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Pathways Study

Evaluation of Pathways to a Future Grid

Todd Schatzki

April 26, 2022

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Overview

Purpose of today's presentation is to provide an overview of comments to the ***Draft* Pathways Study** and summarize our responses and any modifications made for the ***Final* Pathways Study**

- Summarize comments, particularly when commenters opined on common issues, and discuss whether and if so, how, the report was modified
- We identify **Question/Comment** and provide our **Response/Discussion**
- Intention is to identify and discuss key issues – however, we do not intend to limit discussion, so please raise any additional issues deemed relevant that are not raised below
- We do not plan to provide a detailed summary of the study, as this was provided at the March 1 meeting and is included in an appendix

Comments Received

Comments for posting were received from multiple entities (in some cases submitted by consultants) and are available at https://www.iso-ne.com/committees/key-projects/new-englands-future-grid-initiative-key-project/:

- Advanced Energy Economy
- Environmental Defense Fund
- LS Power
- New Hampshire Office of the Consumer Advocate
- NRG Energy
- PowerOptions
- RENEW Northeast

Feedback was also provided in the March 1 Participants Committee meeting

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Revisions to Draft Report

Revisions made to the draft report including the following:

- Revisions in response to comments and feedback received
  - In general and when appropriate, we revised the draft report to clarify further issues raised in comments (written and otherwise)
- Revisions made given further review of the draft report (largely to add further clarification)
- Quantitative analysis has not materially changed*, but we will repost the data file as final

* One minor data reporting issue was corrected related to retirements in one year.

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Common Policy Themes

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Further Elaboration on Study’s Scope

- **Question/Comment:** Further clarification of study’s scope and limits was requested given the many issues that need to be addressed to decarbonize New England’s grid
- **Response/Discussion:**
  - Report has been revised to further clarify that Pathways Study is not intended to meaningfully evaluate many important dimensions of decarbonization policy, including:
    - legal and regulatory issues associated with alternative policy approaches,
    - reliability issues (*see* **Future Grid Reliability Study**), and
    - transmission system needs (*see* **ISO-NE 2050 Transmission Study**)
  - Pathways Study quantitative analysis makes reasonable assumptions about future technologies, market conditions and market rules, along with scenario analysis to test robustness of assumptions
    - However, the Pathways Study is not a forecast or intended to estimate aggregate economic impacts
    - Current market rules are maintained across cases – while market rules are likely to change in the future, nature and specifics of those changes are unknown at present, and thus using current rules is reasonable

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Revised Summary Table of Key Tradeoffs between Policy Approaches

Policy Factor	Status Quo	FCEM	Net Carbon Pricing	Hybrid Approach
Policy Flexibility and Challenges				
Reliance on Regional Coordination and Consensus	• Low (unilateral state policies)	• Can coordinate state clean energy goals • Requires consensus on CEC product definition (and potentially CEC target and state allocations)	• Requires CO2 price or target consensus	• Requires consensus on CO2 price and CEC product
Cost Allocation Flexibility	Low (bound by unilateral policies)	High (through assignment of CEC obligations)	Moderate (through allocation of carbon revenues)	Moderate/High (through assignment of CEC obligations and allocation of carbon revenues)
Emission (and Cost) Uncertainty	Medium		Low-High (varies by design, with tradeoff between emission and cost uncertainty and need for forward policy commitment)	
Implementation Challenges **(Examples)**		• Determining CEC quantity needed to achieve GHG target • Integration of FCEM with FCM (if proposed)	• Determining carbon price needed to achieve GHG target (with a fixed carbon price)	• Risk of existing clean energy resource exit • Tension between retaining existing clean energy resources and potential customer savings from price discrimination • Complexity of administrative calculations of carbon price and CEC quantity
Other Policy Dimensions				
Legal	Pathways Study does not address legal and regulatory issues associated with alternative policy approaches, including jurisdictional issues and compliance with existing federal and state statues and policies, such as requirements not to create undue discrimination in competitive markets			
Reliability	Pathways Study does not address variable renewable integration, capacity market uncertainty, or other dimensions of reliability			
Transmission	The Pathways Study accounts for some (but not all) transmission costs and accounts for certain transmission constraints, but does not provide a thorough analysis of transmission needs of a decarbonized system			

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Revised Summary Table of Key Tradeoffs between Policy Approaches

Policy Factor	Status Quo	FCEM	Net Carbon Pricing	Hybrid Approach
Economic and Market Outcomes				
Cost-effective CO_2 Emission Reduction	Low	Moderate/High	High	Moderate/High
Cost-effective incentives for reductions in carbon-intensity	No	No	Yes (efficient)	Yes (but less than efficient level)
Cost-effective incentives for clean energy investment	NA (no in-market incentive, depends on administrative planning)	Partial (Incents clean energy generation, but not necessarily cost-effective choice among clean energy resources)	Yes (efficient)	Yes (mix of FCEM and carbon price)
Cost-effective incentives for investment across time	No (no in-market incentive, depends on administrative planning)	Yes (for clean energy investment)	Yes (efficient)	Yes (mix of FCEM and carbon price)
Transparent Price Signals	No	Yes (creates carbon or CEC price signal)		
Negative LMPs	Yes (potential storage "churning", inefficient battery use/investment)	Yes (potential storage "churning", inefficient battery use/investment)	No	Yes (potential storage "churning", inefficient battery use/investment, less than Status Quo and FCEM)
Price Discrimination	Yes (risk of inefficient entry/exit, capital turnover; need for additional out-of-market contracts)	No	No	Yes (risk of inefficient entry/exit, capital turnover)
Potential Distortions in Market Offers	Yes (e.g., curtailment based on PPA price, not costs)	No	No	No

Scope of Policy Approaches Considered

- **Question/Comment:** Comment made that actual outcomes would depend on specific design features adopted with each policy approach (such as an FCEM with partial CEC awards for natural gas blended with renewable gas or "green" hydrogen)
- **Response/Discussion**
  - As noted by the commenter, the Report makes clear that actual outcomes would depend on multiple decisions, including the specific approach and many specific design details adopted (which the Pathways Study does not fully assess)
  - The quantitative analysis estimates first-order differences in impacts between the policy approaches
    - Some design issues may meaningfully affect policy outcomes (e.g., CEC and allowance banking, single versus multiple CEC products), but the impact of others on economic and market outcomes would likely be smaller (second-order)
    - We do not evaluate the particular design issue of "clean" fuel blending within an FCEM (and whether this would meaningfully affect FCEM economic and market outcomes), as this would be one of many design issues to be addressed if an FCEM is to be pursued

Policy Development Challenges

- **Question/Comment:** Request to clarify characterization of challenges associated with alternative policy approaches
- **Response/Discussion**
  - Revisions made to further clarify that there are two types of challenges associated with the different policy approaches
  - First, all policy approaches evaluated would, at minimum, require meaningful time and effort to develop
    - Scope of effort may be less when there is prior experience and mechanism is relatively simpler
  - Second, some policy approaches raise feasibility/viability issues – in particular:
    - Integrated Clean Energy Market, which would integrate the FCEM and FCM – raises feasibility questions with respect to auction mechanism
    - Hybrid Approach can be implemented, but its viability is uncertain due to complexity of developing policy parameters (carbon prices and CEC quantities) that produce "desired" LMPs and uncertainty that the policy will lead to the intended outcome (i.e., retention of largest existing clean energy resources)

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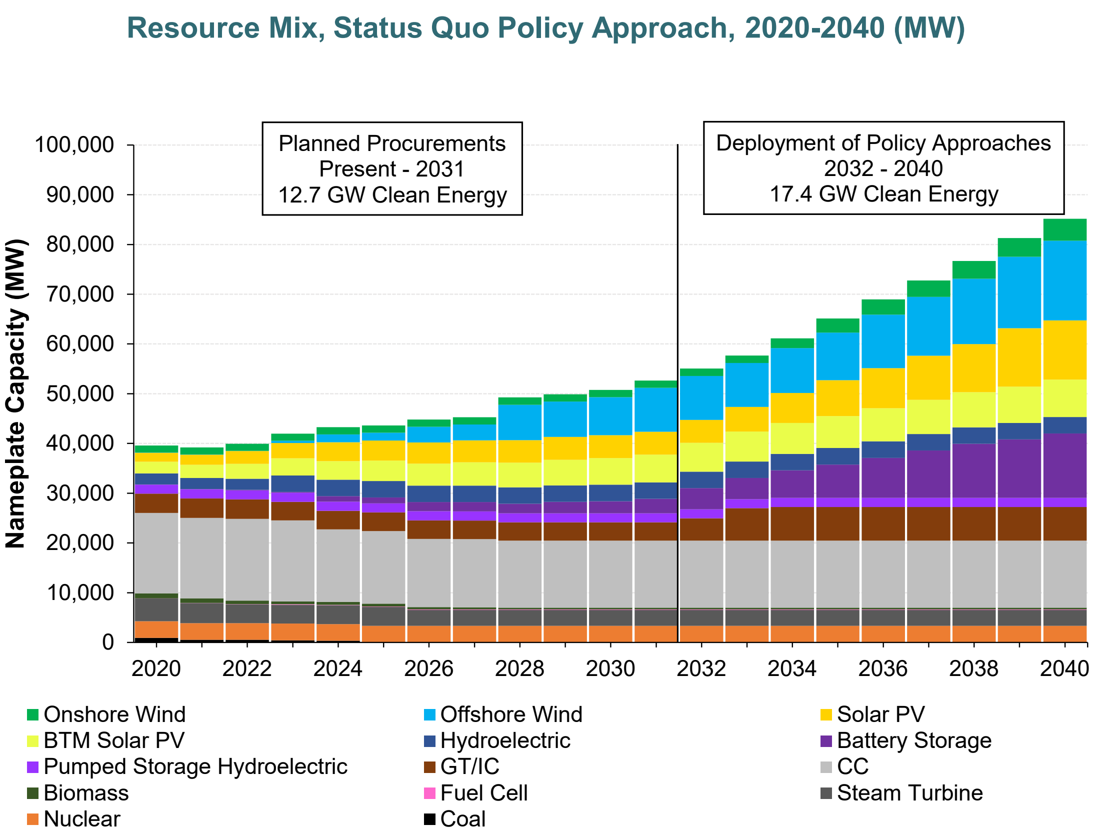
System Transition Assumed in Study

- **Question/Comment:** Which policy/market assumptions contribute to non-uniform patterns of resource (e.g., combined cycle) use over the study period?



Response/Discussion:

- Policy assumptions are a key driver of resource use patterns over time
- **In 2020s**, assumed clean energy procurements produce excess emission reductions relative to near term (assumed) emission targets
- **In early 2030s**, load increases (due to electrification) but incremental clean energy supply not needed to meet emission target
- In **remainder of 2030s**, increasing loads and more stringent emission targets necessitate substantial increase in clean energy supplies

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System Transition Assumed in Study (2)

- **Question/Comment:** Which policy/market assumptions contribute to non-uniform patterns of resource (e.g., combined cycle) use over the study period?
- **Response/Discussion**
  - Decarbonization policy assumptions drive certain observed patterns in resource usage
    - For example, combined cycle output increases temporarily around 2030 as loads increase more than growth in clean energy supplies
  - When considering these patterns, important to note that:
    - Clean energy procurement amount in 2020s reflects current planning and legislation – however, in principle, planning and statute can be changed, and all procurements may not result in new capacity
    - Introduction of CEC or carbon allowance banking would be expected to accelerate investment given trajectory of CEC and allowance prices toward the end of the study period, which would affect some observed outcomes

RPS Policies

- **Question/Comment:** Question regarding RPS outcomes, including compliance costs, in the quantitative analysis
- **Response/Discussion**
  - Over the study period for all policy approaches, renewable energy supplied by the state procurements (through 2030) and by each of the policy approaches (in later years, given the 2040 emission target) exceed currently legislated RPS requirements
  - As a result, REC prices fall to zero and thus the RPS impose no incremental social cost or customer payments

