Locational Marginal Emissions

OPPORTUNITIES TO IMPROVE COST-EFFECTIVE CLEAN ENERGY TRANSITION WITH GRANULAR GREENHOUSE GAS EMISSIONS DATA

PRESENTED BY

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PRESENTED TO

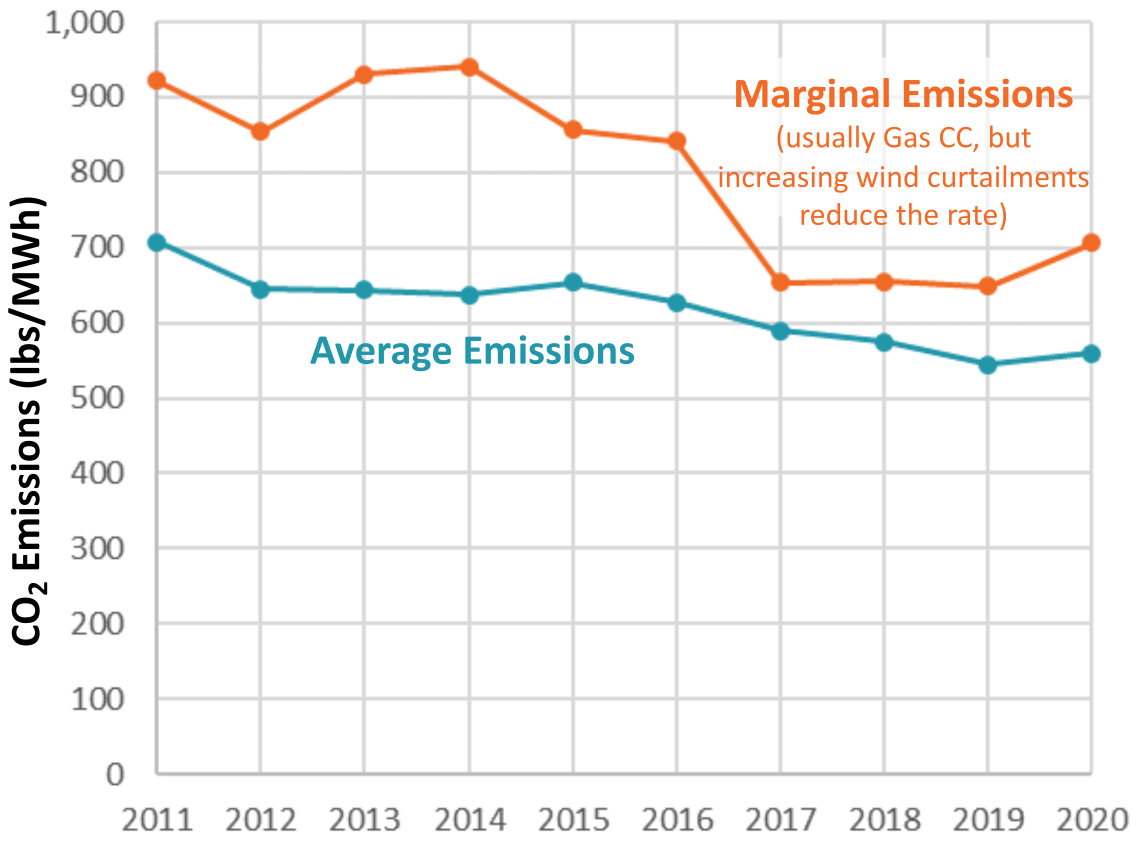
New England Electricity Restructuring Roundtable

DECEMBER 9, 2022

What are Locational Marginal Emissions (LME)?

- Analogous to Locational Marginal Price (LMP), LME is the GHG emissions rate of the incremental resource dispatched in the energy market
- Represents the incremental GHG abatement effect of injecting 1 MWh of energy into the grid at a given node & 5-minute dispatch interval

