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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February 28, 2022

THE Brattle GROUP

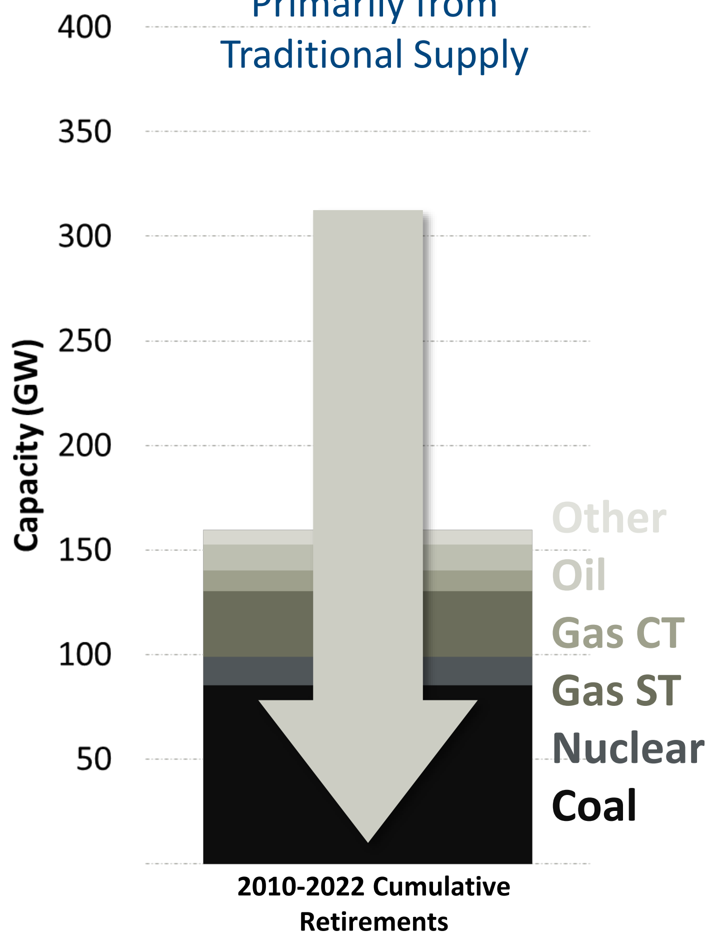
Agenda

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

It's already happening: electricity generation is changing significantly

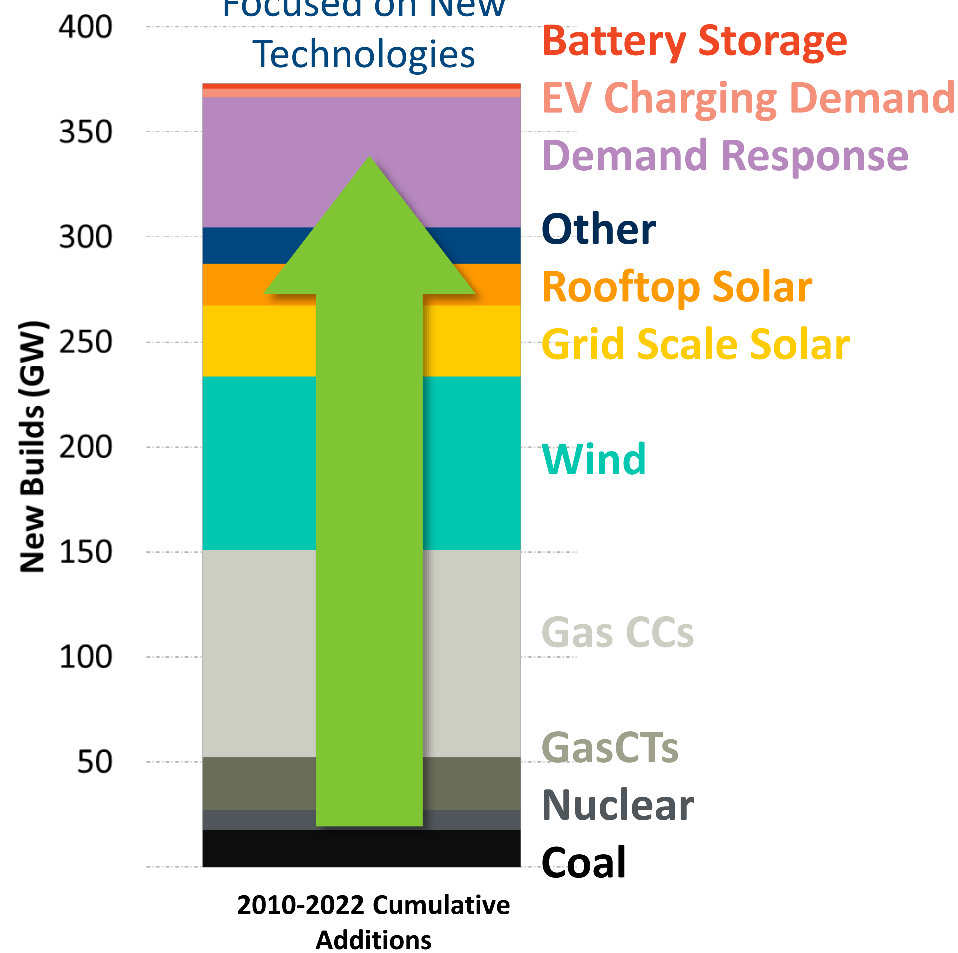
Retirements

Primarily from Traditional Supply



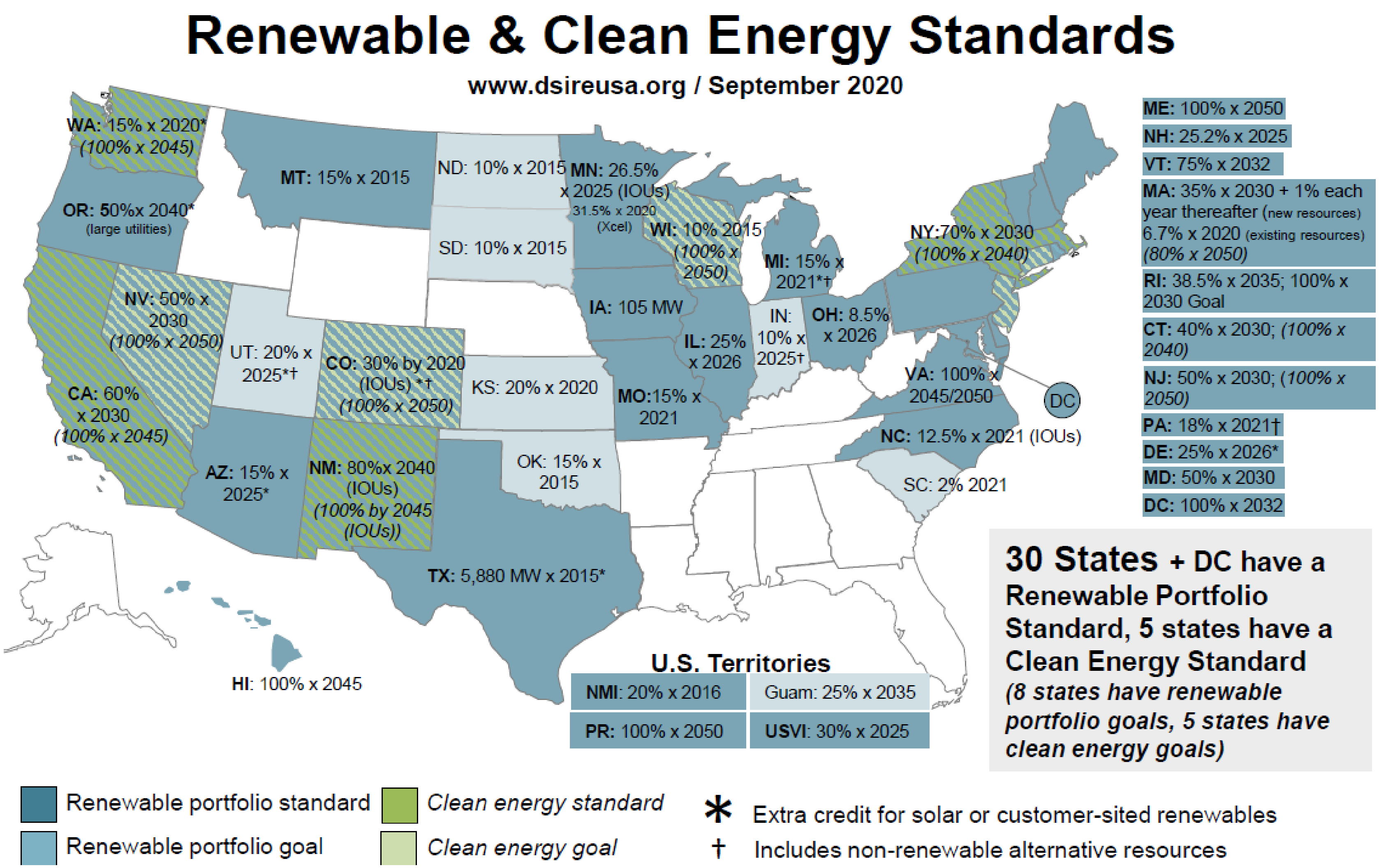
New Builds

Focused on New Technologies



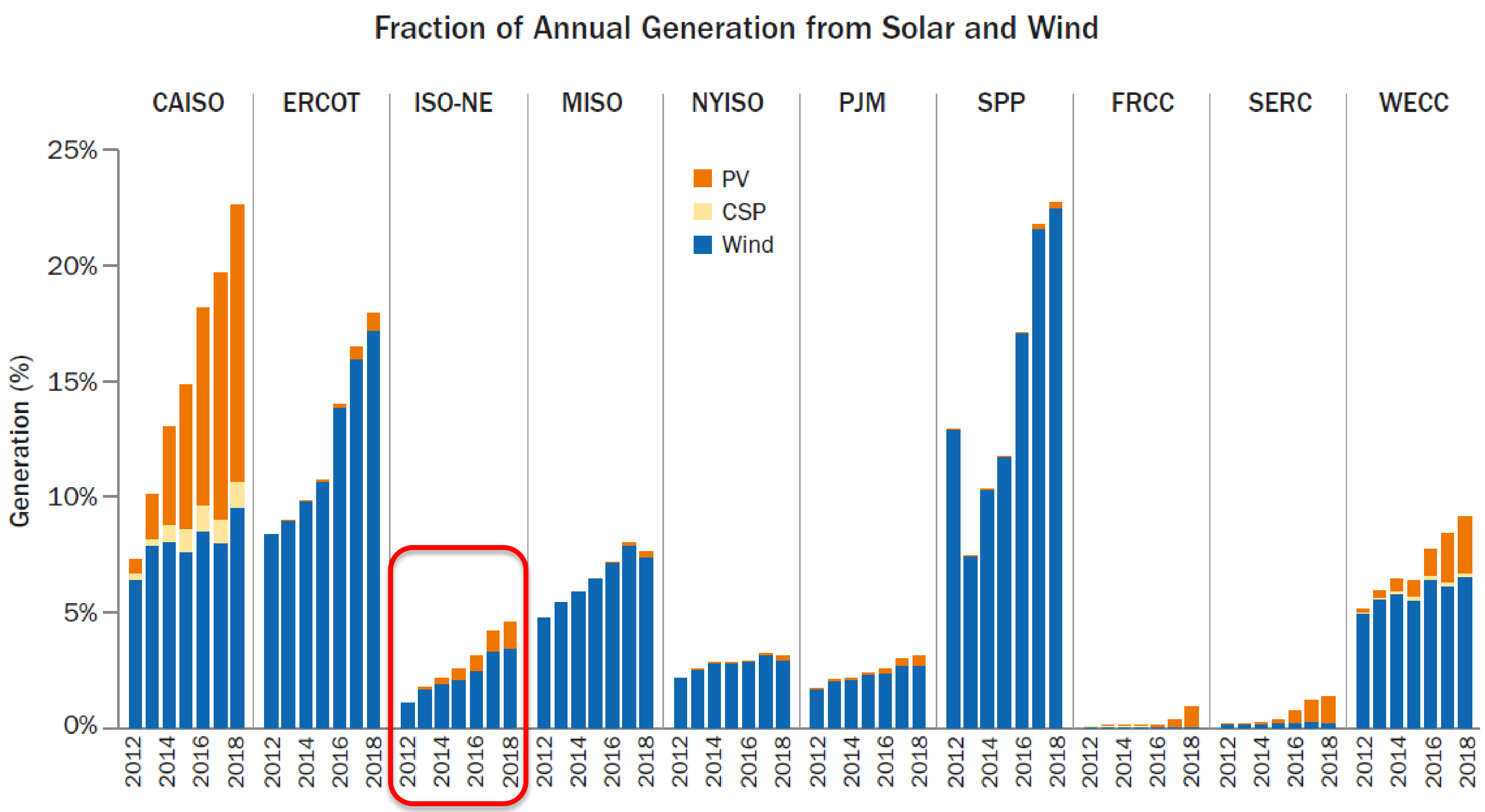
Sources: Energy Velocity Suite (US and Canadian generation) and Brattle research (US-only distributed resource and storage).

