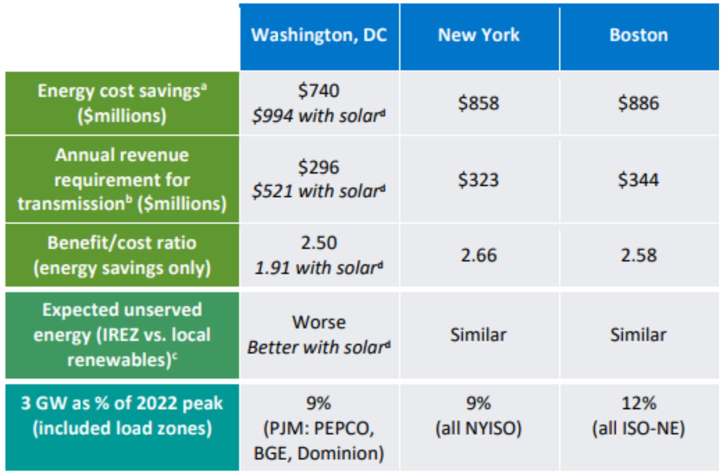
Takeaway

Interregional transmission corridor along Eastern Interconnect generates **significant energy cost savings** even without considering integration of Northeastern OSW resources

- Companion study to DOE's National Transmission Planning Study
- Extending Iowa–DC transmission corridor to New York City and Boston with **3 GW** of transfer capability increases annual energy cost savings from $740 to $886 million while only increasing transmission revenue requirement from $296 to $344 million
  - Incremental benefit: **$146 million/yr**; Incremental cost: $48 million/yr; Benefit-cost ratio of incremental expansion: **3.04**
  - Total benefit-cost ratio of transmission corridor from Iowa to Boston: 2.58
- Did not investigate cost savings of integrating OSW – would provide additional energy cost savings

Destinations

- Washington to New York to Boston
- Chicago/Milwaukee
- Indianapolis



	Washington, DC	New York	Boston
Energy cost savings[a] ($millions)	$740 *$994 with solar[d]*	$858	$886
Annual revenue requirement for transmission[b] ($millions)	$296 *$521 with solar[d]*	$323	$344
Benefit/cost ratio (energy savings only)	2.50 *1.91 with solar[d]*	2.66	2.58
Expected unserved energy (IREZ vs. local renewables)[c]	Worse *Better with solar[d]*	Similar	Similar
3 GW as % of 2022 peak (included load zones)	9% (PJM: PEPCO, BGE, Dominion)	9% (all NYISO)	12% (all ISO-NE)

Source: Interregional Renewable Energy Zones

Gap

Expanding transmission between PJM, New York and New England is low-regrets; potential for **"low-hanging" interregional projects** that are cost effective but highly valuable

8. MIT-CEEPR QC Hydro & Northeast Decarbonization (2020)

Takeaway

Expanding interregional transmission by **4 GW** between both **Quebec and New England** and **Quebec and New York** would **reduce net system costs in 2050** under a range of decarbonization scenarios

- **Quebec–New England:** increasing transfer capability by **4 GW** reduces power system costs (accounting for costs of transmission expansion) by **$913 million/yr** (13%) and **$2,387 million/yr** (24%) under 99% and 100% decarbonization scenarios, respectively
- **Quebec–New York:** increasing transfer capability by **4 GW** reduces power system costs by **$1,121 million/yr** (13%) and **$3,057 million/yr** (23%), respectively
- Value is generated by utilizing the transmission **bidirectionally** to balance Northeast renewables, avoiding firming costs
  - While the 4 GW increase was a model input (not reflective of max possible transmission value), this figure is in line with the low end of the ranges of transmission needs between Quebec and both New England and New York in the MA Decarbonization Pathways Roadmap, which reports 4.1–7.1 GW and 3.8–6.7 GW, respectively, by 2050
- Analysis was constrained to meet the OSW targets of each state
- Economic benefits remain robust under a range of sensitivities, including limited nuclear/carbon capture and sequestration as well as high load growth scenarios

Gap

Bidirectional operation of transmission to Quebec requires significant improvements in **intertie optimization**

Source: Two-Way Trade in Green Electrons: Deep Decarbonization of the Northeastern U.S. and the Role of Canadian Hydropower

