The Electricity Grid's Role in Achieving Carbon Neutrality in the U.S. and New England

PRESENTED TO
Solving for Carbon Neutrality at MIT

PRESENTED BY
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March 17, 2021

Brattle

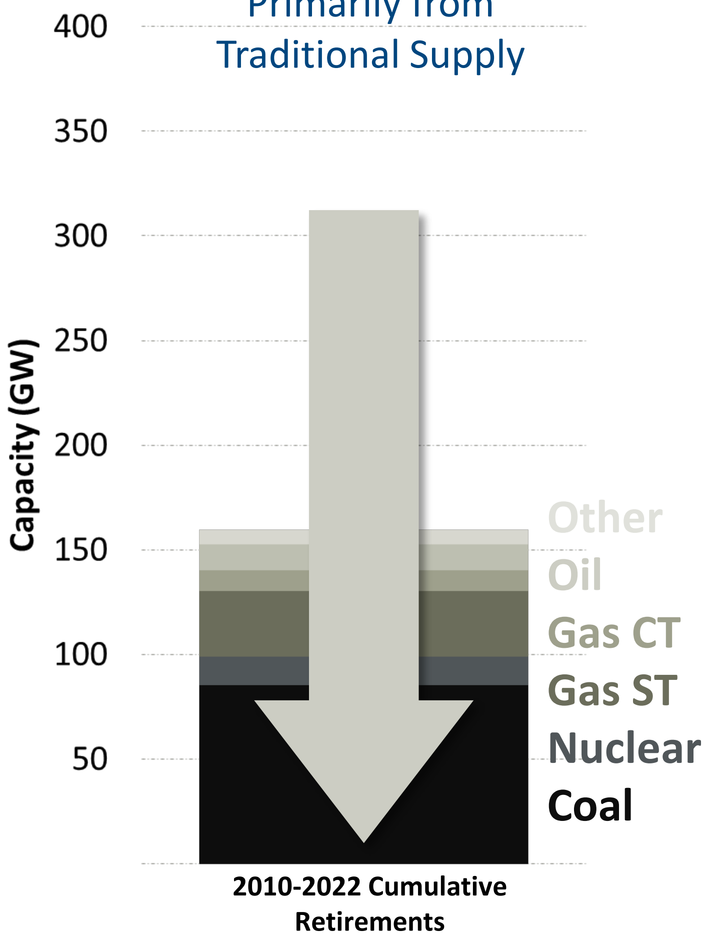
Agenda

- **U.S. Overview**
- **New England Case Studies**

It's already happening: electricity generation is changing significantly

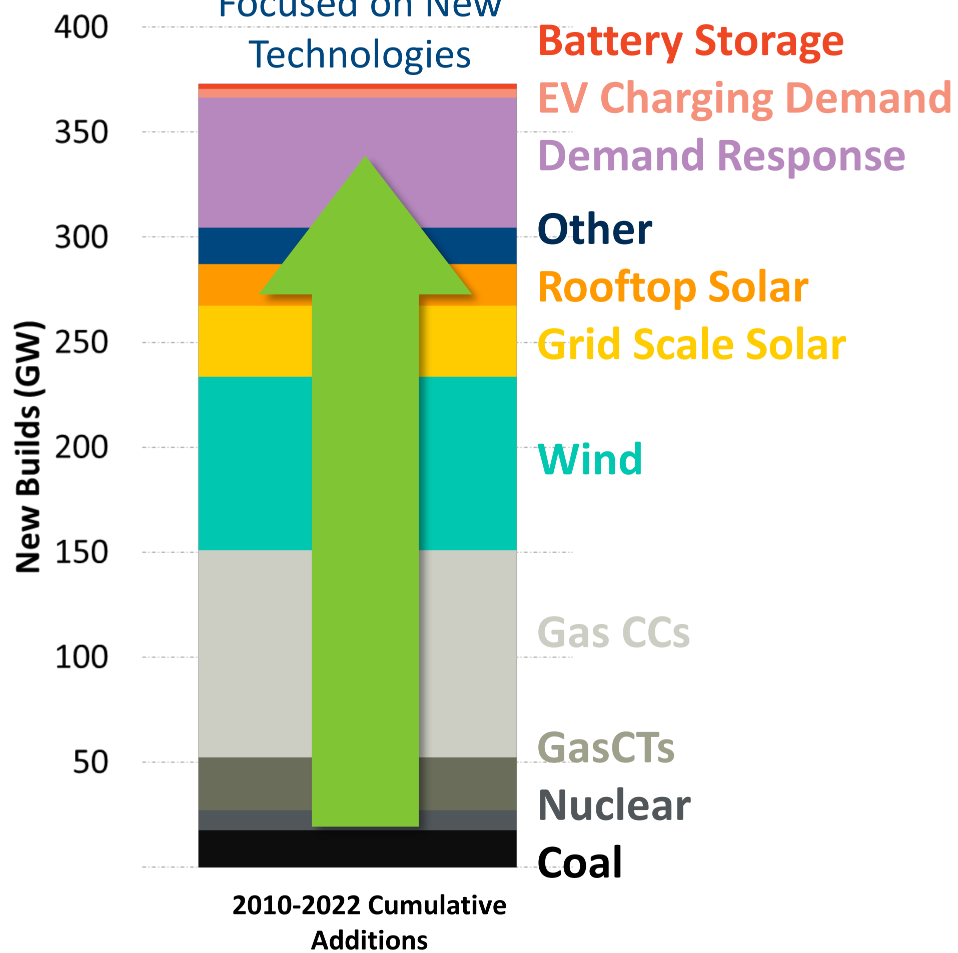
Retirements

Primarily from Traditional Supply



New Builds

Focused on New Technologies

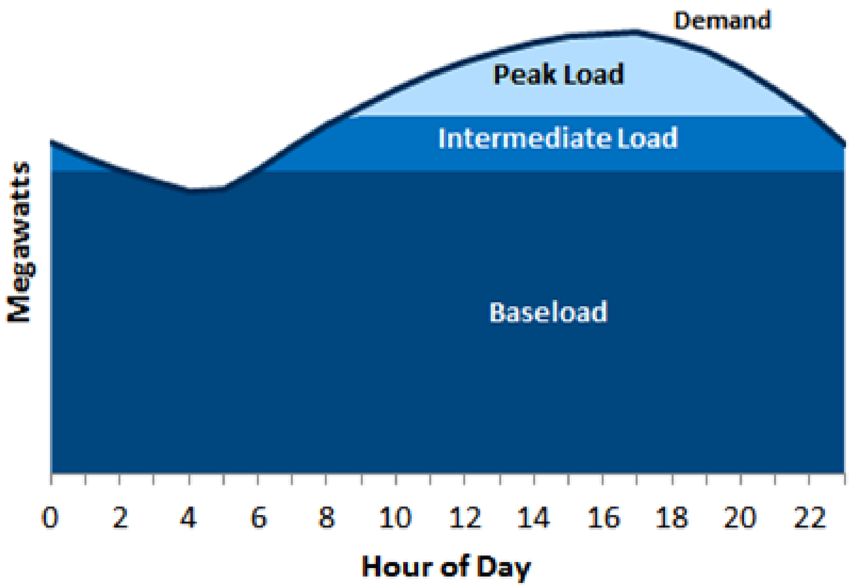


Sources: Energy Velocity Suite (US and Canadian generation) and Brattle research (US-only distributed resource and storage).

The shifting supply mix requires significant changes in grid operations

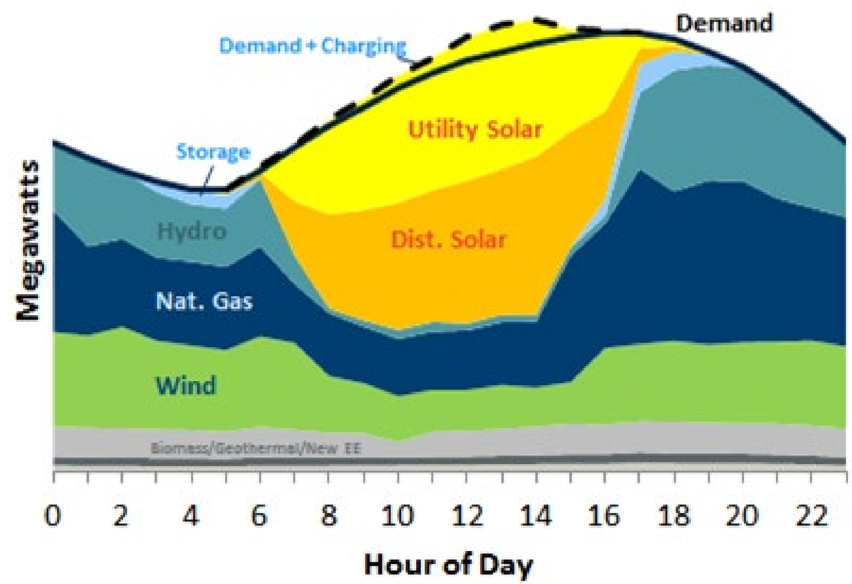
The more diverse supply mix creates challenges and requires more operational flexibility of electricity grid operations, including storage

Electricity Demand and Traditional Supply Mix



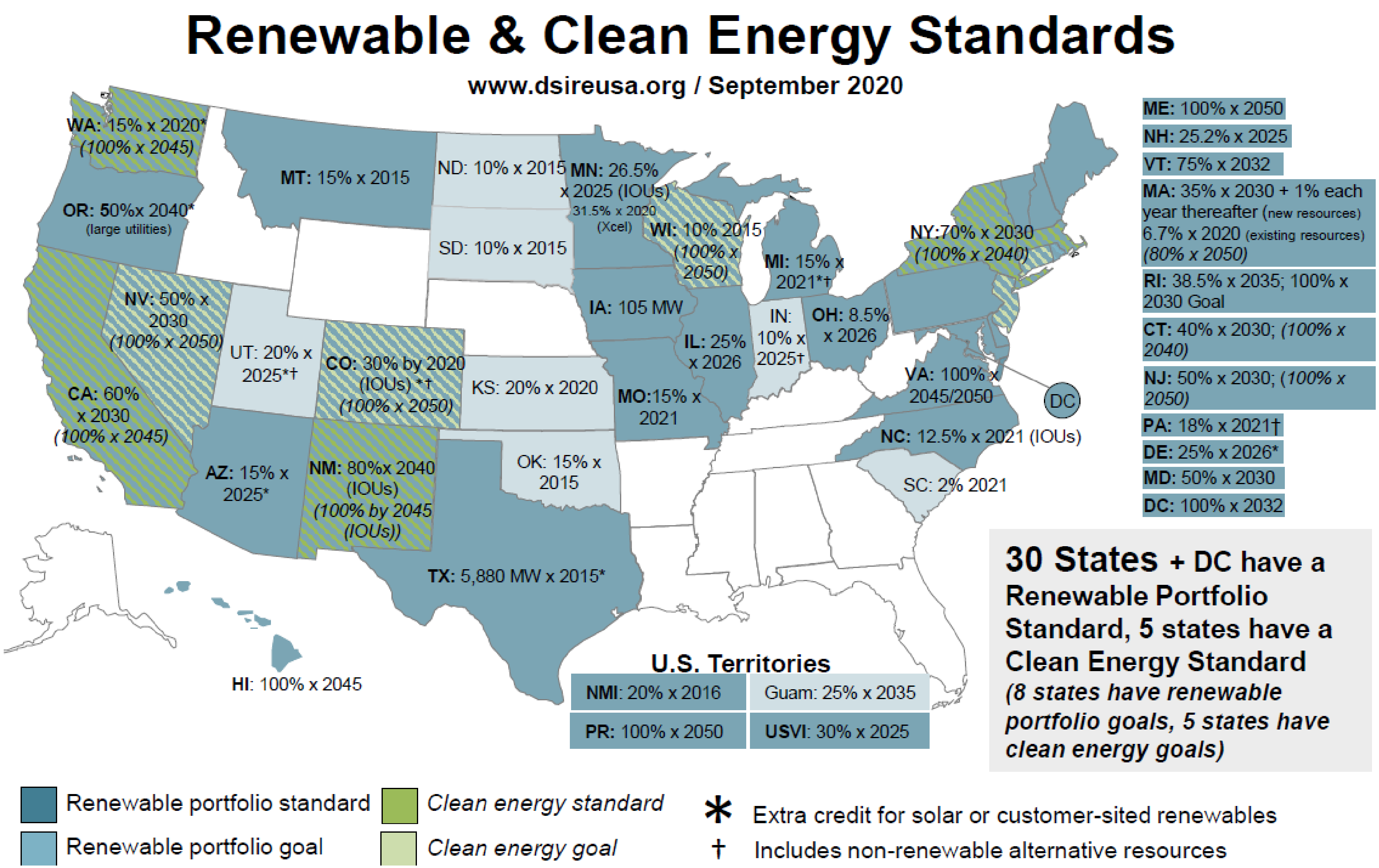
Source: The Brattle Group.