NEW ENGLAND CO_2 EMISSIONS RATES

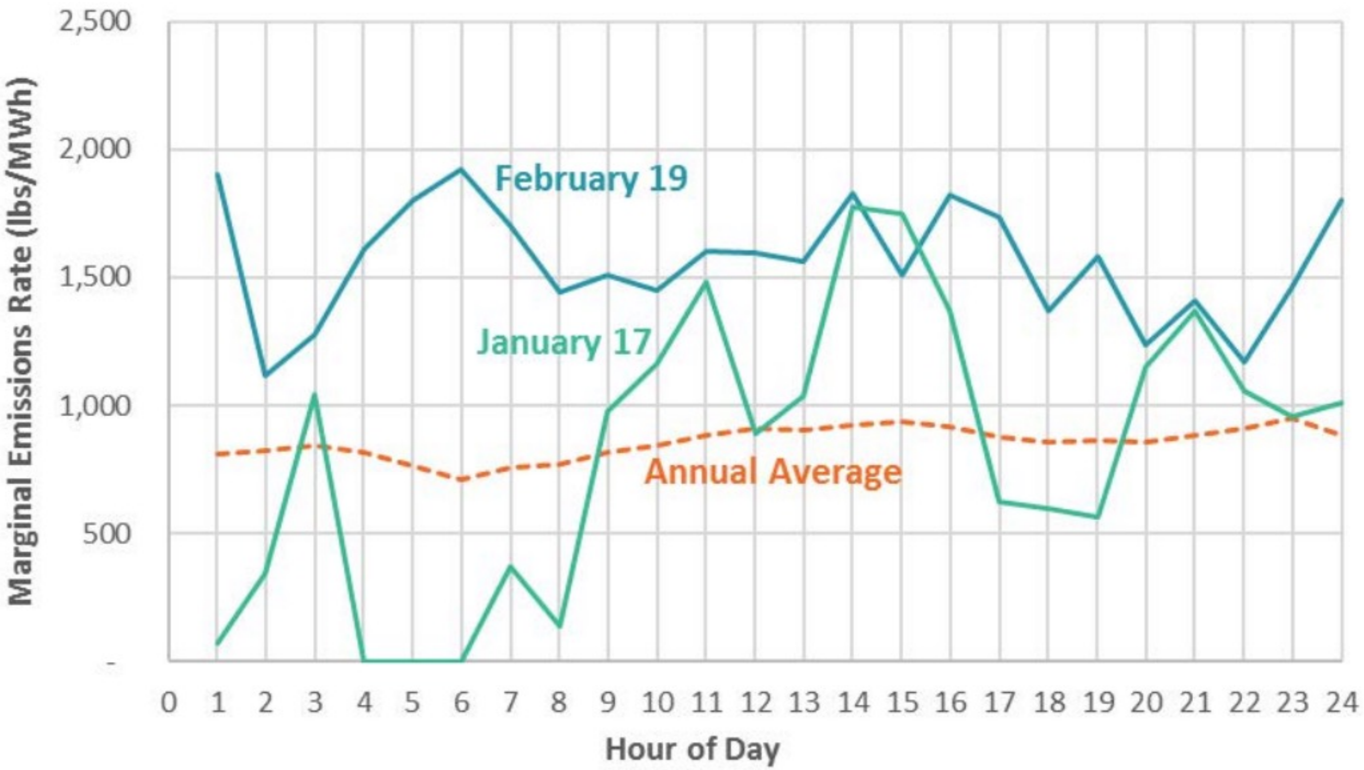


Source and Notes: Data shown are system average emissions rate with imports, and time-weighted all-units locational marginal unit emissions rates. ISO-NE. *2020 ISO New England Electric Generator Air Emissions Report*. April 2022.