9. NERC Interregional Transfer Capability Study (ITCS) (2024)

Takeaway

Significant transmission expansion between **NY–PJM** and from **Quebec to New England and NY** is required in the **next 10 years** to maintain reliability. **Larger additions are likely justifiable when considering economic benefits.**

- Identifies “prudent” interregional transmission additions needed to maintain reliability
  - **Considers resource adequacy only and does not include assessment of economic or public policy benefits:** Transmission expansion results therefore represent only the lower bound of what would be valuable at each interface

New York–PJM transmission expansion is justifiable on a reliability basis alone

- **1.8 GW by 2033** to alleviate significant resource deficiencies in New York

Expansion to Quebec improves resource adequacy in both New England and NY

- **1.9 GW by 2033** between NY–QC (Champlain Hudson Power Express to provide 1.2 GW)
- **400 MW by 2033** between New England–QC (and 300 MW to Maritimes)
  - New England Clean Energy Connect likely to address a significant portion of this need

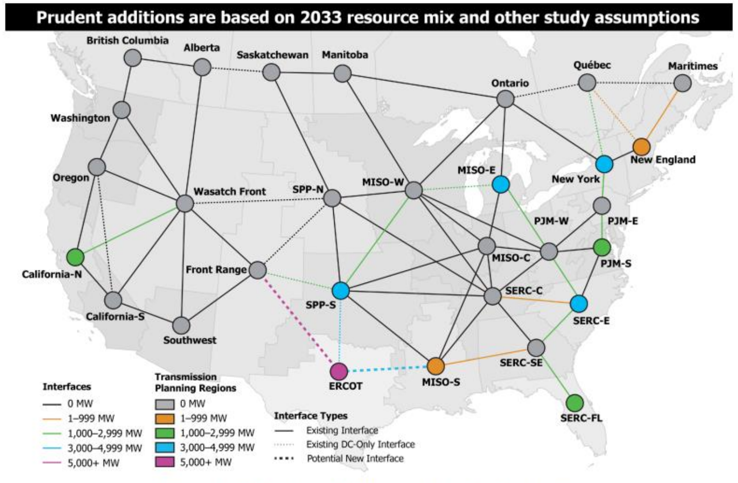

Prudent additions are based on 2033 resource mix and other study assumptions

Figure ES.2: Prudent Additions to Transfer Capability

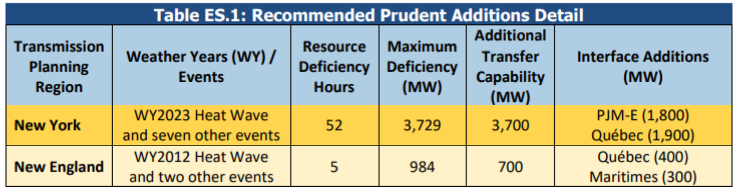


Table ES.1: Recommended Prudent Additions Detail

Transmission Planning Region	Weather Years (WY) / Events	Resource Deficiency Hours	Maximum Deficiency (MW)	Additional Transfer Capability (MW)	Interface Additions (MW)
New York	WY2023 Heat Wave and seven other events	52	3,729	3,700	PJM-E (1,800) Québec (1,900)
New England	WY2012 Heat Wave and two other events	5	984	700	Québec (400) Maritimes (300)

Gap

Consistent **benefit assessment frameworks covering economic, resiliency and public policy benefits**—not solely reliability—are essential to identify valuable transmission expansion opportunities and minimize risk of undersizing

Source: Interregional Transfer Capability Study (ITCS) - Recommendations for Prudent Additions to Transfer Capability (Part 2) and Recommendations to Meet and Maintain Transfer Capability (Part 3)

Appendix: The Need to Address Inefficiencies Across Market Seams

Five Sources of Inefficiencies Created by Market Seams

Seams between RTOs will generally be more efficient than seams between non-market regions that rely entirely on bilateral trades. Nevertheless, significant seams-related inefficiencies exist between RTO markets:

1. **Interregional transmission planning** is ineffective
2. **Generator interconnection** delays and cost uncertainty created by affected system impact studies (and effectiveness coordination through means such as the SPP-MISO JTIQ, reducing costs by 50%)
3. **Resource adequacy** value of interties (often not considered in RTO’s resource adequacy evaluations) and barriers to capacity trades (often created by RTOs’ restrictive capacity import requirements and incompatible resource accreditations)
4. **Loop flow management** inefficiencies through market-to-market coordinated flowgates (with shares of firm flow entitlements) under the existing JOAs
5. ➡ **Inefficient trading** across contract-path market seams and the need for intertie optimization
   - **This is the focus of these appendix slides**