Electricity Demand and Supply Mix with High Renewable Generation



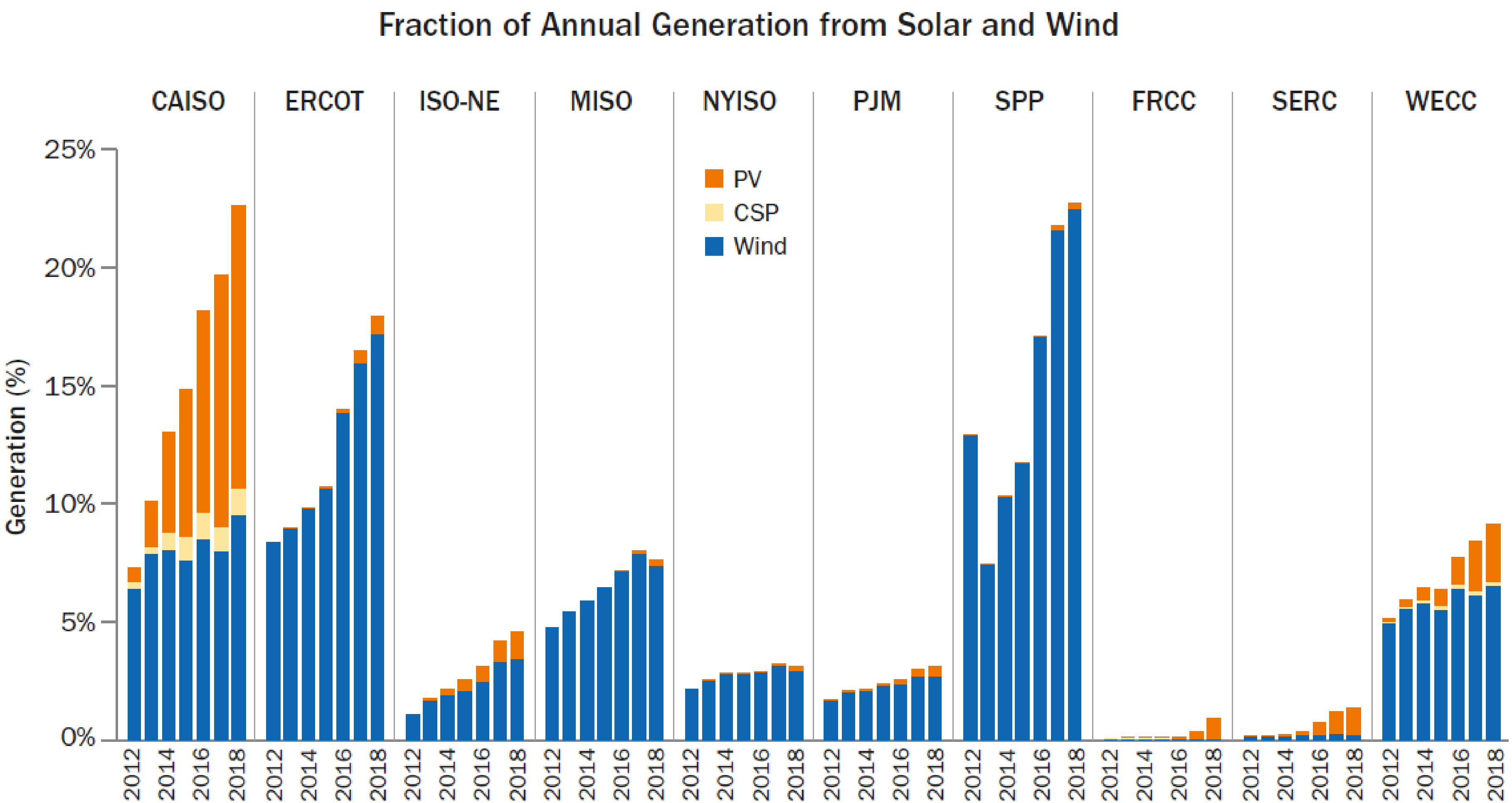
Source: The Brattle Group.

Increasingly ambitious state clean-electricity goals and mandates…



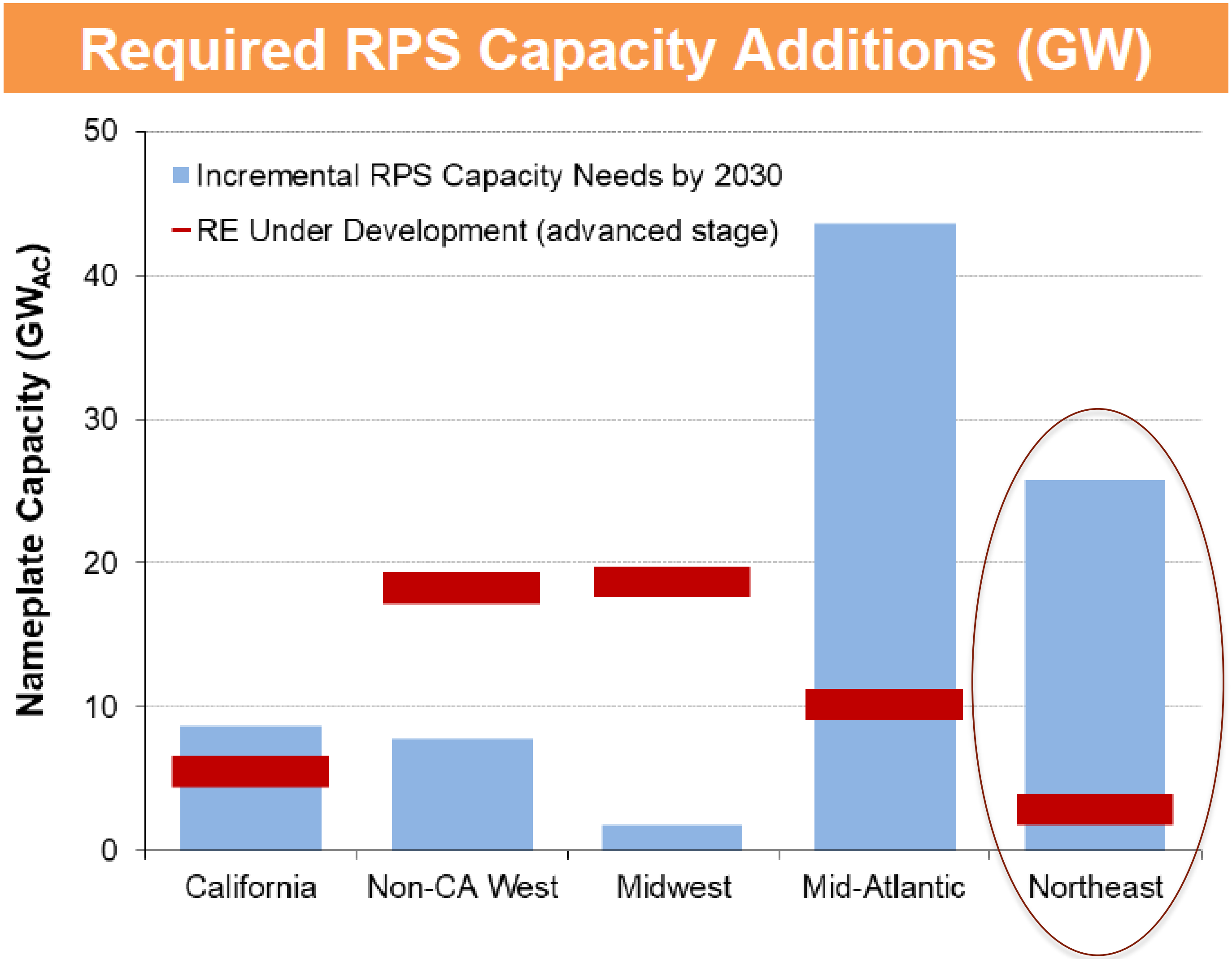
Source: https://s3.amazonaws.com/ncsolarcen-prod/wp-content/uploads/2020/09/RPS-CES-Sept2020.pdf

…are in contrast to still relatively low actual levels of renewable generation…



Source: *2018 Renewable Energy Grid Integration Data Book*, U.S. Department of Energy, National Renewable Energy Laboratory (NREL) and the Lawrence Berkeley National Laboratory (LBNL), March 2020.

…and substantial gaps between goals and renewable development activities



Source: Galen Barbose, "U.S. Renewables Portfolio Standards: 2021 Status Update (Early Release)," Lawrence Berkeley National Lab, Feb 2021. rps.lbl.gov

Also happening: renewable generation investments beyond state mandates

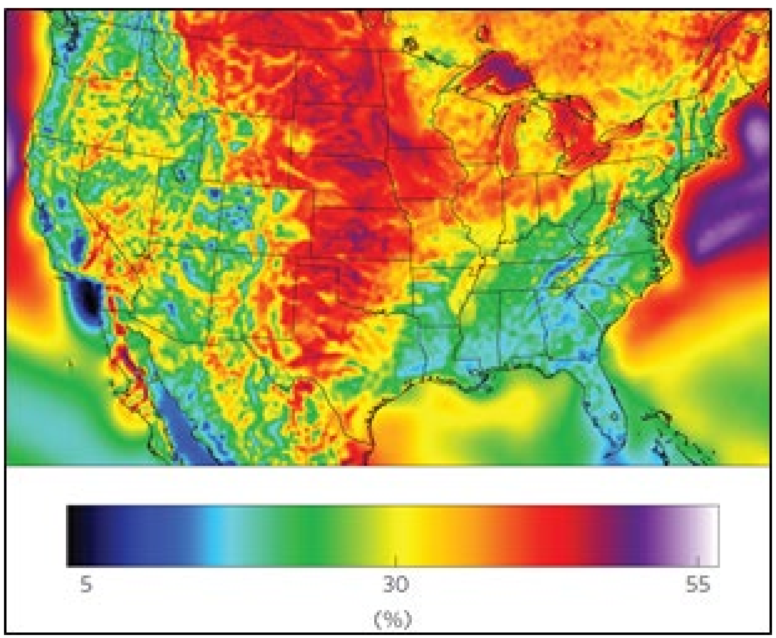
Experience in regional markets with low-cost renewable resources shows significant renewable development beyond mandates:

1. **Voluntary PPAs by Investor-Owned Utilities in Excess of RPS Requirements** due to low-cost resources available and fuel-cost hedge value ("steel for fuel")
2. **Purchases by Public Power and Municipal Utilities Not Subject to RPS** responsible for about a quarter of renewable generation purchases
3. **PPAs with Commercial & Industrial Customers** (such as: Google, Amazon, universities) accounting for increasing shares of renewable deals
4. **Merchant Renewable Generation** developed with financial hedges to support the financing of generation investments (merchant or quasi-merchant wind projects about a third of recent developments)

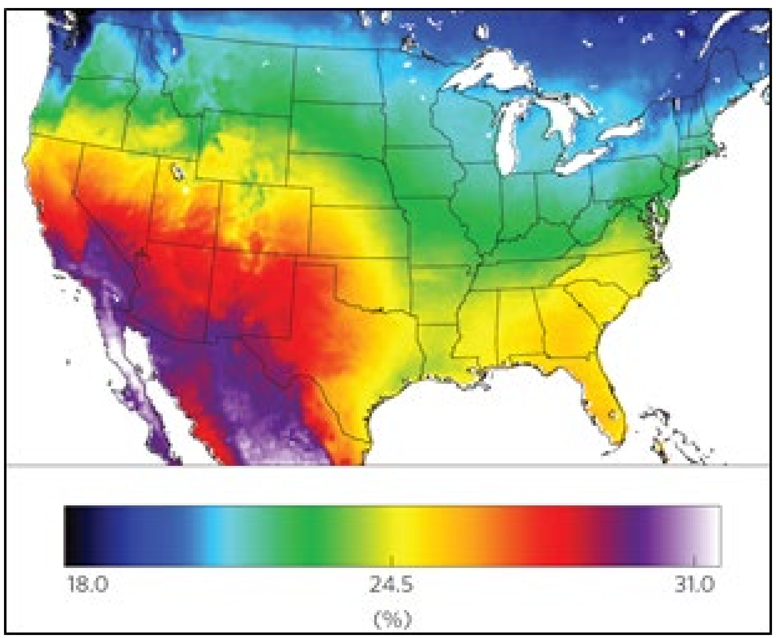
Good news: the U.S. has large amounts of high-quality wind and solar resources