However: increasingly ambitious state clean-electricity goals and mandates…



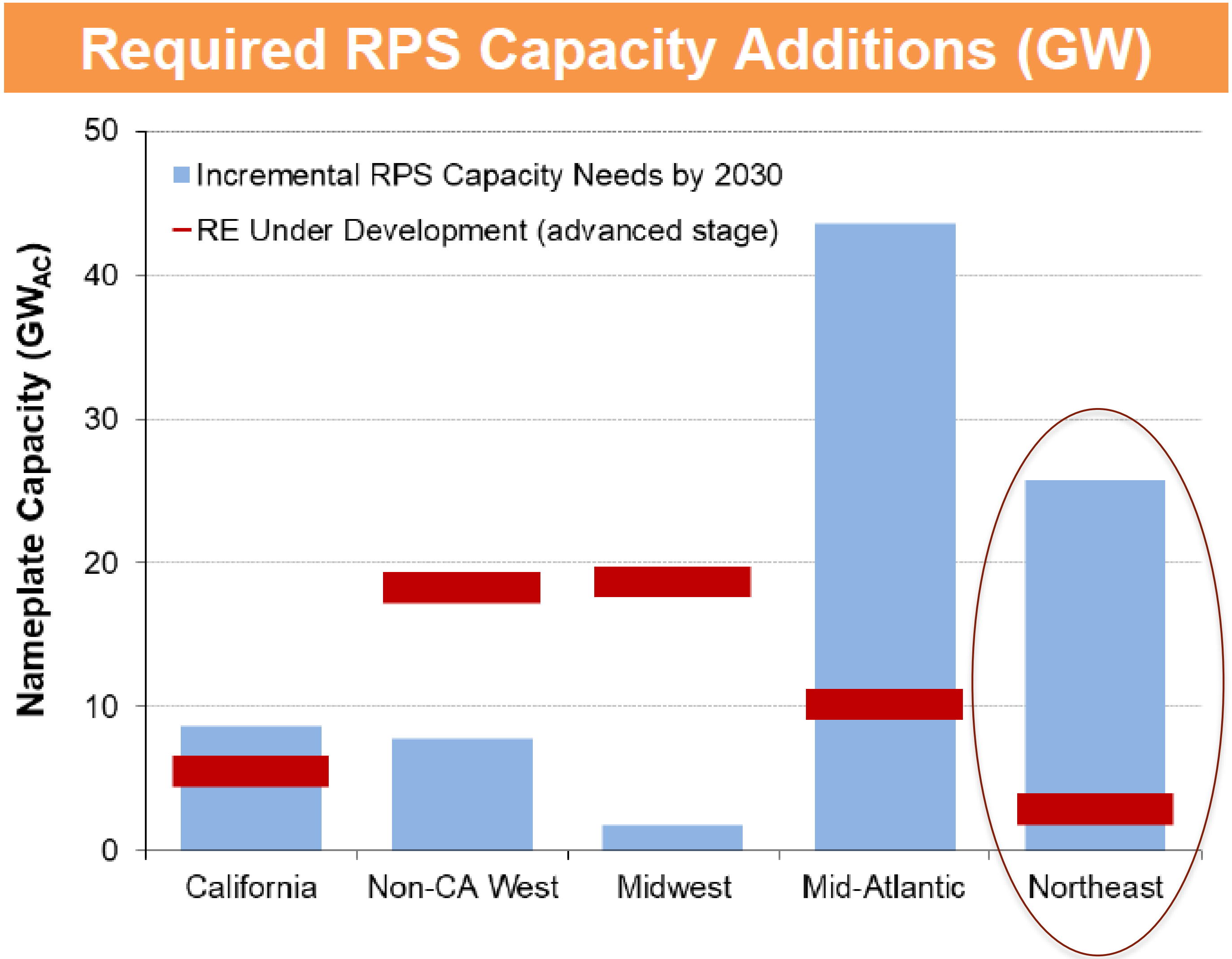
Source: https://www.dsireusa.org/resources/detailed-summary-maps/

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



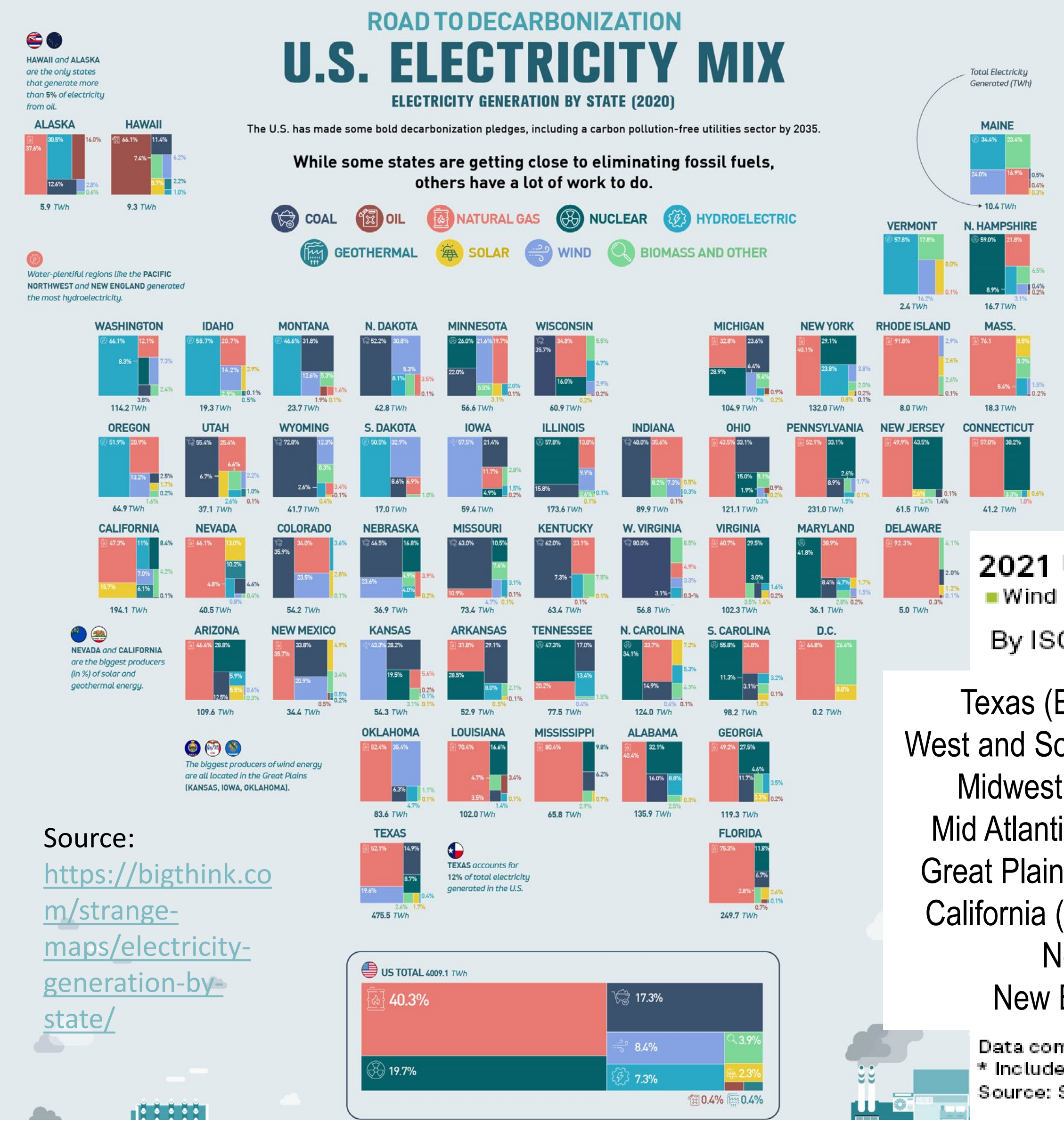
Source: *2018 Renewable Energy Grid Integration Data Book*, U.S. Department of Energy, National Renewable Energy Laboratory (NREL) and the Lawrence Berkeley National Laboratory (LBNL), March 2020.

…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

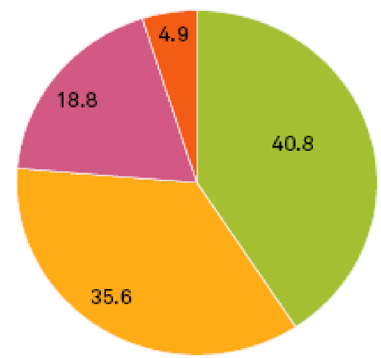
The long way to a carbon-free grid … will be particularly challenging in the Northeast



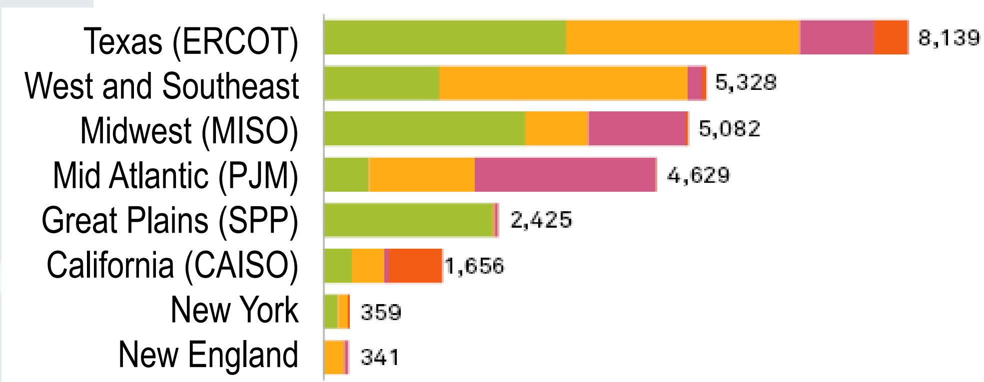
Source:
https://bigthink.com/strange-maps/electricity-generation-by-state/

2020 US generation mix:
40% gas, 17% coal,
20% nuclear, 8% wind,
7% hydro, 4% biomass,
2% solar

By fuel type (%)



2021 US capacity additions
Wind Solar Gas Other*
By ISO/RTO region (MW)

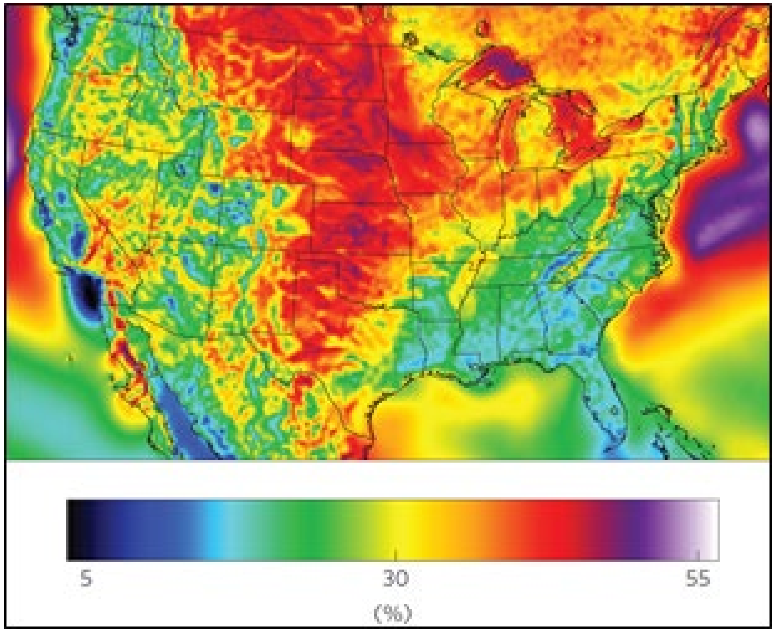


Data compiled Jan. 11, 2022.
* Includes hydro, biomass, oil, geothermal and energy storage capacity.
Source: S&P Global Market Intelligence

