A Dynamic Clean Energy Market in New England

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- Overview of the Forward Clean Energy Market
- Recap of Design Concept
- Recent Design Updates
- Preliminary Modeling Results
- Next Steps
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The Forward Clean Energy Market

- **Objective:** Reduce state carbon emissions at reduced cost
- **Customer Savings:** $450 million annually ($3.60/MWh) with CO_2 emissions down by 740,000 tons per year relative to current practice (preliminary modeling results)
- **Mechanism:** States buy clean energy through a better auction and better product

Overview

A Better Auction

- Designed to **Keep States in Control**

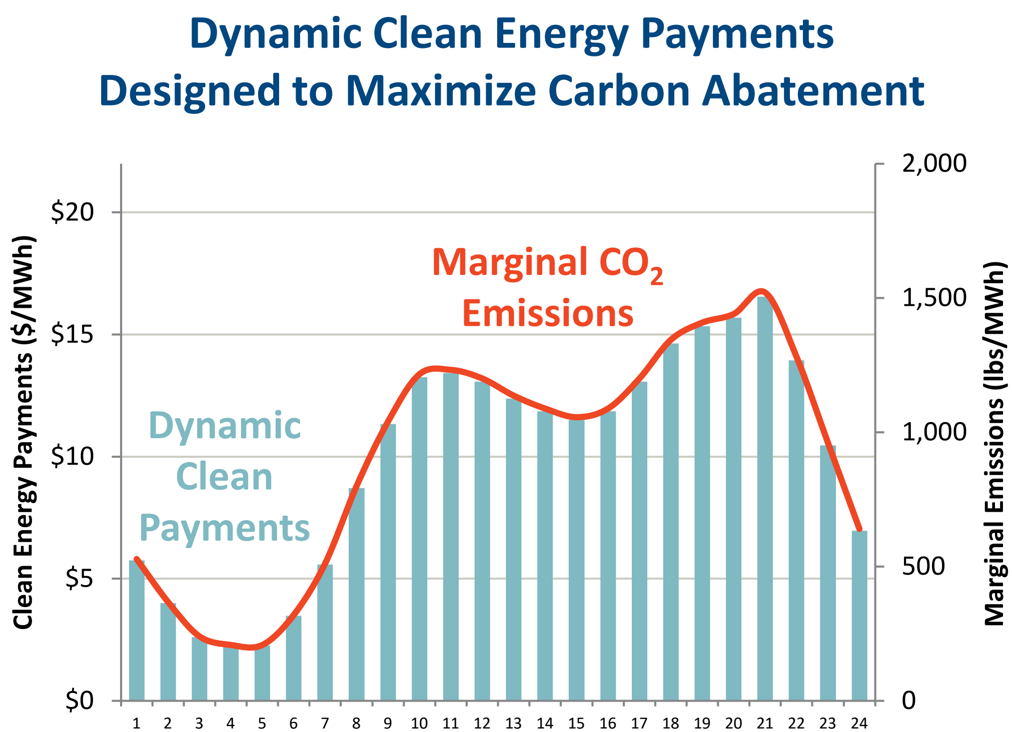
- **Harnesses Competition** between new and existing resources of all types

- Designed to **Ensure Financeability** of new investments

Overview

A Better Product

- **Dynamic payments** incentivize carbon reductions
- **Enables storage** to enter the market and displace emissions
- **Operates well** with existing markets



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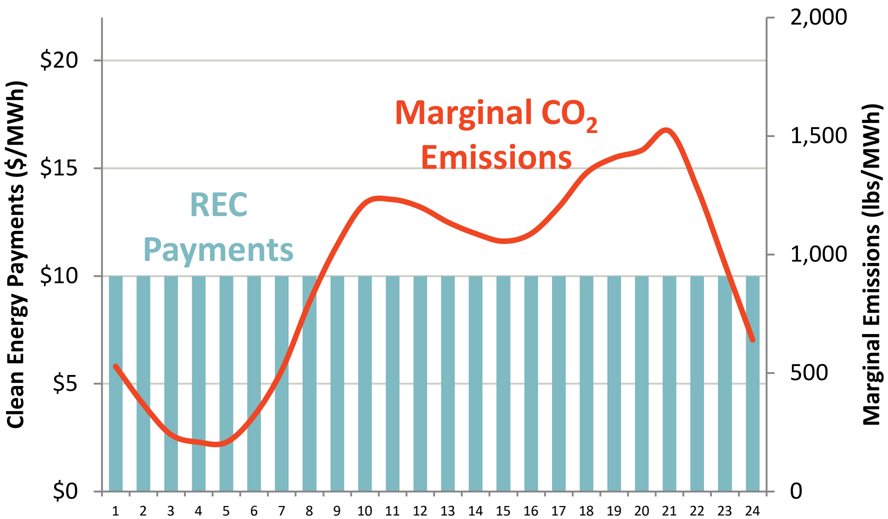
Design Concept

"Dynamic" Clean Energy Payments

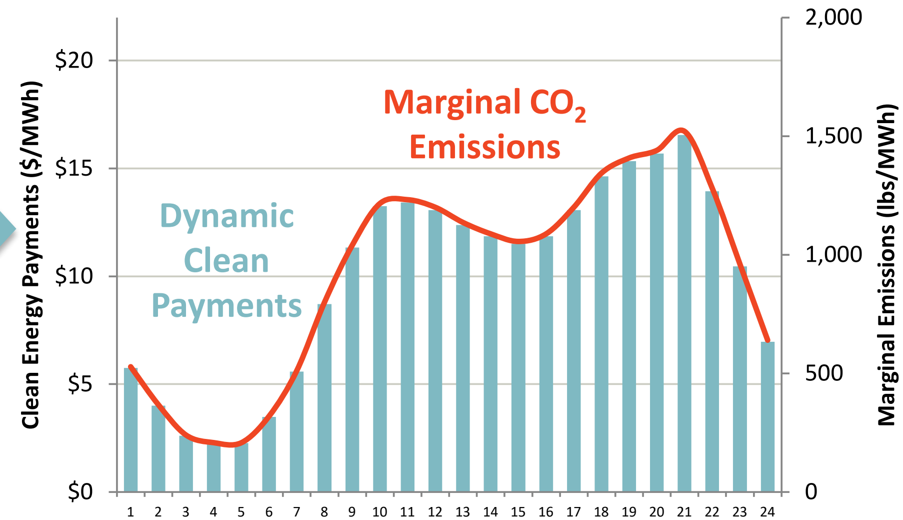
The centerpiece of this design proposal is a new "carbon-linked" dynamic clean energy payment

Illustrative Traditional REC-Payments



- Flat payments over every hour
- Incentive to offer at negative energy prices during excess energy hours

Illustrative "Dynamic" Clean Payments



- Payments scale in proportion to marginal CO_2 emissions
- Incentive to produce clean energy when and where it avoids the most CO_2 emissions
- No incremental incentive to offer at negative prices

Design Concept

Anchor Price and Dynamic Payments

Clean energy suppliers earn payments that scale in proportion to carbon abatement value:

$$\text{Payments} = \frac{\text{Marginal Emissions Rate}}{\text{Reference Emissions Rate}} \times \text{Anchor Price}$$

- **Reference Emissions Rate** is set prior to the forward auction (for example, at the average system-wide marginal emissions rate, such as 1,100 lbs/MWh)
- Clearing price in the forward auction sets an **Anchor Price** based on the Reference Emissions Rate
- **Realized Payments** to individual resources scale dynamically in proportion to realized **Marginal Emissions Rate** calculated by the ISO at the time and place of delivery (mimics CO_2 pricing incentives for clean energy resources)

Incentives for Clean Energy in the Right Locations

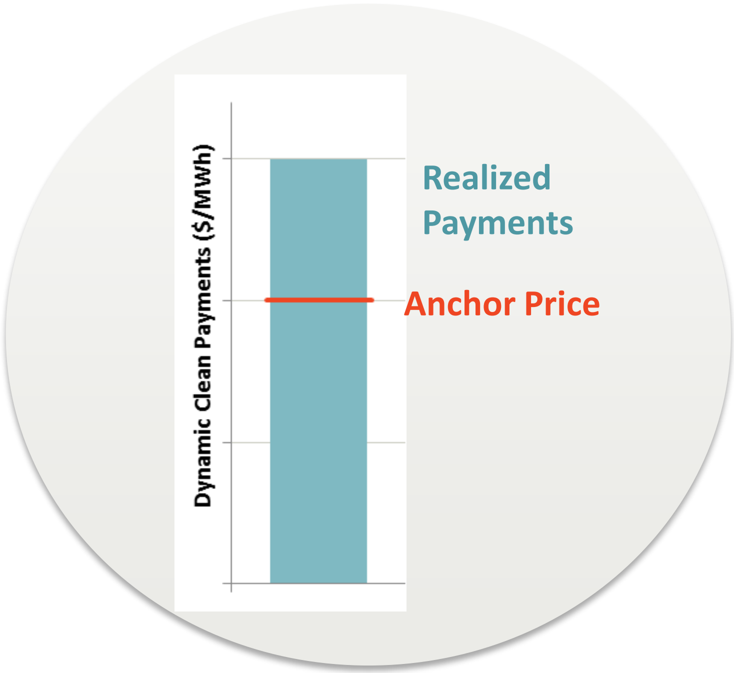
Location-specific payments will focus incentives to develop new clean energy where they will displace the most CO_2 emissions

Low-Emitting Location

Generation pocket that is already saturated with wind. New clean energy will mostly displace the generation of existing wind resources (and will earn fewer payments)

High-Emitting Location

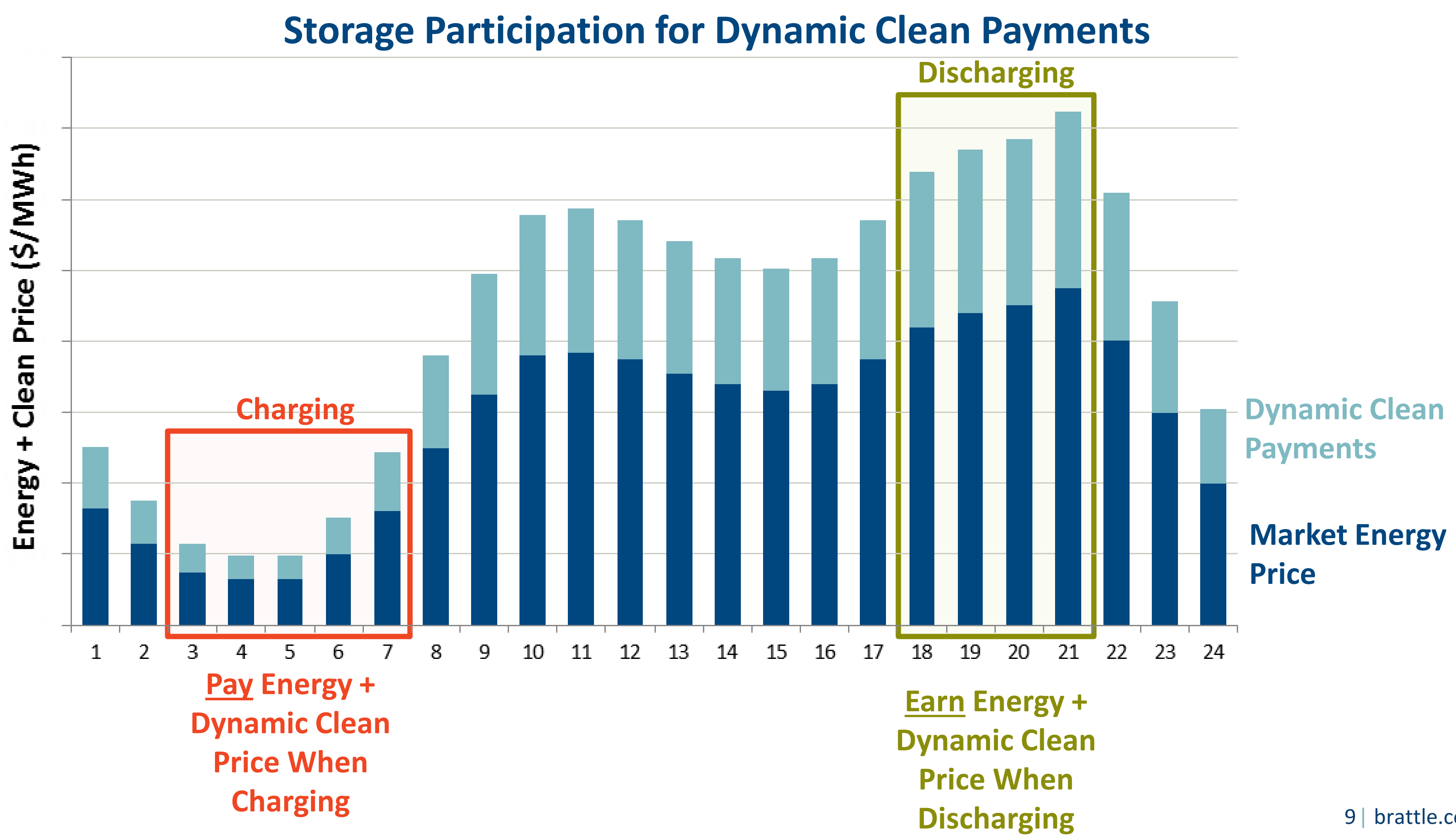
Load pocket where high-emitting steam oil units are often called on. Clean energy will displace more emissions (and earn more payments)



Design Concept

Incentives at the Right Times (Including for Storage)

Dynamic payments incentivize clean energy at the right times to displace the most CO_2 emissions, enabling storage to compete with other technologies



Design Concept

Base and "Targeted" Clean Energy Resources

States submit the demand for clean energy and the maximum willingness to pay. States can choose to purchase:

"Base" Resources	"Targeted" Resources
• Procures the least cost clean supply, whether <u>new or existing</u> • All resources can participate (hydro, wind, solar, nuclear, storage), no restrictions by type or location • 1-year anchor price lock-in for existing; ~7-12 year lock-in for new • State commitment to submit demand bids in future years, e.g. for 10 years	• State carve outs for <u>new</u> resources • State has option to define a <u>specific type</u> (e.g. for emerging technologies) • ~7-12 year anchor price lock-in • No state commitment to submit demand in future years • Option for a "contingent" bid. If targeted resource prices are too high, the state can choose to purchase lower-cost "base" resources instead

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Incorporating Clean Energy as In-Market

This coalition's proposal aims to accommodate a top priority for states: ensuring clean revenues are considered in-market for the purposes of ISO-NE's minimum offer price rule

- As an initial proposal, we suggest that revenues up to the "Base" resource price be considered in-market. The price increment between the "Base" and "Targeted" resource price would be considered out-of-market for Targeted resources
- ISO-NE's FERC-approved Tariff already considers as in-market any clean energy incentives that are broadly available across the New England Control Area, such as renewable energy credits and production tax credits

ISO-NE Tariff: *Revenues will be considered out-of-market that "are: (a) not tradable throughout the New England Control Area or that are restricted to resources within a particular state or other geographic sub-region; or (b) not available to all resources of the same physical type within the New England Control Area, regardless of the resource owner."*

Tariff Section III (Market Rule 1), Appendix A.21.2 (b)(i)

Ensuring the Market is Financeable

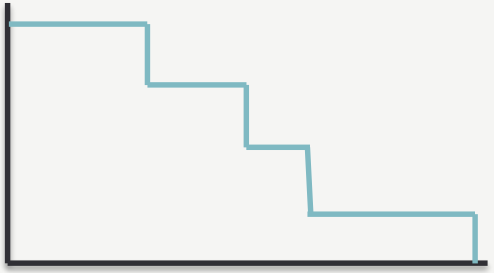
This design intentionally places most fundamentals-based and asset-specific risks on sellers that are in the best position to manage the risks. However, we propose two key design features to mitigate regulatory risks and support financeability :

- **Commitment Period:** New resources will earn a price lock-in for clean energy payments for ~7-12 years (particular term is subject to adjustment)
- **Minimum Payout Guarantee:** At least 80% of revenues determined at auction will be paid out to the market *on average*, even if system marginal emissions rate falls

Allocate Risks to Customers	Allocate Risks to Sellers	
Regulatory Risks	**Market Fundamentals**	**Asset-Specific Risks**
• Unanticipated changes to state policy • Unpredictable changes to state demand bids • Rule changes	• Resource mix • Load growth • Fuel prices • Transmission development • Energy, capacity, and ancillary service prices	• Construction delays • Unanticipated asset costs • Asset performance

How Would States Oversee Demand Bids?