- Wind generation investments occurred almost exclusively in areas with **lowest-cost wind** resources
- Continued cost reductions and technology improvements likely will also create opportunities in regions with access to **high-quality solar**
- Challenge is to cost-effectively balance intermittent energy output (better in regional markets)

Wind Capacity Factor



Solar PV Capacity Factor

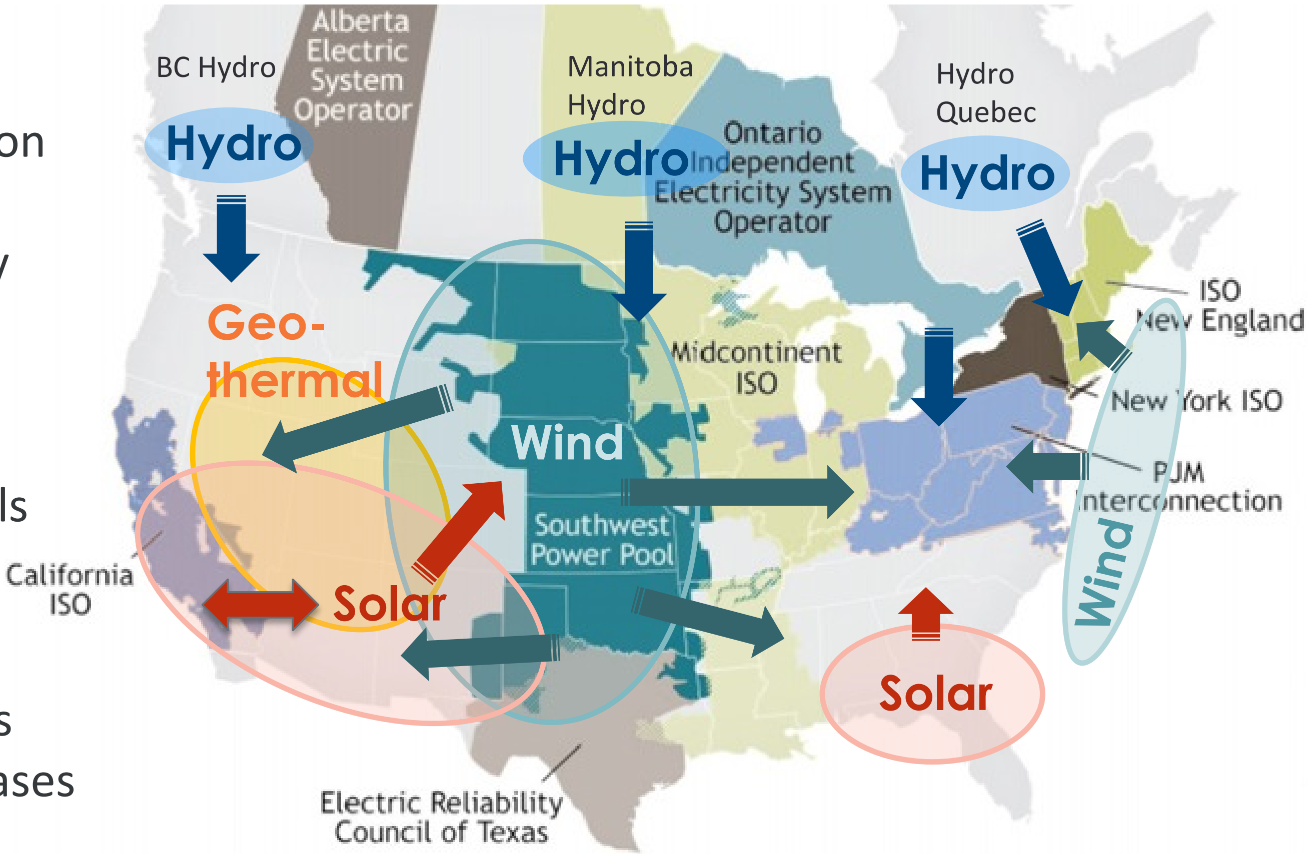


Source: MacDonald, Alexander E, Christopher T.M. Clack, et al., "Future cost-competitive electricity systems and their impact on US CO2 emissions," Nature Climate Change (Jan 2016): DOI: 10.1038/NCLIMATE2921. (Reproduced with permission from Earth System Research Laboratory, NOAA.

Inter-regional transmission will be needed to access & diversify low-cost clean energy

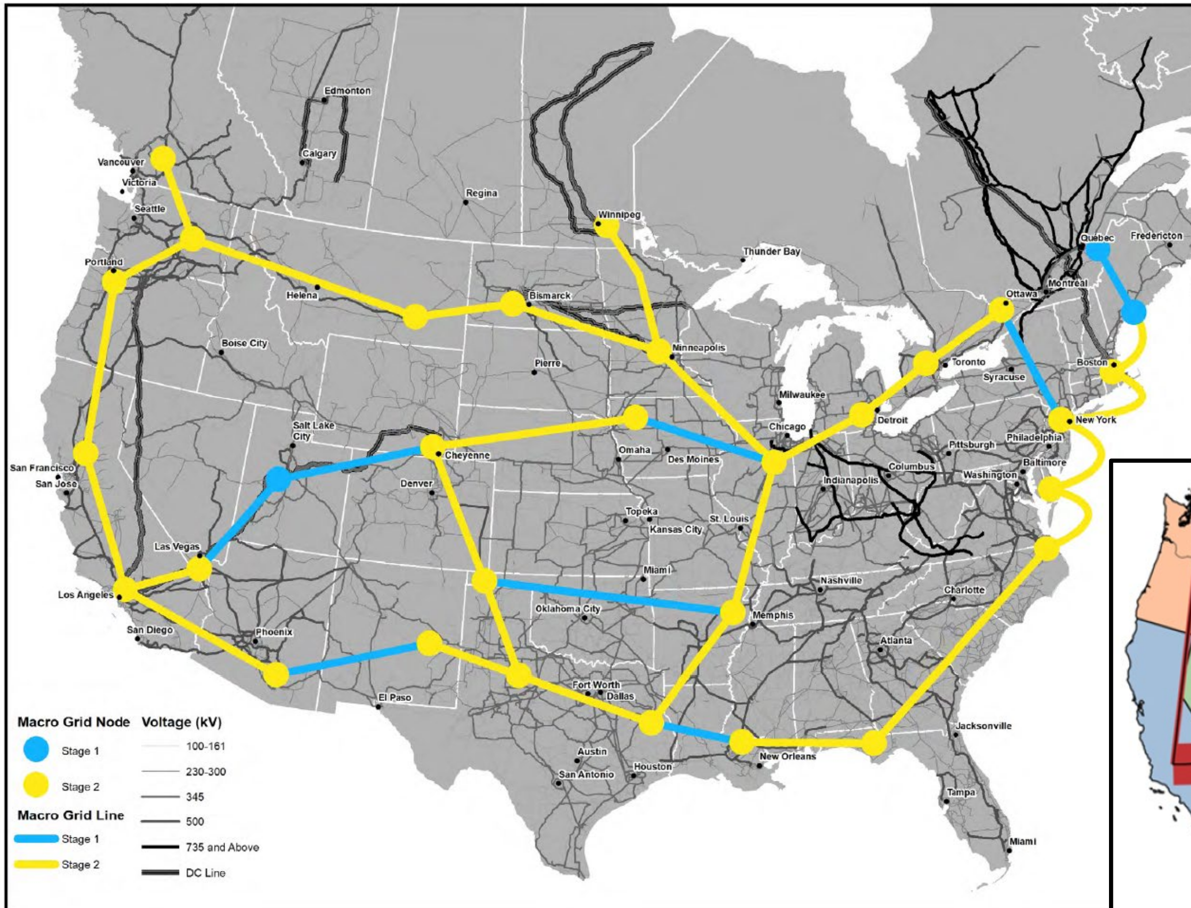
Resource diversification can offer significant benefits:

- Regional diversification of resources (and customers' electricity usage) reduces the investment and balancing cost in a future with high levels of intermittent resources
- Diversity of resources (and load) also increases the value of transmission that interconnects them



Many studies show that more transmission would be needed to achieve cost-effective outcomes

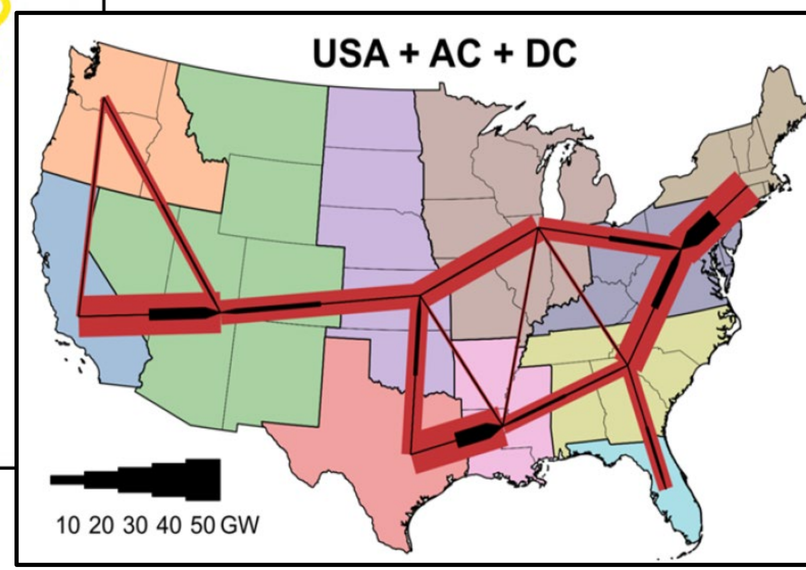
Existing and Conceptual U.S. “Macro Grid” (ESIG)



https://www.esig.energy/wp-content/uploads/2021/02/News-Release-ESIG-Transmission-White-Paper-1.pdf (also summarizes other studies)

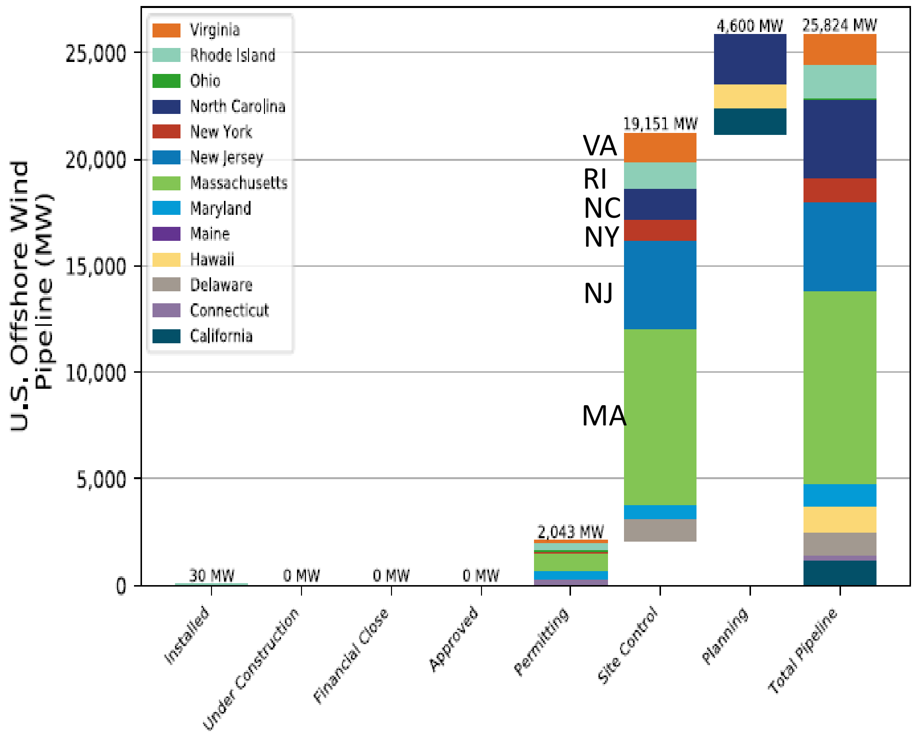
MIT Study

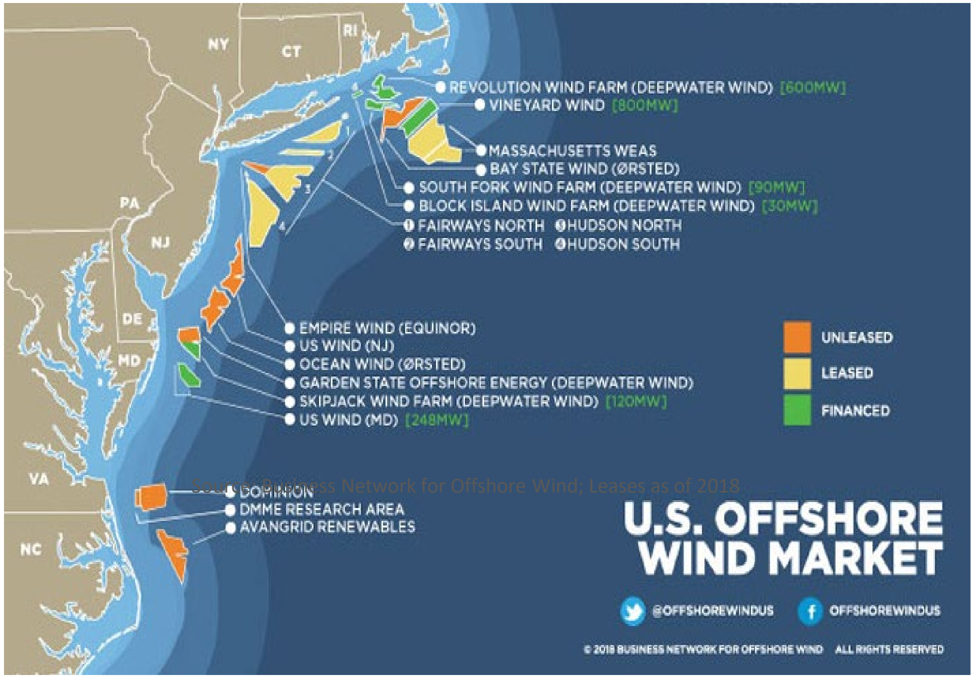
“The Value of Inter-Regional Coordination and Transmission in Decarbonizing the U.S. Electricity System.” Joule 5(1) (2020): 115-134.Summarized at https://www.greentechmedia.com/articles/read/study-transmission-is-the-key-to-a-low-cost-decarbonized-u.s-grid