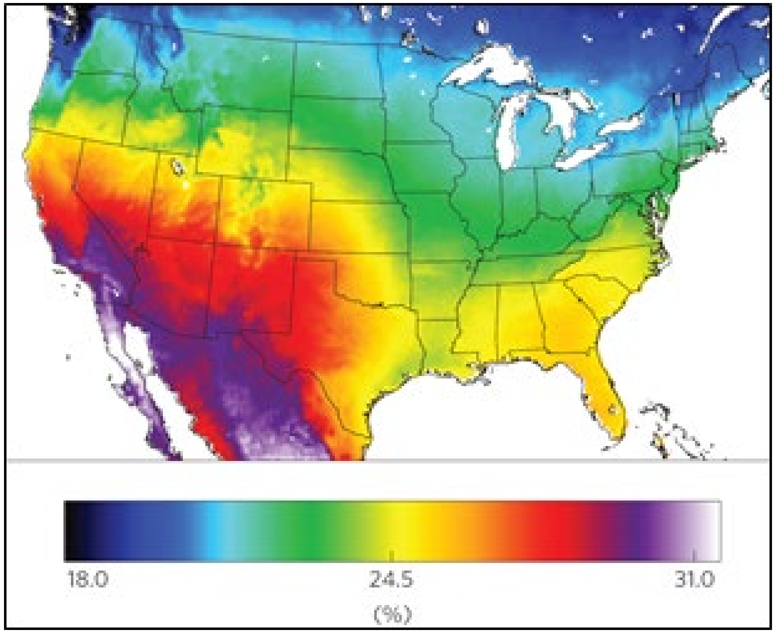
Good news: the U.S. has large amounts of high-quality wind and solar resources

- 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.

Result: renewable generation investments in some states are well beyond mandates

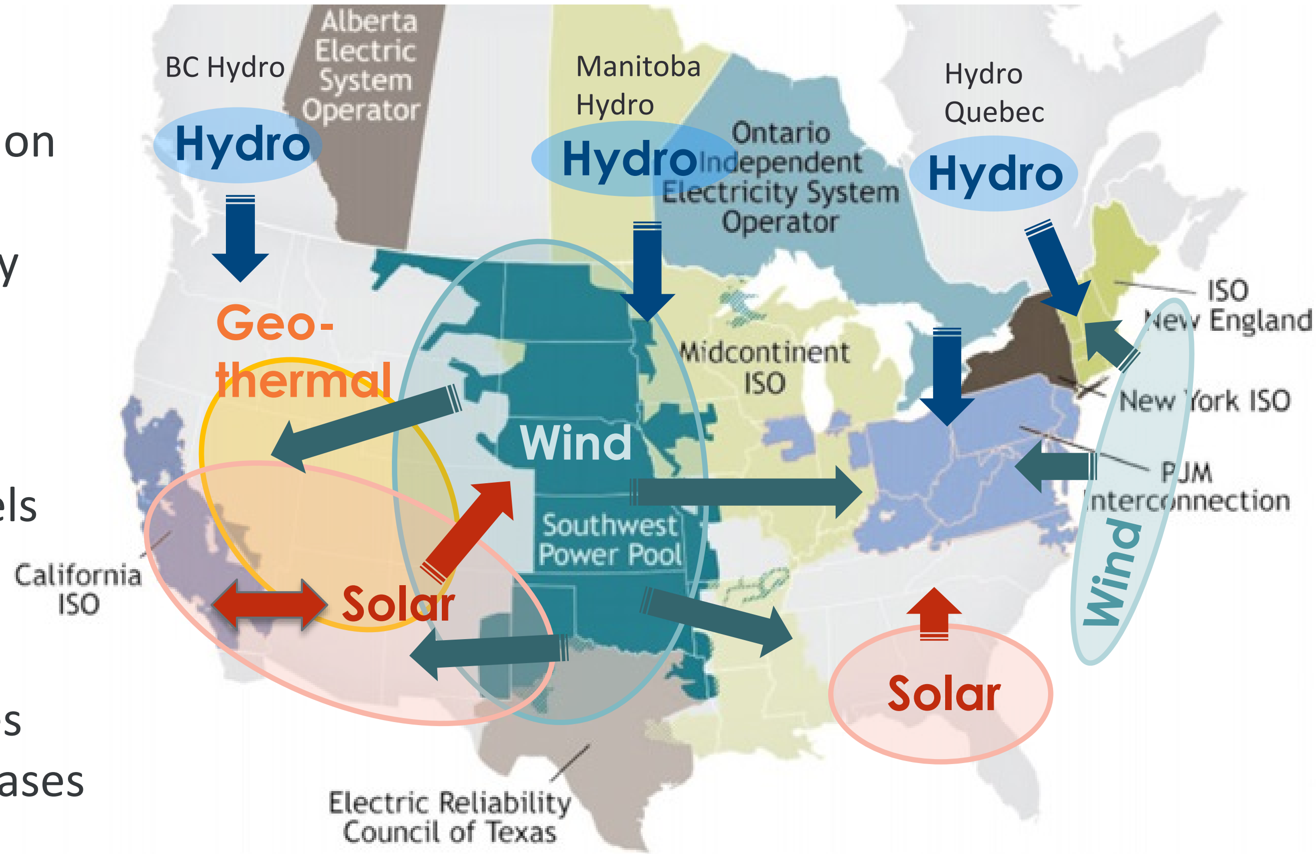
Regional electricity markets with low-cost renewable resources support significant renewable development well beyond mandates through a combination of:

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 are about a third of recent developments; mostly in Texas)

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

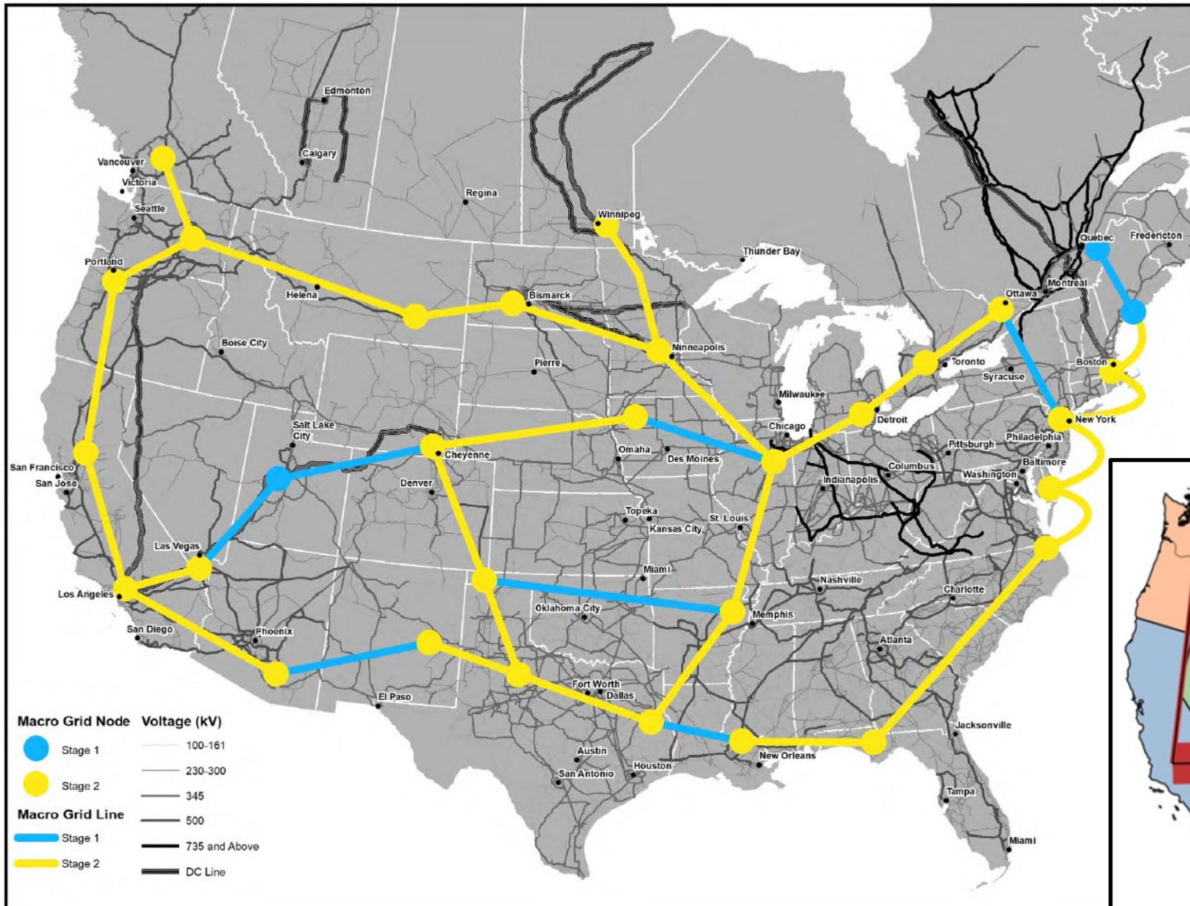
Resource diversification can offer significant benefits:

- 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

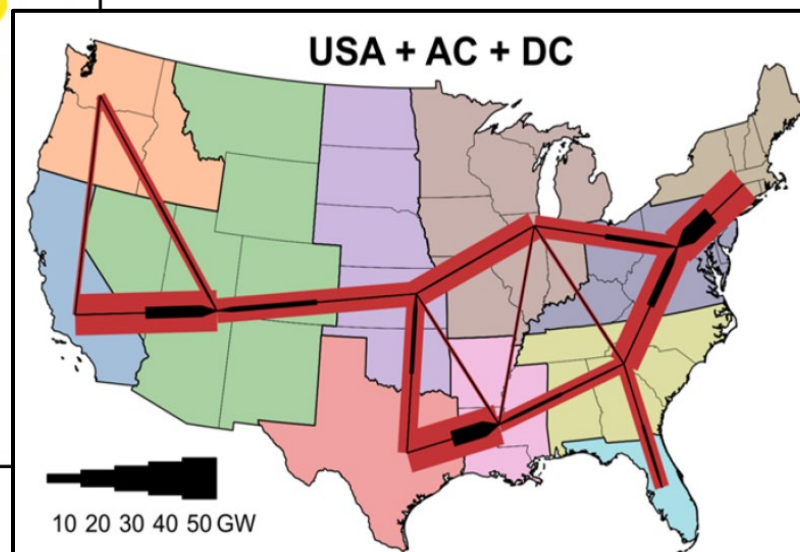
Existing and Conceptual U.S. "Macro Grid" (ESIG)