Status Quo Case

- **Question/Comment:** Questions regarding key source of differences in costs between Status Quo and other policy approaches
- **Response/Discussion**
  - Cannot easily disentangle various factors impacting Status Quo costs
  - The model cannot solve for the Status Quo resource mix because that approach reflects state administrative procurement processes that depend on many cost and non-cost factors – this is inherent to and a feature of this approach to decarbonization
  - Status Quo case reflects current state plans and studies (*see* **Table IV-2**, shown below) – we believe this assumption is reasonable as these reveal state resource preferences, though we acknowledge the inherent uncertainty over outcomes of administrative processes
  - Actual outcomes of the administrative procurement process could result in social costs that are higher or lower than those in our analysis

Status Quo Resource Mix Incremental Build by State (GW)

	2020-2040 Incremental Build (GW)					
State	**Offshore Wind**	**Onshore Wind**	**Solar**	**Storage**	**NECEC**	**Total**
Connecticut	4.7	0.4	2.3	2.2	-	9.7
Maine	-	2.0	0.7	0.5	-	3.2
Massachusetts	9.2	0.4	5.5	0.4	1.2	16.6
New Hampshire	-	-	-	-	-	--
Rhode Island	2.0	-	1.4	1.0	-	4.4
Vermont	-	0.2	0.8	-	-	1.0
Total	16.0	3.0	10.7	4.1	1.2	35.0

Investment Incentives

- **Question/Comment:** Certain comments suggested that the Pathways Study does not account for all factors relevant to determining investment incentives
- **Response/Discussion**
  - The Pathways Study considers all factors relevant to investment incentives, including in-market and out-of-market incentives
    - The Pathways Study does not comprehensively assess new resource financing, but does consider the extent to which such financing is likely to be sufficient to fund needed investment under each policy approach
    - In particular, we find that financing of clean energy projects would likely be feasible in the absence of a multi-year PPA assuming revenue increases from CECs and/or carbon pricing
  - The Pathways Study does not evaluate all potential future design decisions relevant to investment decisions, such as whether to allow a “price lock” for new entry into an FCEM, as the proposed approaches are conceptual and not fully detailed designs

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Technical Questions and Comments

Negative LMPs and Storage "Churning"

- **Question/Comment:** The finding that negative LMPs could lead to storage "churning" prompted multiple comments related to several issues:
  - Acknowledgment that the potential behavior is an important finding
  - Clarification regarding circumstances when churning would be likely
- **Response/Discussion**
  - Assuming spells of negative LMPs of sufficient duration, storage technology within current market structure is generally capable of storage churning
  - Further clarification has been added that potential for storage churning depends on development of alternative technologies that can submit demand bids at higher (less negative) prices than storage resources to consume negative-LMP energy
    - Such technologies include load-shifting (i.e., shifting load from high-demand to low-demand periods) and alternative energy storage technologies (e.g., "green" hydrogen production)

Negative LMPs and Storage "Churning" (2)

- **Question/Comment:** The finding that negative LMPs could lead to storage "churning" prompted multiple comments
  - Belief that policymakers would intervene if inefficient churning occurs
  - Belief that revising FCEM design can mitigate churning incentives
- **Response/Discussion**
  - Report notes that policymakers may attempt to discourage or prohibit "churning" behavior, but such efforts may be only partially effective and may introduce other unintended consequences, and thus may or may not be beneficial on balance
    - Market design that avoids price signals that incent undesirable behavior can avert the need to develop interventions to discourage or prohibit such behavior
  - FCEM policy design does not mitigate incentives to "churn"
    - An FCEM that adjusts the CEC constraint to the quantity of "churning" load would not reduce the incentive to churn (the storage facility does not bear the "cost" associated with the aggregate adjustment)
    - Such an approach would automate the process of adjusting CEC targets to churning (as otherwise, state administrators would need to account *ex ante* for churning when specifying CEC targets)

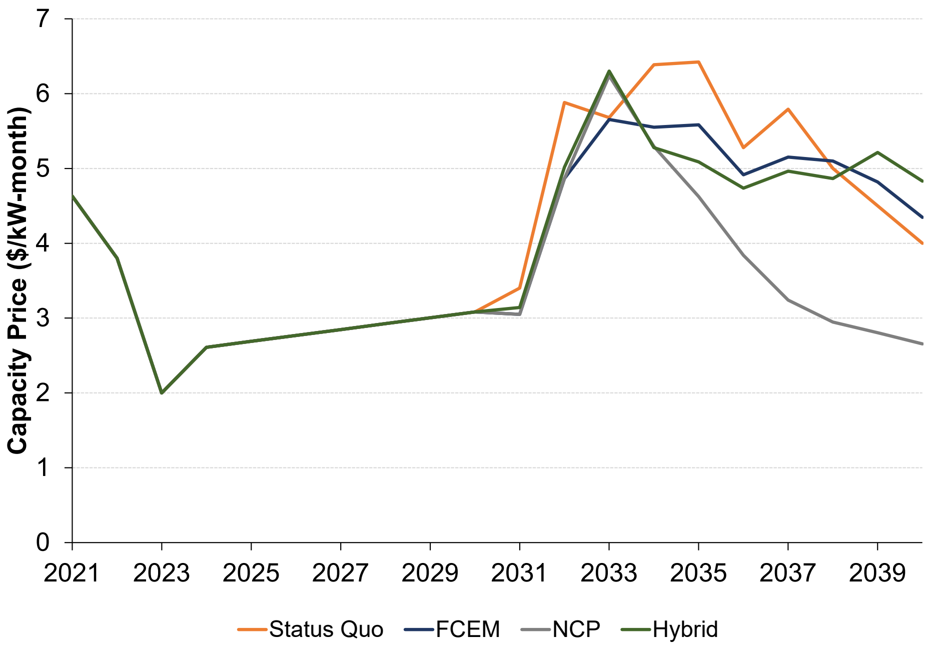
Negative LMPs

- **Question/Comment:** Question regarding source of concentration of negative LMPs at certain price levels (–$30/MWh and –$100/MWh) in the Status Quo
- Response/Discussion
  - In the Status Quo, offers from clean energy resources (with PPAs) are the negative of their PPA energy prices (e.g., a resource with a PPA price for energy of $125/MWh has energy offers at –$125/MWh)
  - Modeling assumes offers at –$30/MWh for existing renewables and –$100/MWh for new variable renewable resources with PPAs, because of complexities of endogenously modeling energy market offers as actual out-of-market revenues

Capacity Market Prices

- **Question/Comment:** Questions regarding drivers of capacity market prices

Annual Forward Capacity Market Prices by Policy Approach, 2021-2040 ($2020/kW-month)

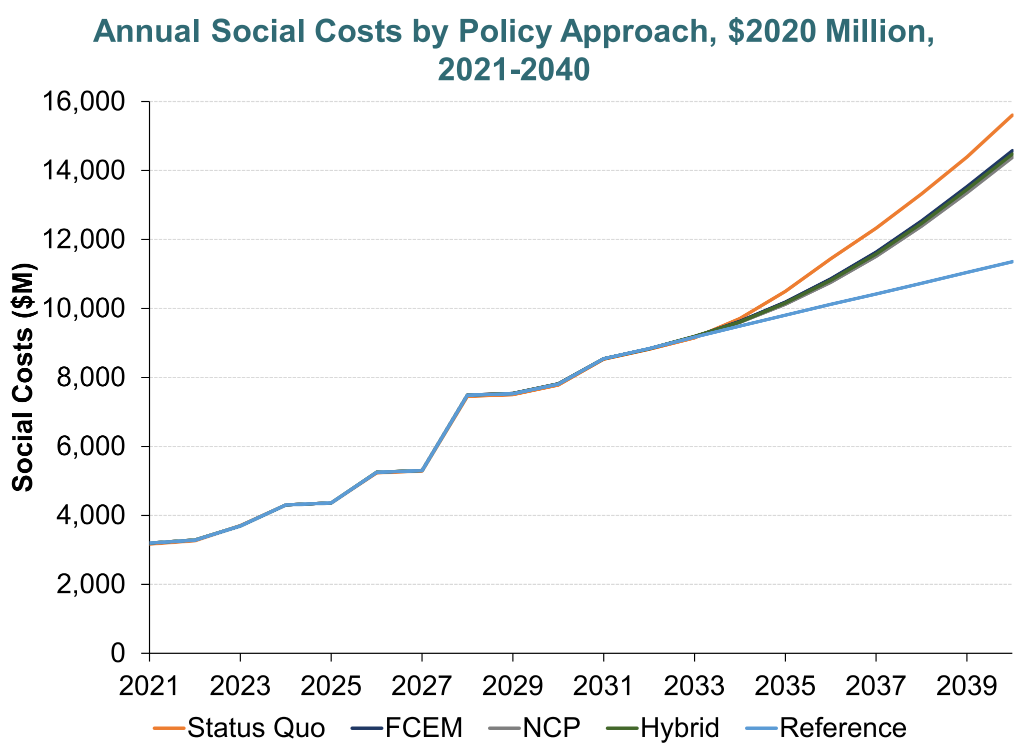


Response/Discussion:

- Prior to 2031, capacity market prices are low, as the resource adequacy constraint is not binding (existing capacity is retained to help meet resource adequacy later in the study period, while state procurements expand operable capacity)
- From 2031 to 2040, capacity market price reflects the cost of entry for storage resources (i.e., the "missing money" needed to support storage entry)
- Storage resource returns increase (to varying degrees) in each policy case, thus decreasing capacity prices over time
- Relative prices (across policy approaches) differ across Central Case and scenarios

Incremental Social Costs and Payments

- **Question/Comment:** Request to provide an estimate of the total social cost and payments associated with decarbonization achieved over the 20-year study period



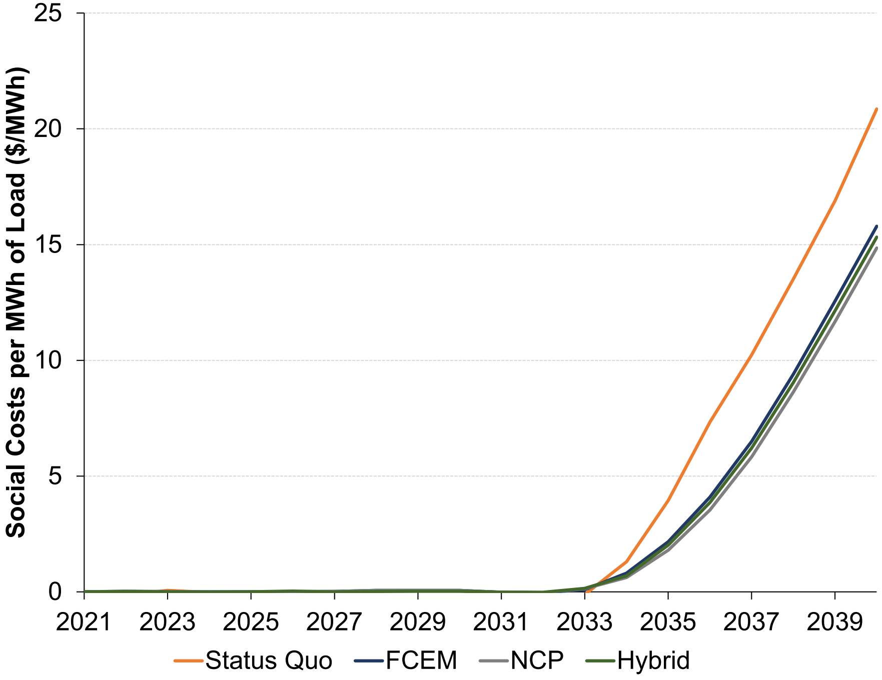
Response/Discussion:

- Cases already analyzed cannot be used to estimate the incremental costs of decarbonization over the 20-year study period (this calculation would require a new case without both baseline state procurements and incremental reductions)
- Pathways Study is intended to inform choice among policy approaches, not forecast economic consequences of decarbonization

Incremental Social Costs and Payments

- **Question/Comment:** Comment that incremental social costs and payments should be compared to the Status Quo, not the Reference Case

Average Incremental Social Costs by Policy Approach (Relative to the Reference Case), 2021-2040 ($2020/MWh)



Response/Discussion:

- Outcomes for each policy approach are compared to **Reference Case** outcomes**,** in which decarbonization is limited to planned state procurements
- Thus, we compare a policy case (the 80% by 2040 target) against a lower-emission baseline
- This is the standard approach to regulatory analysis used by regulatory agencies (e.g., US EPA) – that is:
  - Estimate incremental impacts as comparison of policy case to a "baseline" case that does not include the effects of the regulation being evaluated