States would maintain <u>complete control</u> over demand bids, with each state potentially choosing a different responsible entity and approval process. Here are two possible approaches:

Example	Description	Curve
Clean Net CONE and Target Quantity	• State establishes tariff-like document approving curve shape, cap, and slope that reflect state priorities • State agency estimates "Clean Net CONE" and target quantity using approved method	
Price and Quantity Bids as Complement to Utility Planning	• Utility resource plan recommends quantity and price pairs to procure at auction • Subject to state approval using approaches similar to EE and DR program approvals	

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Modeling Approach

We conducted a preliminary modeling exercise to help quantify the potential benefits of a competitive clean energy market in New England (see detailed appendix)

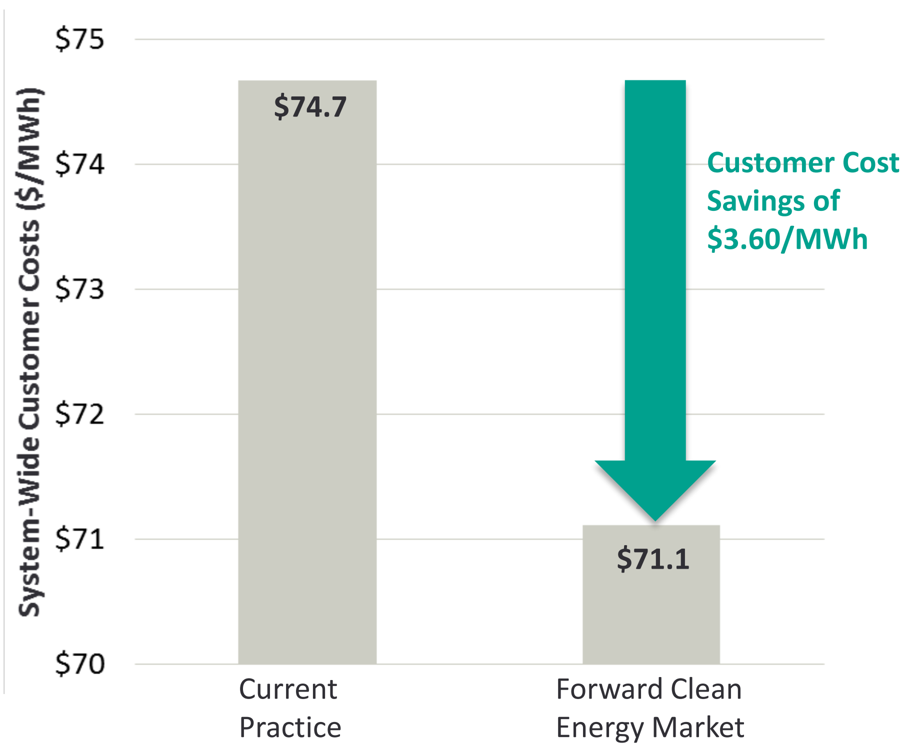
- **Scenarios:** Evaluated eight alternative approaches for achieving states' carbon reductions targets of 80% by 2050. Summary results here focus on:
  - *Current Practice* relying on technology-specific procurement of new resources
  - *Two-Tier New and Existing FCEM* for procuring clean resources using the market-based mechanism proposed by the coalition
- **Approach:** Used Brattle's CO_2 SIM modeling platform, and adopted primary input assumptions from the state-vetted Phase I NESCOE/LEI study
- **Preliminary Findings:** Intended to inform states about the customer, societal, and emissions impacts of alternative market, and non-market approaches to achieving carbon goals

Modeling

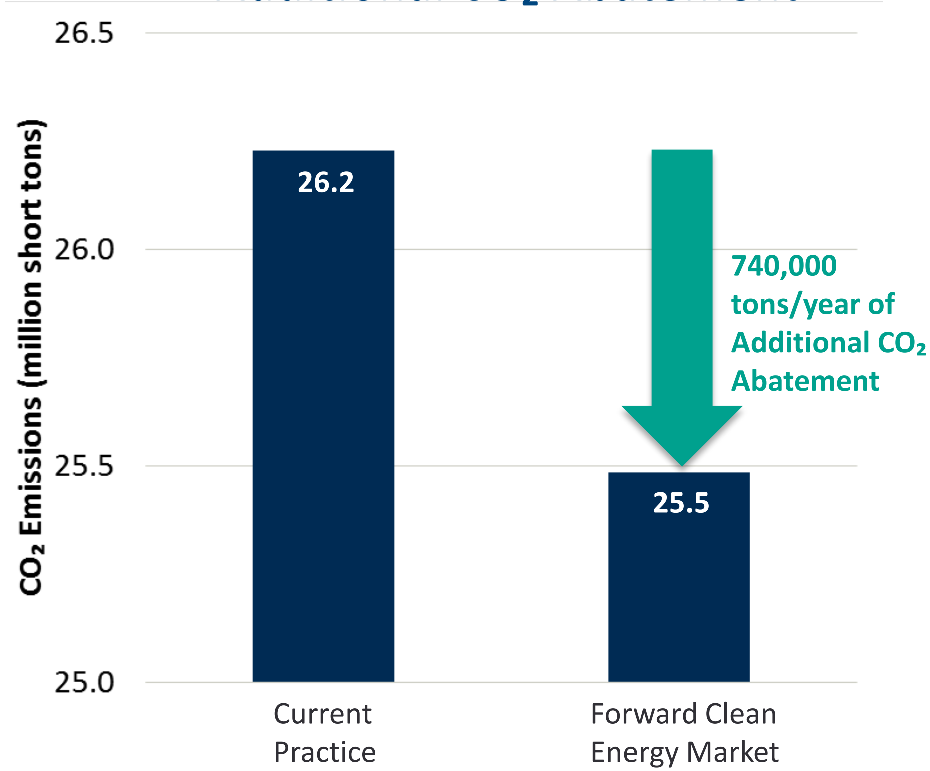
Customer Cost Savings and Emissions Reductions

Preliminary simulation shows clean energy market saves customers $450 million ($3.60/MWh) and reduces CO_2 emissions by 740,000 tons per year relative to Current Practice

Customer Cost Savings



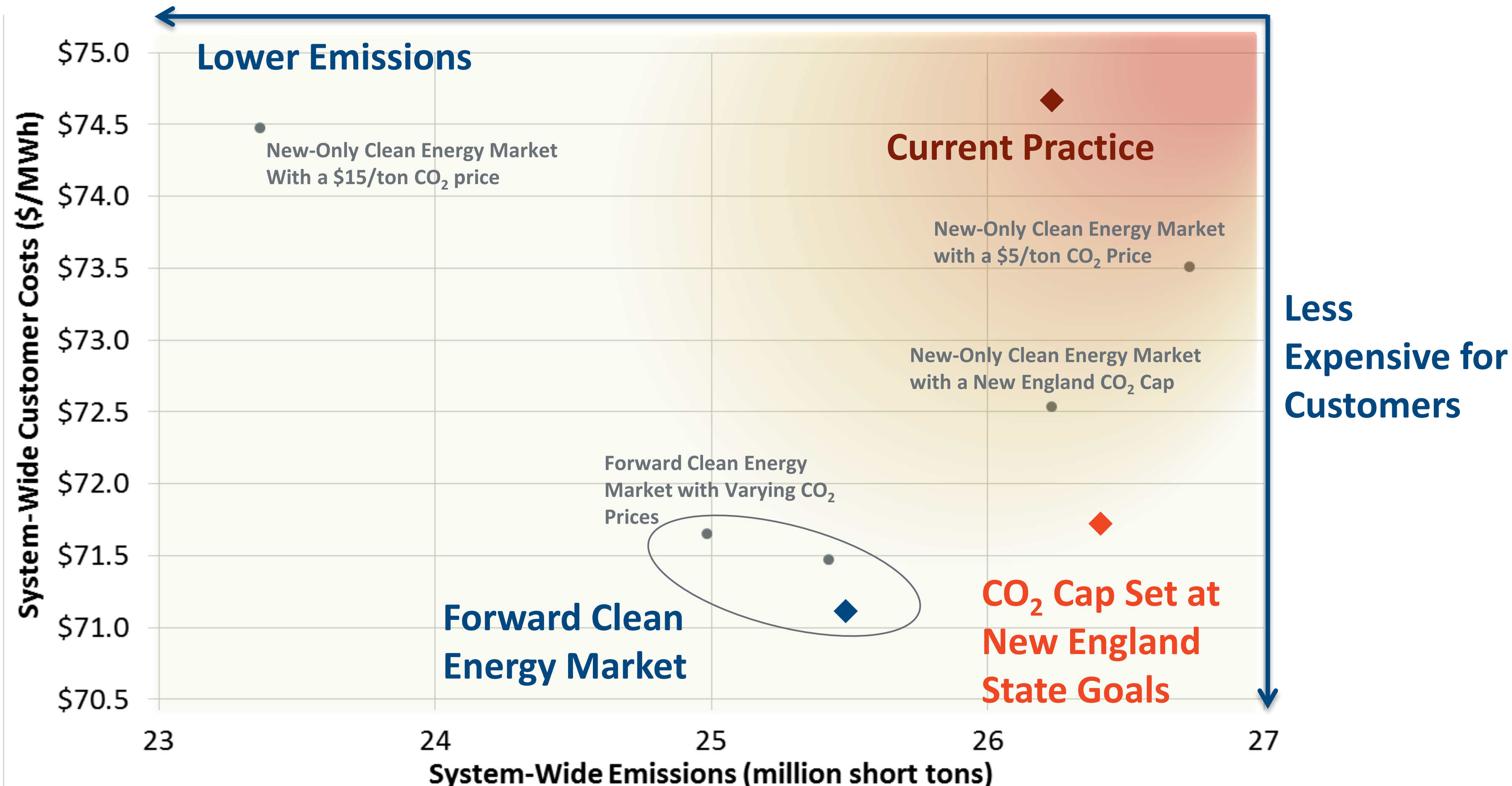
Additional CO_2 Abatement



Note: Simple average of nominal costs and emissions from 2020-2029.

Customer Cost Savings and Emissions Reductions

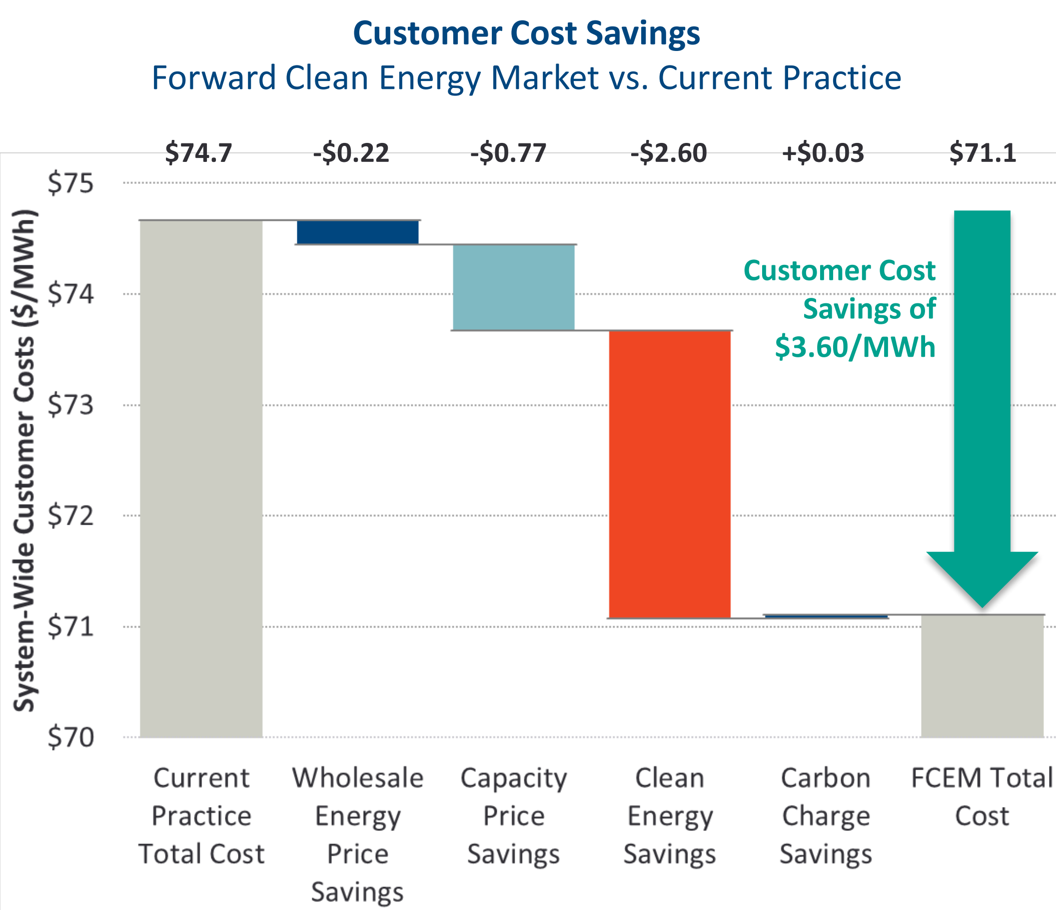
New and existing clean energy market achieves reductions while keeping customer costs lower than with other alternatives



Note: Simple average of nominal costs and emissions from 2020-2029.