Clean resources' time profile can substantially affect GHG value

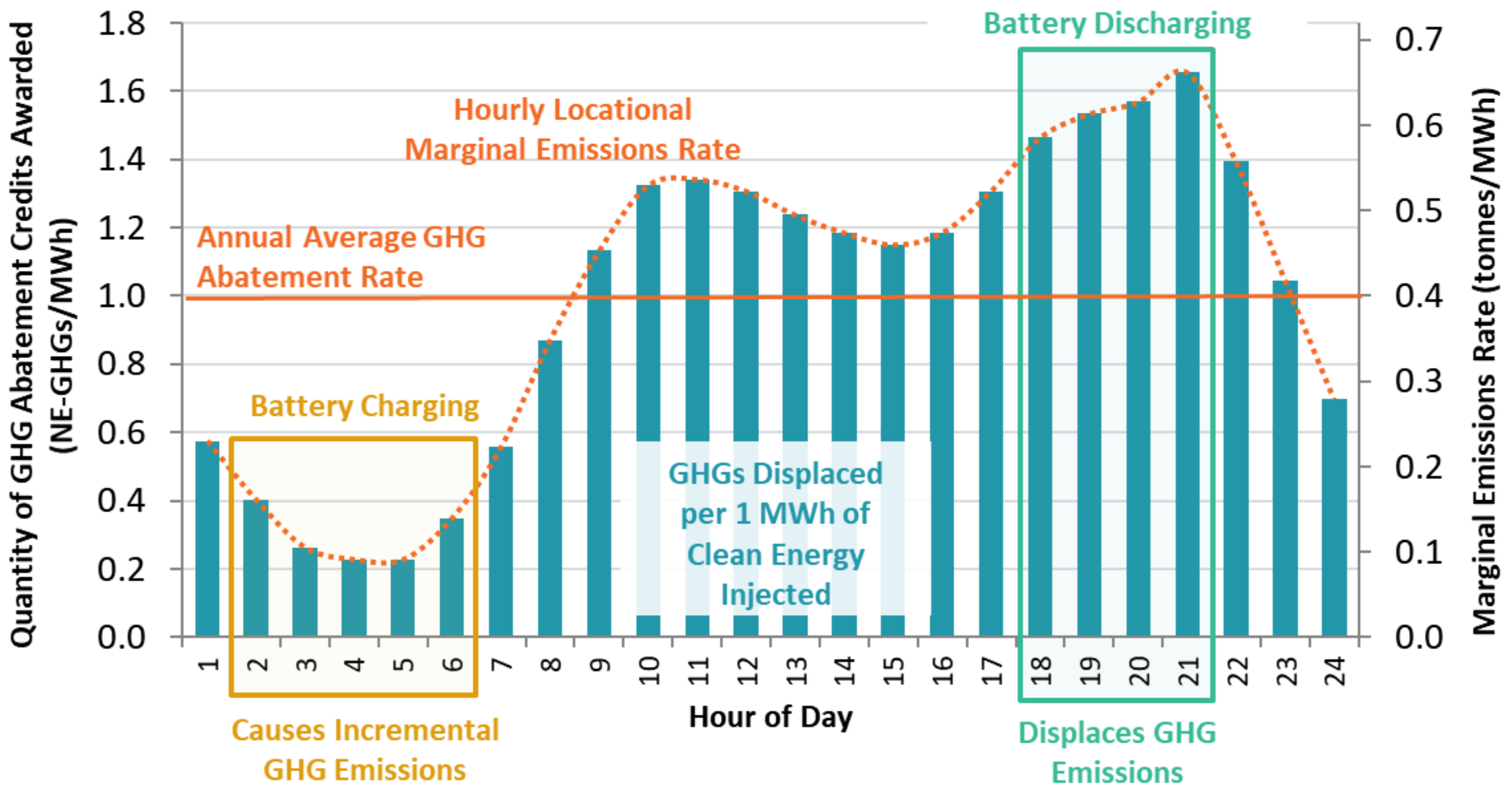
- On an annual average basis, incremental clean energy can be assumed to displace the emissions of a gas CC
- But resources that can focus output during times of greatest need (e.g. cold snap when steam oil is on the margin) can displace substantially more GHGs

NEW ENGLAND MARGINAL GHG EMISSIONS (2015)



Source: ISO-NE 5-minute regional marginal emissions data. See additional discussion discussion in Spees, et al. *Toward 100% Carbon-Free Electricity for Washington DC*.