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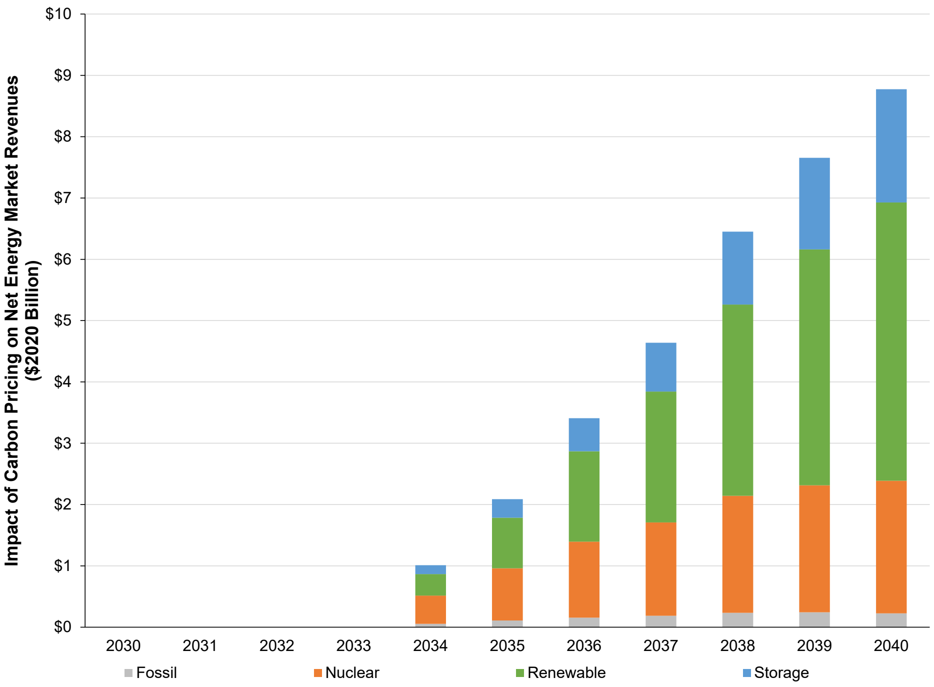
Incidence of Carbon Pricing Revenue Allocation

- **Question/Comment:** Request to provide additional information regarding the distribution of price impacts associated with carbon pricing

Total Impact ($2020 B) of Carbon Pricing on Net Energy Market Revenues by Technology Type



Response/Discussion

- Carbon pricing increases LMP revenues to all energy supply
- With Net Carbon Pricing, total revenues grow over study period
- Non-emitting resources (i.e., renewable, nuclear, storage) receive benefit of LMP increases with no carbon charges
- Fossil generation also receives benefit of LMP increases, but also incurs carbon charges, proportionate with their emissions
  - Only inframarginal natural gas-fired resources earn any net revenues

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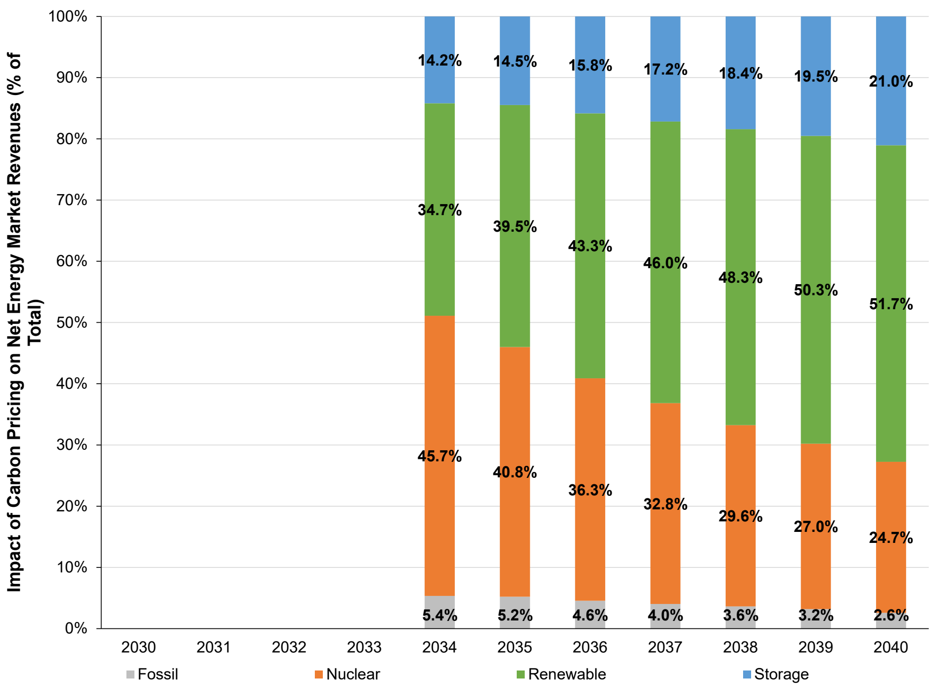
Incidence of Carbon Pricing Revenue Allocation (2)

- **Question/Comment:** Request to provide additional information regarding the distribution of price impacts associated with carbon pricing

Share of Total Impact (%) of Carbon Pricing on Net Energy Market Revenues by Technology Type



Response/Discussion (cont'd):

- Nearly all of the net payment (compensation) associated with Net Carbon Pricing goes to non-emitting resources (i.e., clean, nuclear, storage)
- Fossil resource's share of net payment (compensation) received decreases from 5.4% in 2034 to 2.6% in 2040

Natural Gas Fired Generation

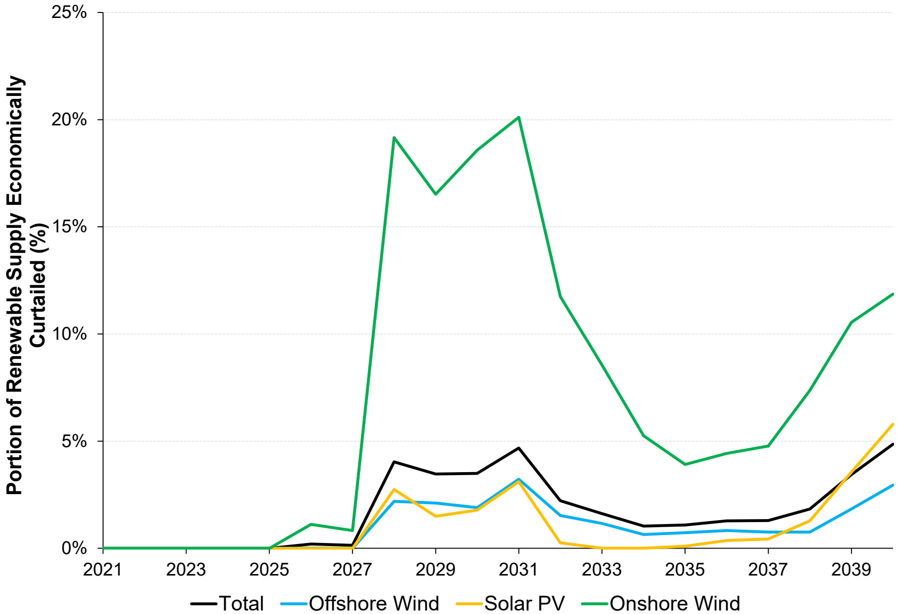
- **Question/Comment:** Questions regarding total supply and emissions from natural gas-fired resources
- **Response/Discussion:**
  - Estimated investment in and supply from gas-fired resources (including the choice between CTs v. CCs) reflects a balancing of multiple factors, including relative capital costs, operational costs and capabilities, and competition with other sources of peak energy (e.g., storage)
  - Natural gas-fired resources represent the vast majority (if not all) of carbon emissions
  - A less carbon-intensive mix of gas-fired resources can generate more energy (MWh) given the fixed carbon "budget"
  - With Net Carbon Pricing and, to a lesser degree, the Hybrid Approach, the market design creates incentives to transition to a more efficient gas-fired fleet that can expand energy output while keeping total emissions unchanged (at the fixed carbon "budget")

Transmission

- **Question/Comment:** Questions regarding whether Pathways Study captures all transmission constraints
- **Response/Discussion:**
  - In the transmission scenario, the Pathways Study captures congestion associated with certain internal interfaces
  - However, the Pathways Study does not capture all transmission constraints and does not reflect contingencies
  - Thus, the Pathways Study will not capture local transmission reliability issues, will not identify all upgrades needed to integrate new variable resources (e.g., offshore wind), and does not identify transmission infrastructure needed to reliably support a decarbonized grid
  - ISO-NE's on-going 2050 Transmission Study represents a more comprehensive assessment of these questions
  - We have not compared the costs of transmission upgrades to those developed in other regions, as such comparisons are outside the scope of our study

Variable Renewable Curtailments

- **Question/Comment:** Question regarding relative magnitude of curtailments between variable renewable supplies
- **Response/Discussion:**
  - Curtailment rate (as a percent of potential supply) varies across technology types (*see* **Figure V-8**, shown below)



  - Curtailment rates reflect many factors, particularly correlation with loads and other variable supplies
  - Increasing capacity of a given technology type (if highly correlated) may thus exacerbate curtailment
    - Poses tradeoff between capital costs and curtailed supply (due to correlated output)
    - More costly resources (with lower curtailments) may be developed before less costly resources (with higher curtailments)

Conclusion

Conclusion

- The Final Pathways Study represents an end point for this part of the process
  - We do not anticipate making any further revisions to the Pathways Study
  - However, the Pathways Study is not an end point to the process
    - Instead, the Study is intended to provide stakeholders with information useful in undertaking policy determinations relevant to a transition to a decarbonized New England electricity grid
    - ISO-NE is continuing to work on the Future Grid Reliability Study and the 2050 Transmission Study, both important to the region's Future Grid efforts
  - We thank NEPOOL Stakeholders and the New England States for their active participation and collaboration in the development of the Pathways Study and hope that it assists in efforts to transition to a decarbonized Future Grid

ISO welcomes stakeholder feedback

- The ISO hopes the Pathways Study has helped stakeholders better understand the various pathways studied and key differences/tradeoffs between them
- At this stage, we invite preliminary written stakeholder feedback for posting on stakeholders' preferred path by **May 17**
  - Address to Chris Geissler at cgeissler@iso-ne.com; Dave Cavanaugh at dcavanaugh@ene.org; and Sebastian Lombardi at slombardi@daypitney.com
  - All submissions must include a brief, one-page comment summary
- Anticipate hearing more about the New England states' preferred path in the May/June timeframe, including at the late June PC meeting. More details TBD
  - Additional written comments from stakeholders on their preferred path should be provided to the contacts above **by June 6,** with a one-page summary, to help guide the discussion
- If there is a consensus on the preferred path, this will help to guide the ISO's work on these efforts for the remainder of 2022 and 2023

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Appendix: March 1, 2022 Presentation of Draft Report

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Pathways Study

Evaluation of Pathways to a Future Grid

Todd Schatzki

March 1, 2022

Overview

Purpose of today's presentation is to provide an overview of the ***Draft*** **Pathways Study**

- Introduction
  - Assignment, scope, approach (Section II)
  - Summary of key findings (Section I)
- Alternative policy approaches evaluated (Section III)
- Approach to quantitative analysis: Central Case assumptions (Section IV)
- Quantitative analysis: decarbonization (Section V)
- Assessment of policy approaches to achieving decarbonization
  - Design considerations affecting achievement of emission targets (Section VI.A)
  - Cost-Effectiveness and market outcomes (Section VI.B-C)
  - Social costs, prices, payments and other environmental, economic and market consequences (Section VI.D-F)
- Scenarios (Section VII)
- Next steps

Updates and Incremental Materials

- Results for Central Case and previously presented Scenarios have been modified, reflecting minor technical changes
  - These changes did not modify any previously reached conclusions
- New scenarios presented today (and included in Draft Pathways Report):
  - Transmission
  - Alternative Hybrid Approach (with alternative LMP target)
- Analytic and qualitative assessments included in the Draft Pathways Report:
  - Key issues for decarbonization in New England
  - Tradeoffs among policy approaches, reflecting results of quantitative analysis
  - Design and implementation issues for particular policy approaches (e.g., Dynamic CEC Appendix)

Introduction (Sections I-II)

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Overview – Assignment and Scope

- Assignment and Scope
  - Pathways Study is evaluating alternative policy approaches to decarbonizing the New England Grid
  - Focus of evaluation is on alternative economic and market outcomes
  - Pathways Study does not evaluate reliability outcomes, which are, in part, being evaluated in the Future Grid Reliability Study (“FGRS”).