New: approx. $80 billion in proposed U.S. offshore wind projects

About 30,000 MW* "under development" in US … mostly in the North Atlantic





US Offshore Wind Lease Areas

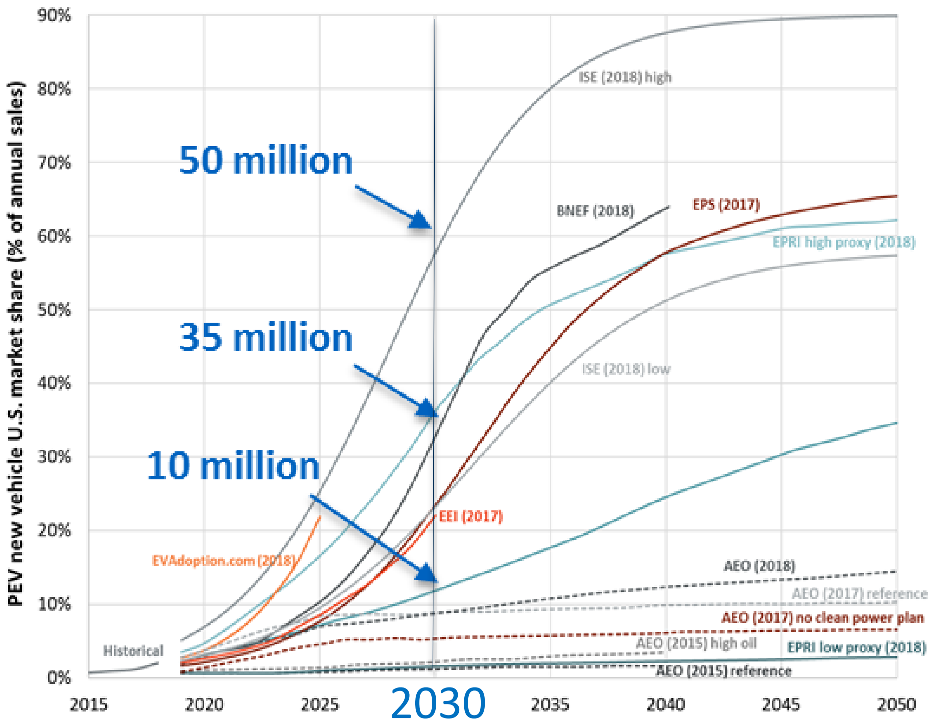
Source: US DOE (2019). 2018 Offshore Wind Technologies Market Report, https://www.energy.gov/sites/prod/files/2019/08/f65/2018%20Offshore%20Wind%20Market%20Report.pdf

See also: Outer Continental Shelf Renewable Energy Leases Map Book, March 2019, BOEM https://www.boem.gov/Renewable-Energy-Lease-Map-Book/

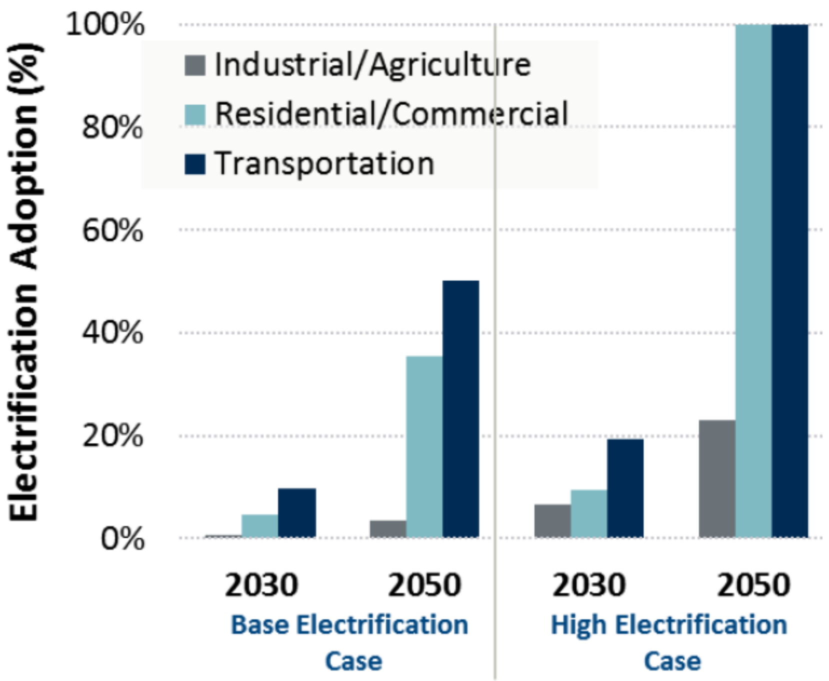
*This number includes the 25,824 MW from the bar chart plus other announced projects, such as Dominion Energy's 2,640 MW VA project.

Electrification of transportation, industry, and homes is important …but moving slowly

Projections of Annual EV Market Share

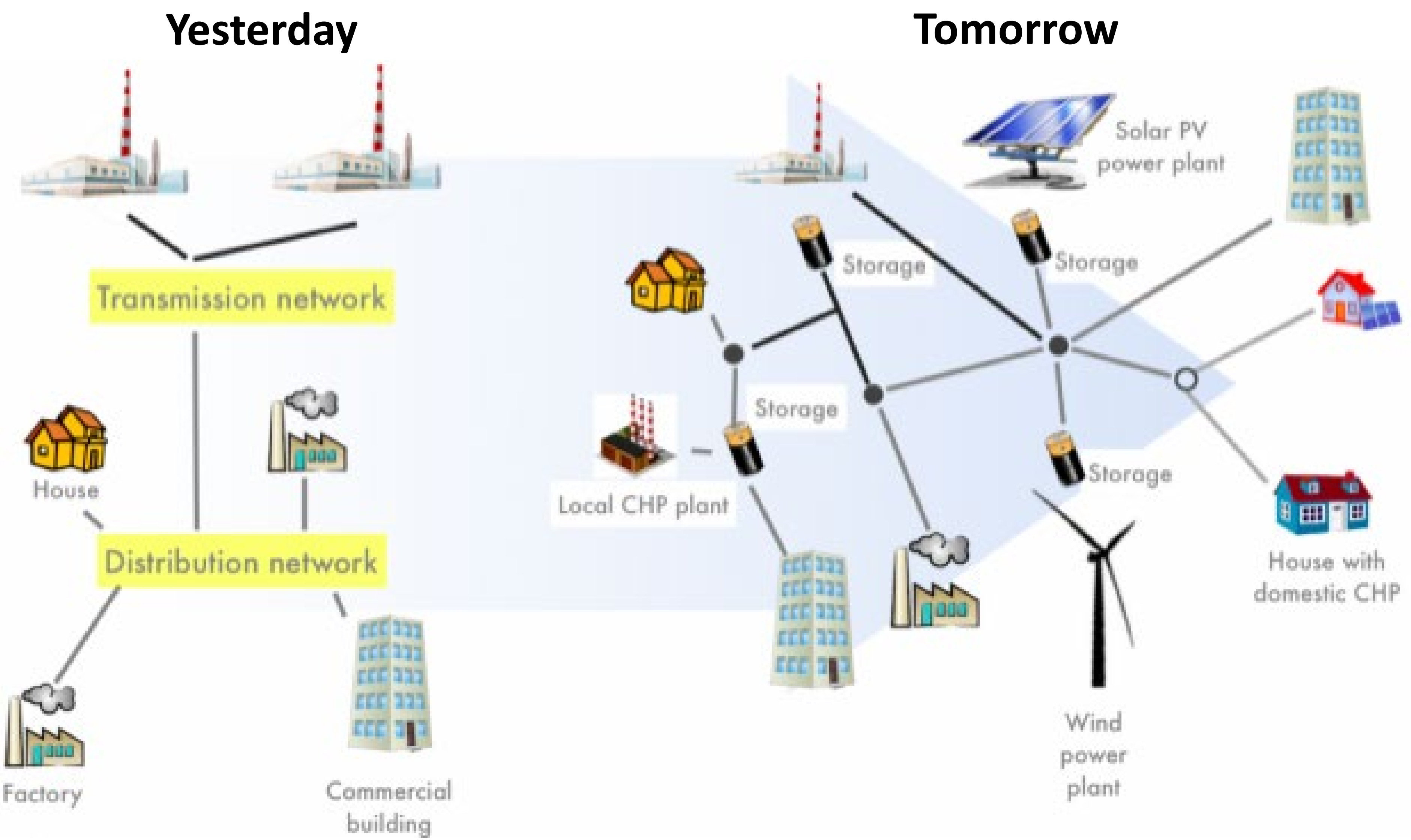


Total Electrification Rates



https://wiresgroup.com/wp-content/uploads/2019/03/Electrification_BrattleReport_WIRES_FINAL_03062019.pdf

The configuration of the electricity grid is also changing at the local level



Case Study: Decarbonizing New England

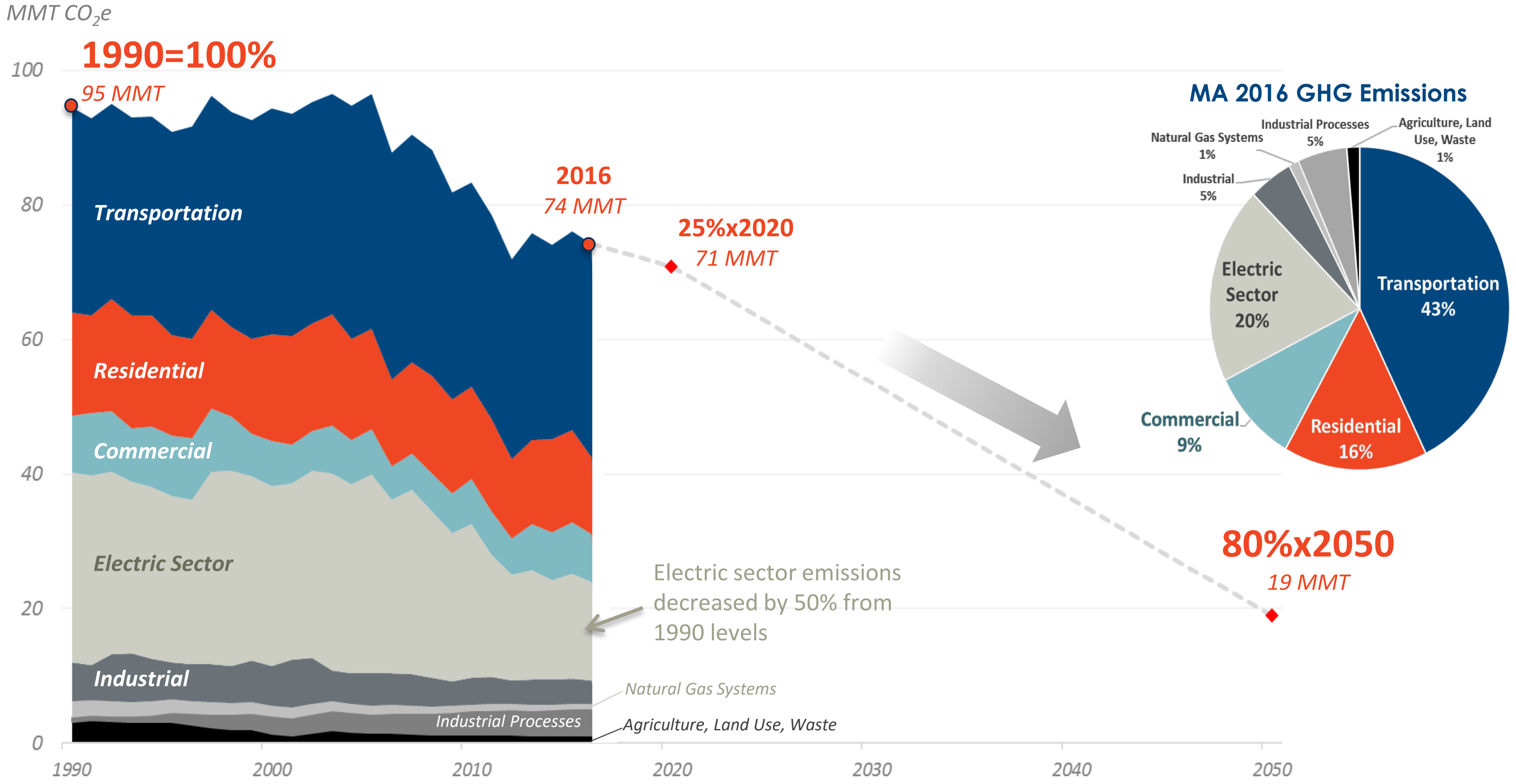
https://brattlefiles.blob.core.windows.net/files/17233_achieving_80_percent_ghg_reduction_in_new_england_by_20150_september_2019.pdf