LME-based storage incentives can incentivize more GHG abatement

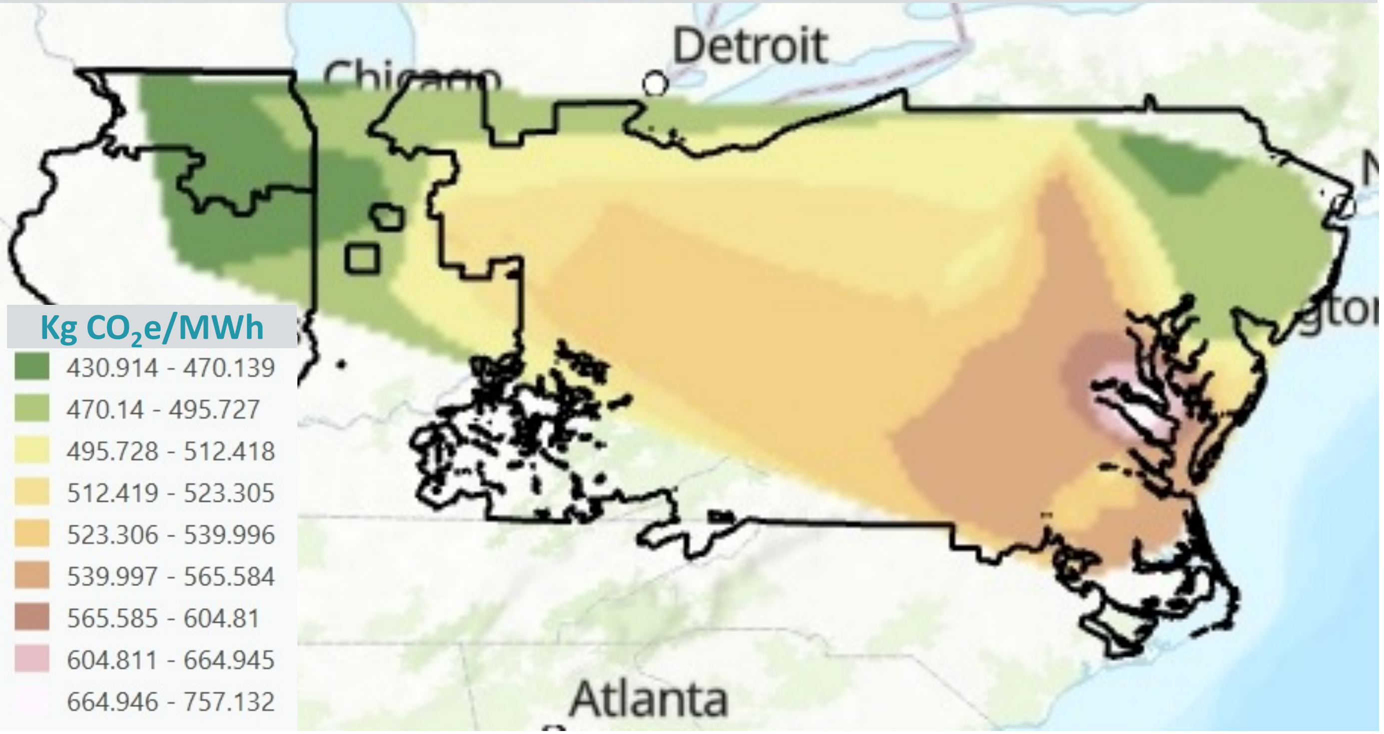


Source: Illustrative example LMEs updated here, originally developed in the context of the New England Integrating Markets and Public Policy (IMAPP) effort, as part of a regional clean energy market design proposal. See Spees, et al. Dynamic Clean Energy Market & Forward Clean Energy Market.

Some locations on the grid can become GHG "hot spots" or high-curtailment zones

- PJM has begun publishing 5-minute nodal LME data alongside LMP
- Informs identification of LME hotspots where locally-sited clean energy and transmission enhancements have higher GHG abatement value (as well as bottlenecked locations with high renewable curtailment)
- States have asked PJM to develop a more granular GHG accounting system to support state policy and corporate tracking; NJ is developing a storage incentive based on LME

PJM ANNUAL AVERAGE LME (2022)