Note

This content is in part based on:

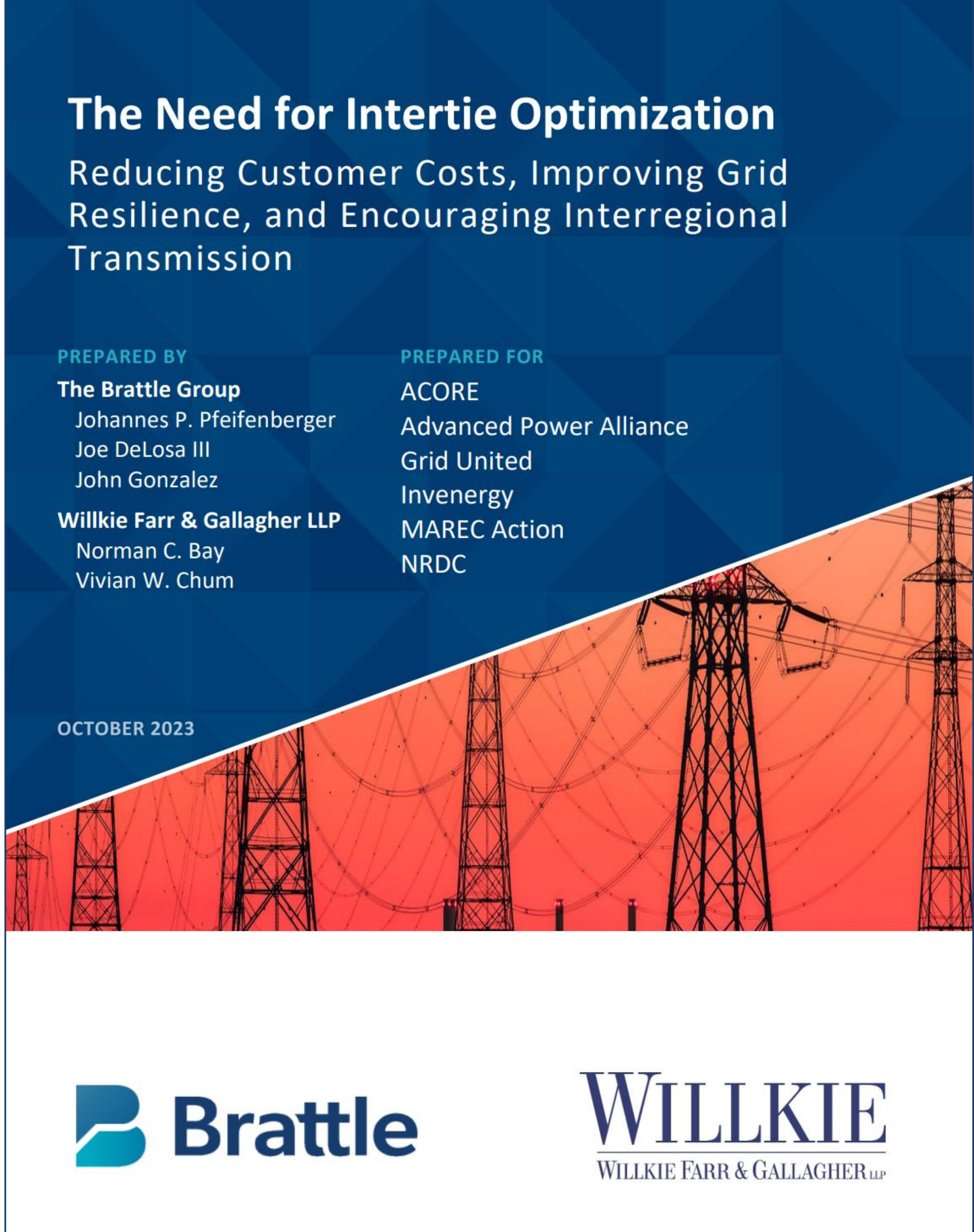
The Need for Intertie Optimization, prepared for ACORE, Advanced Power Alliance, Grid United, Invenergy, MAREC, and NRDC, October 2023

Intertie Optimization FAQs and Implementation Principles, February 2024

Intertie Optimization: Efficient Use of Interregional Transmission (Update), presented to OPSI, April 12, 2024

Market Benefits and Seams: Options and Implications, presented to CREPC-WIRAB, April 24, 2024.