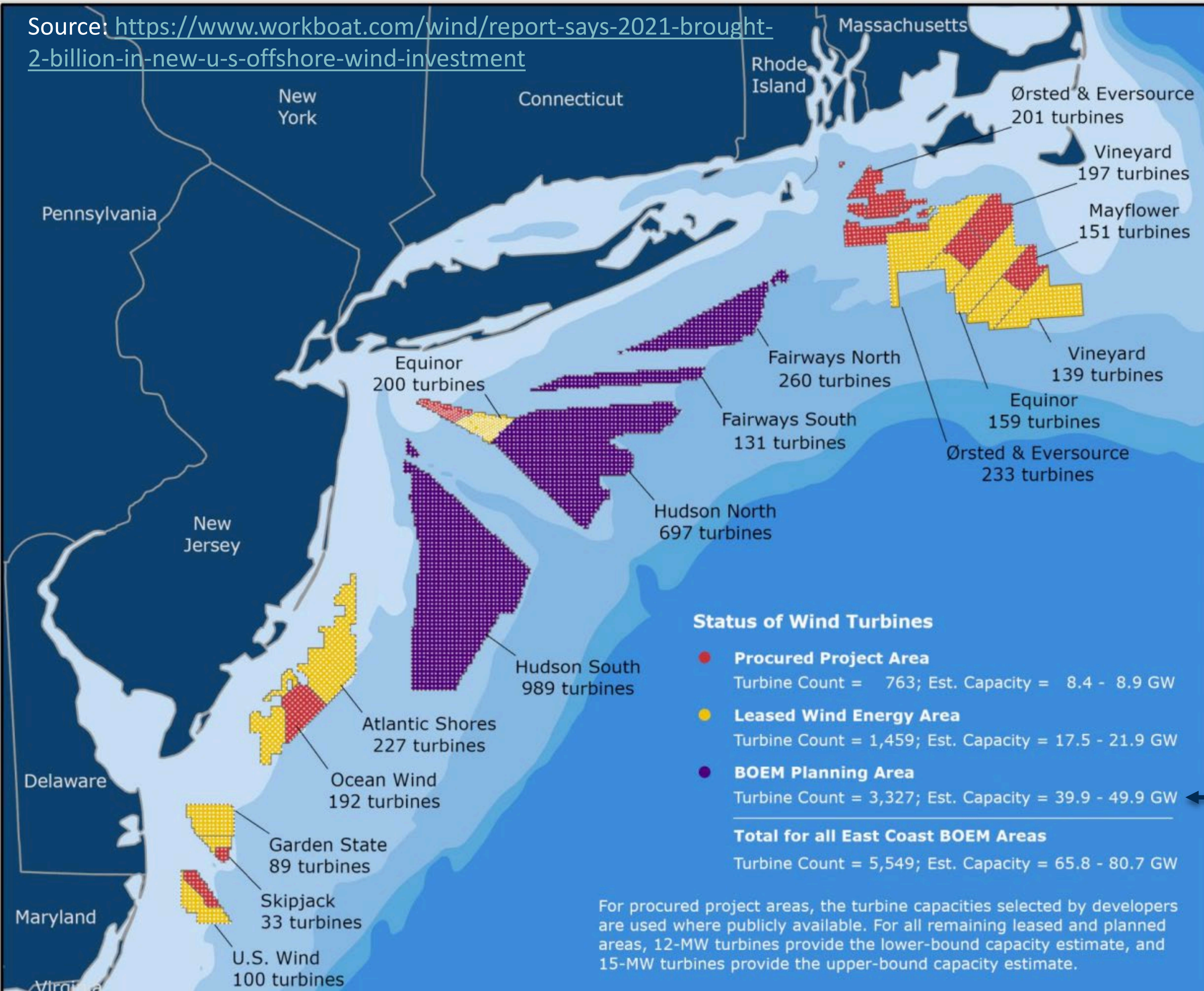
https://www.esig.energy/wp-content/uploads/2021/02/News-Release-ESIG-Transmission-White-Paper-1.pdf (also summarizes other studies)

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



Opportunity for the Northeast -- Offshore Wind: 37 GW leases sold; 25 GW expected online by 2030



Additional Sources:

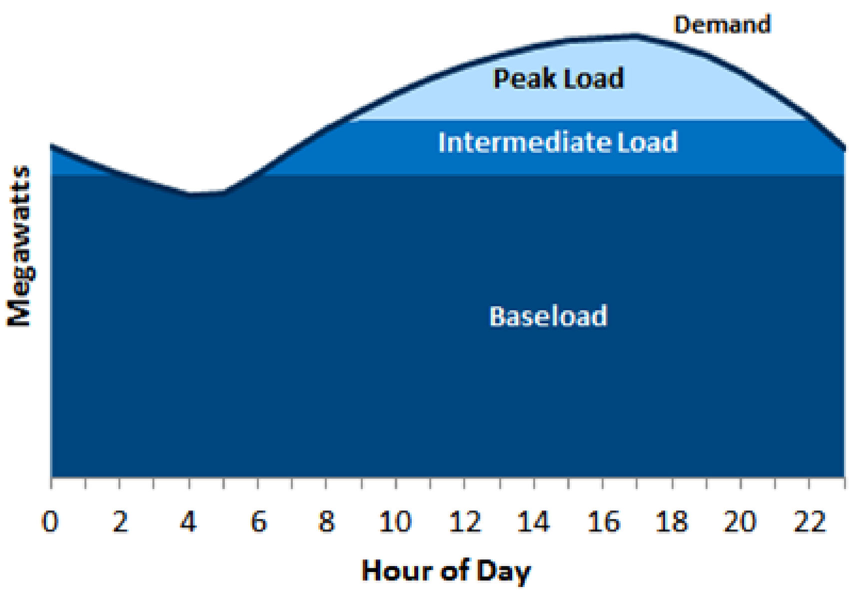
- Wind Market Reports: 2021 Edition | Department of Energy
- New York Bight | Bureau of Ocean Energy Management (boem.gov)

An additional 5.7-7 GW of leases were just auctioned off in shown BOEM Planning Areas for $4.4 billion

The shifting supply mix will require significant changes in grid operations

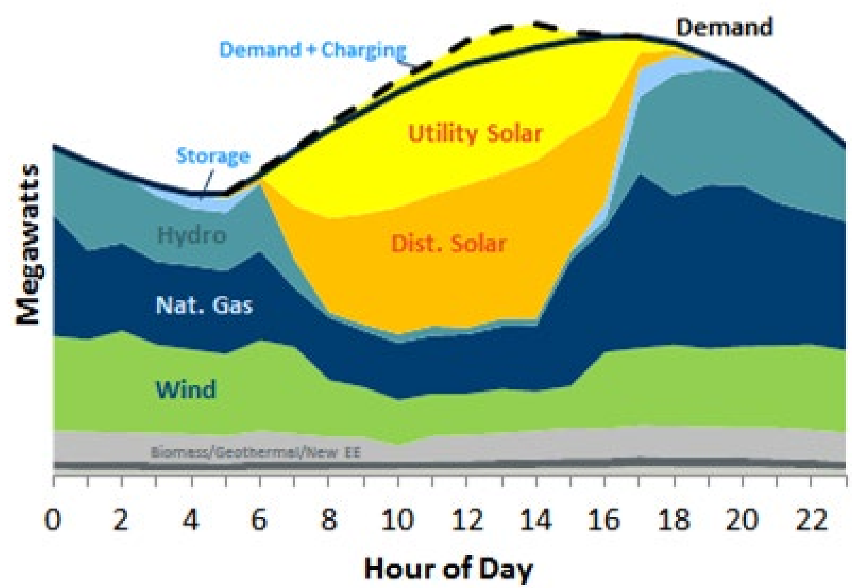
The more diverse supply mix creates challenges and requires more operational flexibility of electricity grid operations, including storage

Electricity Demand and Traditional Supply Mix



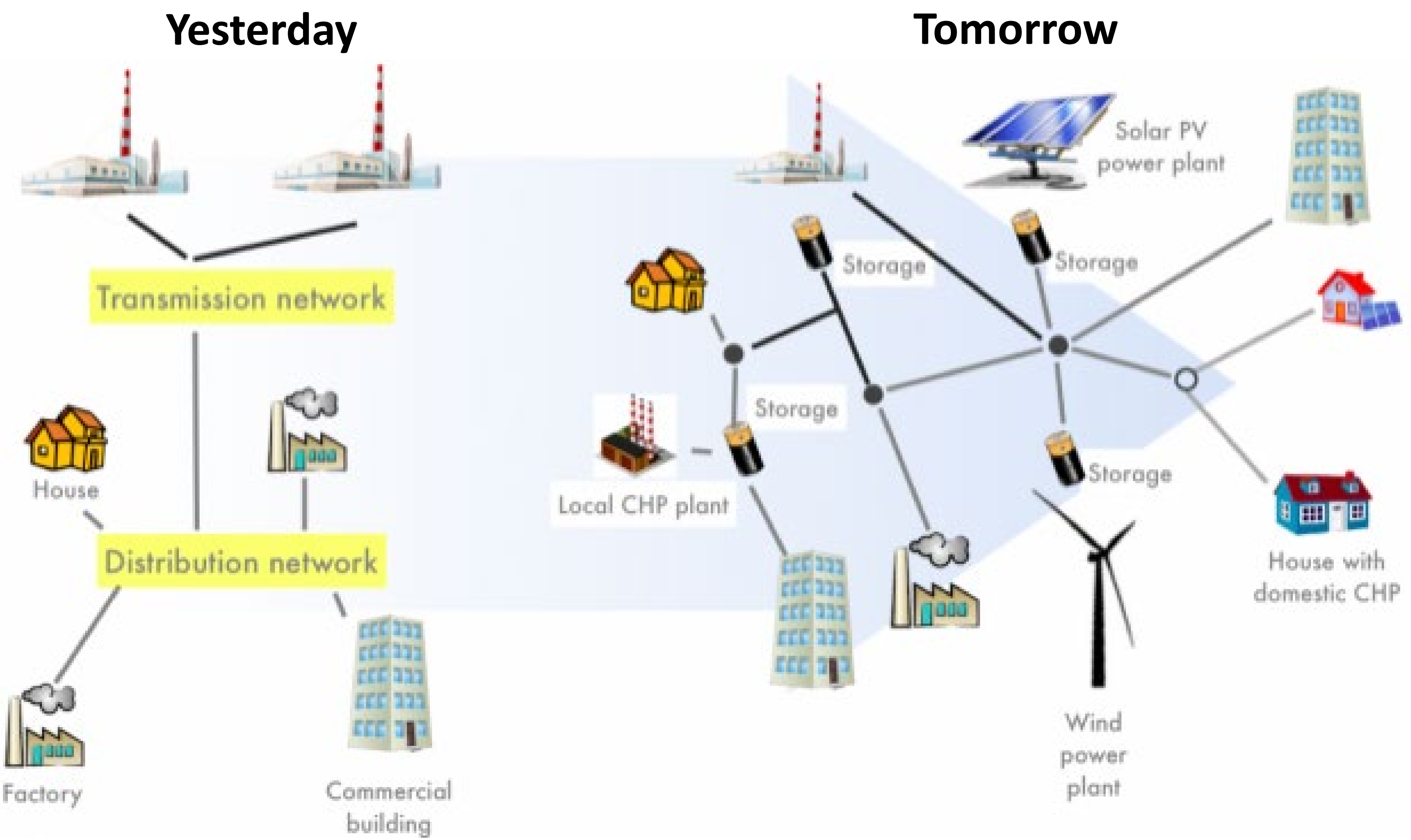
Source: The Brattle Group.

Electricity Demand and Supply Mix with High Renewable Generation



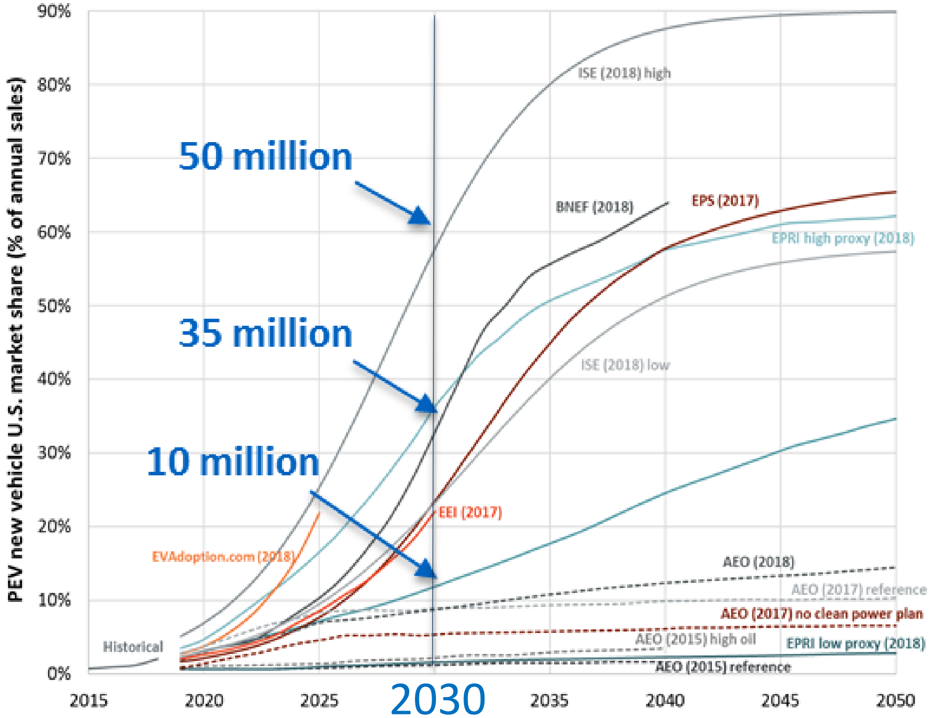
Source: The Brattle Group.