Modeling

How The Market Achieves Customer Benefits



Modeled benefits:

- Clean and conventional investment cost savings
- Operating cost savings
- Customer cost savings
- Reductions in CO_2 emissions

Savings come from broad competition:

- Between new and existing generators
- Across resource types
- Across locations within New England

Modeling

Customer Benefits Detail

Customers save under the coalition's proposal through lower energy payments, lower capacity payments, and lower clean energy procurement costs (see Appendix)

		Modeled Scenarios			Delta Above (Below) Current	
		Current Practice	Regional Cap on CO_2	Two-Tier New and Existing FCEM	Regional Cap on CO_2	Two-Tier New and Existing FCEM
Customer Cost Components						
Energy	*($/MWh)*	$46.4	$50.5	$46.2	$4.1	($0.2)
Capacity	*($/MWh)*	$23.7	$24.4	$23.0	$0.7	($0.8)
Clean Energy	*($/MWh)*	$5.8	n/a	$3.2	($5.8)	($2.6)
CO_2 Revenue Rebate	*($/MWh)*	($1.2)	($3.2)	($1.2)	($2.0)	$0.0
Total Customer Costs	*($/MWh)*	$74.7	$71.7	$71.1	($3.0)	($3.6)
Per Year Total	*($million/year)*	$9,373	$9,002	$8,926	($371)	($447)
Clean Energy Produced	*(TWh)*	68.4	67.5	70.1	(0.9)	1.7
Total CO_2 Emissions	*(million tons)*	26.2	26.4	25.5	0.2	(0.7)

Benefits Not Captured in Initial Modeling

A competitive clean energy market will offer other additional benefits that we have not estimated in our modeling:

- Efficiencies attributable to **Dynamic Payments** to clean resources that encourage generation *where* and *when* it can displace most carbon
- Benefits of dispatching and attracting **storage** to displace carbon emissions
- Improved liquidity and transparency
- Benefits of a more open, competitive process such as attracting **new entrants**, **innovative solutions**, and **unanticipated emerging technologies**
- Benefits to informing more **cost-effective transmission development** for achieving policy goals
- Cost savings due to **clean resources being considered in-market** for FCM

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Next Steps

Further Developing the Design

- Working with states to establish a working group to further develop the design
- Planning a technical conference with stakeholders in 2018

Design Open Questions

- Ensuring robustness and longevity of demand for clean energy
- Transmission upgrade cost representation in offers or market clearing
- Determining auction parameters (price cap and reference emissions rate)
- Interactions with RECs and clean energy contracts (existing and future)
- Incentivizing performance (delivery obligations, reconfiguration auctions, qualification standards and quantities)

Biography and Contact Information

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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.

Kathleen earned a B.S. in Mechanical Engineering and Physics from Iowa State University. She earned an M.S. in Electrical and Computer Engineering and a Ph.D. in Engineering and Public Policy from Carnegie Mellon University.

The views expressed in this presentation are strictly those of the presenter and do not necessarily state or reflect the views of The Brattle Group.

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Ms. Judy Chang is an energy economist and policy expert with a background in electrical engineering and 20 years of experience in advising energy companies and project developers with regulatory and financial issues. Ms. Chang has submitted expert testimonies to the U.S. Federal Energy Regulatory Commission, U.S. state and Canadian provincial regulatory authorities on topics related to transmission access, power market designs and associated contract issues. She also has authored numerous reports and articles detailing the economic issues associated with system planning, including comparing the costs and benefits of transmission. In addition, she assists clients in comprehensive organizational strategic planning, asset valuation, finance, and regulatory policies.

Ms. Chang has presented at a variety of industry conferences and has advised international and multilateral agencies on the valuation of renewable energy investments. She holds a BSc. In Electrical Engineering from University of California, Davis, and Masters in Public Policy from Harvard Kennedy School, is a member of the Board of Directors of The Brattle Group, and the founding Director of New England Women in Energy and the Environment.

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About The Brattle Group

The Brattle Group provides consulting and expert testimony in economics, finance, and regulation to corporations, law firms, and governmental agencies worldwide.

We combine in-depth industry experience and rigorous analyses to help clients answer complex economic and financial questions in litigation and regulation, develop strategies for changing markets, and make critical business decisions.

Our services to the electric power industry include:

- Climate Change Policy and Planning
- Cost of Capital
- Demand Forecasting Methodology
- Demand Response and Energy Efficiency
- Electricity Market Modeling
- Energy Asset Valuation
- Energy Contract Litigation
- Environmental Compliance
- Fuel and Power Procurement
- Incentive Regulation
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- Regulatory Strategy and Litigation Support
- Renewables
- Resource Planning
- Retail Access and Restructuring
- Risk Management
- Market-Based Rates
- Market Design and Competitive Analysis
- Mergers and Acquisitions
- Transmission

Offices

BOSTON

NEW YORK

SAN FRANCISCO

WASHINGTON, DC

TORONTO

LONDON

MADRID

ROME

SYDNEY

Appendix

Design Proposal Detail

Components of the Dynamic Clean Energy Market

	Design Element
Dynamic Clean Energy Market	**Product Definition:** • Clean attribute only (not bundled with energy) • Anchor price determined in the forward auction, but realized payments scaled in proportion to marginal CO_2 emissions rate at the time and place of delivery (replicates the incentives from a CO_2 price)
	Supply and Demand: • “Base” product that includes all qualified clean resources (new and existing) • Base demand quantity should not decrease over time to provide regulatory certainty (perhaps for 10 years) • States have the option to specify “targeted” products (new resources or specific types of new resources) • Base and targeted new resources earn a price lock-in over ~7-12 years • States or their designated entities determine the quantity and price of demand bids • States can submit “contingent” demand bids for targeted resources. If the state’s bid for a newer higher-cost targeted resources does not clear, then the MWh of demand can revert to buying the cheapest “base” clean energy that is available
	Procurement Auction: • Forward clean energy auction conducted immediately prior to the FCM • Transmission development costs can be incorporated into offers or auction clearing
Carbon Pricing	• This coalition continues to recommend enhanced CO_2 pricing as a means to efficiently contribute to achieving decarbonization goals, although it is not the subject of this proposal • The dynamic clean energy market will work well in concert with enhanced CO_2 pricing, but can also be pursued on a stand-alone basis

Design

Base and "Targeted" Clean Energy Resources

	Base Resources	Targeted Resources
Qualified Resources	• All non-emitting resources • New and existing • Storage is qualified (must pay the clean price when charging, earns clean price when discharging)	• New resources • States can determine a specific technology type if desired
Price Lock-in	• 1 year for existing resources • ~7-12 years for new resources	• Targeted resources have a longer lock-in period (e.g. ~7-12 years) for cleared resources
Demand Bid Longevity	• Demand would increase, not decrease, over ~10 years • Limits placed on the size of demand reductions in future years	• Demand may exist for only 1 year and does not need to be resubmitted the following year (but any cleared resources have a price lock-in for ~7-12 years)
Entity Submitting Demand Bids	• State or designated entity (e.g. utility)	• State or designated entity (e.g. utility)
Price and Quantity	• Price-quantity pairs or sloped curve defined by state • ISO-NE to work with each state to determine what input parameters and analytical support is desired each year (e.g. estimate of clean Net CONE or needed quantities)	• Price-quantity pairs or sloped curve defined by state • ISO-NE to work with each state to determine what input parameters and analytical support is desired each year (e.g. estimate of targeted resource Net CONE)
"Contingent" Demand Bids	• n/a	• States have the option to designate bids as "contingent" • Contingent demand bids will procure "targeted" new clean resources as long as the targeted resources are available at or below the bid price. If not enough targeted supply clears, then the uncleared quantity will be procured from the lower-price "base" product • If reverting to demand for the "base" product, the price lock-in period will revert to 1 year and the demand bid can revert to a lower price

Forward Clean Energy Auction

Supply Offers

- Sellers offer in $/MWh
- Offer prices consider sellers' expectations of other revenue streams: capacity, ancillary, and energy (including CO_2 price)
- All sellers qualify as "Base", a subset of new resources can qualify as "Targeted"

Auction Clearing

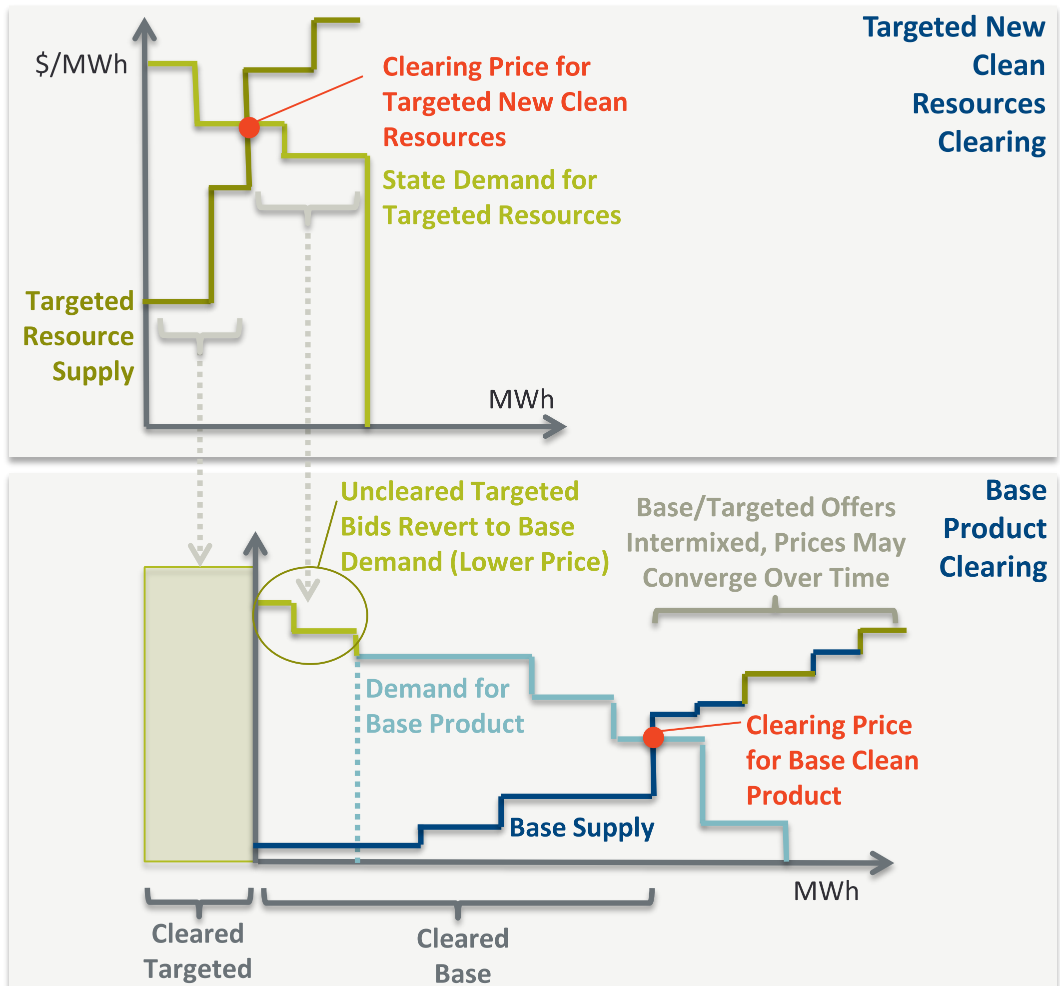
- Co-optimized clearing for all states' demand
- Conducted immediately prior to the FCM
- Uncleared clean resources have the option for a separate capacity-only offer in FCM

Cost Allocation & Supply Accounting

- States pay for their own cleared demand
- Emissions accounting: States can only take credit for clean energy procured in this auction or outside PPA (no state can claim the clean value of uncleared existing supply)

Example: Auction Clearing

Assume: Only One Targeted Category, with All "Contingent" Bids



Design

Pros and Cons of Dynamic Clean Product

Advantages	
Incentives for Clean Resources that Displace the Most CO_2 Emissions	• Clean payments scale in proportion to marginal CO_2 abatement
No Negative Offer Prices	• Unlike many types of clean energy incentives and PPAs, there are no incentives for clean energy to offer negative into the energy market
Economic Efficiency	• Incentives similar to the efficient outcomes from a CO_2 price (at least for covered resources)
Suppliers Bear Most Fundamentals-Based Investment Risk	• Locational energy price risk, fleet mix, technology change, fuel price, and load growth risks mostly borne by suppliers
Customers Take on Most Regulatory Risks	• Risk of policy certainty mostly borne by customers (via price and demand bid lock-ins and minimum payout guarantee) • Over- and under-performance risk also borne by customers
Storage Can Participate	• Storage has opportunities to participate if charge/discharge cycle displaces CO_2 emissions

Disadvantages	
Complexity	• Less intuitive and more complex than historical approaches or CO_2 pricing alone • New product and market pose implementation costs and risks
Lack of Competition between Targeted and Base Resources	• Higher-cost targeted new resources might get built while lower-cost base resource opportunities are forgone/retire • The more targeted categories are introduced, the less competition (and higher societal costs) could be incurred
Losing Some Efficiencies Compared to Enhanced CO_2 Pricing	• May forgo lower-cost CO_2 avoidance options for non-covered resources (e.g. energy efficiency, some types of DR) • No incentives for fossil plants to avoid CO_2 emissions

Example: Dynamic Clean Energy Payments

Concept: Simulate operational and investment incentives for clean energy that mimics the incentives from a CO_2 price

- Clean energy payment is additive to energy payments (not a bundled product)
- Product definition assumes a pre-defined Reference Emissions Rate (e.g. 1,100 lbs/MWh), based on the average marginal emissions rate in the last delivery year (across all delivered clean MWh)
- Realized payments scale dynamically in proportion to marginal emissions displacement at the time and place of delivery (i.e. proportional to the CO_2 component of LMP)
- Sellers displacing more CO_2 earn proportionally higher payments per MWh for the clean product (and in the energy market with CO_2 price), sellers displacing less CO_2 earn less
- Clean energy buyers take on the risk of over- and under-performance in aggregate