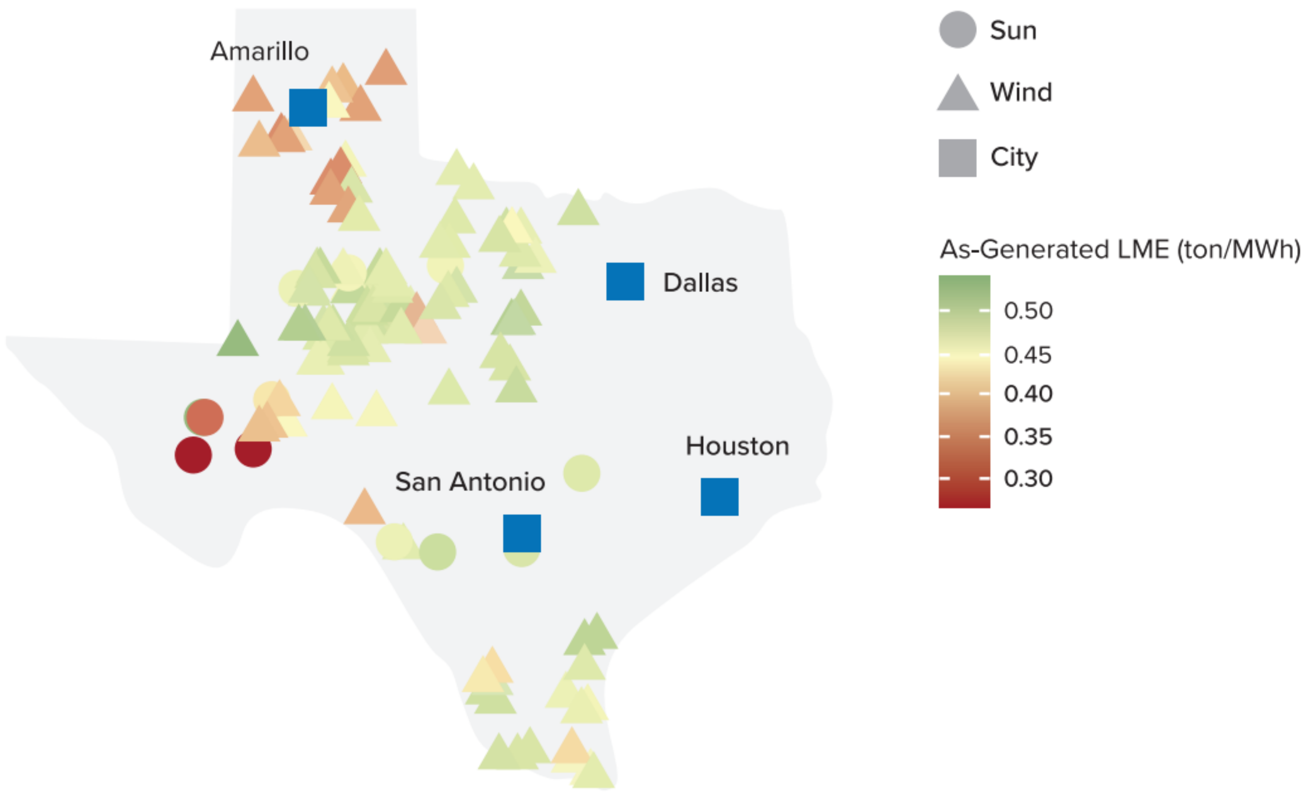


Source: Contour map developed using interpolation from generation node data. Data from ReSurety LME data product, derived from PJM Interconnection 5-minute, nodal LME data.

LME-focused procurement strategies can target resource development based on output profile & location