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

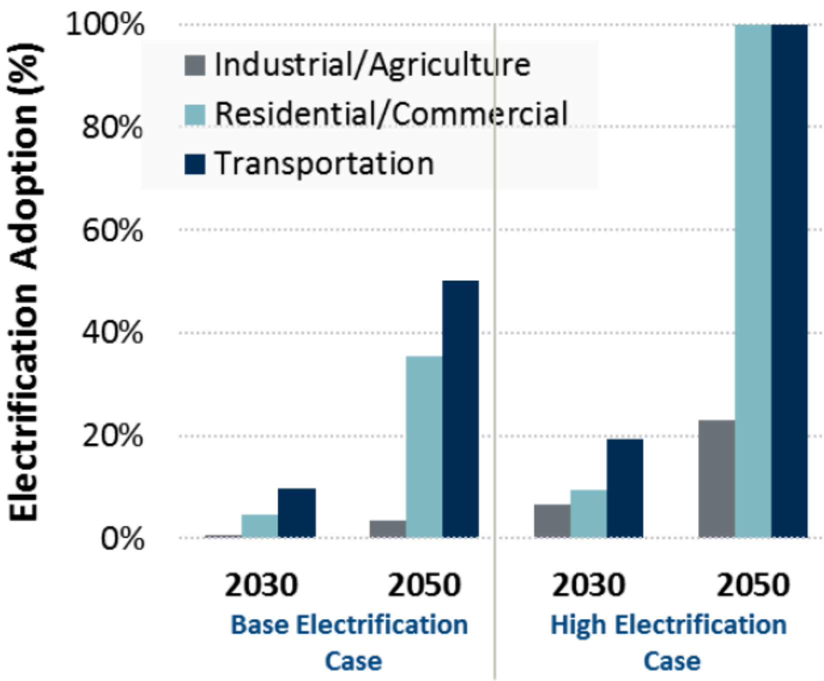


Grid challenges magnified by needed electrification of transportation, industry, and homes

Projections of Annual EV Market Share



Total Electrification Rates



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

Case Studies: Decarbonizing New England

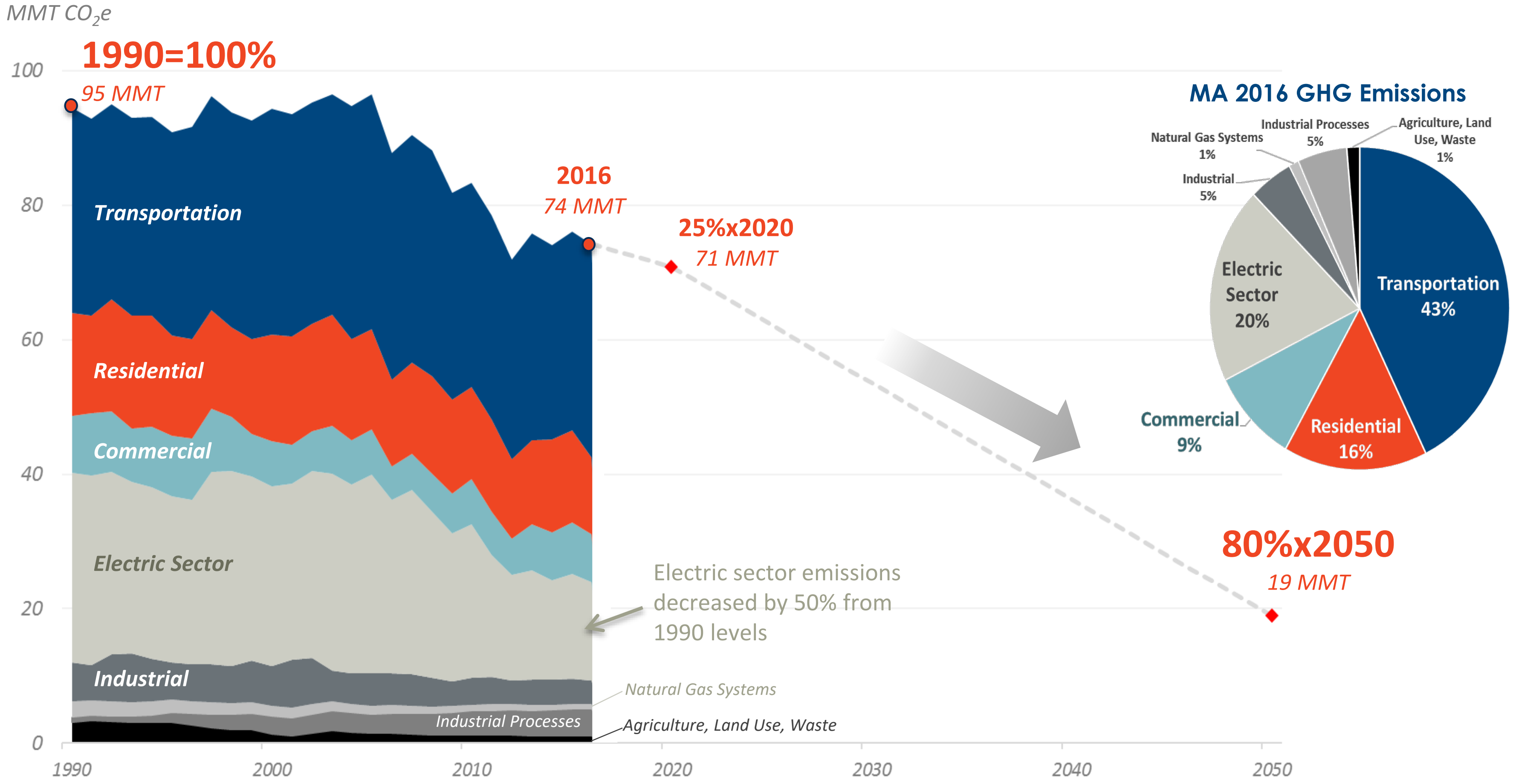
https://brattlefiles.blob.core.windows.net/files/17233_achieving_80_percent_ghg_reduction_in_new_england_by_20150_september_2019.pdf

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

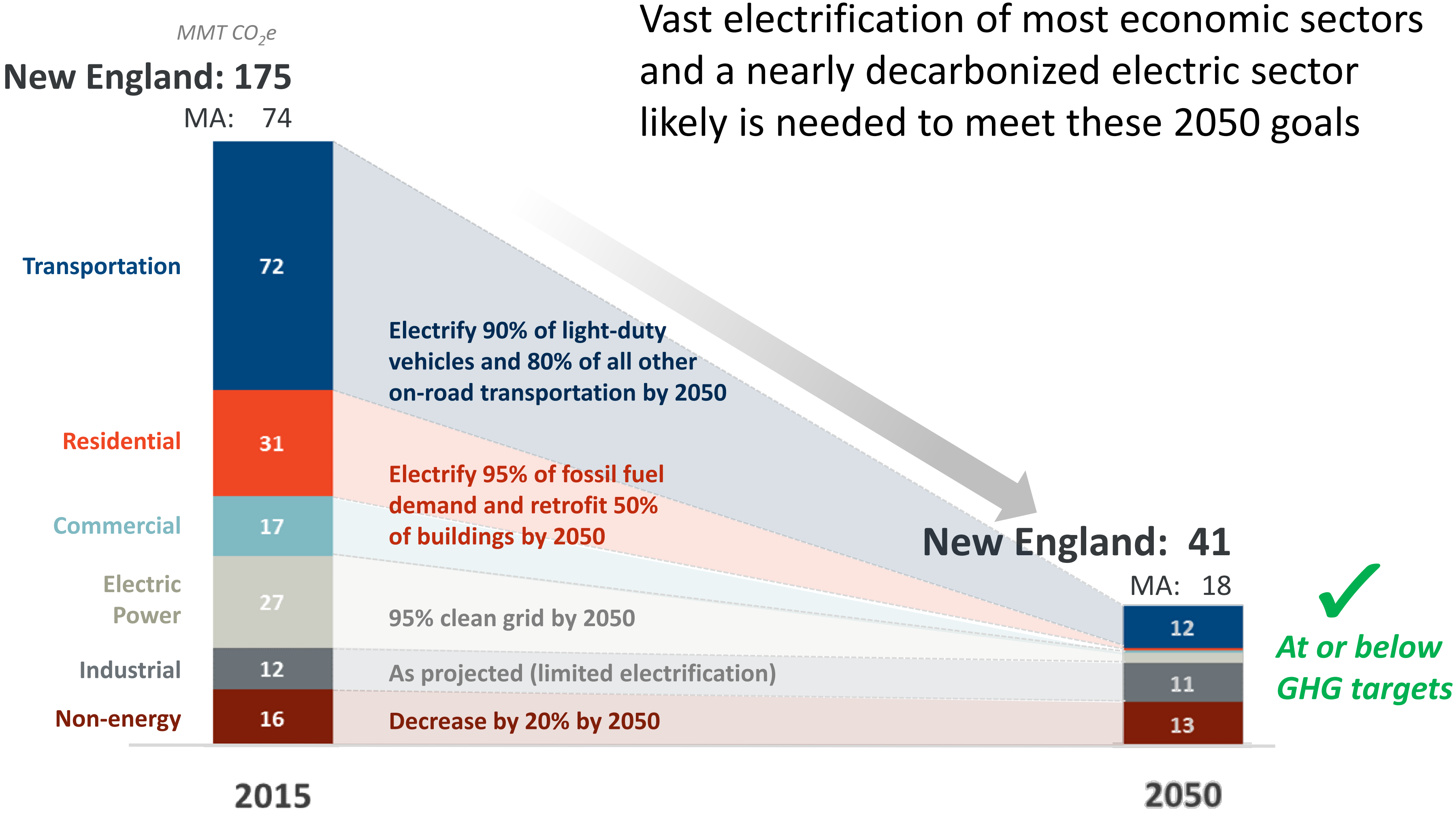
Example: Massachusetts historical GHG emissions and 2050 emissions limit



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

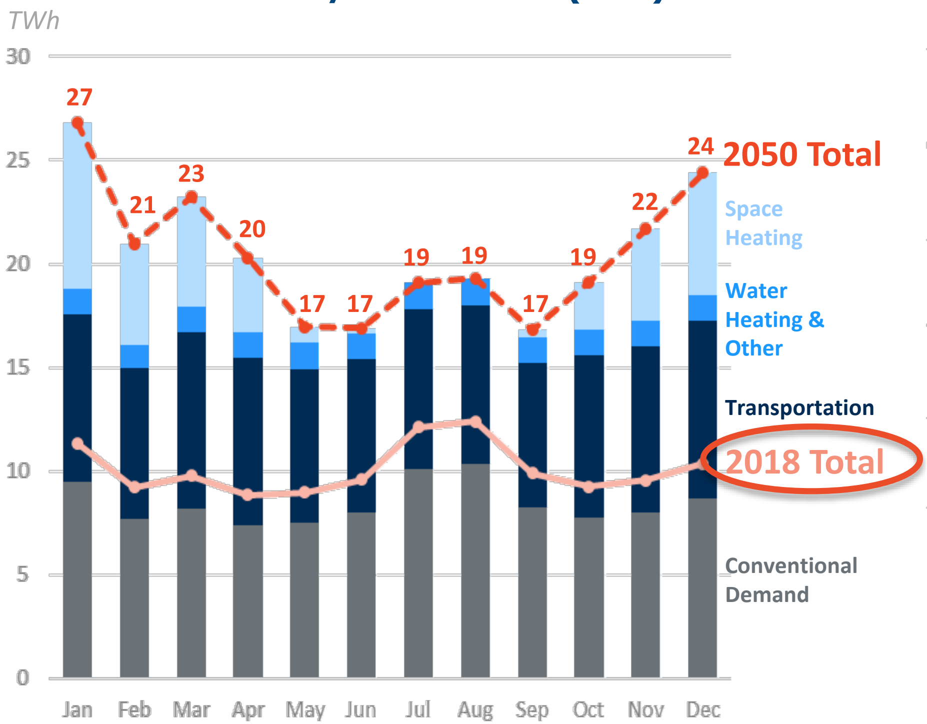


Electrification of transportation and home heating will double electricity demand