Example: Clean Energy Incentives

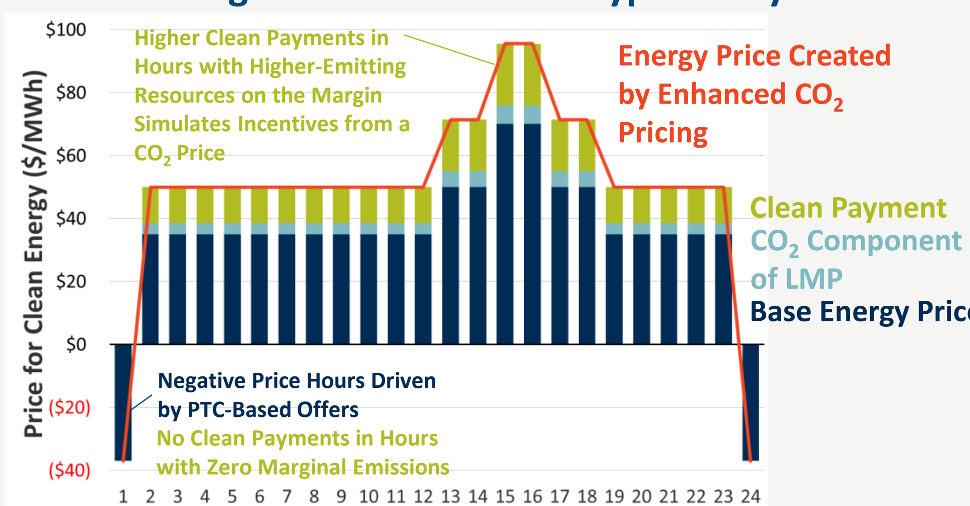
Market and Product Parameters

Reference Emissions Rate	1,100 *(lbs/MWh*
CO_2 Price in Energy Market	$7 *($/ton)*
Clean Energy Anchor Price	$13 *($/MWh)*
Simple Average Energy Price	$38 *($/MWh)*

Realized Revenue

		Wind	Solar
Base Energy Payments	*($/MWh)*	$24	$49
CO_2 Component of LMP	*($/MWh)*	$3	$4
Clean Energy Payments	*($/MWh)*	$10	$14
Total	***($/MWh)***	**$37**	**$67**
Avoided Emissions Rate	***(lbs/MWh)***	**869**	**1,231**

Marginal Incentives in a Typical Day



Appendix

Detailed Modeling Assumptions and Results

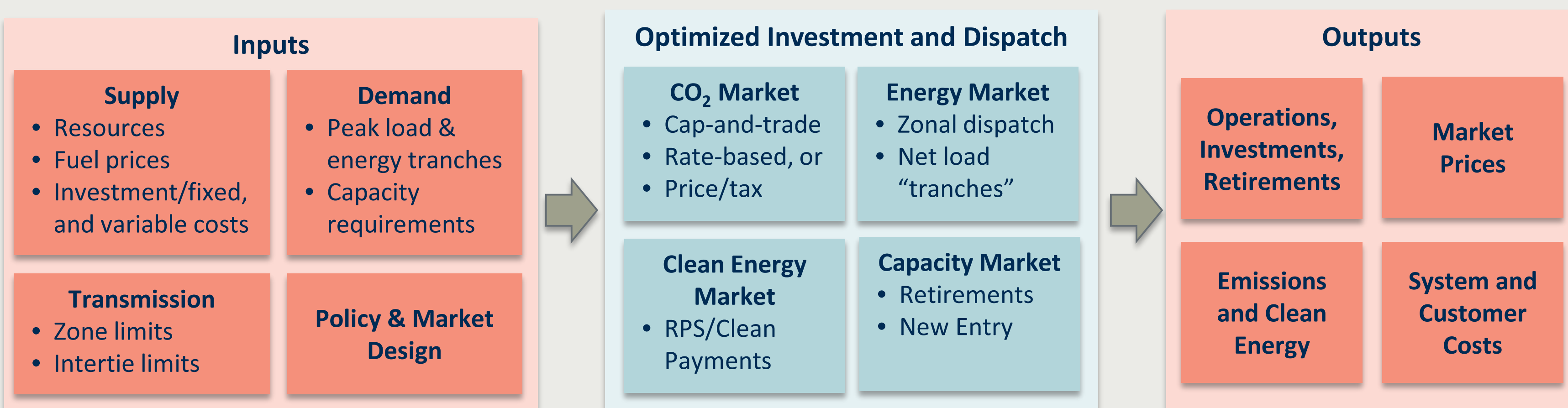
Modeling Framework

- We use an expansion modeling tool CO_2 SIM that models electricity markets and CO_2 policies
- Can be used to evaluate investments, retirements, emissions, customer costs, and system costs under different market designs and CO_2/clean energy policies

Assumptions and Simplifications

- Study of 2016-2050 (focus on results 2020-2030)
- Seasonal periods, with 50 load and clean energy supply tranches each year
- Imports, exports, and hydro modeled as fixed profiles
- No storage modeling
- One weather year for all load and clean energy profiles
- Capacity requirements at vertical demand curve (no sloping curve), no representation of Performance Incentives (PI)

- CO_2 Scenario Impact Model (CO_2 SIM)



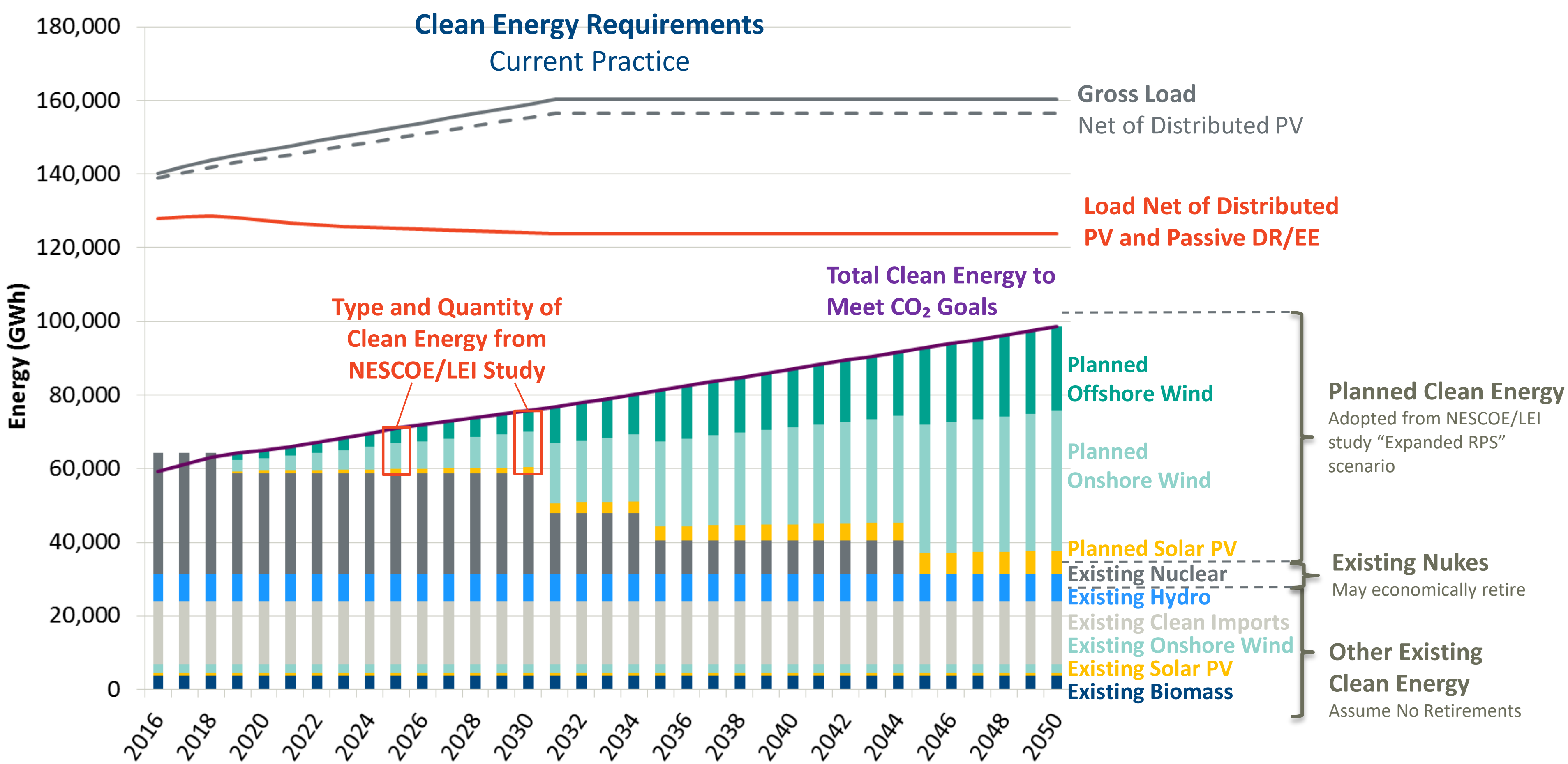
Modeling

Design Alternatives for Meeting CO_2 Targets

Design Concept	Clean Energy Market	CO_2 Pricing
1. Current Practice	• Intended to reflect current clean energy procurement practices • Pre-defined quantity of clean resources • Pre-defined technology types	\$5/ton RGGI CO_2 market price (assumption from NESCOE/LEI study)
2. CO_2 Cap	• None	CO_2 cap imposed on New England, consistent with aggregate target across states
3. New-Only Clean Energy Market	• Market for new clean energy • Eligible to earn payments for first 10 years after online date • Existing resources awarded no payments	Sub-cases with three different CO_2 prices: 3a. \$5/ton RGGI Price 3b. \$15/ton CO_2 Price (Enhanced RGGI) 3c. CO_2 Cap to Meet Targets
4. Two-Tier New/Existing Clean Energy Market	• Two-tier market awarding different payment levels to new and existing clean energy resources • New resources earn higher payments for the first 10 years • Existing resources earn lower payments for helping to meet total clean energy goals • **Most similar to this coalition's FCEM proposal, except that clean energy payments are indifferent to time and place (no dynamic profiling)**	Sub-cases with three different CO_2 prices: 3a. \$5/ton RGGI Price 3b. \$15/ton CO_2 Price (Enhanced RGGI) 3c. CO_2 Cap to Meet Targets

1. Current Practice: Clean Energy Targets

Approach is to procure a pre-defined quantity of a specific resource type



Sources and Notes:

Existing clean energy reflects 2016 ISO-NE generation, planned clean energy based on LEI/NESCOE study's Expanded RPS Scenario extrapolated to meet state CO_2 targets.

Current Practice clean energy targets are resource-specific, based on LEII study (extrapolated to 2050) and consistent with tri-state RFP, MA 83D (offshore wind), and MA 83C (9.5 TWh/year, assumed to be non-imported RPS-eligible)

Requirements assume specific nuke retire dates, but economics can driver earlier (or later) retirement dates

Modeling

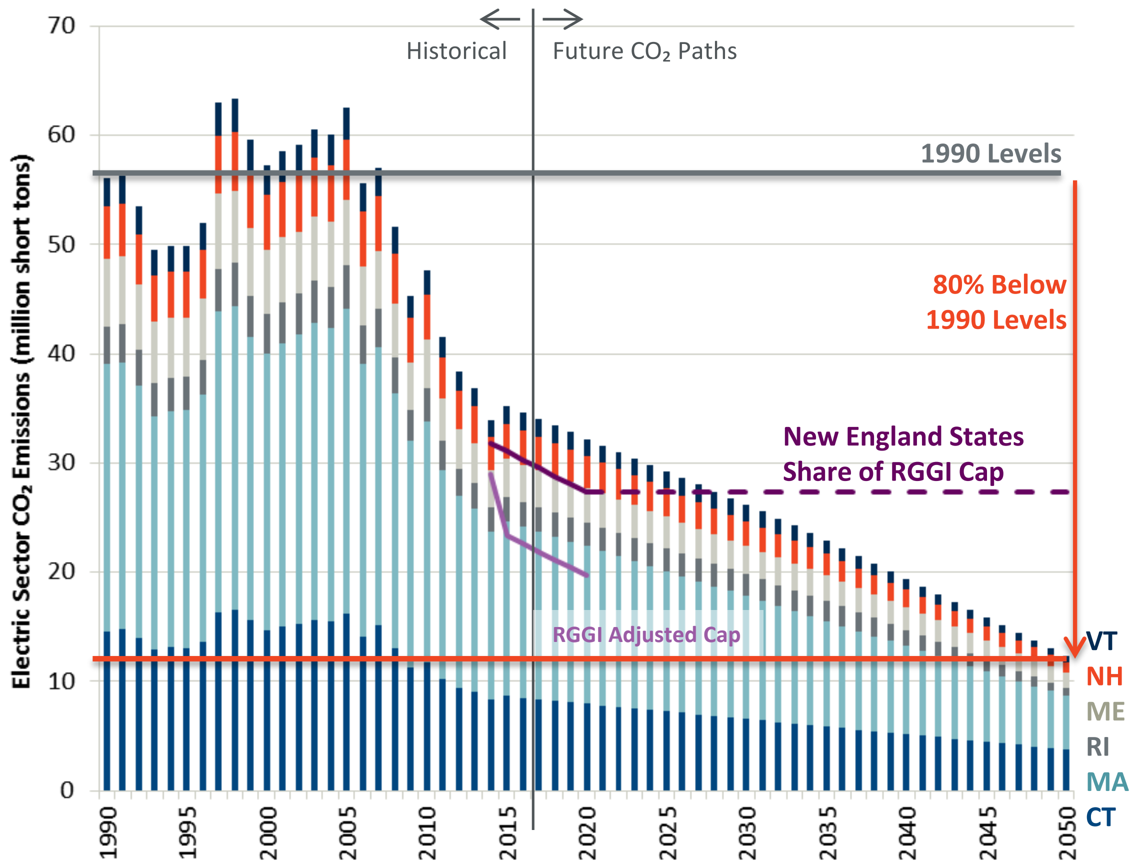
2. CO_2 Cap: System-Wide Reduction Target

- For the CO_2 cap scenario we adopt a system-wide electricity sector reduction target consistent with state goals
- In other scenarios, this same target is translated into a clean energy goal

New England Economy-Wide CO_2 Emissions Reduction Goals

State	Mandate?	GHG Targets
VT	Non-mandated	40% below 1990 levels by 2030, 80-95% below by 2050.
NH	Non-mandated	20% below 1990 levels by 2025, 80% below by 2050.
ME	Non-mandated	10% below 1990 levels by 2020, 75-80% below 2003 levels by 2050.
RI	Non-mandated	10% below 1990 levels by 2025, 45% below by 2035, and 80% below by 2050.
MA	Mandated	10-25% below 1990 levels by 2020, interim targets for 2030 and 2040 (TBD), and 80% below by 2050.
CT	Mandated	10% below 1990 levels by 2020, 75-85% below 2001 levels by 2050.