Various State of Market, LBNL, and NREL reports
(as cited in the slides)



The Need for Intertie Optimization

Reducing Customer Costs, Improving Grid Resilience, and Encouraging Interregional Transmission

PREPARED BY

The Brattle Group
Johannes P. Pfeifenberger
Joe DeLosa III
John Gonzalez

Willkie Farr & Gallagher LLP
Norman C. Bay
Vivian W. Chum

PREPARED FOR

ACORE
Advanced Power Alliance
Grid United
Invenergy
MAREC Action
NRDC

OCTOBER 2023

Brattle

WILLKIE
WILLKIE FARR & GALLAGHER LLP

NREL Report: Barriers and Opportunities to Realize the System Value of Interregional Transmission (June 2024)

NREL recommends reforms to “significantly enhance the value of interregional transmission and deliver additional within-region benefits”:

Common Actions

- Develop a framework for resource adequacy sharing among regions
- Support joint studies to identify transfer needs during extreme events and develop operational procedures to mitigate issues
- Evaluate internal transmission system ability to accommodate large power transfers as the underlying generation mix changes

Nonmarket and Hybrid Actions

- Implement coordinated scheduling and operations platforms or consolidation
- Pursue joint congestion management programs and reevaluate qualified paths for congestion management
- Develop consistent methods to calculate available transfer capacity
- Update processes to prioritize system reliability in scheduling market and wheeling transactions

Market Actions

- Eliminate fees and improve price forecasting for coordinated transaction scheduling or move toward intertie optimization
- Update corridor flow limits, automate procedures, and align assumptions for congestion management programs
- Revise interface pricing methods and validate interregional transactions
- Integrate operational control of merchant HVDC lines with regional market operations

Transformative Actions

- Conduct long-range, nationwide interregional transmission planning
- Implement interconnection-wide intertie optimization
- Establish a national system operator and planner to coordinate national network planning, scheduling, and resource adequacy functions

- Recognize resource-adequacy and resilience value of interregional transmission
- Improved coordination and joint congestion management
- De-pancaking
- Improved intertie pricing