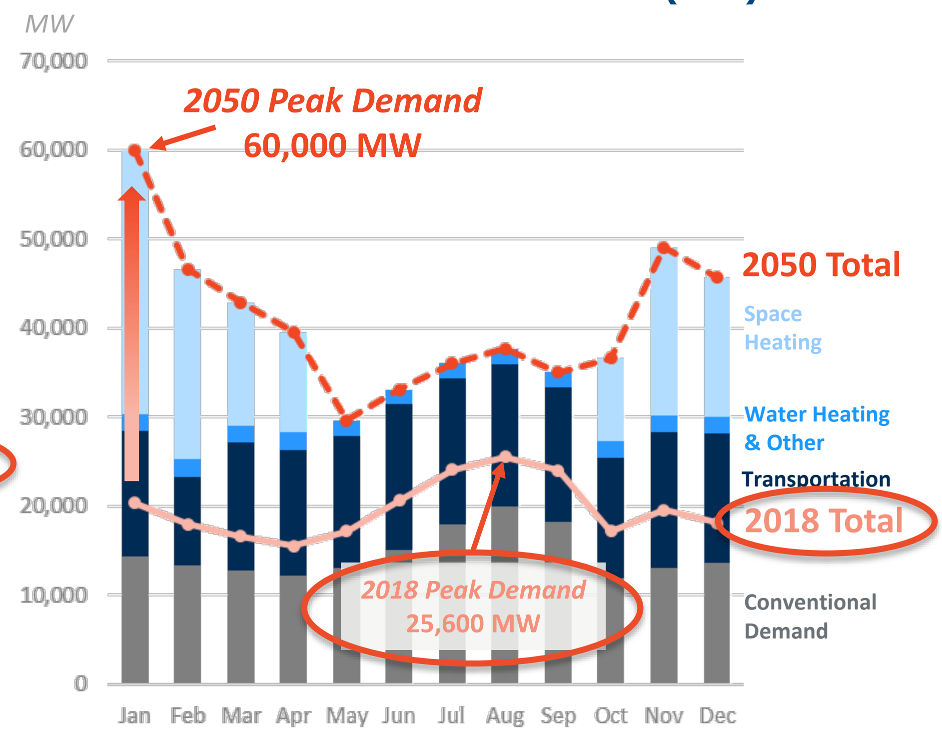
Projected 2050 New England Demand

Scenario: Electrification Focused

Electricity Consumed (TWh)



Peak Generation Needed (MW)



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.

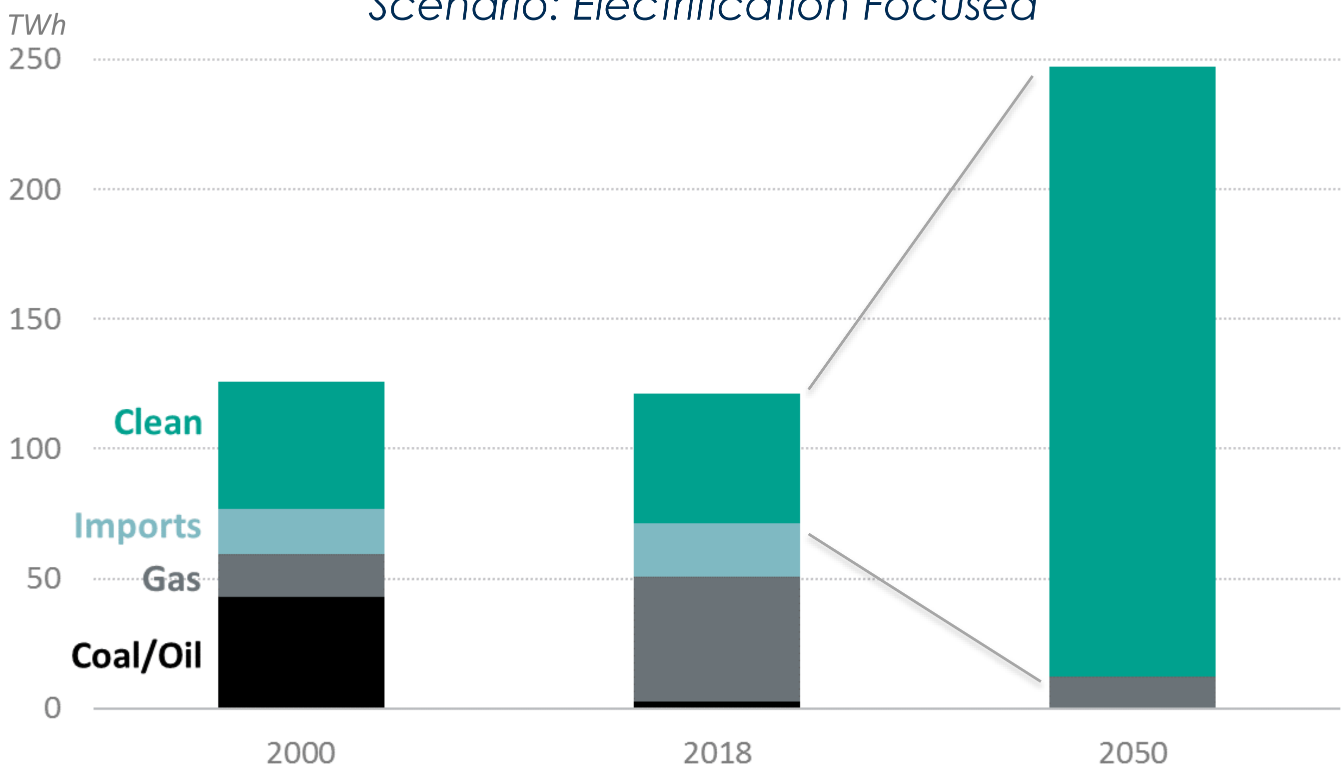
The 2050 portfolio of generation resources will need to meet this new pattern of demand.

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

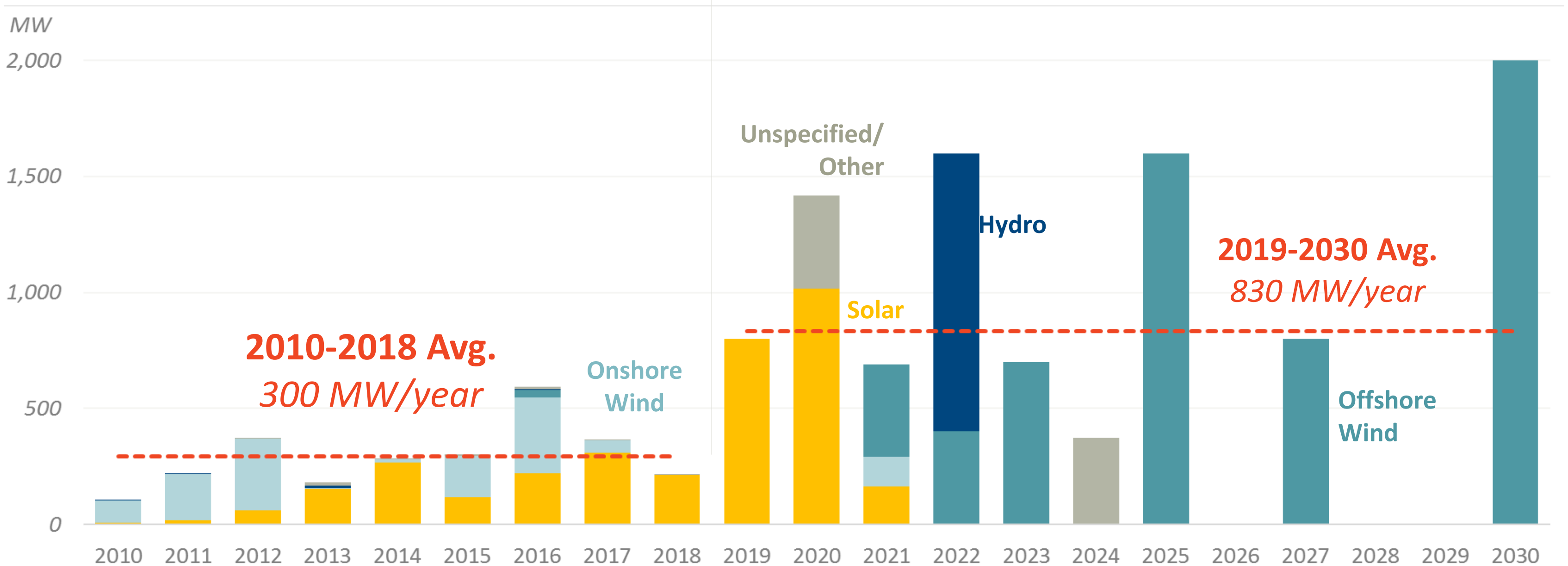


Source: ISO-NE, Key Grid and Market Stats, https://www.iso-ne.com/about/key-stats/, accessed June 28, 2019.

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
- Rate of clean energy addition is expected to increase from 300 MW/year (last decade) to 830 MW/year (through 2030)

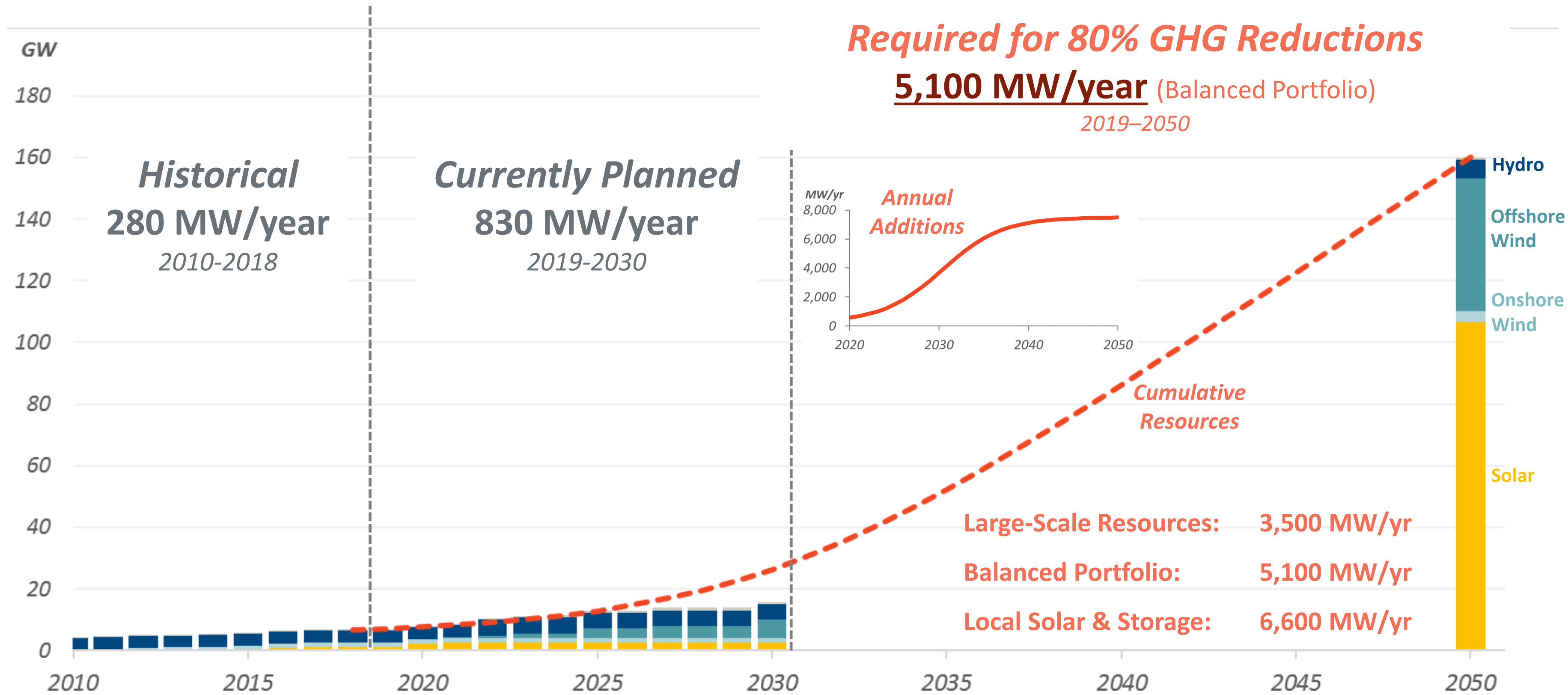
Historical and Planned Renewable Procurements in New England