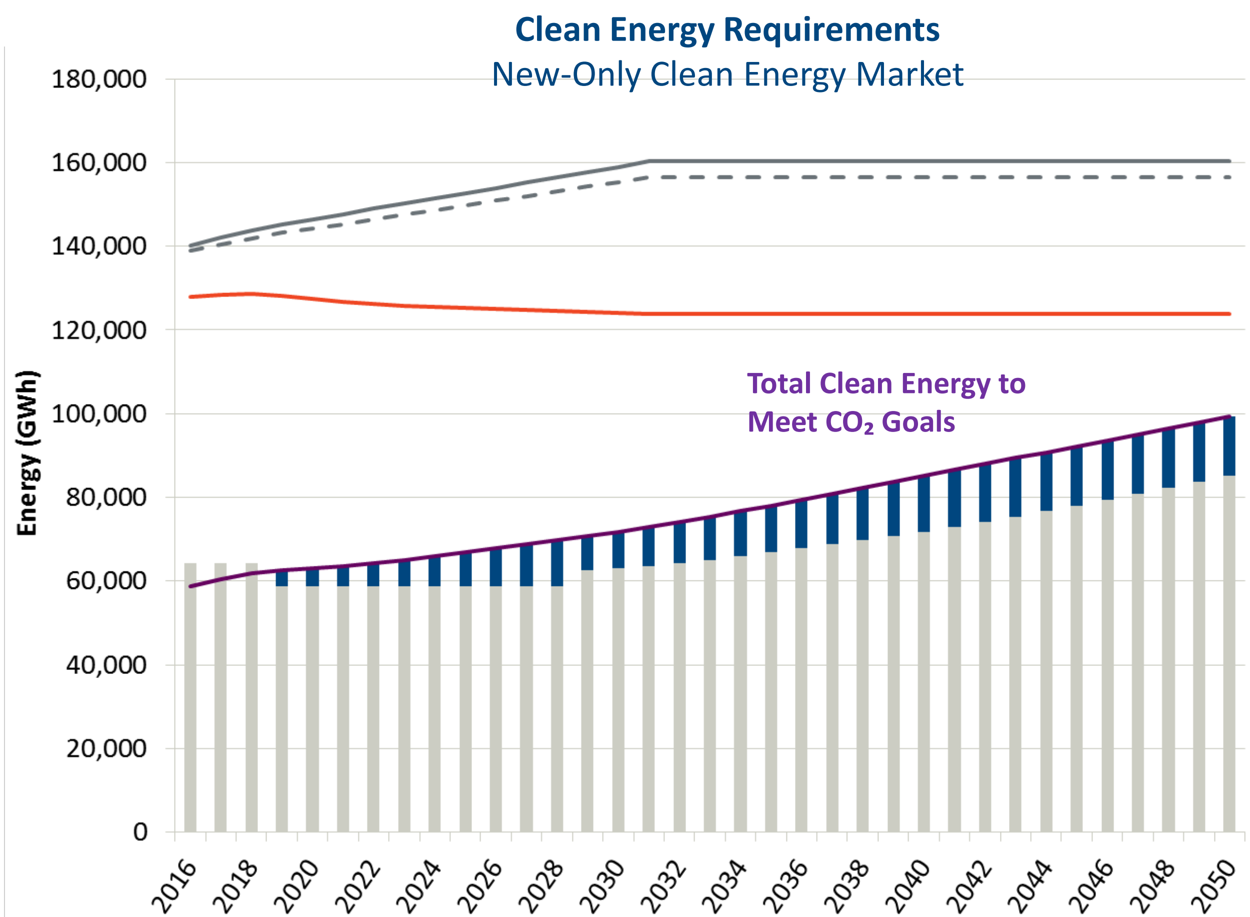
Historical Electric Sector CO_2 Emissions and Future Targets



Sources: EIA, U.S. Electric Power Industry Estimated Emissions by State (EIA-767, EIA-906, EIA-920, and EIA-923). https://www.eia.gov/electricity/data/state/
ISO-NE, http://isonewswire.com/updates/2017/3/1/the-new-england-states-have-an-ongoing-framework-for-reducin.html

3. New-Only: Clean Energy Targets

Approach is to procure a specific quantity of new clean resources (technology-neutral). New resources earn New Clean Energy payments for the first 10 years.



Gross Load
Net of Distributed PV

Load Net of Distributed PV and Passive DR/EE

New Clean Energy Requirement
- Remain New for the First 10 Years After Online Date
- Earn clean energy payments of New Clean Energy price (plus energy and capacity)

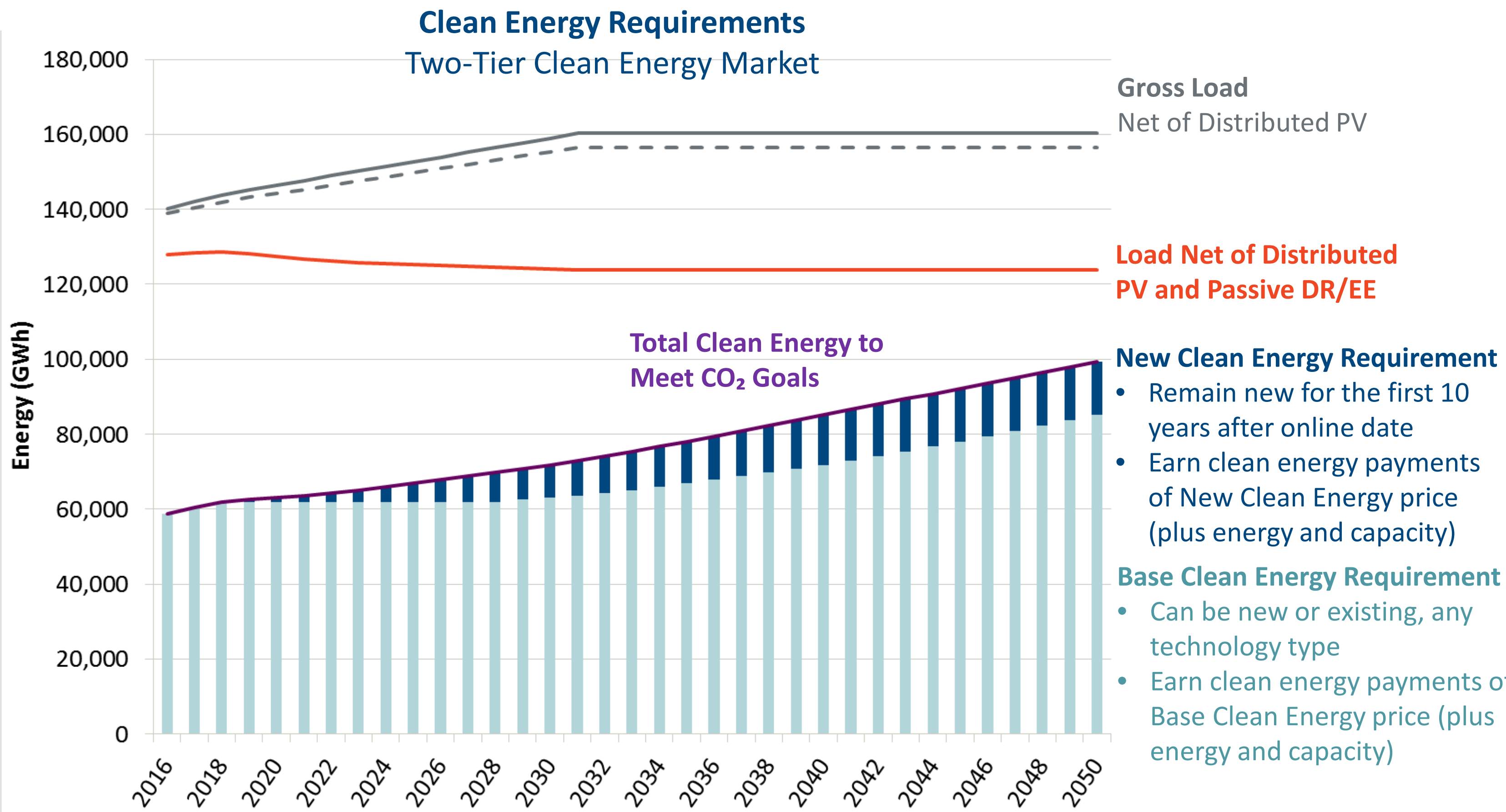
Existing Clean Energy Assumption
- Do not earn any clean energy payments (but do earn energy and capacity revenues)
- Not a modeled constraint. Design may achieve more or less than this projected quantity

Sources and Notes:
Existing clean energy reflects 2016 ISO-NE generation, planned clean energy based on LEI/NESCOE study's Expanded RPS Scenario extrapolated to meet state CO_2 targets.
Total clean energy needed to meet carbon goals is the same as Current Practice (purple line), but imposed on a resource-neutral basis
Ineligible existing clean energy resources do not earn any clean energy payments, may retire based on economics

Modeling

4. Two-Tier Market: Clean Energy Targets

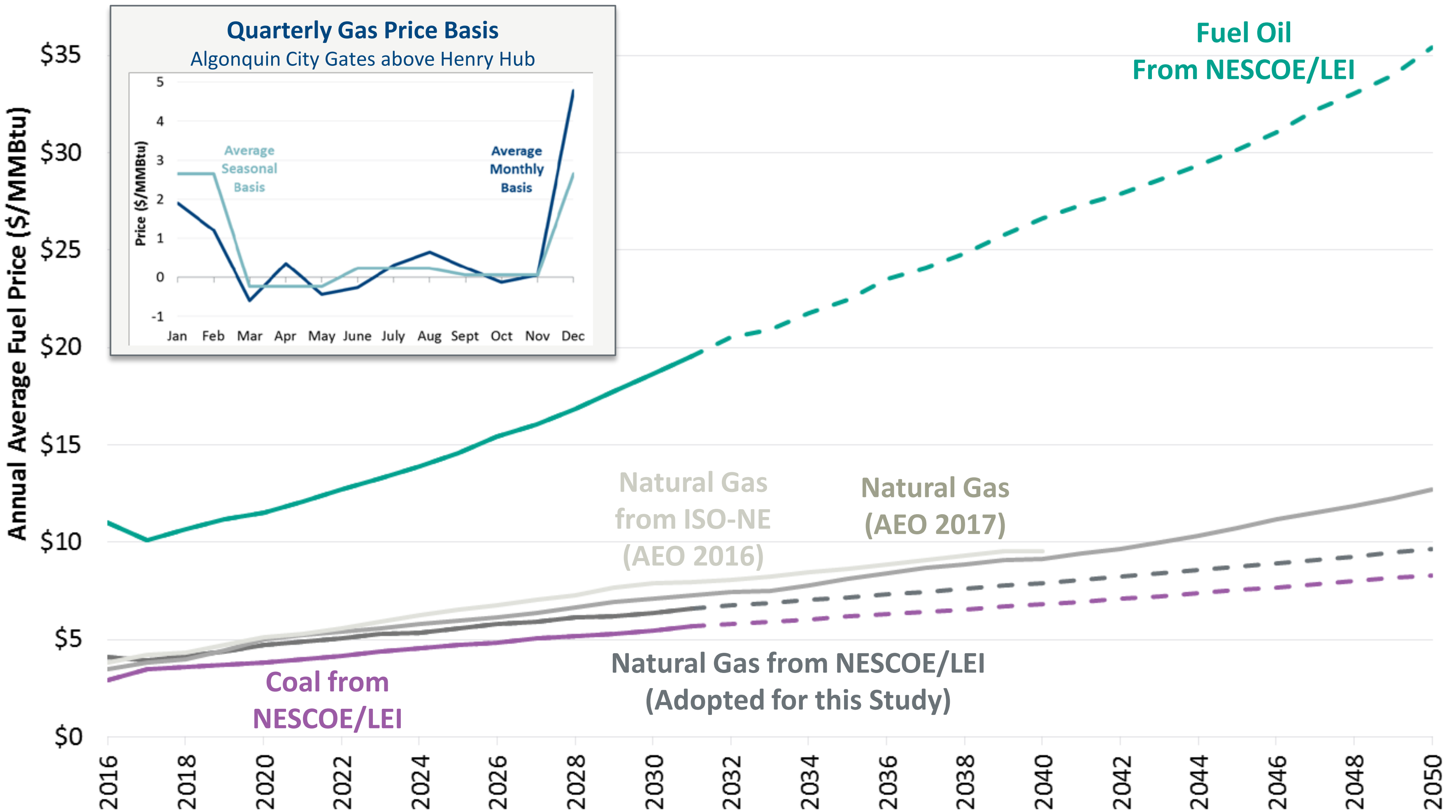
Two-tier market with new resources earning higher payments for the first 10 years. Existing resources help meet the total clean energy need, but earn a lower price.



Sources and Notes:
Existing clean energy reflects 2016 ISO-NE generation, planned clean energy based on LEI/NESCOE study's Expanded RPS Scenario extrapolated to meet state CO_2 targets.
All clean resources paid the Base price, so fewer expected retirements mean that the new clean energy requirement can be lower than in New-Only Scenario.

Modeling

Fuel Prices



Source and Notes: Fuel oil, natural gas, and coal prices until 2030 adapted from NESCOE/London Economics International's *Renewable and Clean Energy Scenario Analysis and Mechanisms 2.0 Study.* After 2030, prices are grown at inflation for coal and natural gas and at the EIA 2017 Annual Energy Outlook (AEO) forecast growth rate for fuel oil. Natural gas prices as forecasted in the 2016 and 2017 AEO are also shown for comparison.

Existing Plant Going-Forward Costs

- Known retirements consistent with FCM results and owner announcements
- Existing fossil steam plants can retire economically based on going-forward costs
- Nuclear plants can retire economically (forced retirement at 60 years). Significant uncertainty exists in these costs and consequently in potential retirement risks and dates

Existing Nuclear

		Seabrook	Millstone 2	Millstone 3	Pilgrim
Capacity	*(ICAP MW)*	1,329	941	1,394	684
Capacity Factor	*(%)*	90%	90%	90%	90%
Age	*(years)*	26	41	31	44
Forced Retirement	*(year)*	2051	2036	2046	2019
Fuel Costs	*(2017$/MWh)*	$8.57	$8.57	$8.57	$8.57
FOM and CapEx by Plant Age					
30	*(2017$/MWh)*	$22	$22	$22	$22
40	*(2017$/MWh)*	$25	$25	$25	$25
50+	*(2017$/MWh)*	$35	$35	$35	$35

Source and Notes: Cost are based analysis of NEI's April 2017 Nuclear Costs in Context. We assume nuclear plants (with the exception of Pilgrim) retire after 60 years in service, or earlier if going-forward costs exceed market revenues.

Existing Fossil Plants

FOM + Capex

Plant Age		Gas/Oil ST	Coal ST
30	*(2017$/ICAP kW-yr)*	$23	$53
40	*(2017$/ICAP kW-yr)*	$39	$67
50	*(2017$/ICAP kW-yr)*	$65	$85
60	*(2017$/ICAP kW-yr)*	$109	$109

Source and Notes: Costs at age 30 are from EPA IPM assumptions, increase with plant age.

New Resource Investment Costs & Assumptions

- Model determines least-cost combination of new entry to meet clean energy, capacity, and energy needs
- Consider new entry from Gas CCs/CTs, onshore wind, offshore wind, PV, and demand response
- We use NESCOE/LEI assumptions for renewable costs; we use capacity factors from ISO-NE's 2017 ORTP/CONE study
- Fossil plants costs based on the ORTP and parameters from the 2017 ORTP/CONE study

New Renewables

Levelized Costs

	2025 (2017$/kW-yr)	2030 (2017$/kW-yr)
Onshore Wind	$240	$226
Offshore Wind	$616	$552
Solar	$168	$148

Capacity Factors

	Onshore Wind	Offshore Wind	Solar
CT	34%		15%
MA	34%	42%	16%
ME	38%	40%	14%
NH	32%		16%
RI	31%	42%	15%
VT	34%		15%

Source and Notes: Costs from the NESCOE/LEI Report and represent costs in NH for onshore wind and solar and SEMA for offshore wind. Adjustments were made to reflect the regional costs based on the EIA's November 2016 Capital Cost Estimates for Utility Scale Electricity Generating Plants.
Capacity factors are from the ORTP/CONE study, adjusted to the state level using NREL data. We extrapolate prices prior to 2030 using the implied growth rate. The expectation is after 2030, where we reduce the prices from $100/MWh (pre PTC) in 2016 to 2025 levels. After 2030 we keep the costs constant in real terms after 2030.