https://www.brattle.com/news-and-knowledge/news/study-coauthored-by-brattle-economists-assesses-policies-and-pathways-for-achieving-100-renewable-electricity-in-rhode-island-by-2030

https://brattlefiles.blob.core.windows.net/files/21229_offshore_wind_transmission_-_an_analysis_of_options_for_new_england_and_new_york_offshore_wind_integration.pdf

All New England states aim to reduce GHG emissions by 80% in 2050

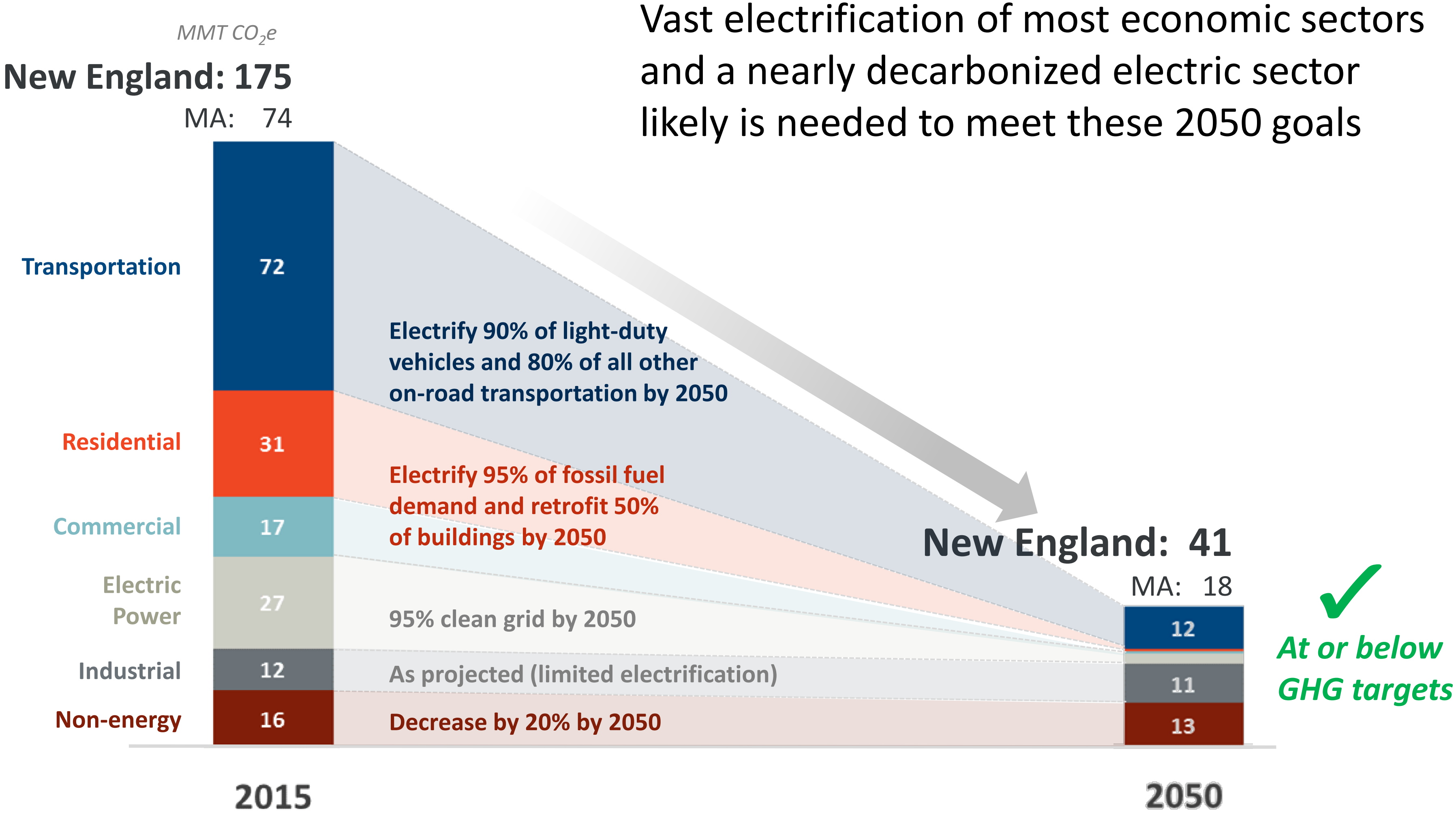
Example: Massachusetts historical GHG emissions and 2050 emissions limit



Source: MA GHG Emissions Inventory, December 2018. Note: Energy-related emissions (e.g., transportation, electricity, buildings, industrial) in this figure are based on state inventory.

One potential path to meet New England's 2050 decarbonization goals

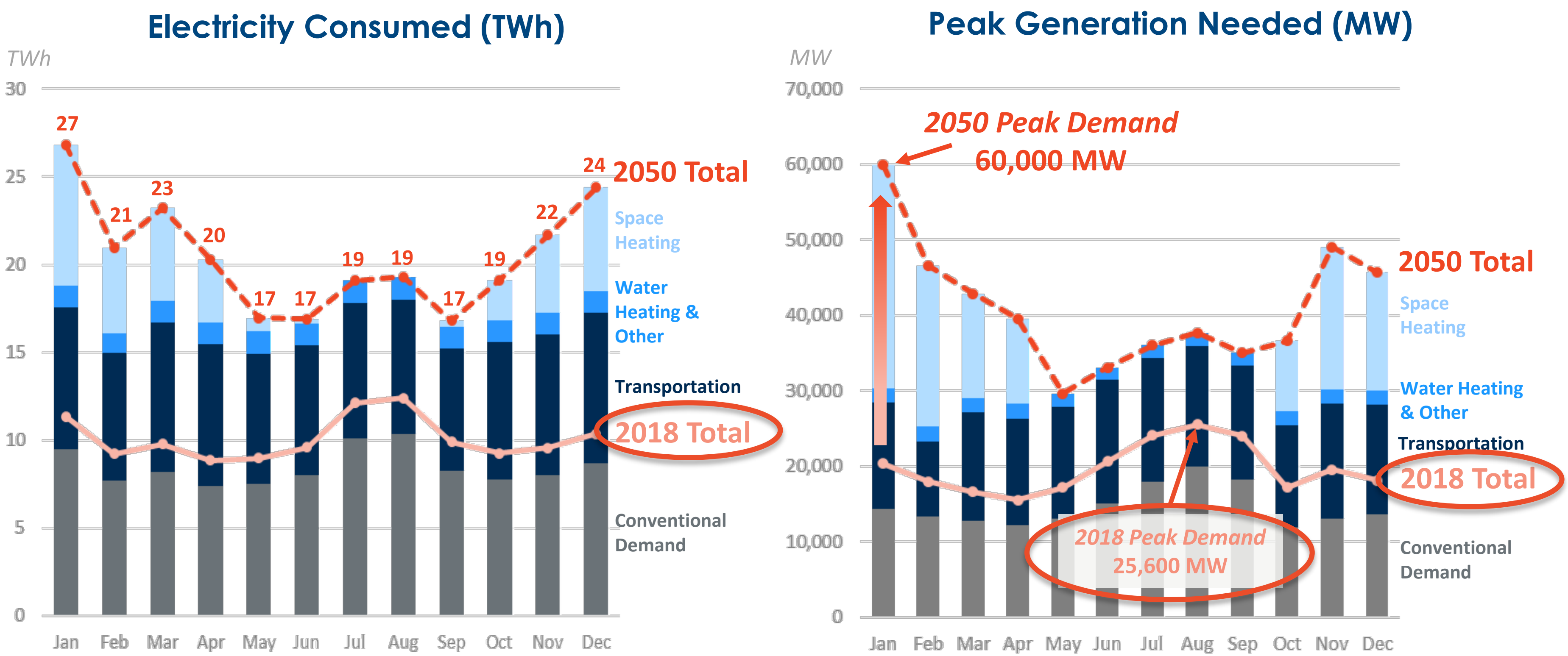
Vast electrification of most economic sectors and a nearly decarbonized electric sector likely is needed to meet these 2050 goals



Electrification of transportation and home heating will double electricity demand

Projected 2050 New England Demand

Scenario: Electrification Focused



Source: Monthly conventional demand based on ISO-NE 2018 monthly demand pattern. See appendix slides for more detail. Hourly temperatures based on 2018 weather conditions, which was an average year for heating demand, but had a relatively warm February. Incremental electrified demand based on Brattle analysis.

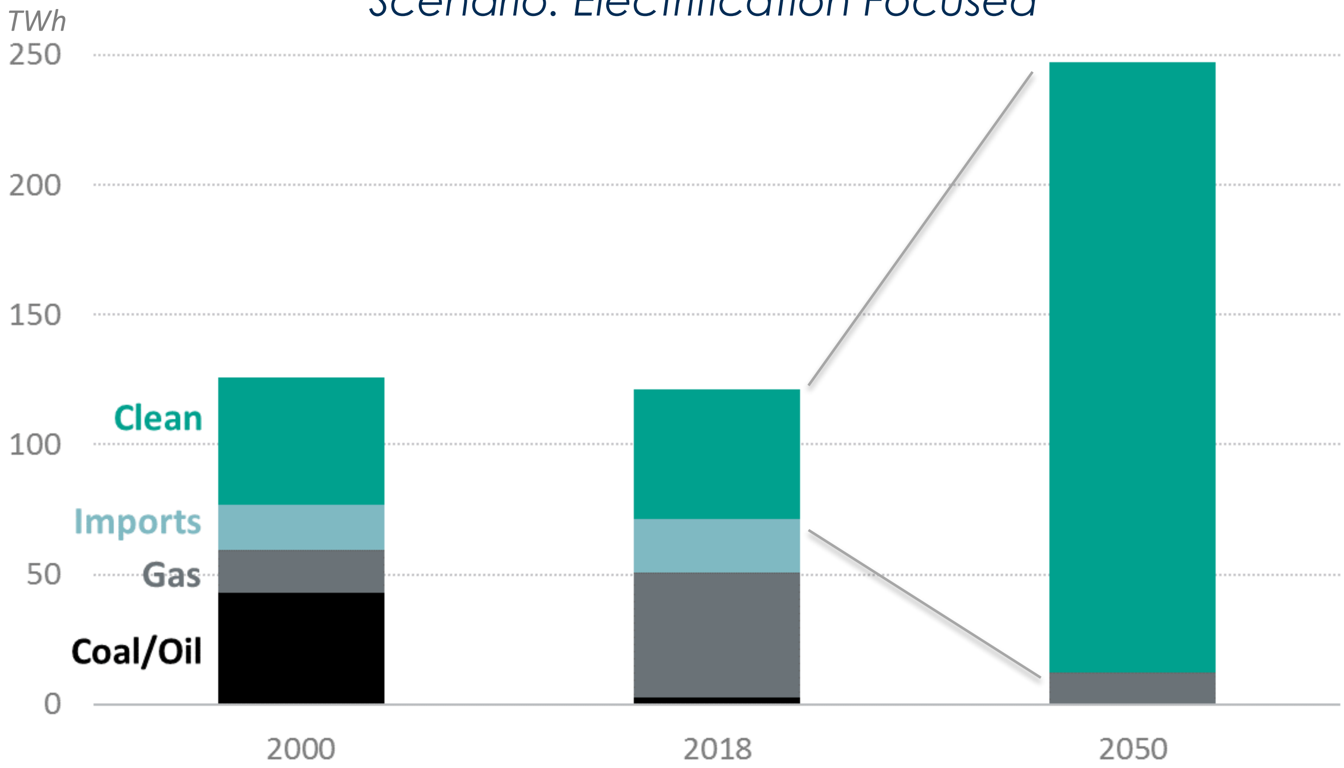
The 2050 portfolio of generation resources will need to meet this new pattern of demand.