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Overview – Policy Approaches

- Analysis considers the continuation of current policies pursued by New England states to achieve decarbonization:
  - ***Status Quo (SQ)***
- And three alternative, centralized approaches:
  - ***Forward Clean Energy Market (FCEM)***
  - ***Net Carbon Pricing (NCP)***
  - ***Hybrid Approach***
- While these are not the full universe of potential alternatives, the New England States, NEPOOL stakeholders, and the ISO expressed interest in analyzing these approaches:
  - Other "hybrid" approaches that combine elements of procurements, carbon pricing, and new environmental certificates (e.g., CECs)
  - Phasing-in or transitioning of instruments over time (e.g., gradual increasing of carbon pricing over time, with diminishment of procurements (e.g., shorter contract terms))
  - Other policy approaches (e.g., others identified in 2020 Potential Pathways process)
  - The present study does not evaluate these types of alternatives

Overview – Quantitative Analysis

- Quantitative analysis is designed to illustrate and measure differences in key economic and market outcomes between policy approaches under reasonable assumptions about future demand, technologies, costs and market structure
  - Key differences reflect analytic/economic differences in how each approach incents investments, affects market and operational incentives, etc. – quantitative analysis illustrates and measures these differences
  - Quantitative analysis is ***not a forecast*** – assumptions reflect current technologies, expected costs and market rules, but with technological change, uncertainty in market conditions and changes in ISO-NE market rules, actual outcomes will likely differ
  - Assumptions related to technology options ***do not reflect an assessment of future viability or merit***, and assumptions related to market rules ***do not reflect an endorsement or proposal*** for preferred future rules
  - Reasonable assumptions were selected to evaluate differences in policy approaches, with scenario analysis used to test the robustness of conclusions to changes in assumptions

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Summary of DRAFT Key Conclusions

- Approaches differ in various policy design considerations, such as the extent to which they accommodate different levels of regional coordination and consensus, implementation challenges, and uncertainty about emission or economic outcomes
- Approaches differ in the way in which they incent emission reductions, with implications for the cost-effectiveness of emission reductions, price discrimination and creation of transparent price signals
- Approaches differ in the extent and nature of other market consequences, such as negative LMPs and the factors affecting economic curtailments across variable renewables
- Social cost is lowest with Net Carbon Pricing, higher for the FCEM and Hybrid Approach, and notably higher for the Status Quo
  - Differences in outcomes reflect cost-effectiveness, assumptions regarding resources mix, and other factors
- Customer Payments vary across policy approaches, lowest for the Hybrid Approach, next highest for Net Carbon Pricing, and higher for Status Quo and FCEM
  - Differences reflect the combined effect of multiple factors, including cost-effectiveness, price discrimination, assumptions regarding resources mix, and assumed payments for existing clean energy resources (among other factors)
- The scenario analysis changes magnitude of results, but not the general findings

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Summary of Key *Preliminary* Modeling Results

Policy Factor	Status Quo	FCEM	Net Carbon Pricing	Hybrid Approach
Reliance on Regional Coordination and Consensus	Low	Moderate	Moderate/High	Moderate/High
Cost Allocation Flexibility	Low	High	Moderate	Moderate
Cost-effective CO_2 Emission Reduction	Low	Moderate/High	High	Moderate/High
Incentives for Reductions in Carbon-Intensity	No	No	Yes (efficient)	Yes (below efficient)
Incentives and Cost-Effective Investment in All Clean Energy Resources	No	Yes	Yes	Yes
Efficient Incentives for Storage Resource Use and Investment	Not Efficient (storage “churning,” incentive reflects PPA price)	Not Efficient (storage “churning,” incentive reflects CEC prices)	Efficient	Not Efficient (storage “churning,” incentive reflects CEC prices)
Transparent Price Signals	No	Yes	Yes	Yes
Creates Potential Distortions in Market Offers (e.g., curtailment based on PPA price not costs)	Yes	No	No	No
Negative LMPs (“churning,” inefficient battery use/investment, inefficient commitment and uplift)	Yes	Yes	No	Yes (less frequently than Status Quo and FCEM)
Price Discrimination (capital allocation between new / existing assets, need for additional out-of-market contracts)	Yes	No	No	Yes (risk of resource exit may remain)

Policy Approaches (Section III)

Four Policy Approaches Evaluated

- Four approaches evaluated
  - Status Quo
  - Net Carbon Pricing
  - Forward Clean Energy Market
  - Hybrid Approach

- Report provides a review of each policy approach, including a description of how the approach achieves emission reductions and key design components
- Report does not provide a detailed assessment of each policy approach, particularly with regard to key design decisions
- If the region decides to pursue one of these alternatives to the Status Quo, substantial additional time and effort would be required to develop design details

Status Quo

- Reflects outcomes of unilateral policies by each of the six New England States
- Assumes continuation of current direction of state policy of procuring clean energy supplies through bilateral multi-year contracts
  - New resources incented by energy resource procurements resembling recent competitive procurements, such as those for offshore wind in southern New England
  - Provides a benchmark for comparison given recent trends and direction, given feedback from New England States and NEPOOL stakeholders
- Procurement process generally involves multiple steps, including:
  - Planning stages (e.g., specifications including technology eligibility, quantities, contract terms, need parameters, etc.)
  - Procurement implementation (RFP development, determination of selection criteria and processes, review and selection of offers to be awarded contracts, contract negotiation and execution, etc.)
  - Contract execution (over life of contract)
- Policy with respect to existing (and off-contract) clean energy resources in the future is not clear

Forward Clean Energy Market

- Compensates non-emitting resources via a centralized, forward market for clean energy certificates ("CECs") with corresponding costs allocated to electricity consumers
- Creates a market (like a Renewable Portfolio Standard) for CECs
  - CEC demand created by state-imposed utility CEC requirements
  - CEC supply created by awarding CECs to clean energy resources for energy generation
- Forward centralized auction
- Many important and potentially challenging outstanding design questions – for example:
  - CEC product definition and resource eligibility
  - CEC demand formation and supply participation
  - Market settlement
  - Interactions with existing state policies
  - Whether to integrate forward market with FCM
  - Dynamic CECs

Forward Clean Energy Market

- **Dynamic CECs**
  - **Appendix C** provides an evaluation of issues associated with a dynamic CEC
  - Dynamic CEC awards would vary over time to better match CEC awards with marginal emission reductions
  - Key observations regarding potential benefits
    - Dynamic CECs do not make FCEM incentives comparable to Net Carbon Pricing
    - Dynamic CEC would not necessarily improve incentives to avoid delivery of energy during periods when variable renewable output is curtailed relative to static CECs
    - Benefits (relative to static CECs) limited to improving incentives to develop variable renewables that supply in periods with higher relative fossil-fired marginal emission rates
    - Reduces the frequency and magnitude of negative LMPs, but diminishes incentive for storage resources by compressing LMP spreads
  - Practical implementation considerations
    - Dynamic CECs based on actual marginal emission rates appear to be impractical and/or infeasible
    - Efficacy of dynamic CECs based on proxy marginal emission rates (using historical data) depends on reliability/uncertainty of these metrics given scope of potential improvements in incentives

Net Carbon Pricing

- Impose a price on CO_2 emissions from wholesale electricity generators
  - Cost a generator incurs is proportional to its CO_2 emissions
- Two general types of carbon pricing
  - Cap-and-trade (with tradeable emission allowances)
  - Fixed (predetermined) carbon price
- Revenues from carbon pricing collected by centralized authority (e.g., ISO-NE)
- Collected revenues can be used for one of many purposes
  - Credited to customers (based on various formulas/criteria)
  - Used for other purposes (e.g., RGGI allocates allowance auction revenues to states, that then use them for various purposes, such as funding energy efficiency programs)

Hybrid Approach

- Stakeholder requested that this approach be included in the study (from New England States Committee on Electricity, "NESCOE")
- Combines two elements:
  - Carbon price set to allow the largest clean energy plant in the region (i.e., Millstone Power Plant) have sufficient revenues to remain financially viable
  - An FCEM with CEC awards limited to "new" resources
- Requires an administrative process to determine (1) target revenues (e.g., LMPs), (2) carbon prices that would achieve target revenues, and (3) CEC targets for new clean energy resources
  - Process would be computationally complex given interactions between carbon prices, CEC target and evolving market conditions

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Approach to Quantitative Analysis: Central Case Assumptions (Section IV)

Central Case Assumptions: Period, Targets

- **Central Case** assumptions are held constant across each policy approach studied
  - Further detail on Central Case assumptions has been provided in prior presentations to the Participants Committee
- Overview of Central Case assumptions
  - Time period: **2020 to 2040**
  - Geographic scope: **ISO New England system only**, with assumed imports
  - 2040 decarbonization target: **80% of 1990 carbon emissions for the New England electricity sector**
  - No MOPR
- **Reference Case** is analyzed in which the region achieves less ambitious decarbonization reflecting only certain planned procurements
  - This case does *not* achieve the 2040 decarbonization target
  - All other assumptions (including loads) the same as the Central Case
  - Not intended as an alternative Pathway, but as a benchmark against which to measure the incremental change in economic outcomes from greater decarbonization

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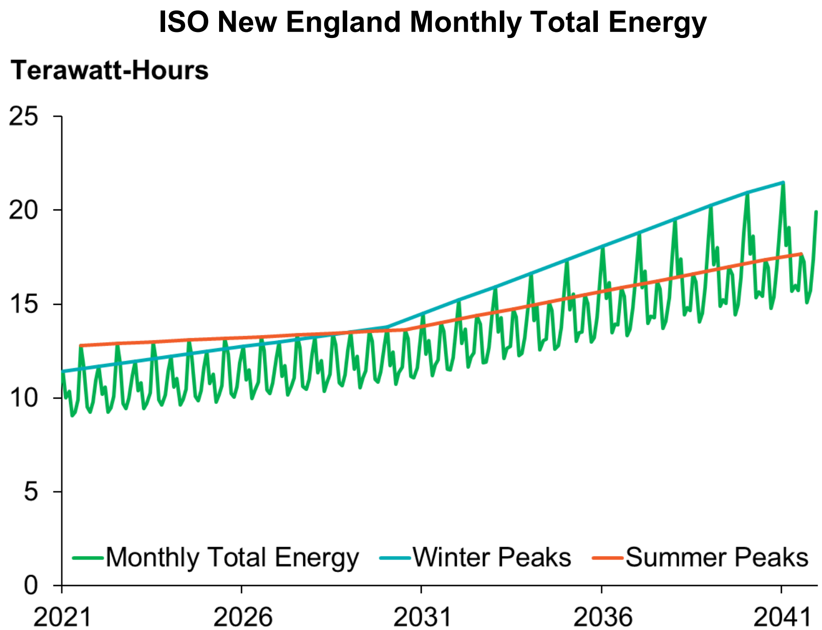
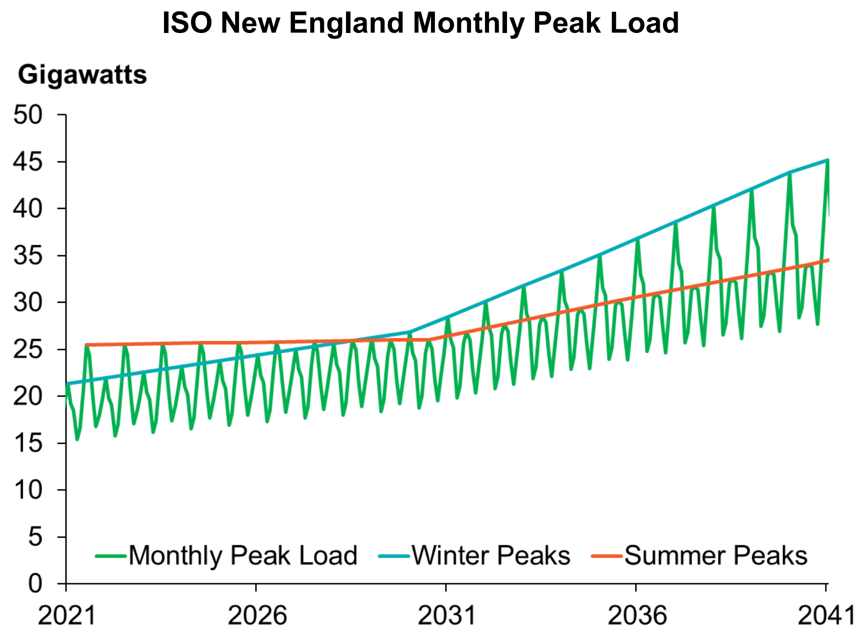
Central Case Assumptions: Loads