New Fossil Plants

		CC	CT
Baseload Capacity	*(ICAP MW)*	491	338
Capacity w/ Duct firing	*(ICAP MW)*	533	
Baseload Heat rate	*(Btu/kWh)*	6,381	9,220
Heat rate w/ Duct firing	*(Btu/kWh)*	6,546	
Levelized Gross Cost	*($2017/ICAP kW-yr)*	$149	$109
VOM	*($2017/MWh)*	$3.23	$4.16

Source and Notes: Based on the ORTP values and Plant parameters used in ISO-NE's CONE and ORTP Updates filing in January 2017. Numbers presented are for the SEMA capacity region. Adjustments were made to other zones to reflect the regional costs based on the EIA's November 2016 Capital Cost Estimates for Utility Scale Electricity Generating Plants.

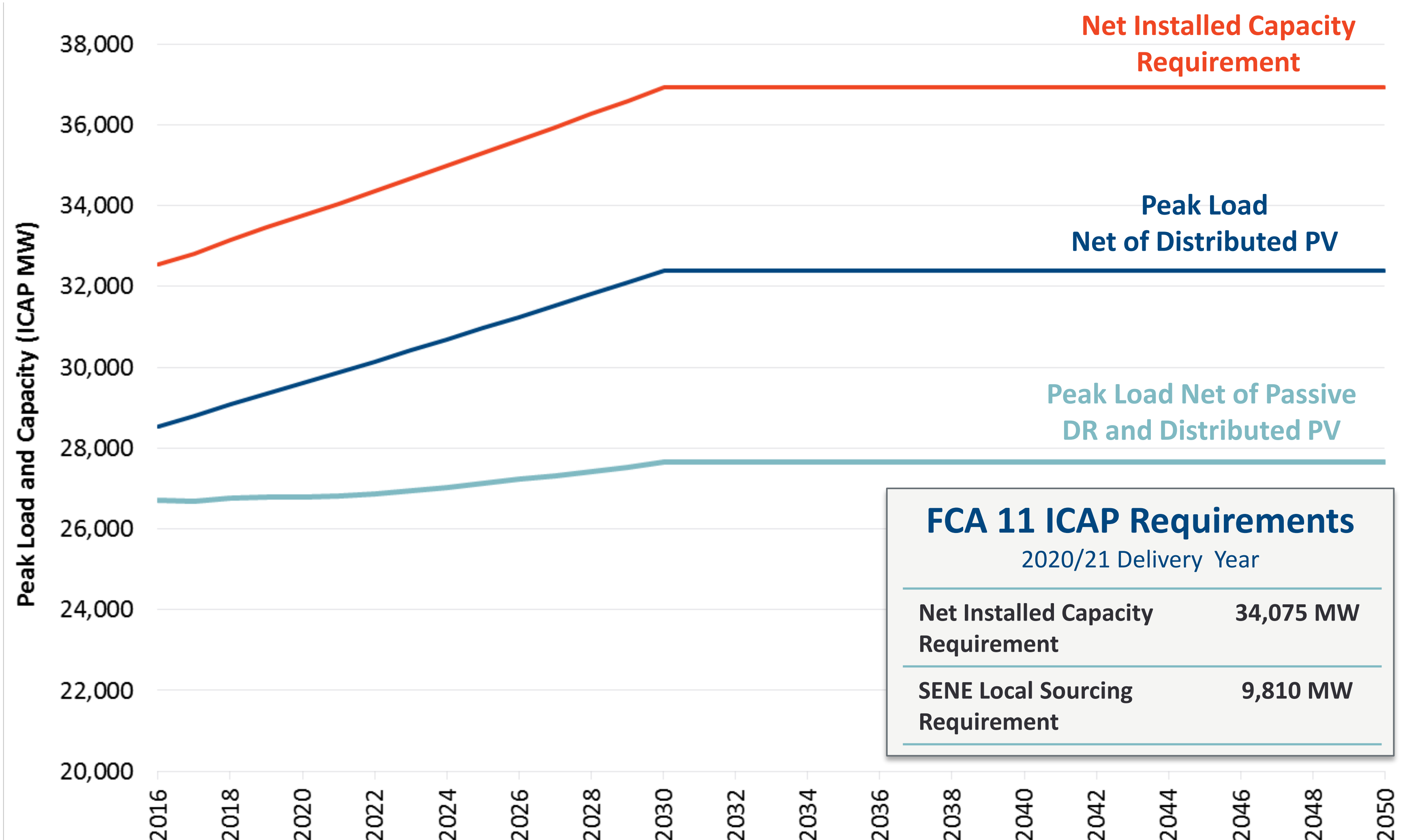
Demand Response

		Inexpensive	Middle	Expensive
Percent of Peak Load	*(%)*	0-12%	12-16%	16-24%
Levelized Gross Cost	*($2017/ICAP kW-yr)*	$37	$92	$135
VOM	*($2017/MWh)*	$1,000	$2,000	$3,000

Source and Notes: Assumptions developed based on FCM results and other studies.

Modeling

Demand



FCA 11 ICAP Requirements

2020/21 Delivery Year

Net Installed Capacity Requirement	34,075 MW
SENE Local Sourcing Requirement	9,810 MW

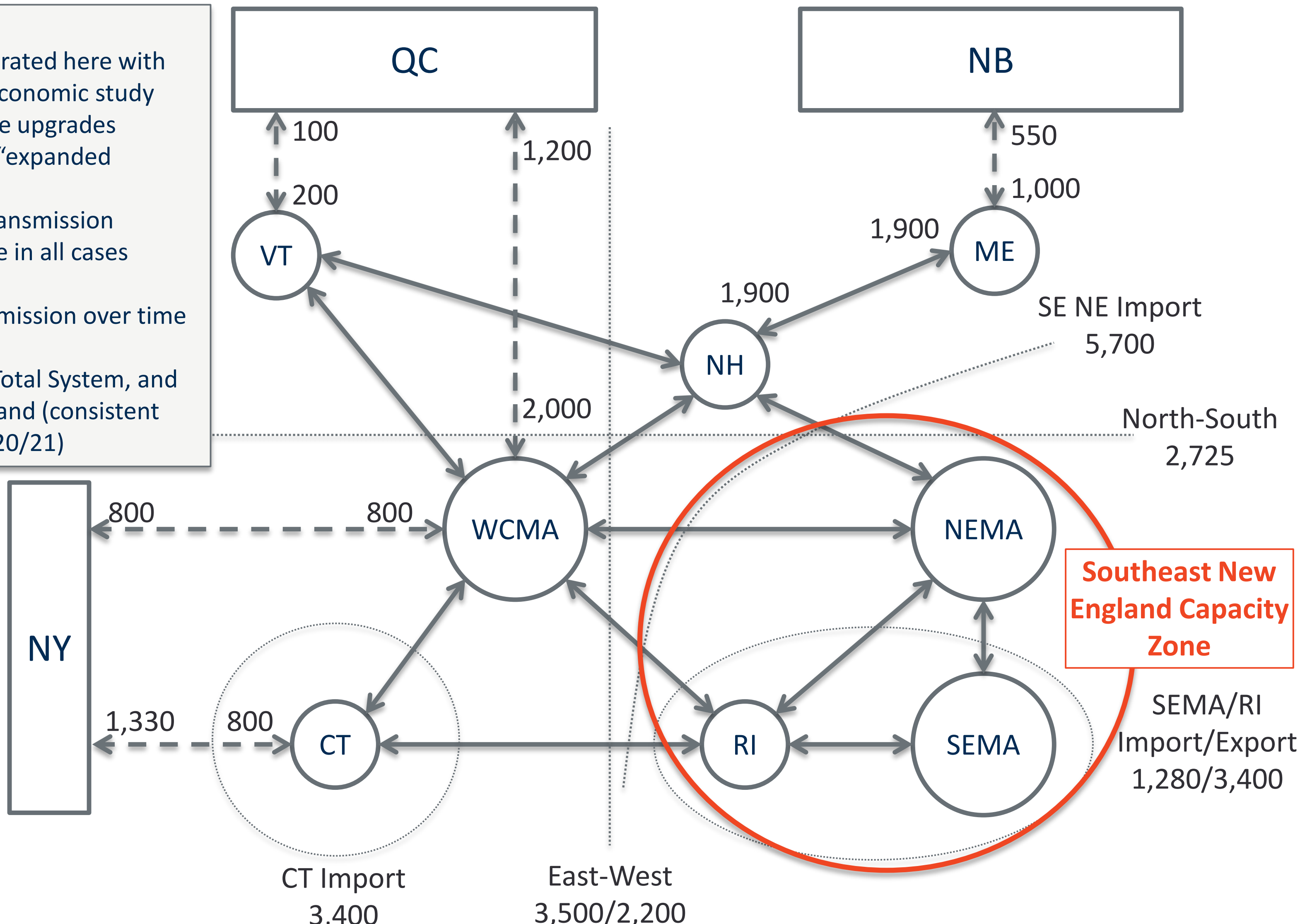
Source and Notes: ISO-NE *2016-2025 Forecast Report of Capacity, Energy, Loads, and Transmission*. FCA requirements grow proportional to system (or local) peak load.

Modeling

Transmission

Energy Market
- Zonal model as illustrated here with limits from ISO-NE economic study
- No additional intertie upgrades (consistent with LEI "expanded renewables" case)
- Add 2,400 MW of transmission upgrades with Maine in all cases (from LEI study)
- No changes to transmission over time

Capacity Market
- Two requirements: Total System, and Southeast New England (consistent with FCA #11 for 2020/21)

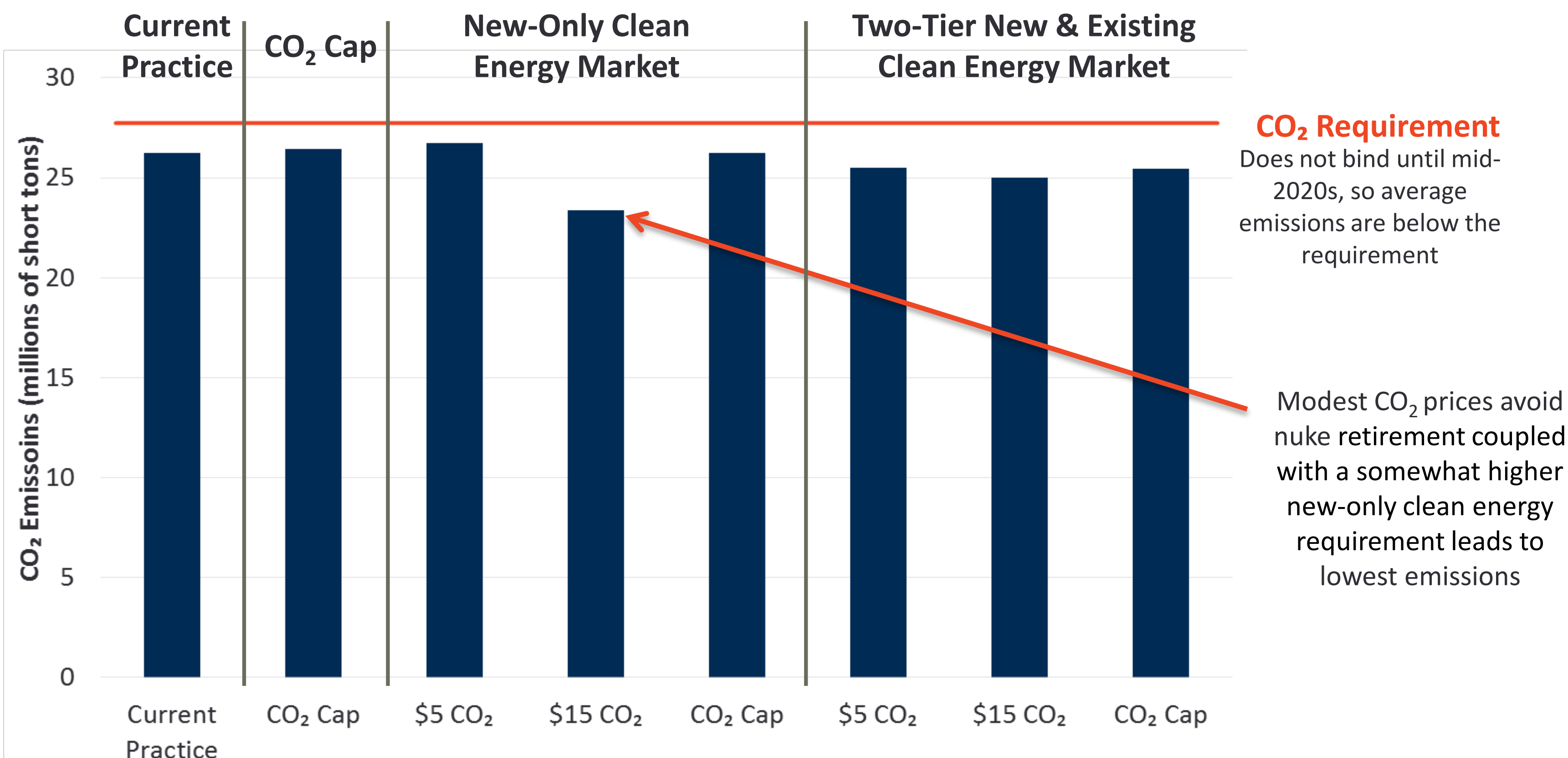


Source: Adapted from 2016 ISO-NE Economic Study

Modeling

Annual Average CO_2 Emissions (2020-2029)

- By design, average annual simulated average CO_2 emissions are similar across scenarios
- However, there are some differences due primarily to the imprecision in translating from the CO_2 target to the MWh of clean energy requirements (e.g. "new-only" cases do not always accurately predict timing of nuclear retirements)