Decarbonizing New England will require a massive buildout of clean energy resources

- Replace about **50% of supply** currently from fossil fuel-fired resources
- Supply the **100% increase in demand** from electrification

Historical and Projected 2050 New England Generation Mix

Scenario: Electrification Focused

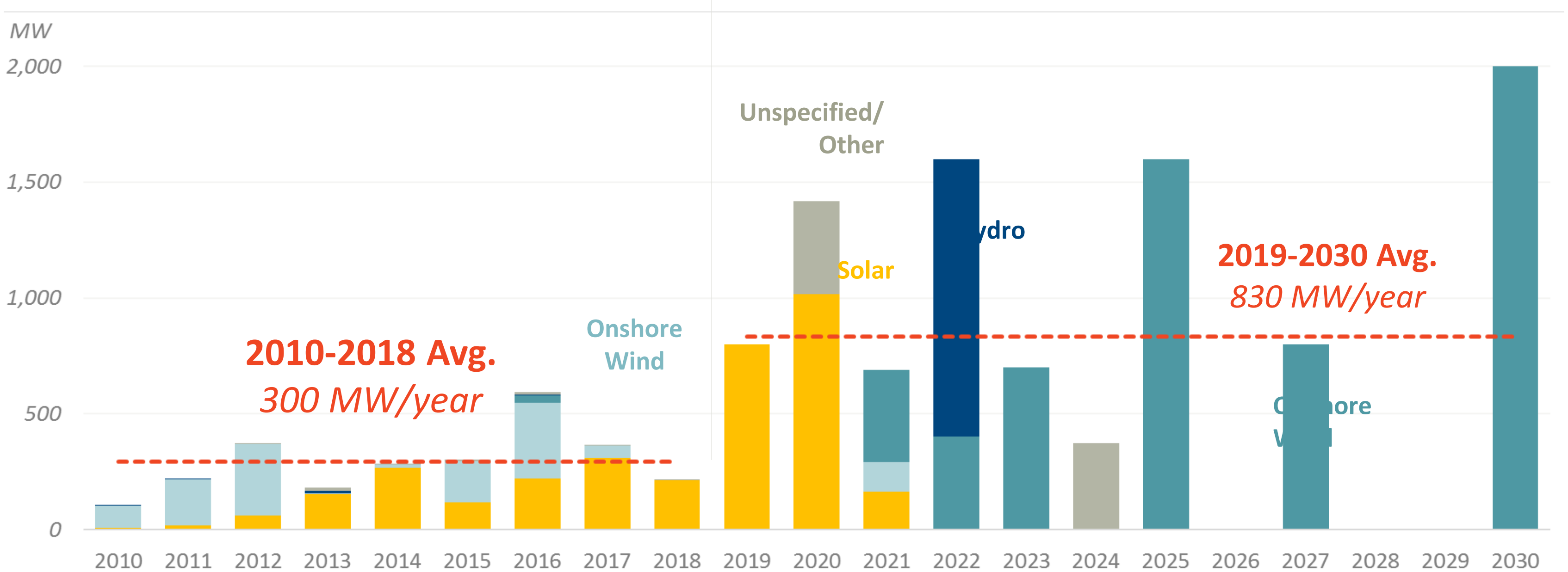


Source: ISO-NE, Key Grid and Market Stats, https://www.iso-ne.com/about/key-stats/, accessed June 28, 2019.

Is New England adding enough clean energy?

- State-by-state commitments to adding clean energy resources in New England have accelerated substantially over the past decade and are expected to increase

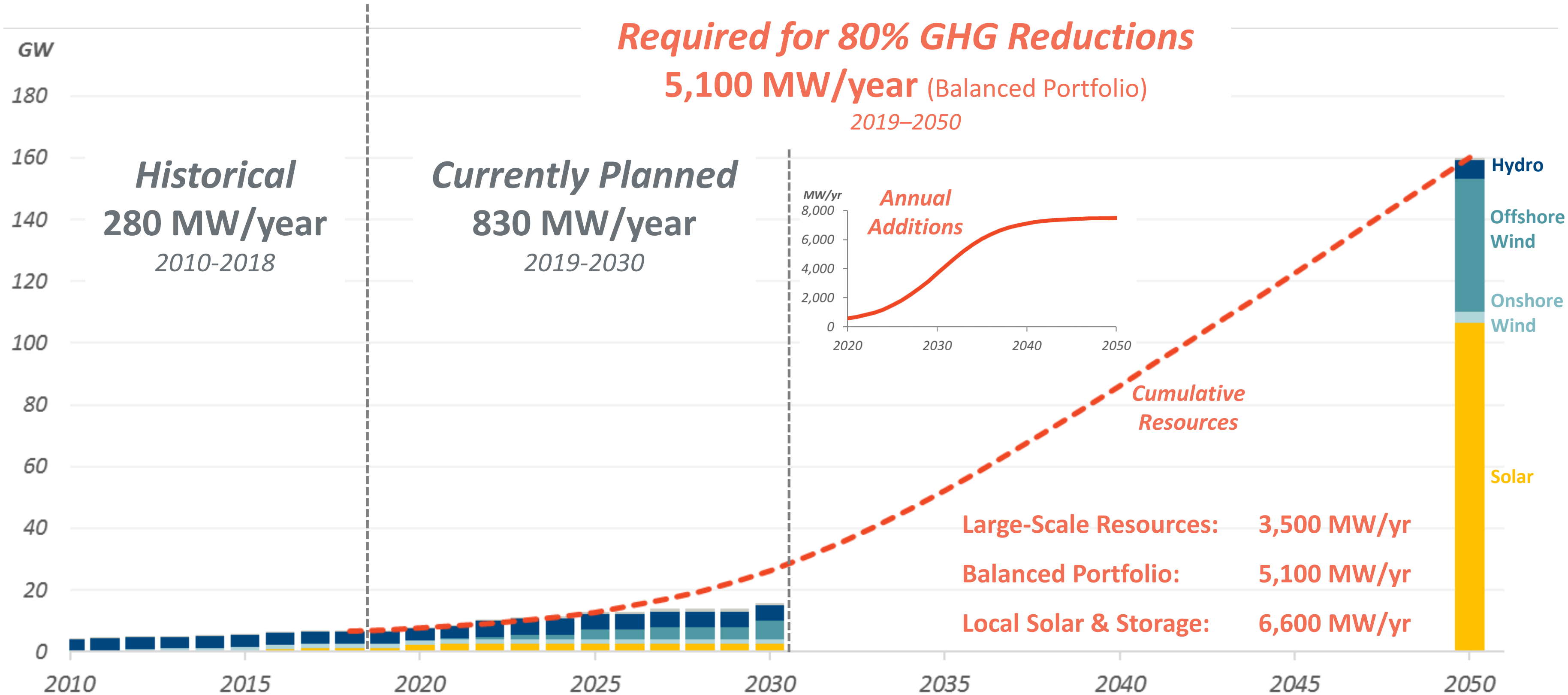
Historical and Planned Renewable Procurements in New England



Sources and notes: ABB, Velocity Suite and Brattle analysis of state r`enewable procurement programs. Historical solar capacity includes only installations over 1 MW. Planned solar procurements include MA 83A resources, SMART program resources, and CT Public Act 17-3 resources.

Achieving 2050 goals requires <u>significant</u> acceleration of clean-energy investments

Cumulative Clean Energy Resources in New England

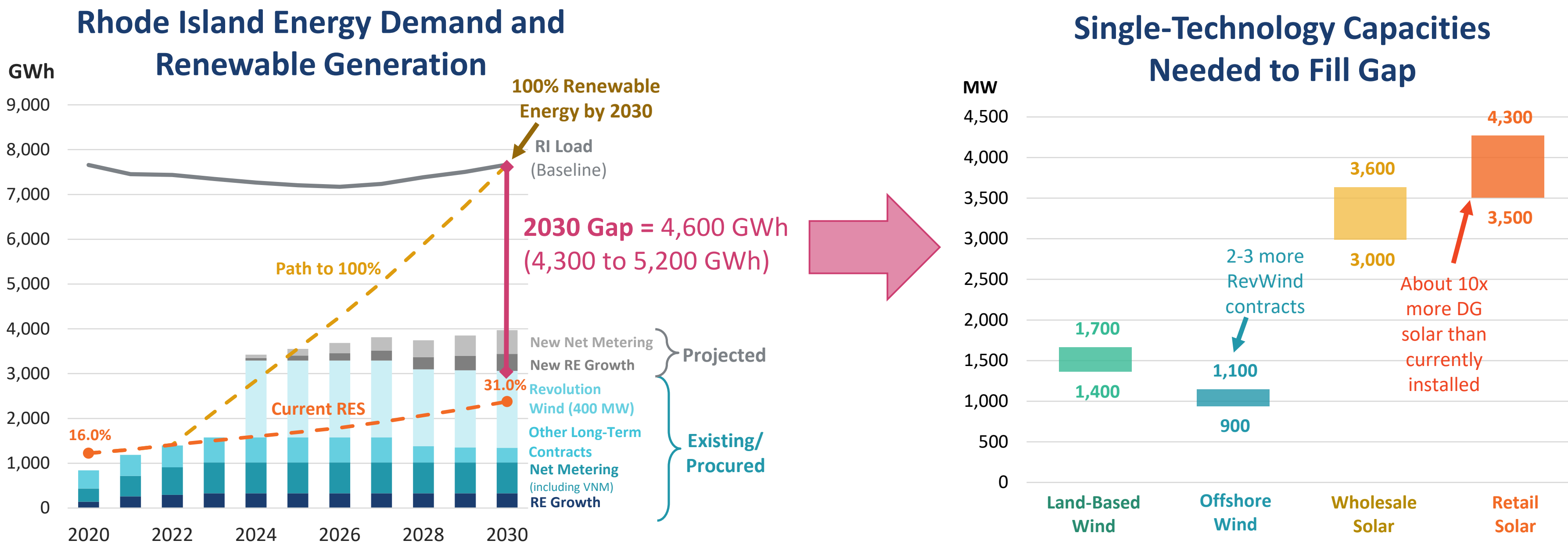


Annual clean energy resource additions need to increase by <u>4–8x</u> overall

Large-scale solar resource additions will need to increase by <u>10–25x</u> to meet these goals

Progress: Rhode Island is targeting a 100% clean electricity grid by 2030

To achieve carbon-free electricity supply, Rhode Island must substantially accelerate renewables procurement, well beyond its existing renewable energy standard (RES)



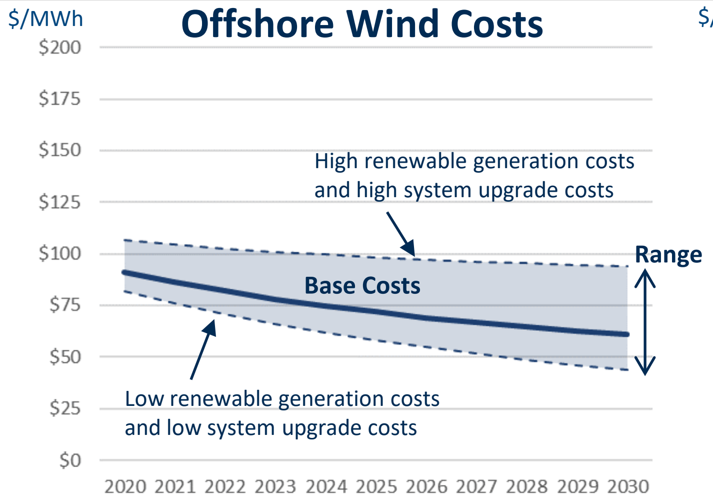
Note: Load is grossed up to account for BTM PV that produces RECs.