- **High load** assumed, reflecting electrification of transportation and heating (consistent with FGRS Scenario 3)





Central Case Assumptions: Supply-Side

- Resource mix includes existing and new resources
- ***Baseline state policies***:
  - All studies assume baseline state clean energy policies, including: offshore wind procurements, New England Clean Energy Connect, and mix of other resources
  - Resource mix is generally the same across policy approaches in first half of study period because of these common policies
- ***Incremental resource entry: technological options***
  - All cases assume the same set of potential new generation technologies (and associated costs)
  - Set of potential technologies considers only existing, commercially available technologies – costs over time reflect technological improvements (which lowers cost over time) and siting/delivery factors (which increase with cumulative capacity builds)
  - Do not consider advanced technologies, not yet commercially available (e.g., flow batteries or combustion turbines fired with “green” hydrogen)
- ***Fossil Resources.*** Some fossil resources remain under all policy approaches as we assume the region has some carbon emissions (declining to 80% below 1990 emission levels)

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Central Case Assumptions: Supply-Side (2)

- ***Incremental resource entry: differences across policy approaches***
  - ***Status Quo case***: assumes variable renewables from state plans, roadmaps, and studies (see table below)
  - ***FCEM, Net Carbon Pricing, Hybrid Approach***: for each policy approach, new entry (and retirement) reflects profit opportunities available to resources, given increasingly stringent carbon targets and expanding resource adequacy needs
    - Key variable renewables include: solar, offshore wind, onshore wind
    - Key dispatchable resources include: battery storage and gas-fired resources

Assumed Resources in State Clean Energy Policies

	2020-2040 Incremental Build (GW)					
State	**Offshore Wind**	**Onshore Wind**	**Solar**	**Storage**	**NECEC**	**Total**
Connecticut	4.7	0.4	2.3	2.2	-	9.7
Maine	-	2.0	0.7	0.5	-	3.2
Massachusetts	9.2	0.4	5.5	0.4	1.2	16.6
New Hampshire	-	-	-	-	-	--
Rhode Island	2.0	-	1.4	1.0	-	4.4
Vermont	-	0.2	0.8	-	-	1.0
Total	16.0	3.0	10.7	4.1	1.2	35.0

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Quantitative Analysis: Decarbonization (Section V)

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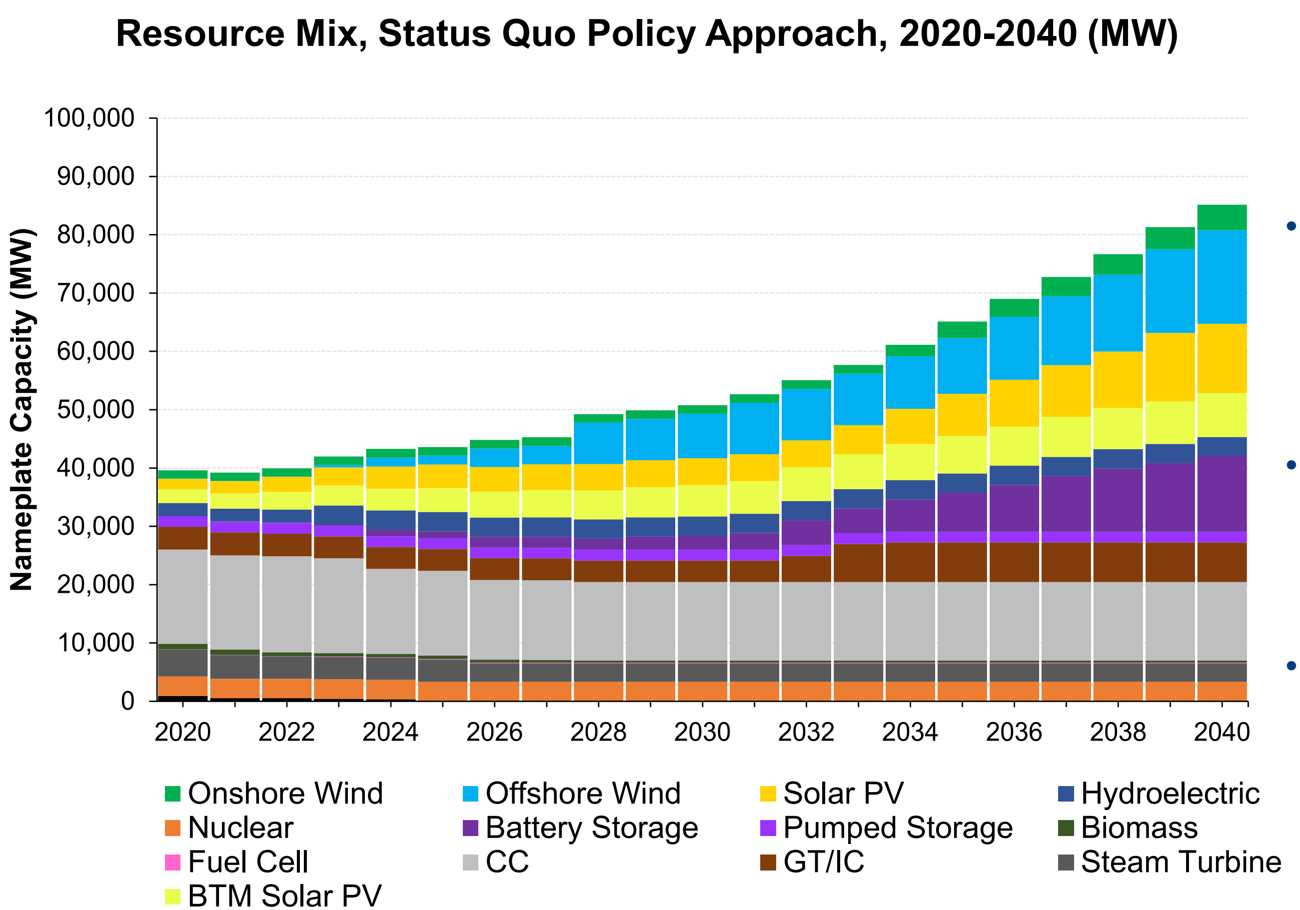
Evolution of System Resources to Lower Emissions

Policy approach affects renewable resource mix



- **Increased variable renewable capacity** (solar PV, onshore and offshore wind) to increase clean energy share of supply
- **Increase in battery storage capacity** to shift excess variable renewable supplies to displace carbon emissions
- **Reduced fossil resource capacity**, but large fraction retained to maintain resource adequacy
- **Increased total capacity** to meet higher loads from heating and transportation electrification

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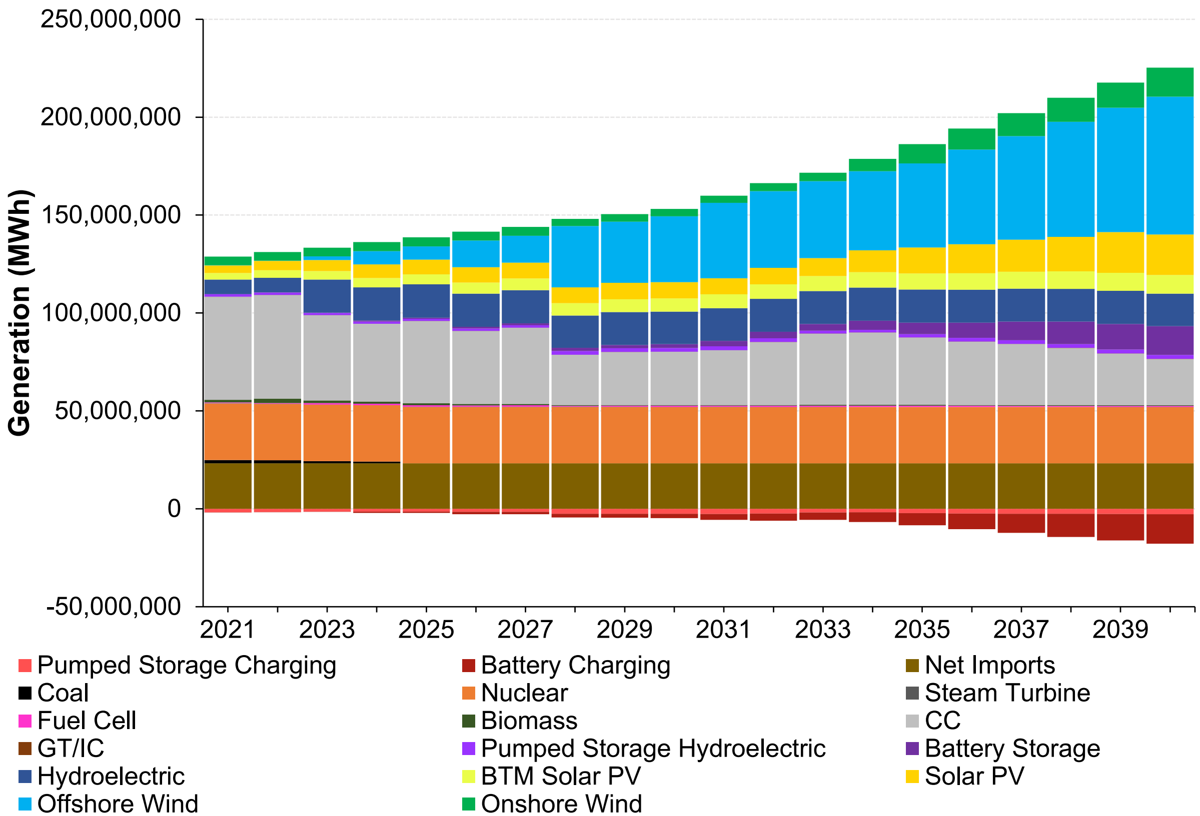
Substantial Increases in Clean Energy Output

Clean energy growth needed to meet emission targets

Generation Mix, Status Quo Policy Approach, 2021-2040 (MWh)



- **Shift in energy output parallels shift in capacity**
- **Output from variable renewable resources is weather dependent,** with capacity utilization varying by resource type
- **Increase in storage operation**, including charging and discharging
- **Reduced fossil resource capacity utilization**

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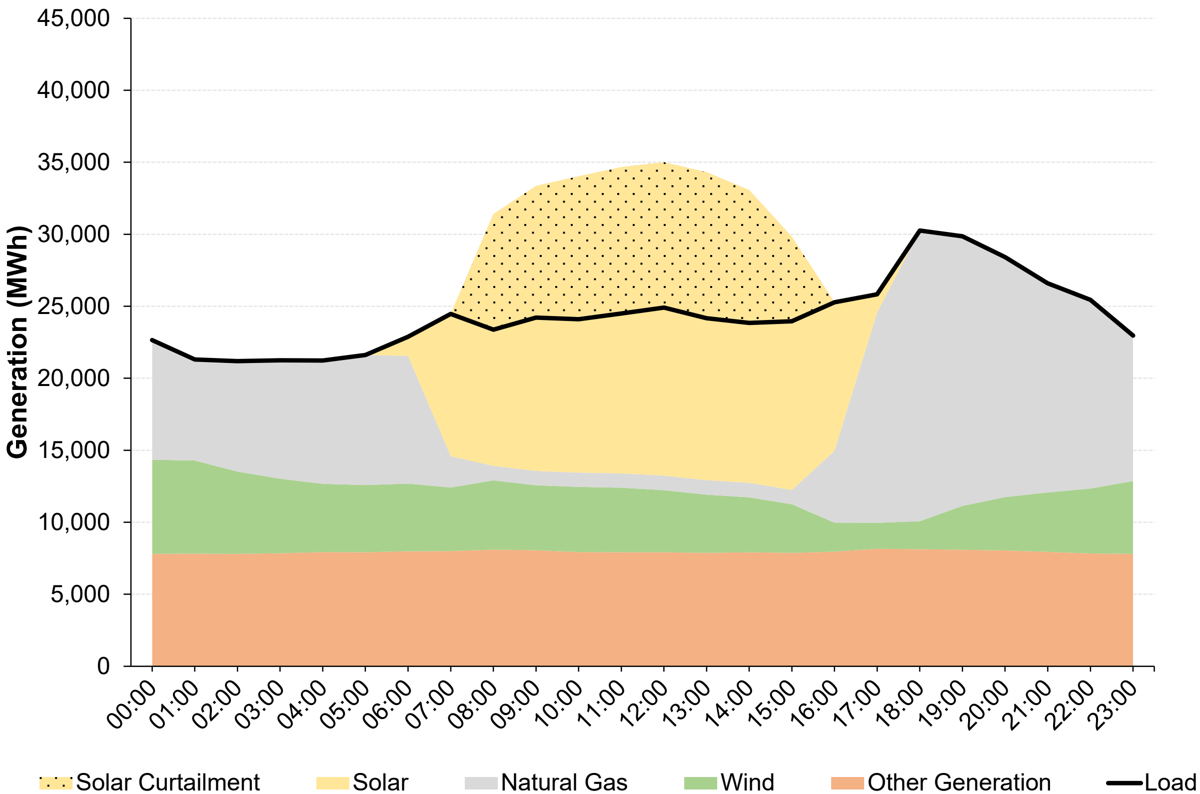
Excess variable renewable generation