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 significant further acceleration of clean-energy investments

Cumulative Clean Energy Resources in New England

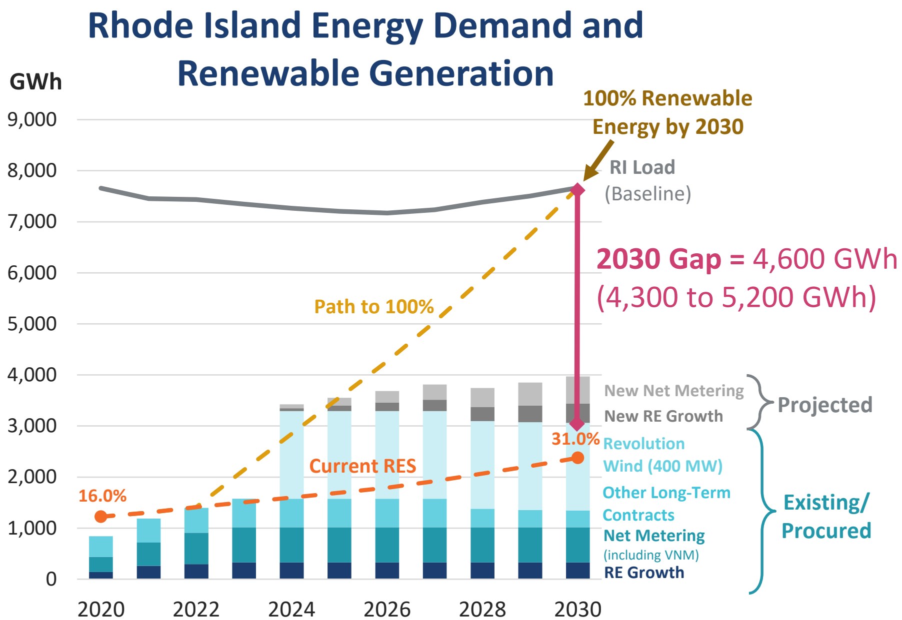


Annual clean energy resource additions need to increase by 4–8x overall

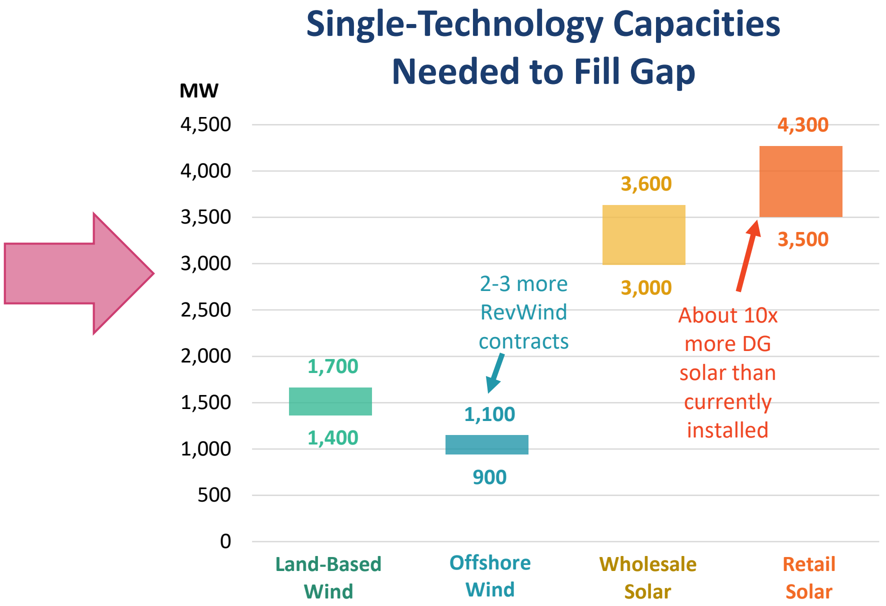
Large-scale solar resource additions will need to increase by 10–25x to meet these goals

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.

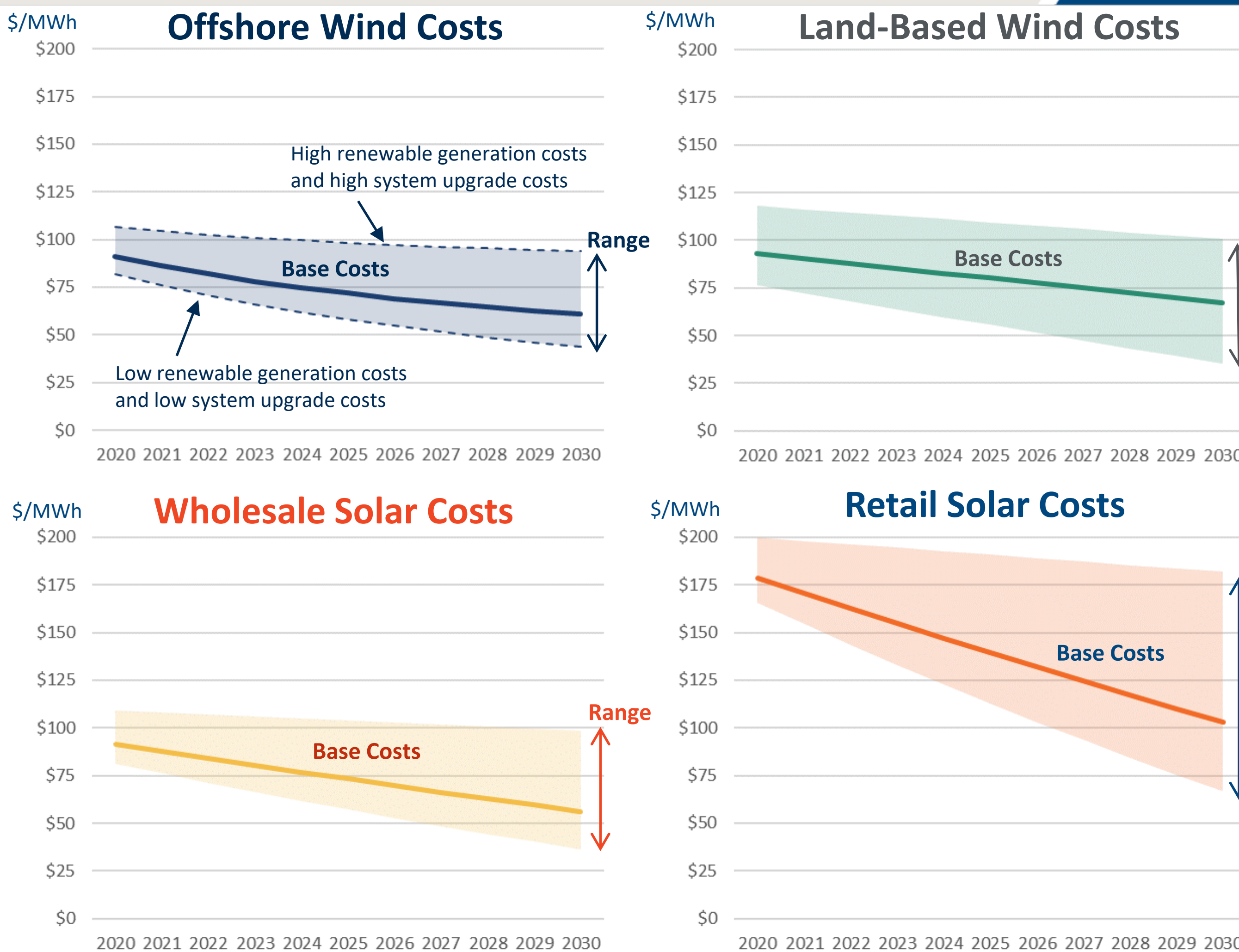


Source: https://www.brattle.com/news-and-knowledge/news/study-coauthored-by-brattle-economists-assesses-policies-and-pathways-for-achieving-100-renewable-electricity-in-rhode-island-by-2030

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

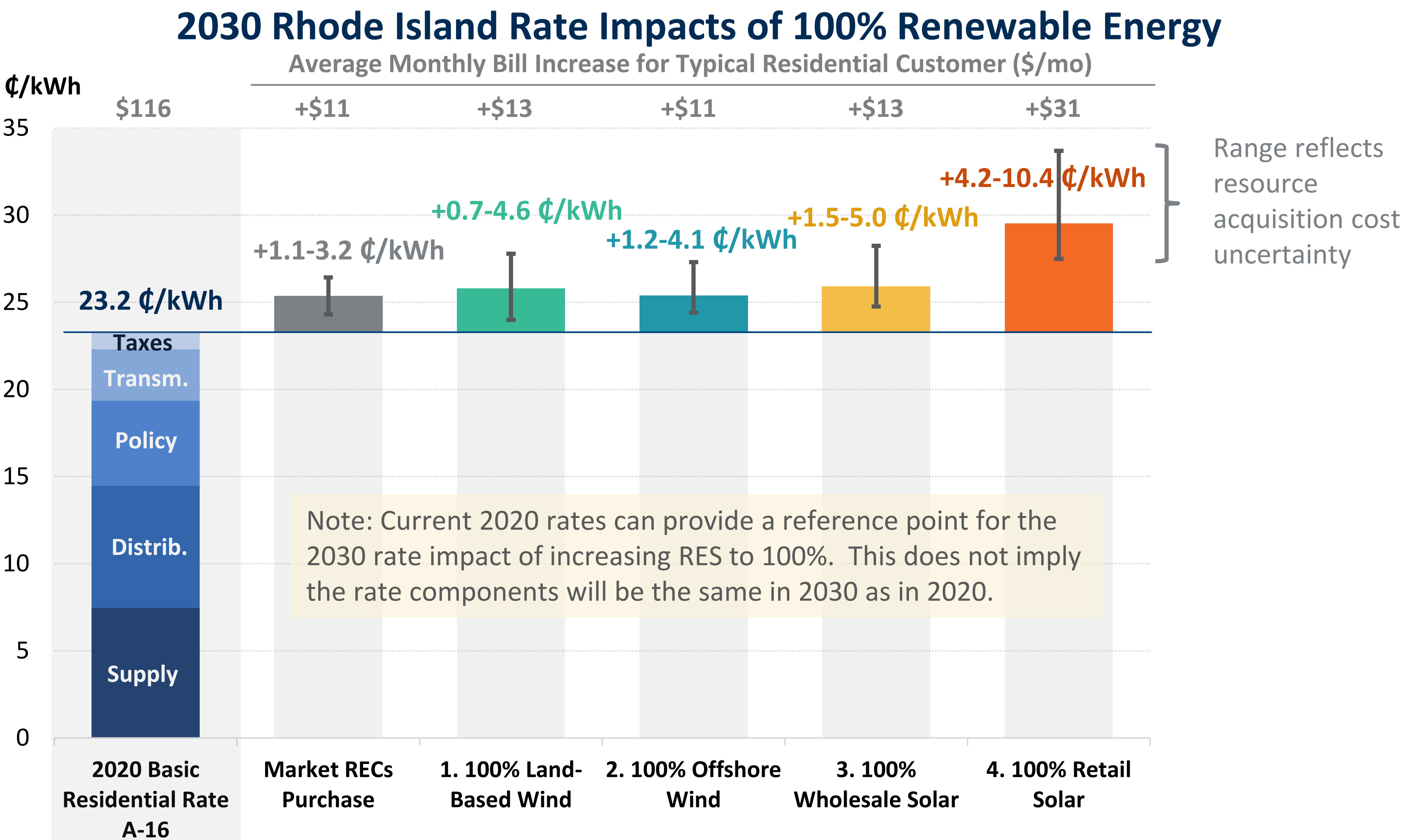
System Upgrade Costs: based on best available market data on system capacity and upgrade costs for each resource type