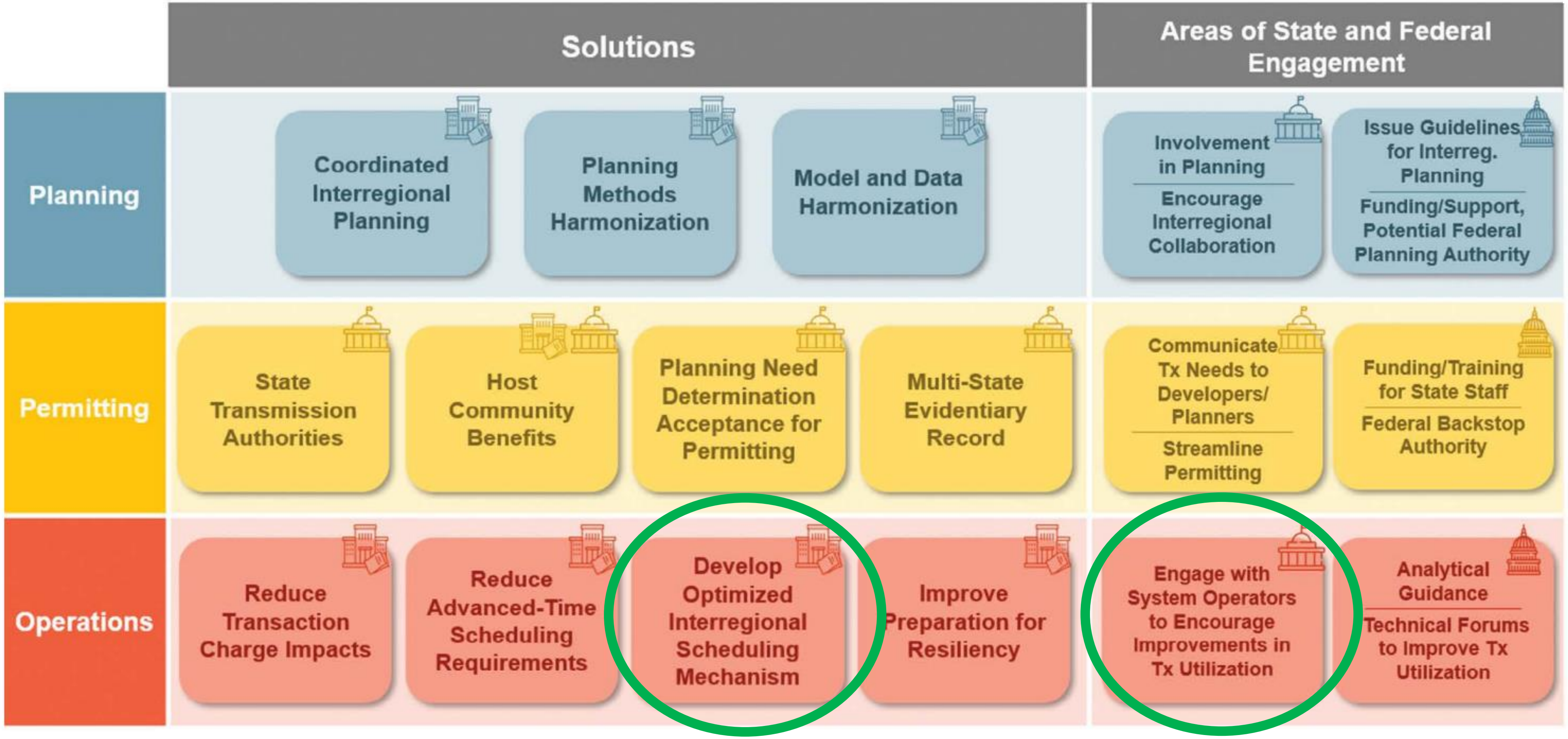
➡ **“Move toward intertie optimization”**

- Interregional planning
- Interconnection-wide optimization

NARUC Report: Collaborative Enhancements to Unlock Interregional Transmission (June 2024)

NARUC
National Association of
Regulatory Utility Commissioners

Recommends reforms improve planning, permitting, and operational utilization of interregional transmission, including intertie optimization:



	Solutions				Areas of State and Federal Engagement	
Planning	Coordinated Interregional Planning	Planning Methods Harmonization	Model and Data Harmonization		Involvement in Planning Encourage Interregional Collaboration	Issue Guidelines for Interreg. Planning Funding/Support, Potential Federal Planning Authority
Permitting	State Transmission Authorities	Host Community Benefits	Planning Need Determination Acceptance for Permitting	Multi-State Evidentiary Record	Communicate Tx Needs to Developers/ Planners Streamline Permitting	Funding/Training for State Staff Federal Backstop Authority
Operations	Reduce Transaction Charge Impacts	Reduce Advanced-Time Scheduling Requirements	Develop Optimized Interregional Scheduling Mechanism	Improve Preparation for Resiliency	Engage with System Operators to Encourage Improvements in Tx Utilization	Analytical Guidance Technical Forums to Improve Tx Utilization

Source: https://pubs.naruc.org/pub/BACDBB9D-02BF-0090-0109-B51B36B74439

Promising Initiative: SPP’s Inter-Market Optimization Framework

SPP Southwest Power Pool

INTER-MARKET OPTIMIZATION FRAMEWORK

ANTOINE LUCAS, VP-MARKETS

STRATEGIC PLANNING COMMITTEE

OCTOBER 2024

- SPP staff has been exploring an Inter-Market Optimization Framework to improve the efficiency of transfers between SPP and its neighbors, resulting in increased economic benefits for SPP’s market participants
- On October 16, 2024, SPP’s Strategic Planning Committee (SPC) endorsed that staff’s work on this concept be prioritized within the “Optimized Seams” objectives of SPP’s strategic planning roadmap
- SPP’s proposed next steps:
  - Further evaluate potential value of adding this feature to the market design
  - Prioritize inter-market optimization within the Optimized Seams strategic opportunity
  - Develop policy proposals to address challenges identified

Source: SPP Documents & Filings – SPC Meeting Materials, Oct 8, 2024