"Overgeneration" from correlated output of variable renewables

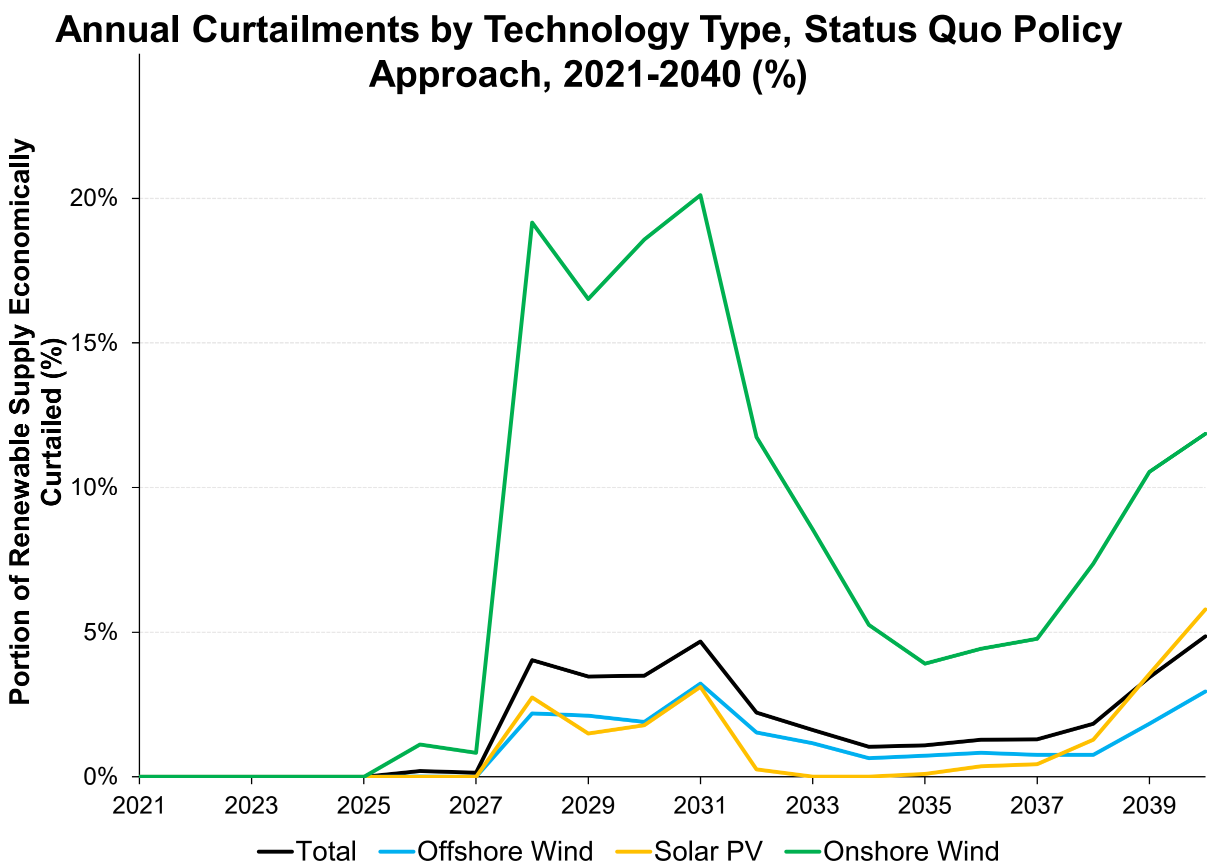
Illustration of Excess Generation from Variable Renewable Resources



- **Expanded variable renewable output** primary sources of clean (non-emitting) energy
- **Variable renewable output correlated** due to reliance on same weather-dependent technologies
- **Correlated output can lead to overgeneration and "energy droughts"**
- Study does not address the likelihood or implications of energy droughts (e.g., reliability risks)

Economic curtailments

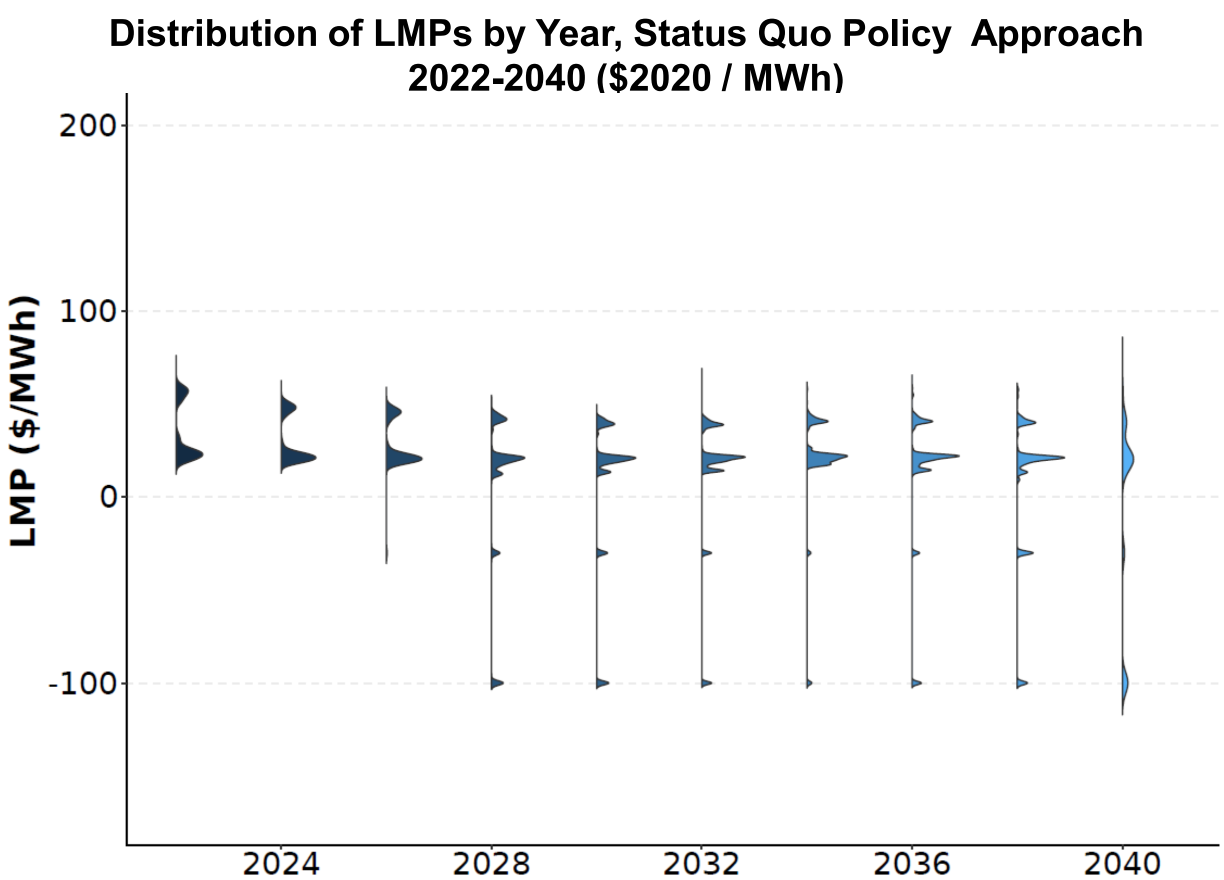
Variable renewable energy economically curtailed with overgeneration



- **Overgeneration "economically" curtailed** based on energy market offer prices (i.e., higher-priced offers do not deliver)
- **LMPs (generally) reflect variable renewable offers** during overgeneration periods
- **Curtailments are costly**, as they reduce the quantity of fossil generation variable renewable plant can displace
- **Analysis:** curtailments high in two periods: (1) 2027-33, state baseline policies increase overgeneration before significant electrification demand growth occurs; (2) 2038-40 with more stringent emission targets

Frequent, large negative LMPs

Negative LMPs from out of market energy compensation

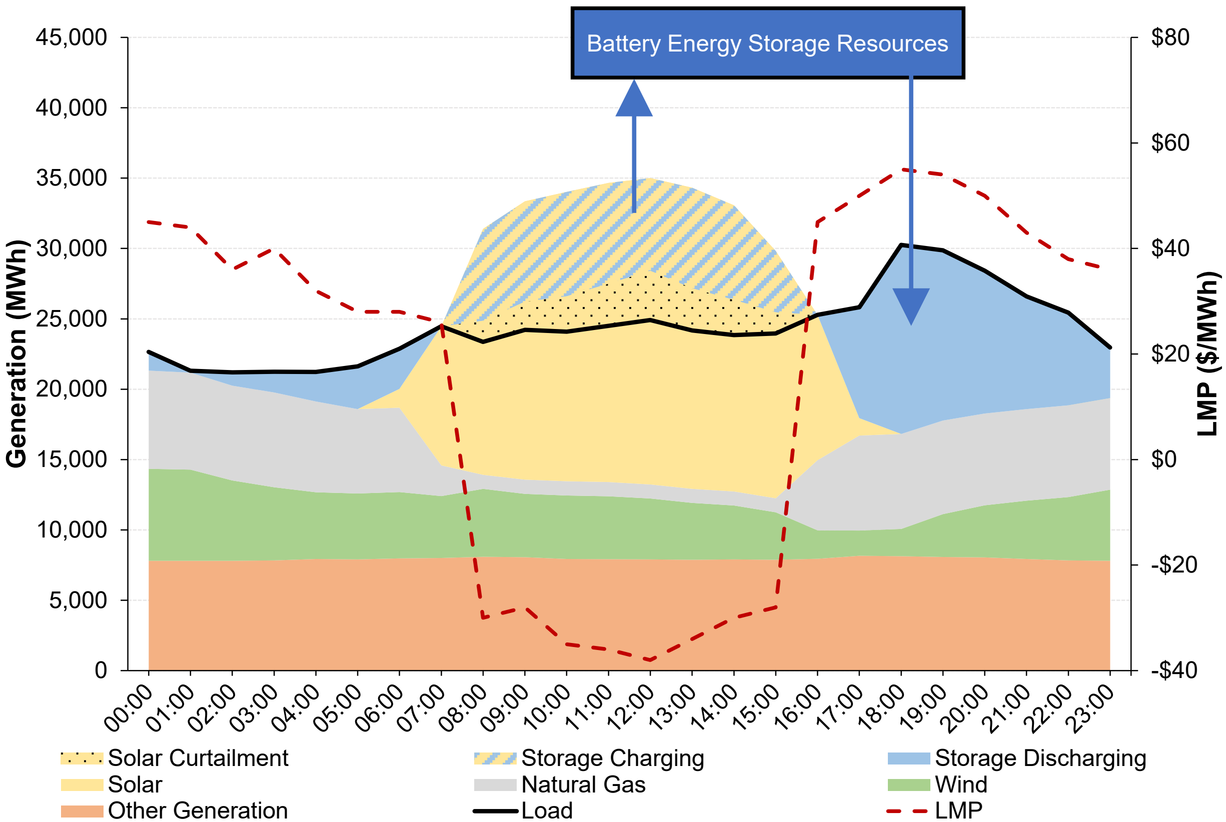


- **Variable renewable resources offer energy at negative prices** – offer energy at negative price due to out-of-market reward: PPA payment (Status Quo) or incremental compensation (CECs)
- **Negative offer prices** reflect magnitude of out-of-market reward: PPA price or CEC value
- **Market clears at these (negative) offers** when variable renewable are on the margin
- **Variable renewables more frequently on margin** as correlated output of variable renewables leads to overgeneration