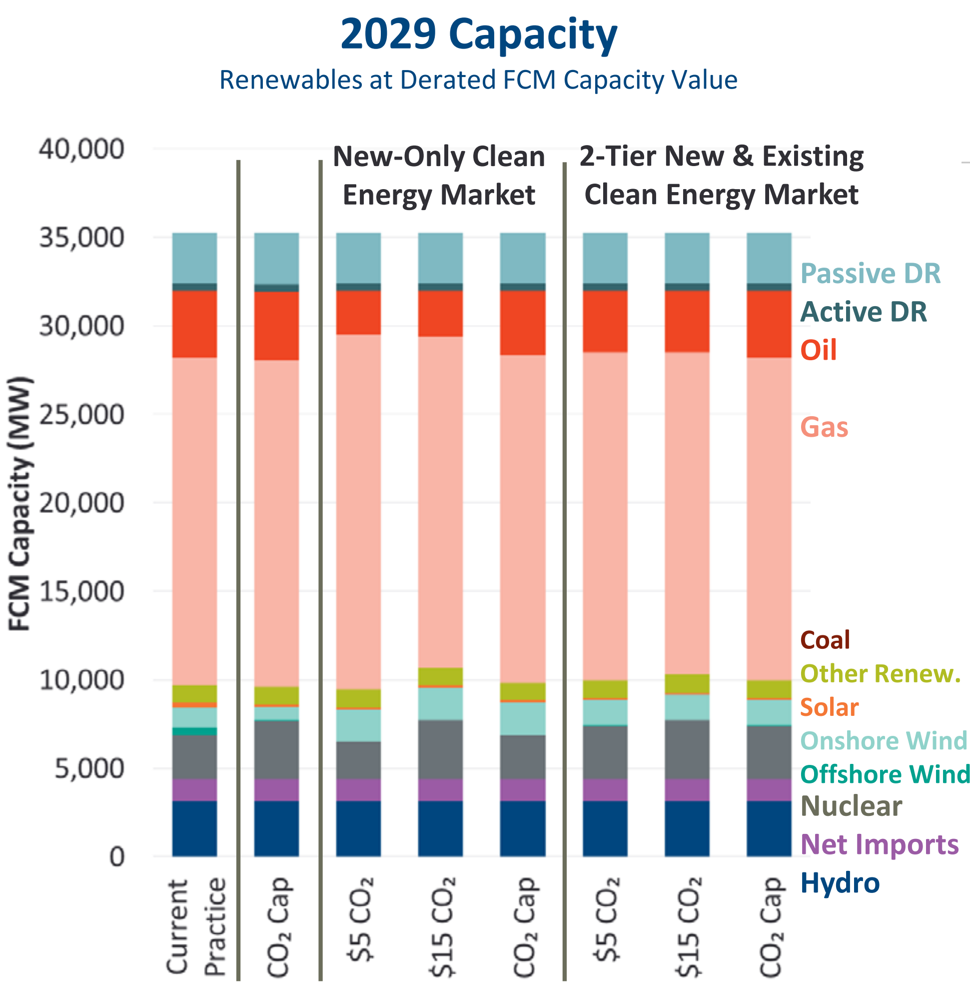


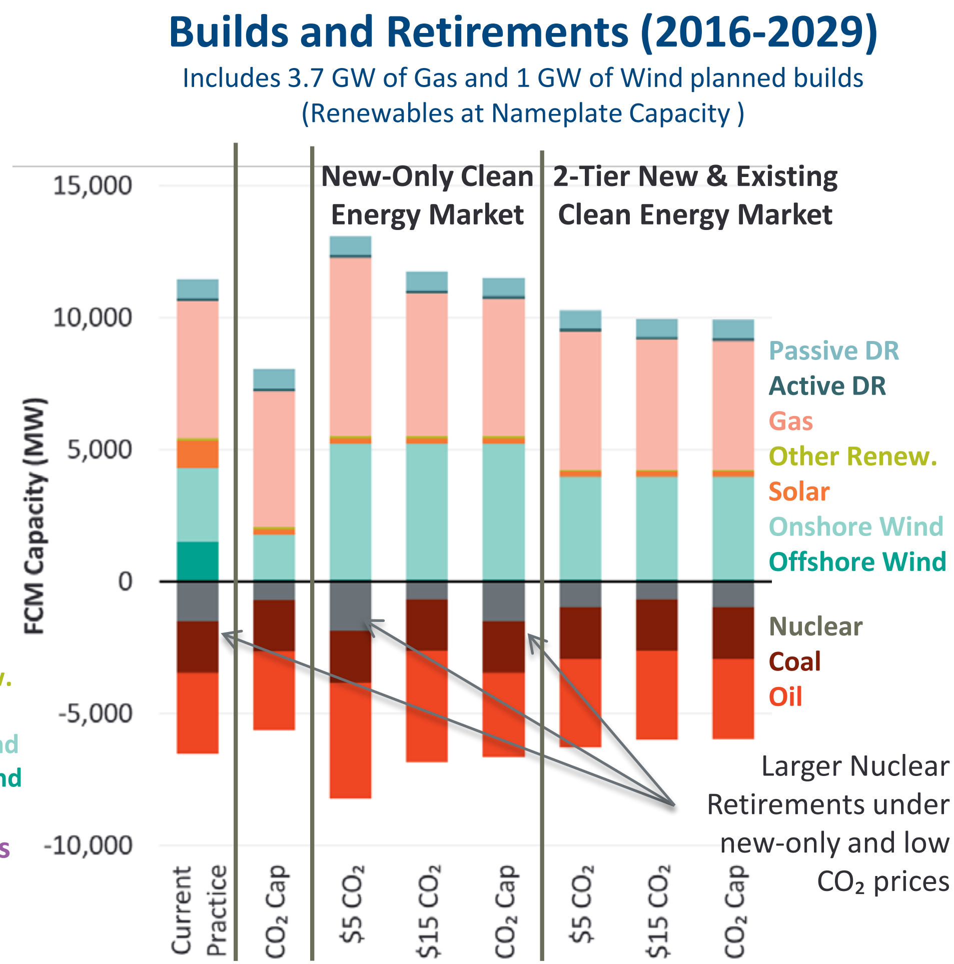
Note: Simple average from 2020-2029.

Modeling

Capacity Additions and Retirements

More new clean energy is built in the New-Only and Current Practice cases in order to replace nuclear retirements

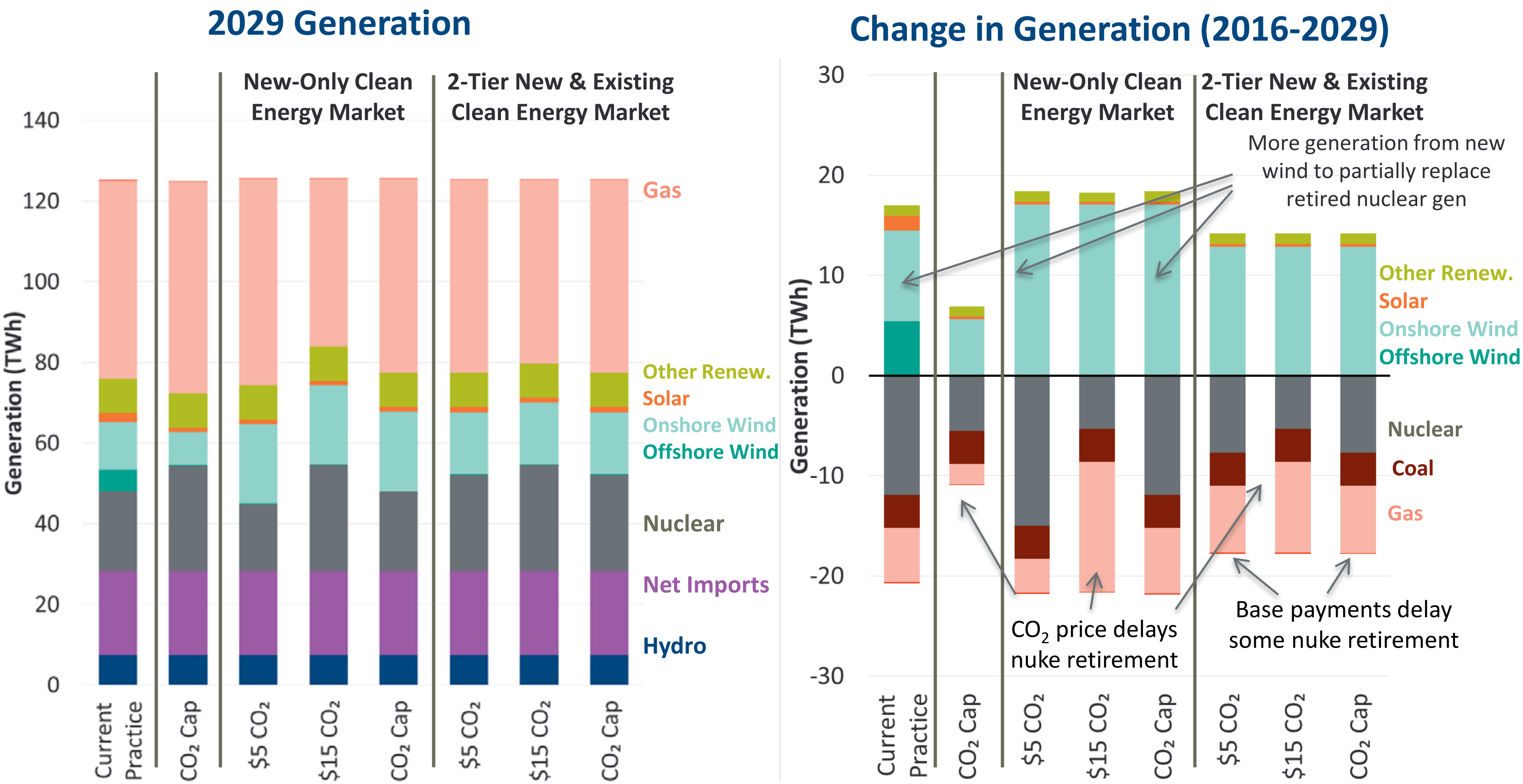




Modeling

Generation Output

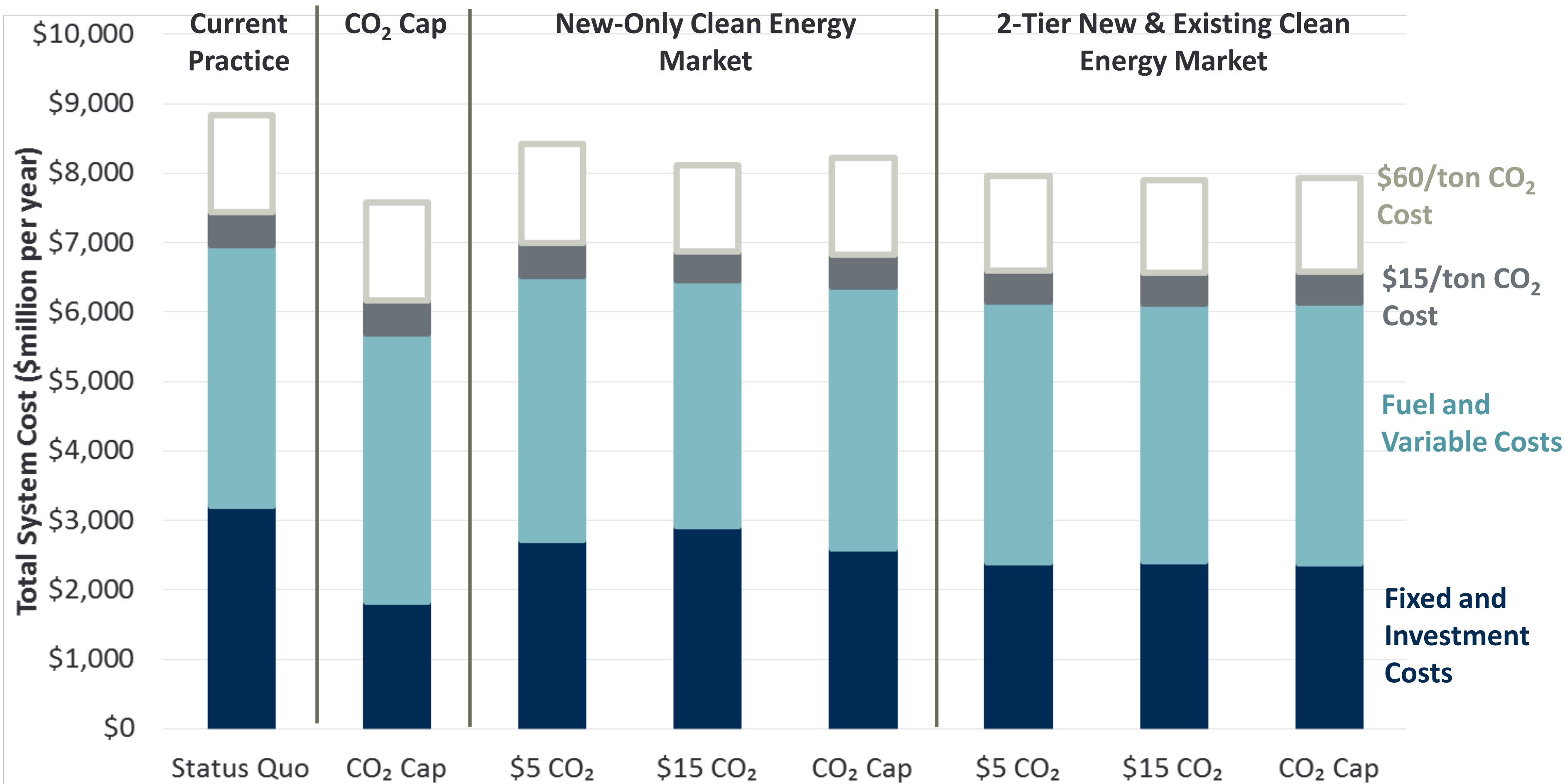
New clean resources primarily displace fossil generation, but must also replace clean generation from retiring nukes in the Current Practice and New-Only cases



Modeling

Societal Costs with CO_2 Costs

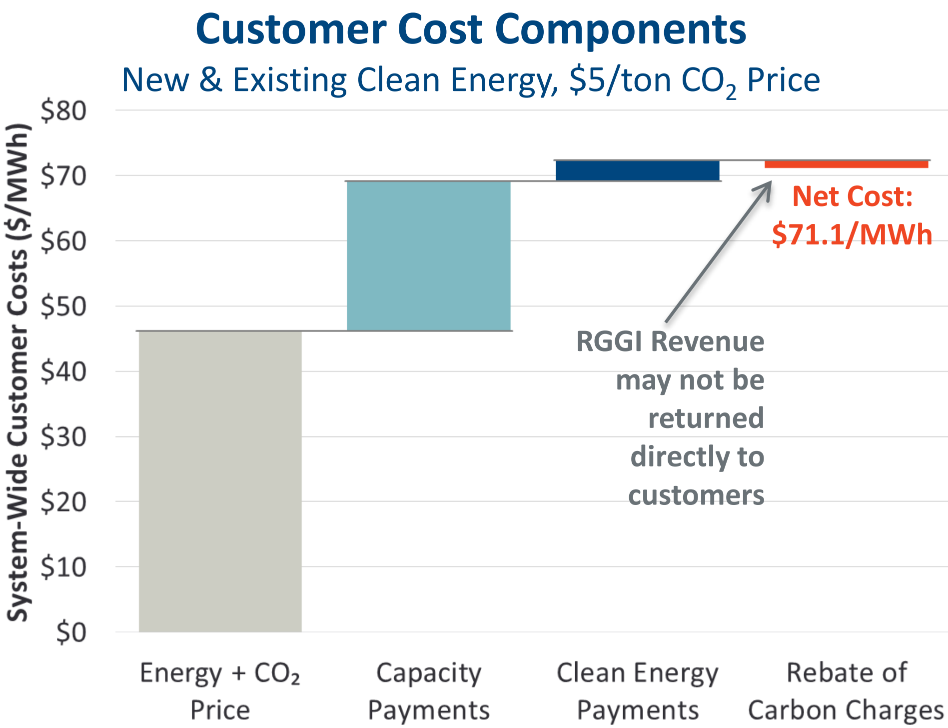
- Societal costs are lowest with a CO_2 Cap and highest with Current Practice.
- Two-tier market is second most efficient, and would achieve lower costs if it also incorporated a dynamic clean energy product