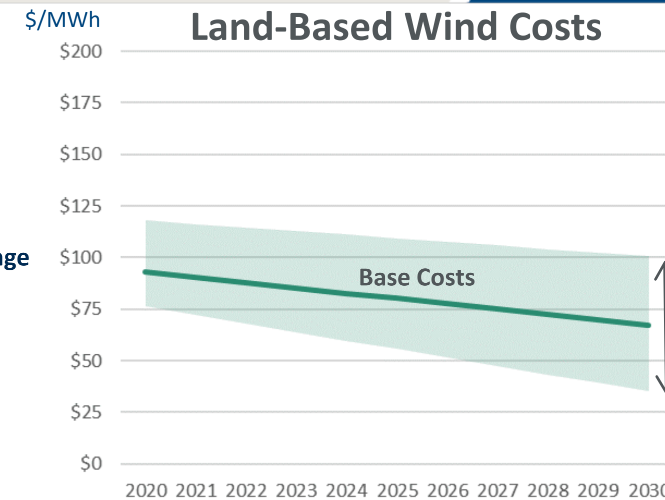
Source: https://www.brattle.com/news-and-knowledge/news/study-coauthored-by-brattle-economists-assesses-policies-and-pathways-for-achieving-100-renewable-electricity-in-rhode-island-by-2030

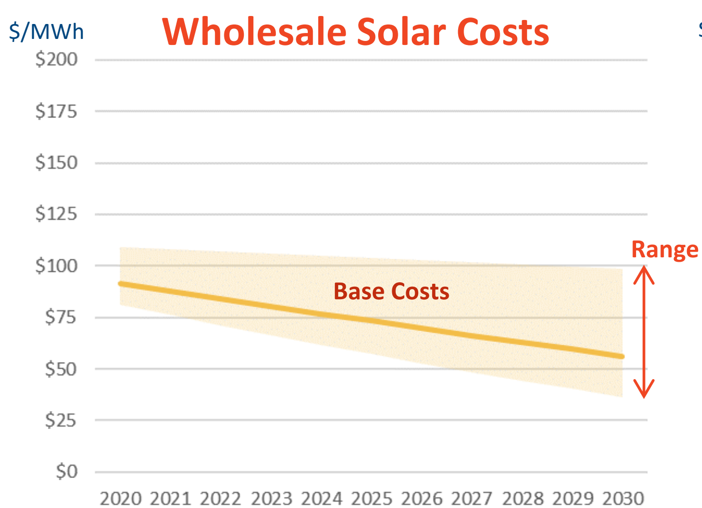
The cost of renewable resources are decreasing, even in New England

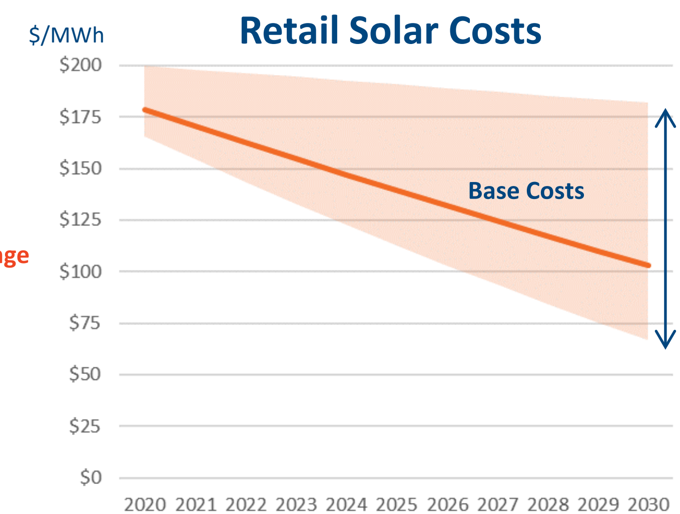
Renewable Generation Costs: based on NREL's 2020 ATB, including "conservative" case with limited cost declines

System Upgrade Costs: based on best available market data on system capacity and upgrade costs for each resource type





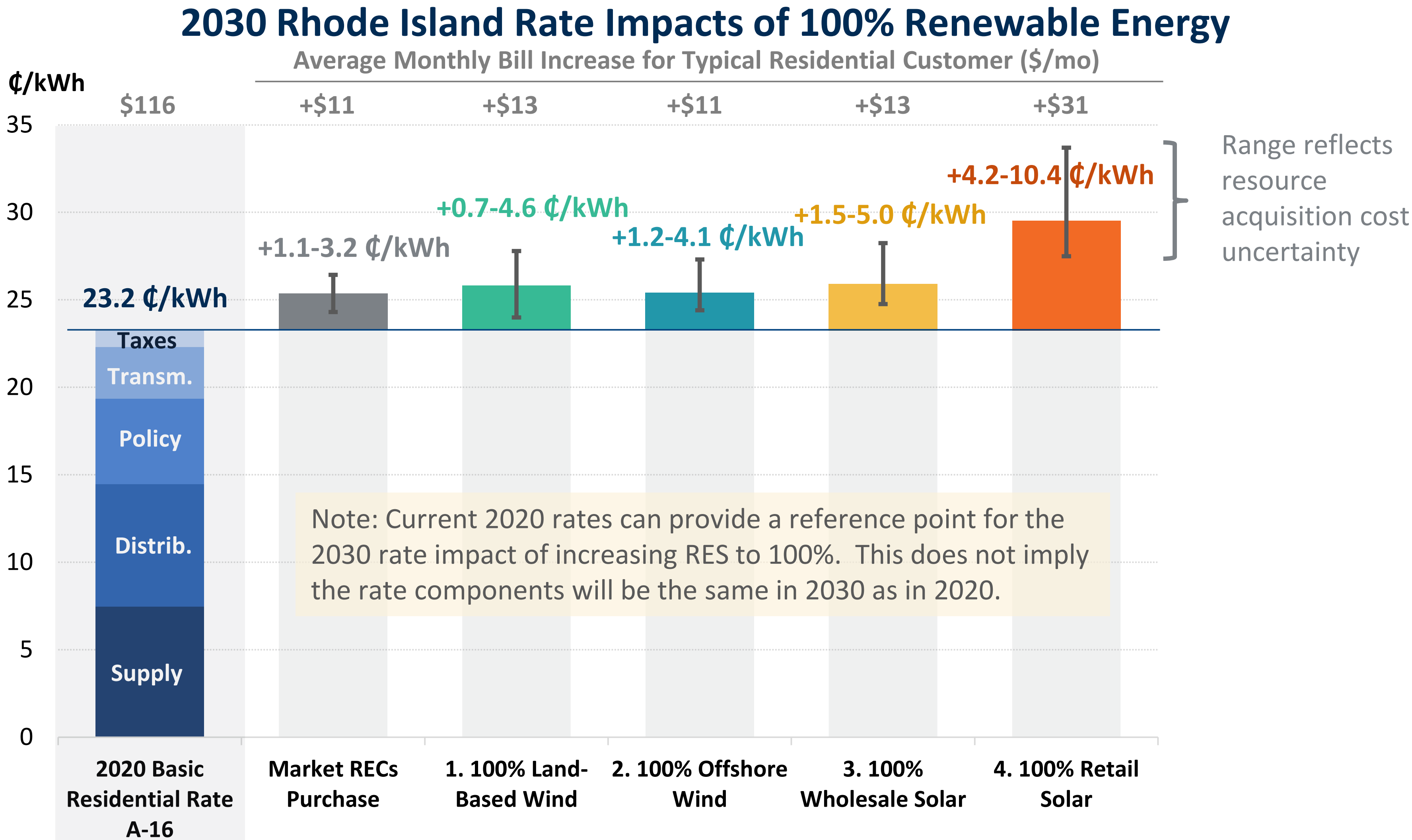




Notes: All monetary values in 2020 dollars. Total resource costs account PTC and ITC phaseout, maintaining 10% ITC for solar through 2030.

Source: https://www.brattle.com/news-and-knowledge/news/study-coauthored-by-brattle-economists-assesses-policies-and-pathways-for-achieving-100-renewable-electricity-in-rhode-island-by-2030

… which requires only a modest premium above existing electricity rates



Notes: All monetary values are shown in 2020 dollars. Assumes typical residential customer consumes 500 kWh/mo.

Source: https://www.brattle.com/news-and-knowledge/news/study-coauthored-by-brattle-economists-assesses-policies-and-pathways-for-achieving-100-renewable-electricity-in-rhode-island-by-2030

But developing clean-energy resources in New England faces many barriers

Onshore Wind

- **Transmission needs:** ISO-NE analysis found that an additional 700 MW can be added in northern Maine before transmission upgrades are likely necessary, and states have not agreed on how to plan or pay for the upgrades to the highest quality resources.
- **Local opposition:** ME placed a moratorium on new wind farms in 2018 that was recently lifted.

Offshore Wind

- **Nascent industry:** Large-scale capacity has yet to be built and regulatory hurdles still exist to their development, but New England states procured 1,500 MW by 2025 and are targeting 5,900 MW by 2035. Current BOEM wind energy areas in New England support about 11 GW and DOE is targeting 86 GW nationwide by 2050.
- **Transmission needs:** Transmission is necessary to connect to the existing network and upgrade the network. Integrating 15–24 GW of offshore wind will require about 3,000 miles of lines.

Solar PV

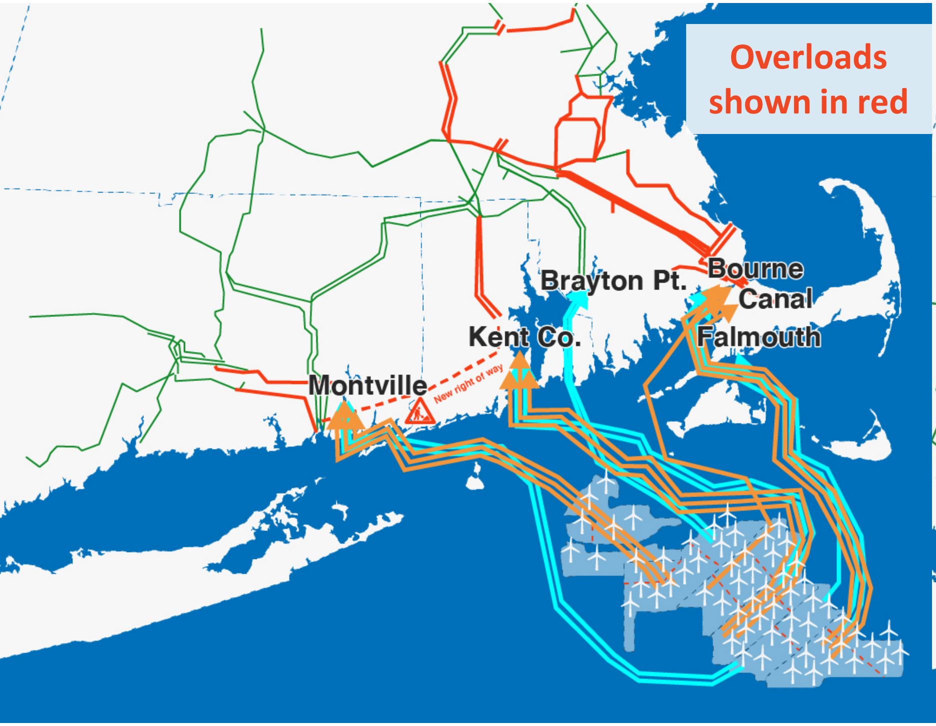
- **Generation profile:** Generates solely during daytime hours and less in winter than summer.
- **System balancing needs:** Significant storage resources will be necessary to match solar output to demand and other clean energy resources needed to meet growing winter demand.

Hydro Imports from Canada

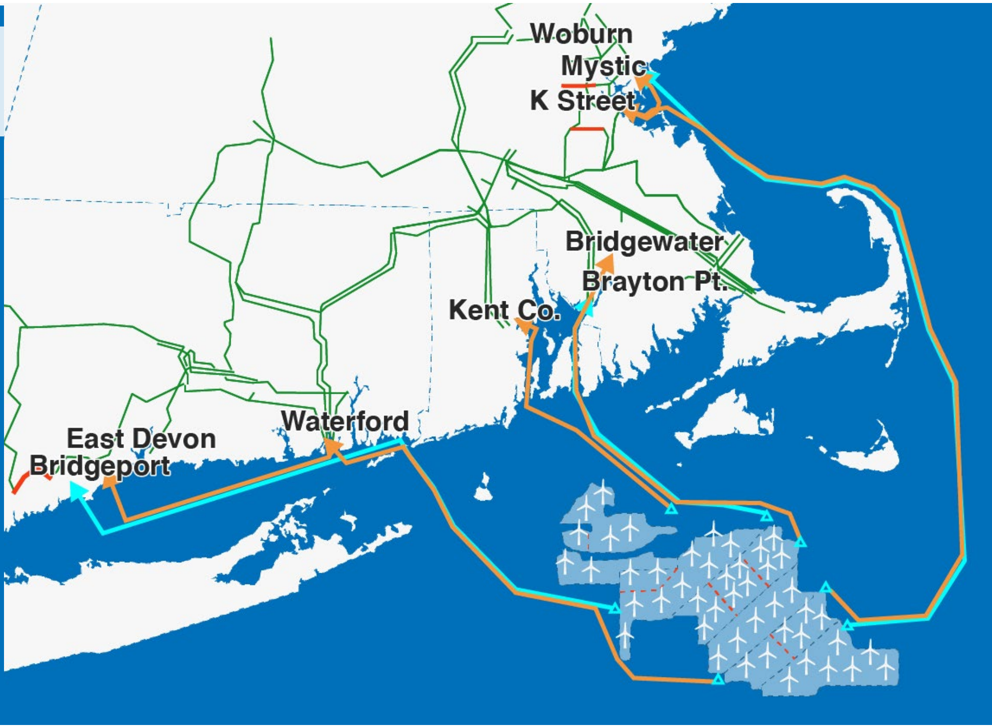
- **Transmission needs:** Additional transmission infrastructure required to import hydro resources from Quebec or other provinces. Each HVDC line can provide 1,000–1,200 MW of import capacity.
- **Local opposition:** Denial of Northern Pass permit in NH demonstrates challenges to new lines.