Excess variable renewable generation

"Overgeneration" from correlated output of variable renewables

Illustration of Role of Storage in Mitigating Economic Curtailments



- **Storage can mitigate curtailments** by charging during periods of overgeneration and discharging when fossil generation is on the margin
- **LMP price spreads provide economic incentive** for batteries to shift variable renewable energy
- **Discharge of energy reduces emissions** by displacing fossil generation with storage energy (charged using variable renewable energy)

Other Factors Affecting Energy Market Outcomes

- Variable renewable resource fleet diversity
  - Greater fleet diversity can reduce the correlation in variable renewable output, thus reducing curtailments
  - More costly (higher capital cost, lower capacity factor) resources may be more cost-effective because output is less correlated
- Existing and new firm, dispatchable clean energy resources
  - Firm clean energy resources (e.g., nuclear) reduce the need to rely on variable renewable resources, which reduces magnitude of overgeneration
  - Dispatchable clean energy resources (e.g., combustion turbines with "green" hydrogen) can displace fossil generation directly while avoiding exacerbation of overgeneration
- Competition among variable renewable resources
  - Economic curtailments determined by energy offers, which reflect revenues earned outside the market
  - If PPA prices vary across resources, resource with lowest (or no) PPA price are more likely to be curtailed

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Assessment of Policy Approaches to Achieving Decarbonization: Design Considerations Affecting Achievement of Emission Targets (Section VI.A)

Regional Coordination and Consensus

- Policy approaches differ in how readily they can accommodate different levels of cooperation and coordination among the New England States
- Status Quo reflects unilateral actions of six New England States, assuming no coordination or consensus
- All centralized approaches can accommodate outcomes in which there is coordination and consensus among the New England States
  - Consensus could reflect, for example, regional CEC target, emission cap or carbon price
- Centralized approaches vary in their ability to accommodate coordination without consensus
  - In principle, FCEM can coordinate procurement of environmental attributes of generation (e.g., CECs) across (all or a subset of) the New England States without consensus, though this requires agreement on certain policy issues (e.g., what constitutes clean energy)
  - A policy approach with carbon pricing (in Net Carbon Pricing or Hybrid Approach) would require consensus on carbon cap or carbon price

Uncertainty over Emissions (and Cost) Outcomes

- Approaches differ in the degree of certainty they provide in whether a particular desired emission target will be achieved (and the cost of achieving a particular emission or environmental target)
- Quantity-based approaches
  - Carbon cap-and-trade – greatest emission certainty
  - FCEM – certainty over CEC quantity, but not resulting emission outcomes
  - Greater environmental certainty achieved at the expense of greater cost uncertainty
- Price-based approaches
  - Fixed carbon pricing – achieves greater cost certainty, but less environmental (emission) certainty
- In practice, many design features can moderate emission and cost uncertainty
  - Price caps and floors
  - Adjustment of emission targets/carbon prices over time (while avoiding regulatory uncertainty that may create uncertainty for investors) stable
- Centralized approaches require credible forward commitments regarding program elements (e.g., CEC/emission targets, carbon prices) by the states to provide investors with confidence about supporting revenues streams for clean energy investments

Assessment of Policy Approaches to Achieving Decarbonization: Cost-Effectiveness and Market Outcomes (Section VI.B-C)

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Cost-effectiveness

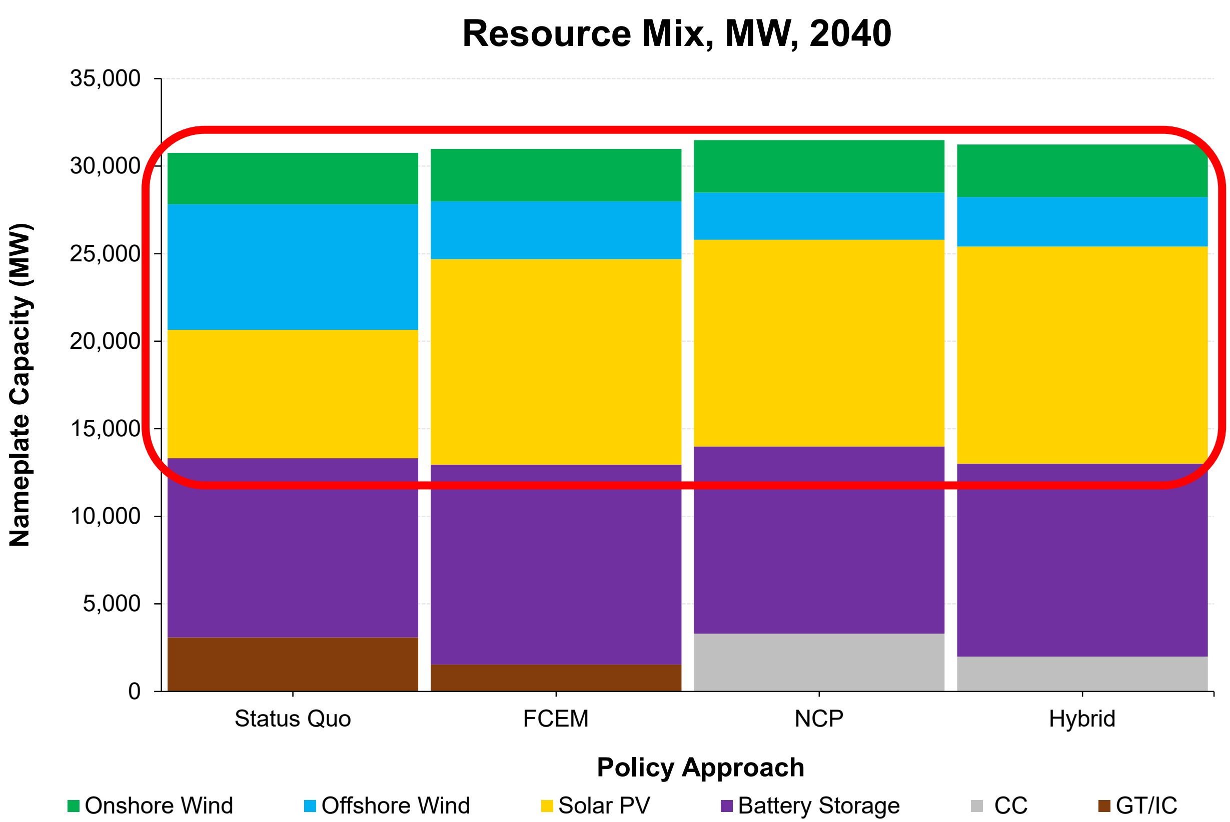
In-market incentives for emission reductions vary across policy approaches

Cost-Effectiveness of Incentives for Emission Reductions Under Alternative Policy Approaches

Cost-Effectiveness of Key Resource Decisions	*Status Quo*	*FCEM*	*FCEM w/ Dynamic CECs*	*Net Carbon Pricing*	*Hybrid Approach*
Substitution of Clean for Fossil-Fuel Resources	*NA*	High	High	High	High
Choice Among Clean Energy Resources	*NA*	Low-Medium	Medium	High	Medium
Choice Among Fossil-Fuel Resources	Low	Low	Low	High	Medium

New Resource Entry Given Policy Approach Incentives

Policy approach affects renewable resource mix



- **Mix of new variable resources varies across policy approaches**, reflecting most-profitable resource able to meet more stringent carbon targets and expanding resource adequacy needs
- In particular, balance between offshore wind and solar PV varies across cases – Status Quo has largest share of offshore wind, while NCP has the lowest share

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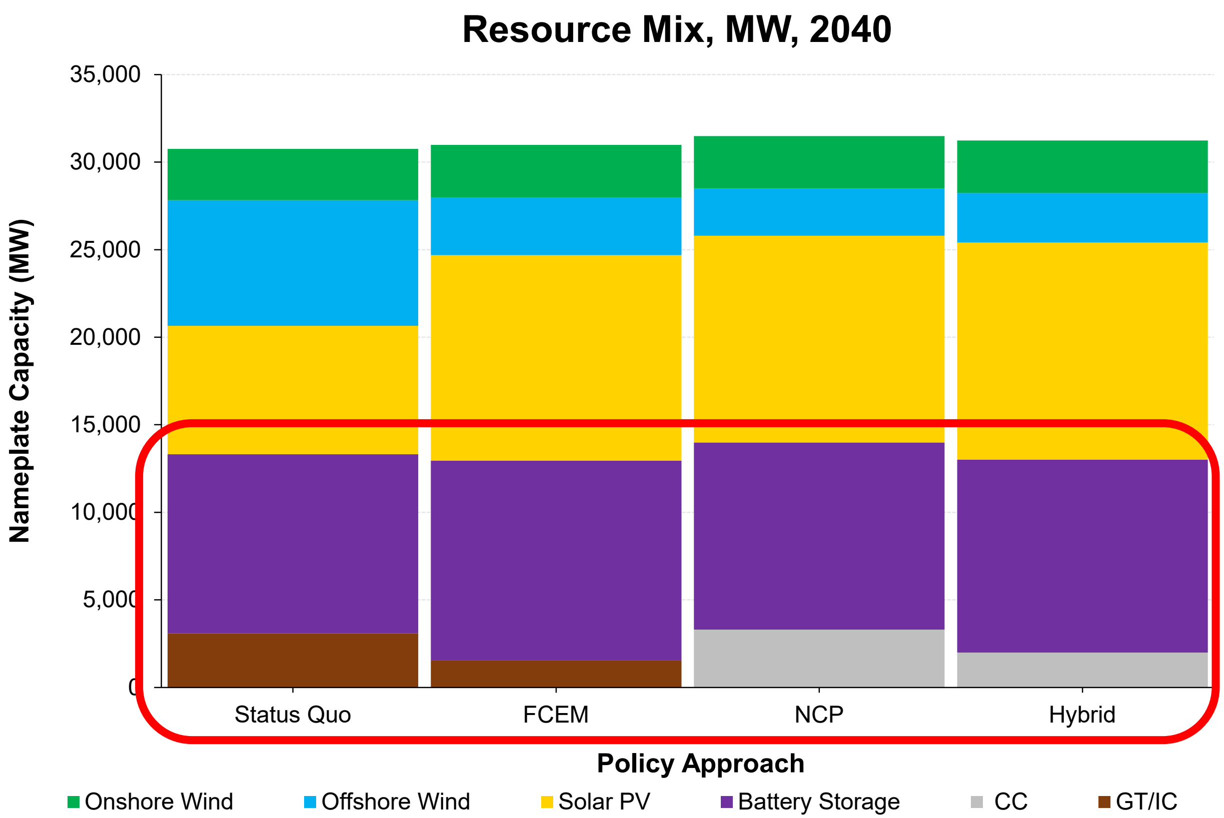
New Resource Entry Given Policy Approach Incentives

Policy approach affects dispatchable resource mix



- Battery storage capacity similar across approaches
- Fossil-fuel mix reflects incentives for fossil fuel efficiency across approaches
  - Hybrid and NCP are sensitive to carbon-intensity, thus incent new CCs, while Status Quo and FCEM include new CTs, as they do not incent lower fossil carbon-intensity