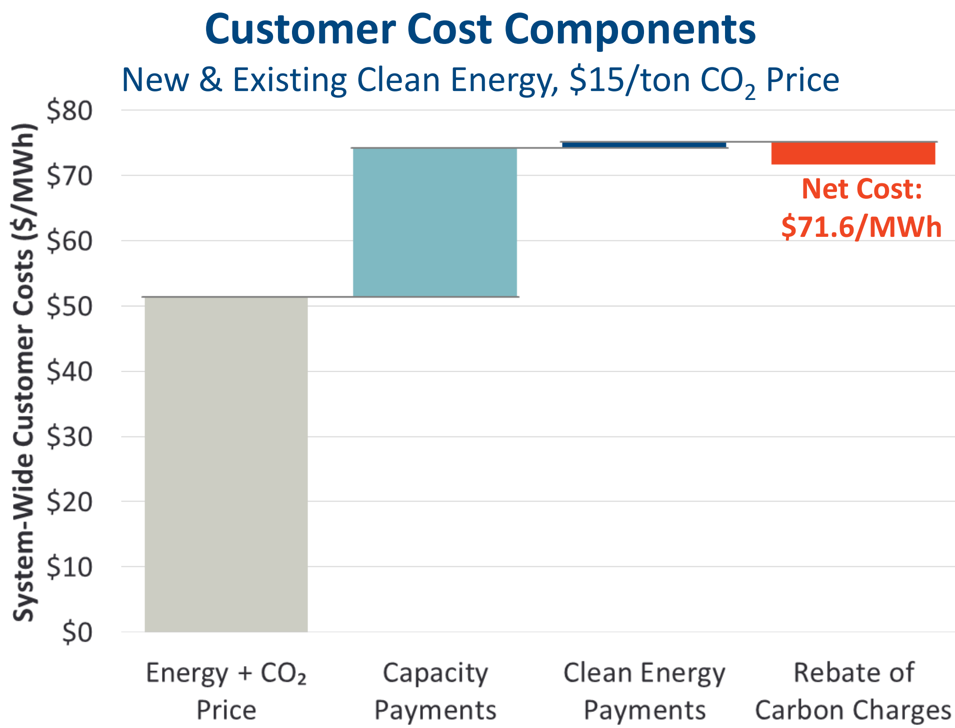


Notes: Simple average of nominal costs from 2020-2029.

Customer Cost Components

Energy, capacity, and clean energy payments are assessed to customers, with an offset from rebating CO_2 revenues from RGGI



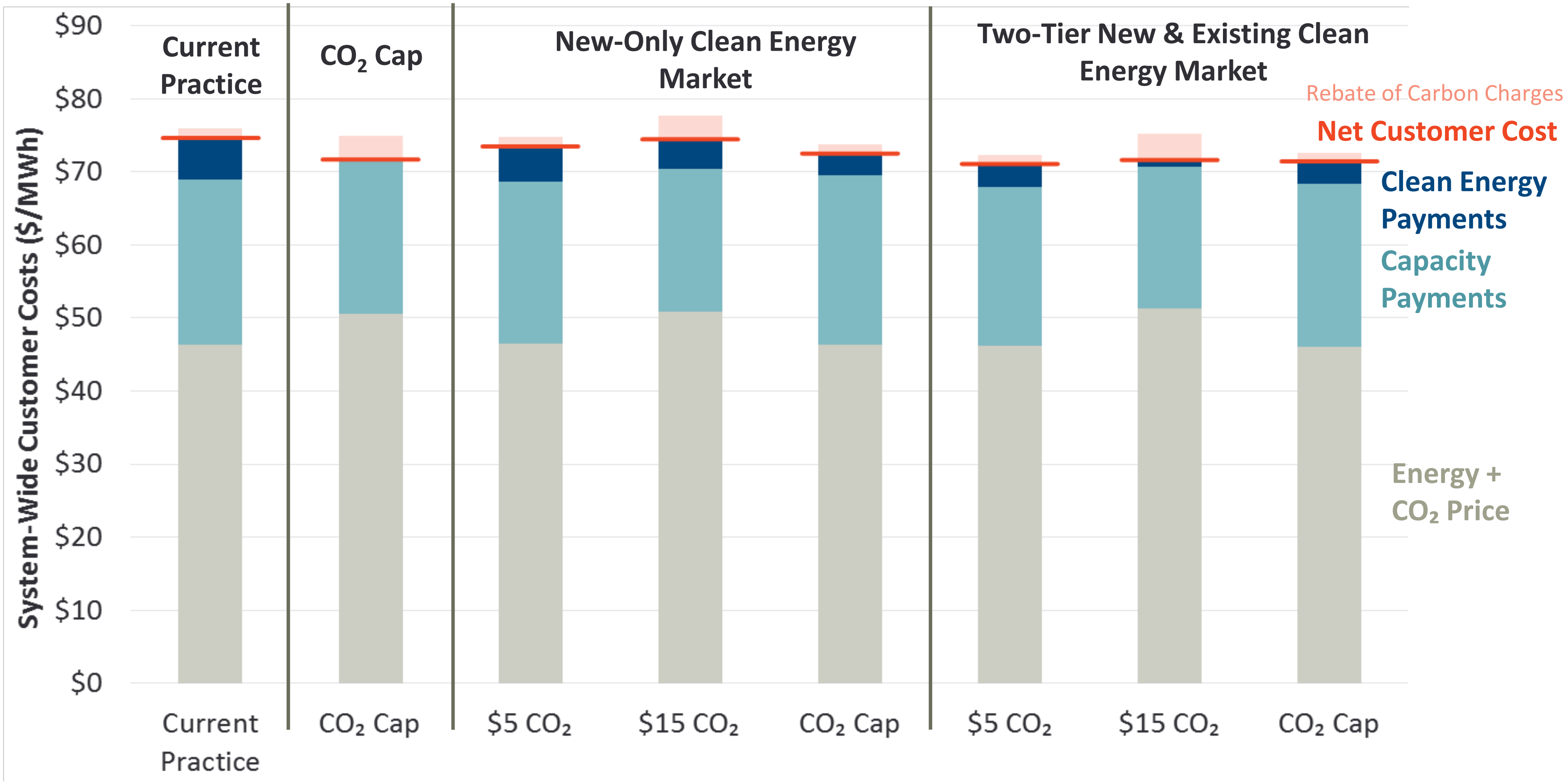


Note: Simple average of nominal costs from 2020-2029.

Modeling

Customer Costs

Current Practice and New-Only Clean Energy Market have the highest customer costs. Two-Tier and CO_2 Cap are more resource-neutral, translating to lower customer costs

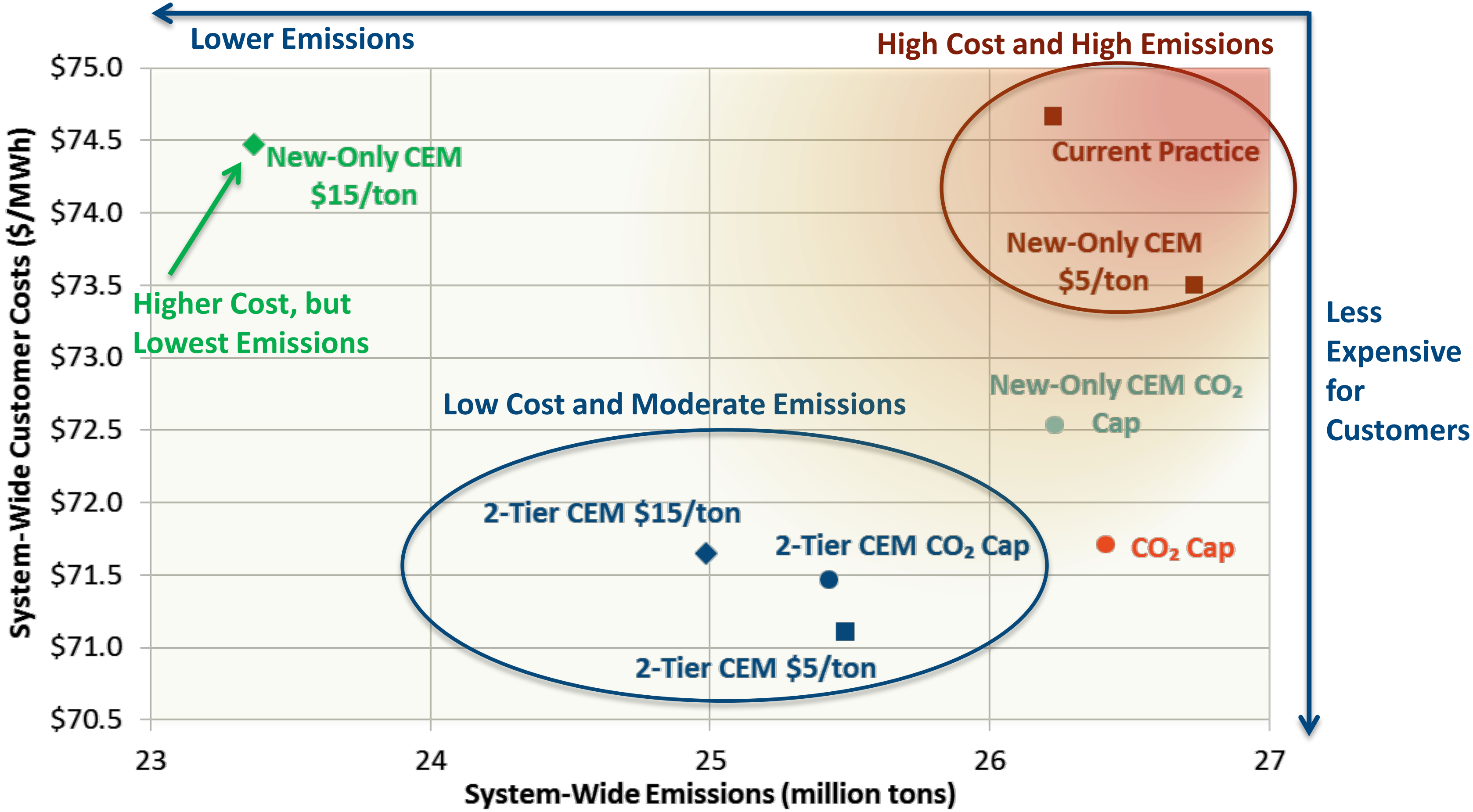


Note: Simple average of nominal costs from 2020-2029.

Modeling

Customer Cost Savings and Emissions Reductions

Preliminary simulation shows clean energy market (with $5/ton RGGI) **saves customers $440 million ($3.50/MWh)** and **reduces CO_2 emissions by 740,000 tons** per year relative to Current Practice



Note: Simple average of nominal costs and emissions from 2020-2029.

Market Prices Across Scenarios

Simple Average Prices from 2020-29

		Current Practice	CO_2 Cap	New-Only Clean Energy Market			2-Tier Clean Energy Market		
				$5 CO_2	$15 CO_2	CO_2 Cap	$5 CO_2	$15 CO_2	CO_2 Cap
Electricity Market Prices									
Energy	*($/MWh)*	$46	$51	$47	$51	$46	$46	$51	$46
Capacity	*($/kW-year)*	$86	$88	$85	$83	$88	$83	$83	$85
Clean Energy Payments/Prices									
Solar REC	*($/MWh)*	$86	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Onshore Wind REC	*($/MWh)*	$35	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Offshore Wind REC	*($/MWh)*	$116	n/a	n/a	n/a	n/a	n/a	n/a	n/a
New Clean Energy	*($/MWh)*	n/a	n/a	$53	$46	$38	$18	$15	$18
Existing Clean Energy	*($/MWh)*	n/a	n/a	n/a	n/a	n/a	$4	$0	$4
CO_2 Market									
Emissions	*(million tons/year)*	26.2	26.4	26.7	23.4	26.2	25.5	25.0	25.4
Price	*($/ton)*	$6	$16	$6	$18	$6	$6	$18	$6

Notes: Simple average of emissions and nominal costs from 2020-2029.

Modeling

Customer Costs Across Scenarios

Simple Average Customer Costs from 2020-29

		Current Practice	CO_2 Cap	New-Only Clean Energy Market: \$5 CO_2	New-Only Clean Energy Market: \$15 CO_2	New-Only Clean Energy Market: CO_2 Cap	2-Tier Clean Energy Market: \$5 CO_2	2-Tier Clean Energy Market: \$15 CO_2	2-Tier Clean Energy Market: CO_2 Cap
Customer Costs									
Energy	*(\$/MWh)*	\$46.4	\$50.5	\$46.6	\$50.8	\$46.4	\$46.2	\$51.3	\$46.1
Capacity	*(\$/MWh)*	\$23.7	\$24.4	\$23.4	\$22.9	\$24.4	\$23.0	\$23.0	\$23.4
Clean Energy	*(\$/MWh)*	\$5.8	n/a	\$4.8	\$4.1	\$3.0	\$3.2	\$0.9	\$3.1
CO_2 Revenue Rebate	*(\$/MWh)*	(\$1.2)	(\$3.2)	(\$1.3)	(\$3.3)	(\$1.2)	(\$1.2)	(\$3.5)	(\$1.2)
Total Customer Costs									
Per Load MWh	*(\$/MWh)*	**\$74.7**	**\$71.7**	**\$73.5**	**\$74.5**	**\$72.5**	**\$71.1**	**\$71.6**	**\$71.5**
Delta Above (Below) Current Practice	*(\$/MWh)*		(\$3.0)	(\$1.2)	(\$0.2)	(\$2.1)	(\$3.6)	(\$3.0)	(\$3.2)
Total Market-Wide	*(\$million/year)*	**\$9,373**	**\$9,002**	**\$9,226**	**\$9,347**	**\$9,105**	**\$8,926**	**\$8,994**	**\$8,971**
Delta Above (Below) Current Practice	*(\$million/year)*		(\$371)	(\$146)	(\$26)	(\$268)	(\$447)	(\$379)	(\$402)

Notes: Simple average of nominal costs from 2020-2029.