Even interconnecting only 8,500 MW of OSW generation is challenging

Generator Lead-Line Approach

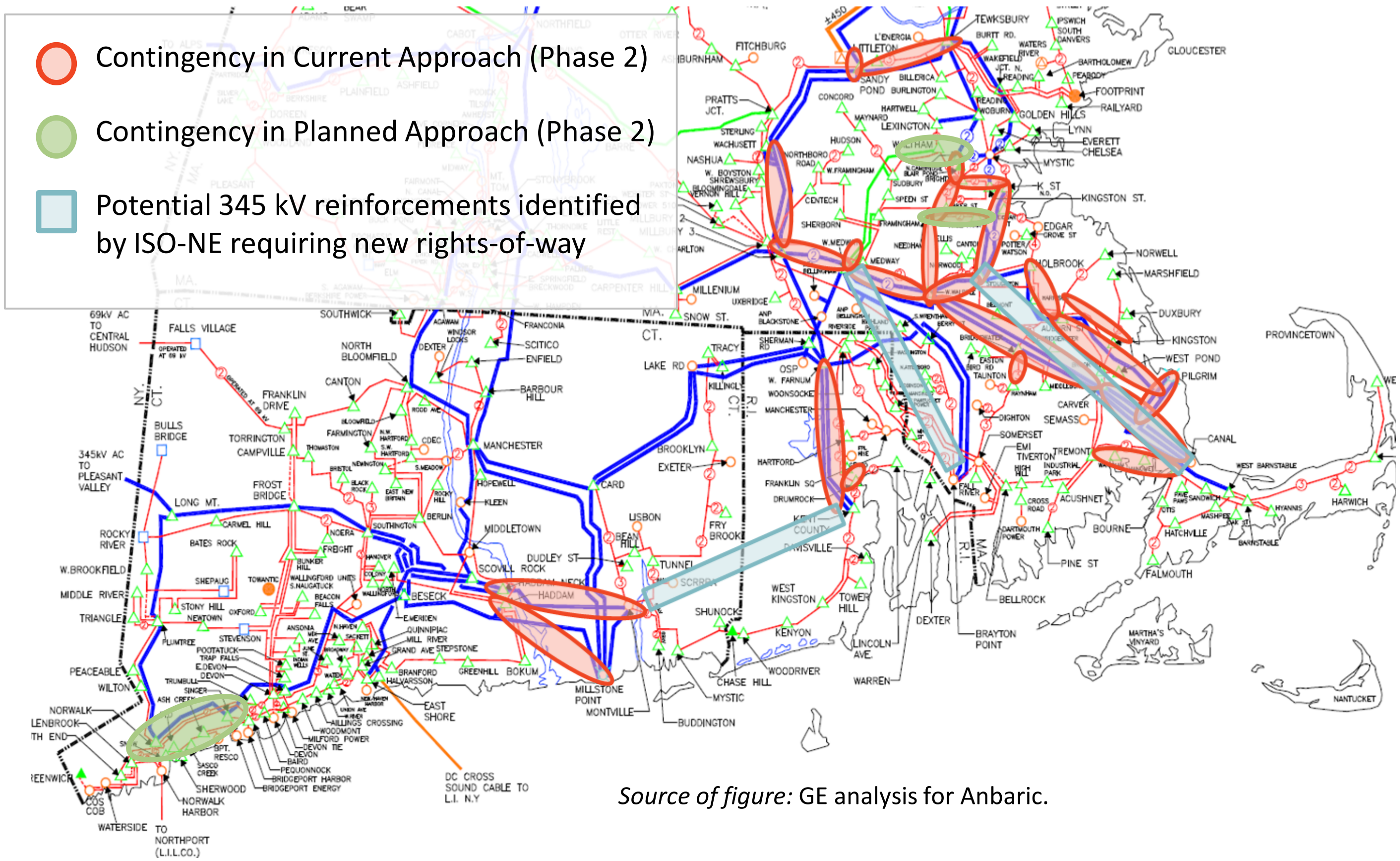


Planned Network Approach



Planning ahead would avoid costly onshore transmission upgrades

Already selected projects connecting to Cape Cod face up to $787 million in onshore transmission upgrades,* and continuing this approach for even the next 3600 MW of procurements could lead to an additional $1.7 billion in onshore upgrades.



Source of figure: GE analysis for Anbaric.

Planned off-shore transmission could significantly reduce the necessary onshore upgrades.

Given the difficulty of permitting and building new onshore trans-mission, a planned approach also reduces the risk of cost overruns and delays

* ISO-NE's Feasibility Study for interconnecting three projects totaling 2,400 MW to Cape Cod (QP 828)

… but effective regional transmission planning faces many barriers

A. Leadership, Trust & Understanding	1. Lack of aligned leadership from federal, state & RTO policy makers 2. Mistrust amongst states, RTOs & utilities 3. Limited understanding of transmission issues, benefits & proposed solutions 4. Misaligned interests of RTOs, TOs, generators & policymakers 5. State preferences for local renewables
B. Planning Process and Analytics	6. Benefit analysis too narrow 7. Lack of proactive planning for a full range of future scenarios 8. Sequencing of local, regional, and interregional planning 9. Cost allocation (too contentious or overly formulaic)
C. Regulatory Constraints	10. Overly-prescriptive tariffs and joint operating agreements 11. State need certification, permitting, and siting

Thank you!

About the Author

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Johannes (Hannes) Pfeifenberger, a Principal and former electricity practice area leader at The Brattle Group, is an economist with a background in electrical engineering and over twenty-five years of experience in wholesale power market design, renewable energy, electricity storage, and transmission. He also is a Senior Fellow at Boston University's Institute of Sustainable Energy (BU-ISE), a Visiting Scholar at MIT's Center for Energy and Environmental Policy Research (CEEPR), and serves as an advisor to research initiatives by the Lawrence Berkeley National Laboratory's (LBNL's) Energy Analysis and Environmental Impacts Division and the US Department of Energy's (DOE's) Grid Modernization Lab Consortium.

Mr. Pfeifenberger recently studied New York power grid needs, evaluated offshore wind transmission options in New York State and New England, discussed role of offshore wind in economy-wide decarbonization on a panel organized by the Atlantic Council, and presented on offshore wind development trends, transmission needs, and renewable integration challenges at a number of industry meetings, including the Harvard Electricity Policy Group.

Mr. Pfeifenberger received an M.A. in Economics and Finance from Brandeis University's International Business School and an M.S. and B.S. ("Diplom Ingenieur") in Power Engineering and Energy Economics from the University of Technology in Vienna, Austria.

Additional Reading on Transmission

Well-Planned Electric Transmission Saves Customer Costs:
Improved Transmission Planning is Key to the Transition to a Carbon-Constrained Future

Link: https://bit.ly/3dnKrxe

PREPARED FOR
WIRES

PREPARED BY
Judy W. Chang
Johannes P. Pfeifenberger

May 2016

THE Brattle GROUP

Toward More Effective Transmission Planning:
Addressing the Costs and Risks of an Insufficiently Flexible Electricity Grid

PREPARED FOR
WIRES

PREPARED BY
Johannes P. Pfeifenberger
Judy W. Chang
Akarsh Sheilendranath

April 2015

Link: https://bit.ly/2GU4h7w

The Brattle Group

Link: https://bit.ly/3jS0PsB

The Benefits of Electric Transmission: Identifying and Analyzing the Value of Investments

July 2013

Judy W. Chang
Johannes P. Pfeifenberger
J. Michael Hagerty

Link: https://bit.ly/34slZai

BU
Boston University Institute for Sustainable Energy

The Value of Diversifying Uncertain Renewable Generation through the Transmission System

September • 2020

Additional Reading on Transmission

Pfeifenberger et al., "Initial Report on the New York Power Grid Study," prepared for NYPSC, Jan 19, 2021.

Pfeifenberger, "Transmission Cost Allocation: Principles, Methodologies, and Recommendations," prepared for OMS, Nov 16, 2020.

Pfeifenberger, Ruiz, Van Horn, "The Value of Diversifying Uncertain Renewable Generation through the Transmission System," BU-ISE, October 14, 2020.

Pfeifenberger, Newell, Graf and Spokas, "Offshore Wind Transmission: An Analysis of Options for New York", prepared for Anbaric, August 2020.

Pfeifenberger, Newell, and Graf, "Offshore Transmission in New England: The Benefits of a Better-Planned Grid," prepared for Anbaric, May 2020.

Tsuchida and Ruiz, "Innovation in Transmission Operation with Advanced Technologies," T&D World, December 19, 2019.

Pfeifenberger, "Cost Savings Offered by Competition in Electric Transmission," Power Markets Today Webinar, December 11, 2019.

Pfeifenberger, "Improving Transmission Planning: Benefits, Risks, and Cost Allocation," MGA-OMS Ninth Annual Transmission Summit, Nov 6, 2019.

Chang, Pfeifenberger, Sheilendranath, Hagerty, Levin, and Jiang, "Cost Savings Offered by Competition in Electric Transmission: Experience to Date and the Potential for Additional Customer Value," April 2019. "Response to Concentric Energy Advisors' Report on Competitive Transmission," August 2019.

Ruiz, "Transmission Topology Optimization: Application in Operations, Markets, and Planning Decision Making," May 2019.

Chang and Pfeifenberger, "Well-Planned Electric Transmission Saves Customer Costs: Improved Transmission Planning is Key to the Transition to a Carbon-Constrained Future," WIRES and The Brattle Group, June 2016.

Newell et al. "Benefit-Cost Analysis of Proposed New York AC Transmission Upgrades," on behalf of NYISO and DPS Staff, September 15, 2015.

Pfeifenberger, Chang, and Sheilendranath, "Toward More Effective Transmission Planning: Addressing the Costs and Risks of an Insufficiently Flexible Electricity Grid," WIRES and The Brattle Group, April 2015.

Chang, Pfeifenberger, Hagerty, "The Benefits of Electric Transmission: Identifying and Analyzing the Value of Investments," on behalf of WIRES, July 2013.

Chang, Pfeifenberger, Newell, Tsuchida, Hagerty, "Recommendations for Enhancing ERCOT's Long-Term Transmission Planning Process," October 2013.

Pfeifenberger and Hou, "Seams Cost Allocation: A Flexible Framework to Support Interregional Transmission Planning," on behalf of SPP, April 2012.

Pfeifenberger, Hou, "Employment and Economic Benefits of Transmission Infrastructure Investment in the U.S. and Canada," on behalf of WIRES, May 2011.

Our Practices and Industries

ENERGY & UTILITIES

- Competition & Market Manipulation
- Distributed Energy Resources
- Electric Transmission
- Electricity Market Modeling & Resource Planning
- Electrification & Growth Opportunities
- Energy Litigation
- Energy Storage
- Environmental Policy, Planning and Compliance
- Finance and Ratemaking
- Gas/Electric Coordination
- Market Design
- Natural Gas & Petroleum
- Nuclear
- Renewable & Alternative Energy

LITIGATION

- Accounting
- Analysis of Market Manipulation
- Antitrust/Competition
- Bankruptcy & Restructuring
- Big Data & Document Analytics
- Commercial Damages
- Environmental Litigation & Regulation
- Intellectual Property
- International Arbitration
- International Trade
- Labor & Employment
- Mergers & Acquisitions Litigation
- Product Liability
- Securities & Finance
- Tax Controversy & Transfer Pricing
- Valuation
- White Collar Investigations & Litigation

INDUSTRIES

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- Financial Institutions
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- Natural Gas & Petroleum
- Pharmaceuticals & Medical Devices
- Telecommunications, Internet, and Media
- Transportation
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