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

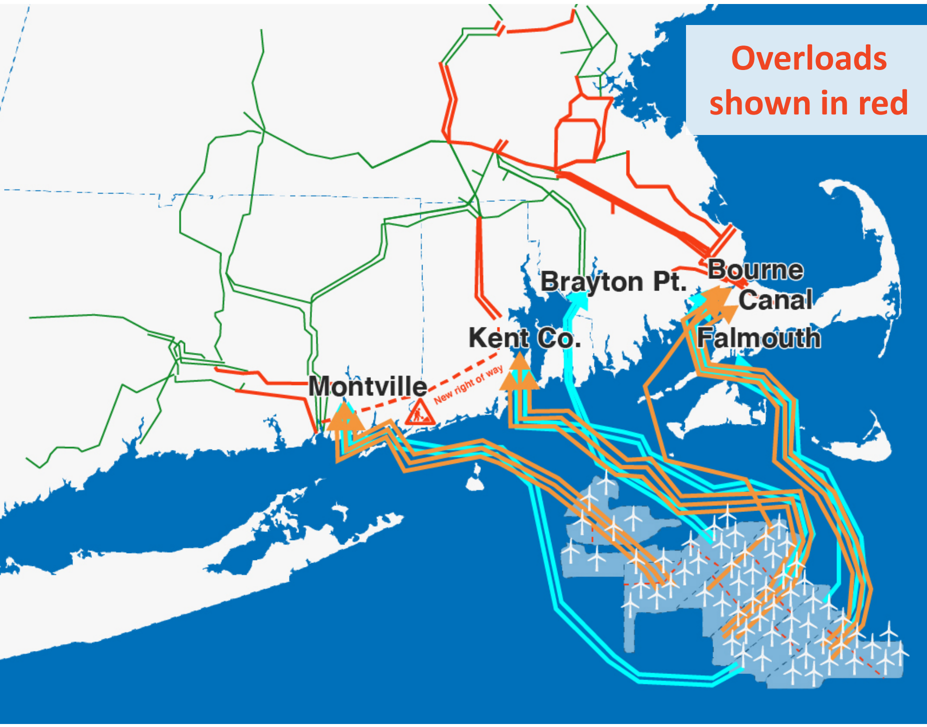
- **Generation profile:** Generates solely during daytime hours and less in winter than summer.
- **System balancing needs:** Significant storage resources will be necessary to match solar output to demand and other clean energy resources needed to meet growing winter demand.

Hydro Imports from Canada

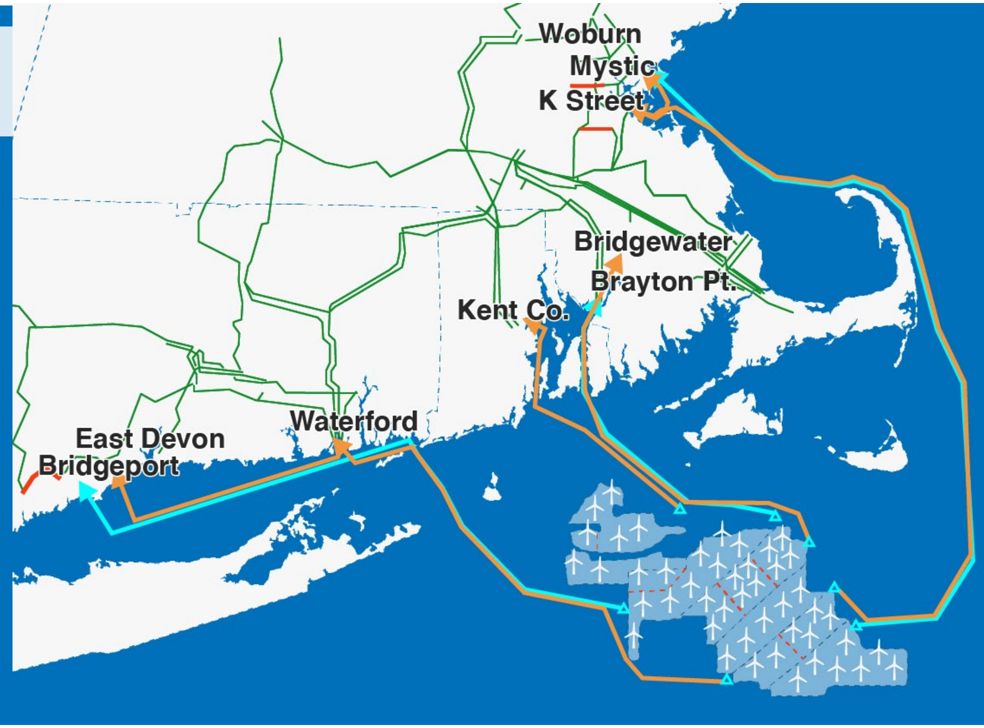
- **Transmission needs:** Additional transmission infrastructure required to import hydro resources from Quebec or other provinces. Each HVDC line can provide 1,000–1,200 MW of import capacity.
- **Local opposition:** Denial of Northern Pass permit in NH demonstrates challenges to new lines.

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

Generator Lead-Line Approach

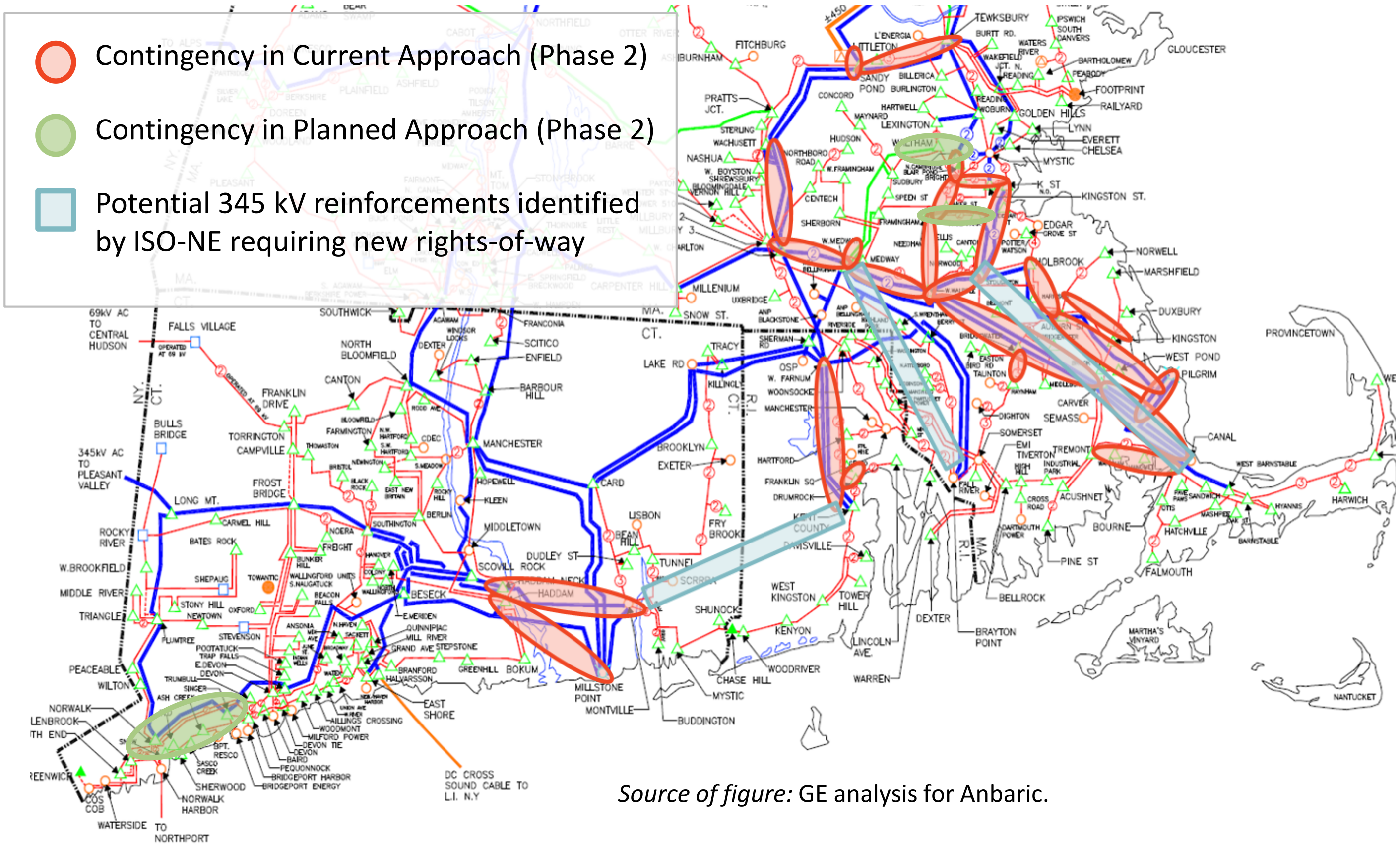


Planned Network Approach



Planning ahead would avoid costly onshore transmission upgrades

Already selected projects connecting to Cape Cod face up to <u>$787 million</u> in onshore transmission upgrades,* and continuing this approach for even the next 3600 MW of procurements could lead to an <u>additional $1.7 billion</u> 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 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 Visiting Scholar at MIT's Center for Energy and Environmental Policy Research (CEEPR), a Senior Fellow at Boston University's Institute of Sustainable Energy (BU-ISE), a IEEE Senior Member, and currently serves as an advisor to research initiatives by the U.S. Department of Energy, the National Labs, and the Energy Systems Integration Group (ESIG).

Hannes specializes in wholesale power markets and transmission. He has analyzed transmission needs, transmission benefits and costs, transmission cost allocations, and transmission-related renewable generation challenges for independent system operators, transmission companies, generation developers, public power companies, industry groups, and regulatory agencies across North America. He has worked on transmission, resource adequacy, and wholesale power market design matters in SPP, MISO, PJM, New York, New England, ERCOT, CAISO, WECC, Alberta and Ontario.

He 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, 21st Century Transmission Planning: Benefits Quantification and Cost Allocation, Prepared for the NARUC members of the Joint Federal-State Task Force on Electric Transmission, January 19,2022.

Pfeifenberger, Spokas, Hagerty, Tsoukalis, A Roadmap to Improved Interregional Transmission Planning, November 30, 2021.

Pfeifenberger, Transmission–The Great Enabler: Recognizing Multiple Benefits in Transmission Planning, ESIG, October 28, 2021.

Pfeifenberger et al., Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs, Brattle-Grid Strategies, October 2021.

Pfeifenberger, Transmission Options for Offshore Wind Generation, NYSERDA webinar, May 12, 2021.

Pfeifenberger, Transmission Planning and Benefit-Cost Analyses, presentation to FERC Staff, April 29, 2021.

Pfeifenberger et al., Initial Report on the New York Power Grid Study, prepared for NYPSC, January 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.

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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

Electric Power
Financial Institutions
Infrastructure
Natural Gas & Petroleum
Pharmaceuticals & Medical Devices
Telecommunications, Internet, and Media
Transportation
Water

Our Offices

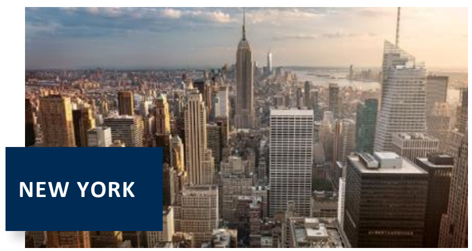

BOSTON


BRUSSELS


CHICAGO


LONDON


MADRID

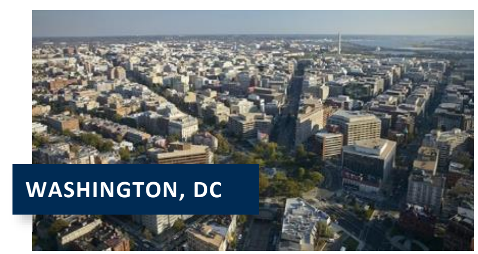

NEW YORK


ROME


SAN FRANCISCO


SYDNEY


TORONTO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