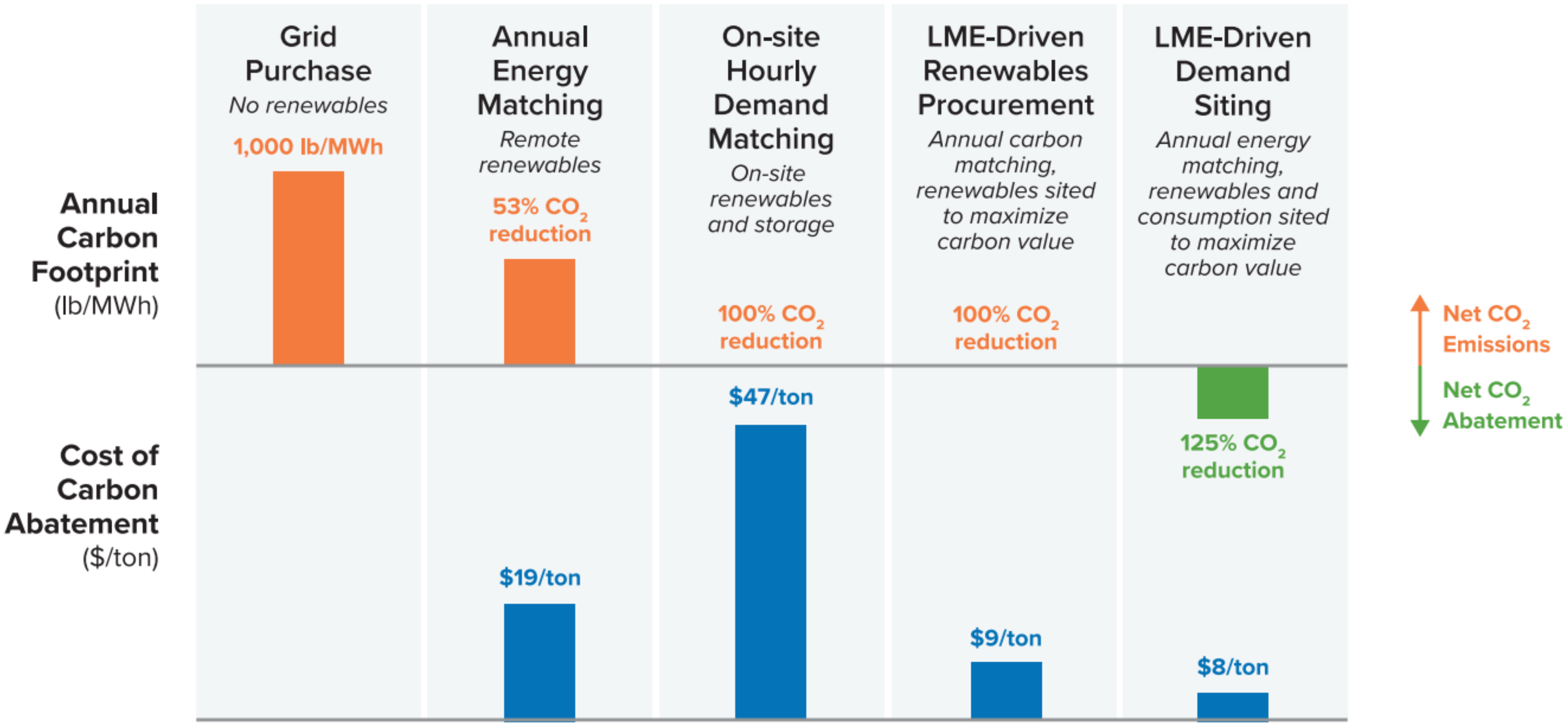
- Texas has enormous wind and solar resource potential, much of the lowest-cost wind in relatively more remote areas
- LME-based analysis of all renewable projects in Texas reveals that some resources offer 2x the GHG abatement value of others, based on output profile and location

TEXAS PROJECT-SPECIFIC LME VALUE (2018-19)



Source: Oates, Spees. *Locational Marginal Emissions: A Force Multiplier for the Carbon Impact of Clean Energy Programs*. May 2021.

Clean energy procurement dollars can go further when focused $/tonne (rather than $/MWh)



Source: Oates, Spees. *Locational Marginal Emissions: A Force Multiplier for the Carbon Impact of Clean Energy Programs*. May 2021.

Takeway: Granular LME data can supplement and inform policy and contracting choices to accelerate GHG reductions and reduce cost

Examples of opportunities to consider LME data:

- Considering resources' LME value in resource selection for contract procurement (particularly for buyers that consider themselves to be "price takers")
- Locating incremental demand (e.g. data centers)
- Prioritizing transmission upgrades to hot spots (and from gen pockets)
- Incentivizing storage, vehicle, DR, and DER operations that maximize GHG abatement value
- LME or other granular time- and location-based GHG data may improve GHG accounting and attribution
- Develop next generation of REC products focused on GHG abatement value (rather than treating all MWh as equal)

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Dr. Kathleen Spees is a Principal at The Brattle Group with expertise in designing and analyzing wholesale electric markets and carbon policies. Dr. Spees has worked with market operators, transmission system operators, and regulators in more than a dozen jurisdictions globally to improve their market designs for capacity investments, scarcity and surplus event pricing, ancillary services, wind integration, and market seams. She has worked with U.S. and international regulators to design and evaluate policy alternatives for achieving resource adequacy, storage integration, carbon reduction, and other policy goals. For private clients, Dr. Spees provides strategic guidance, expert testimony, and analytical support in the context of regulatory proceedings, business decisions, investment due diligence, and litigation. Her work spans matters of carbon policy, environmental regulations, demand response, virtual trading, transmission rights, ancillary services, plant retirements, merchant transmission, renewables integration, hedging, and storage.

Dr. Spees earned her PhD in Engineering and Public Policy within the Carnegie Mellon Electricity Industry Center and her MS in Electrical and Computer Engineering from Carnegie Mellon University. She earned her BS in Physics and Mechanical Engineering from Iowa State University.