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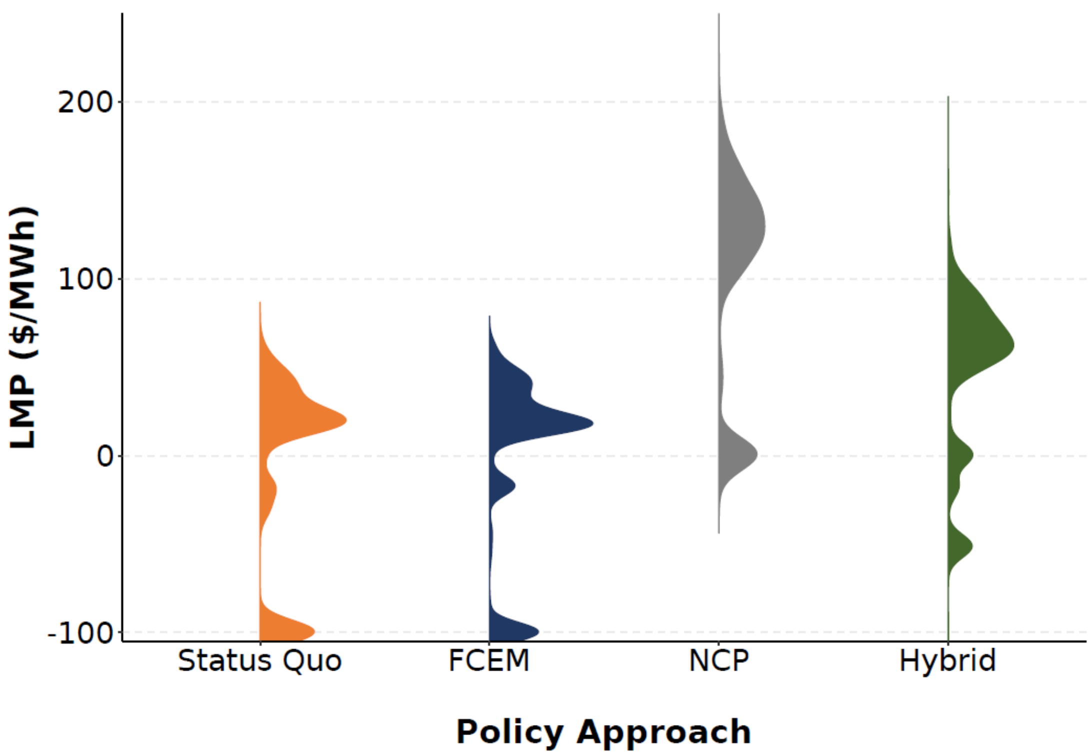
Distribution of LMPs

Distribution of LMPs varies across policy approaches

LMP Distribution by Policy Approach, 2040 ($2020/MWh)



- **All policy approaches result in larger LMP spreads,** thus incenting battery storage, which can arbitrage large price spreads
- Policy approaches differ in how approaches shift LMPs
- **Negative LMPs** with Status Quo, FCEM and Hybrid Approach, to varying degrees, but no shift in LMPs relative to current policy (when fossil is on the margin)
- **Higher LMPs** with Net Carbon Pricing (and to a lesser degree, the Hybrid Approach), but no negative pricing (when variable renewables are on the margin)

Distribution of LMPs

Distribution of LMPs varies across policy approaches

Summary Statistics for Energy Market LMPs by Policy Approach, 2040

LMP ($2020/MWh)	Status Quo	FCEM	NCP	Hybrid
Load-Weighted LMP	-2	4	106	51
Standard Deviation	54	49	60	45
Maximum LMP	68	359	325	184
Minimum LMP	-100	-100	-17	-100
% Hours with $0 LMP	0%	0%	7%	1%
% Hours with Negative LMP	33%	28%	1%	17%

- **Price spreads reflect many factors,** including variable renewable offers (given revenues outside the market), extent of economic curtailment given battery storage entry, etc.
- **Spread greatest in Net Carbon Pricing**, lowest in Hybrid Approach, as measured by standard deviation of prices

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Distribution of LMPs

Distribution of LMPs varies across policy approaches

Summary Statistics for Energy Market LMPs by Policy Approach, 2040

LMP ($2020/MWh)	Status Quo	FCEM	NCP	Hybrid
Load-Weighted LMP	-2	4	106	51
Standard Deviation	54	49	60	45
Maximum LMP	68	359	325	184
Minimum LMP	-100	-100	-17	-100
% Hours with $0 LMP	0%	0%	7%	1%
% Hours with Negative LMP	33%	28%	1%	17%

- **Fraction of hours with negative LMPs varies across approaches,** largest in Status Quo and smallest in Net Carbon Pricing (all policy approaches include baseline policy resources, which offer energy at negative of PPA price)
- **Frequency of negative prices is large** (e.g., one-in-three hours in Status Quo) even after accounting for substantial battery storage builds (12.9-14.1 GW)
- **Region has not experience frequently, large negative pricing** – consequences for region's markets would require further investigation, including implications for resource adequacy, capacity markets, etc.

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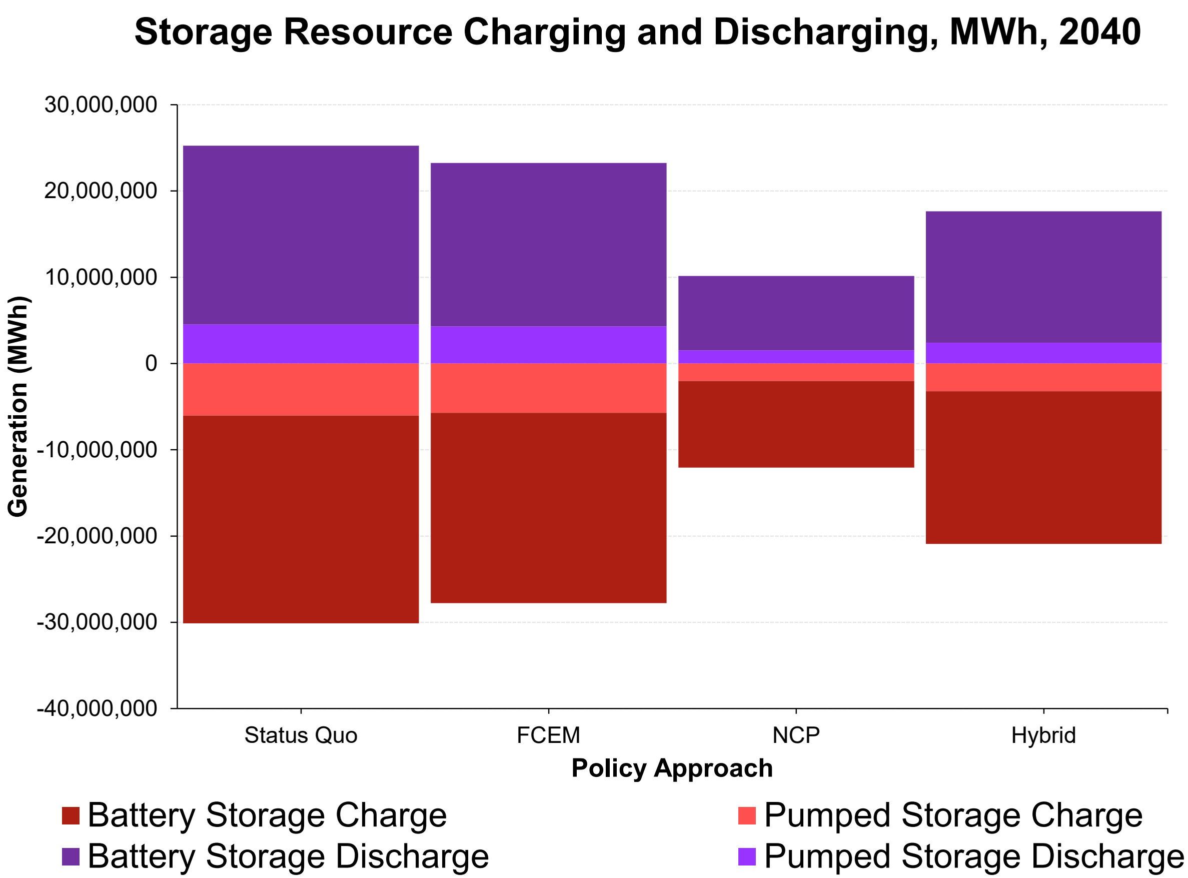
Central Case Results: Storage Charging/Discharging

Market incentives affect opportunities for storage



- **Higher level of storage charging and discharging with Status Quo, FCEM and Hybrid Approach** incented by greater frequency of negative pricing
- **Lower level of energy storage utilization in NCP** because of fewer hours with negatively charged pricing

Storage (Battery) “Churning”

- “Churning” occurs when batteries consume otherwise-curtailed variable renewable energy and earn net revenues through energy losses
  - In effect, with negative prices, the battery is paid to consume energy and then pays to discharge, but the quantity of energy discharged is smaller due to energy losses, thus allowing the battery to earn a positive return
- Example (see next slide, hours 0:00 to 9:00):

1. the battery is paid $100/MWh to charge the battery with 54 MWh of energy in each hour, earning $5,400 per hour
2. the battery pays $100/MWh to discharge 46 MWh of energy (lower than amount charged, due to losses), paying $4,600 per hour
3. the battery earns a net revenue of $800 (= $5,400 – $4,600) by “consuming” 8 MWh of energy through energy losses (difference between 54 MWh charged in Step 1 and 46 MWh discharged in Step 2), and in the process creating 8 MWh of CECs that are earned by variable renewable resources, even though these CECs do not correspond with a reduction in carbon emissions

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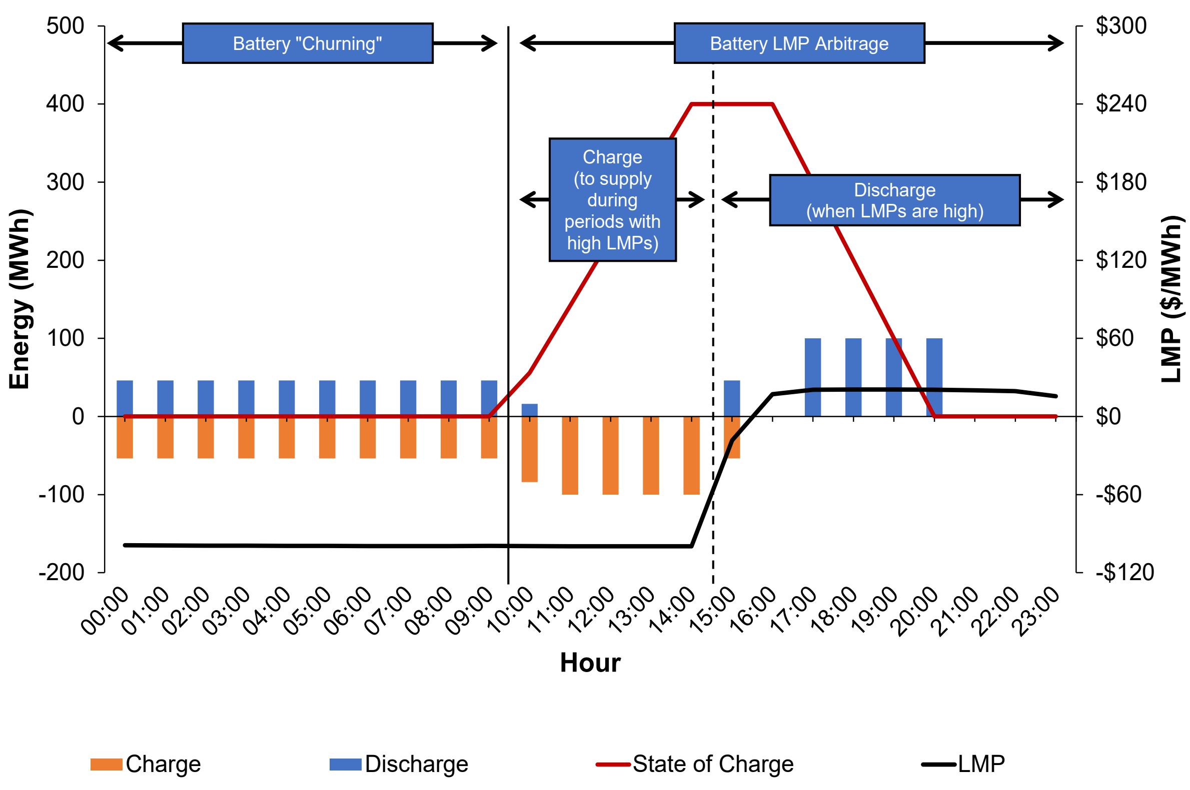
Storage (Battery) “Churning” (2)

Illustration of storage churning



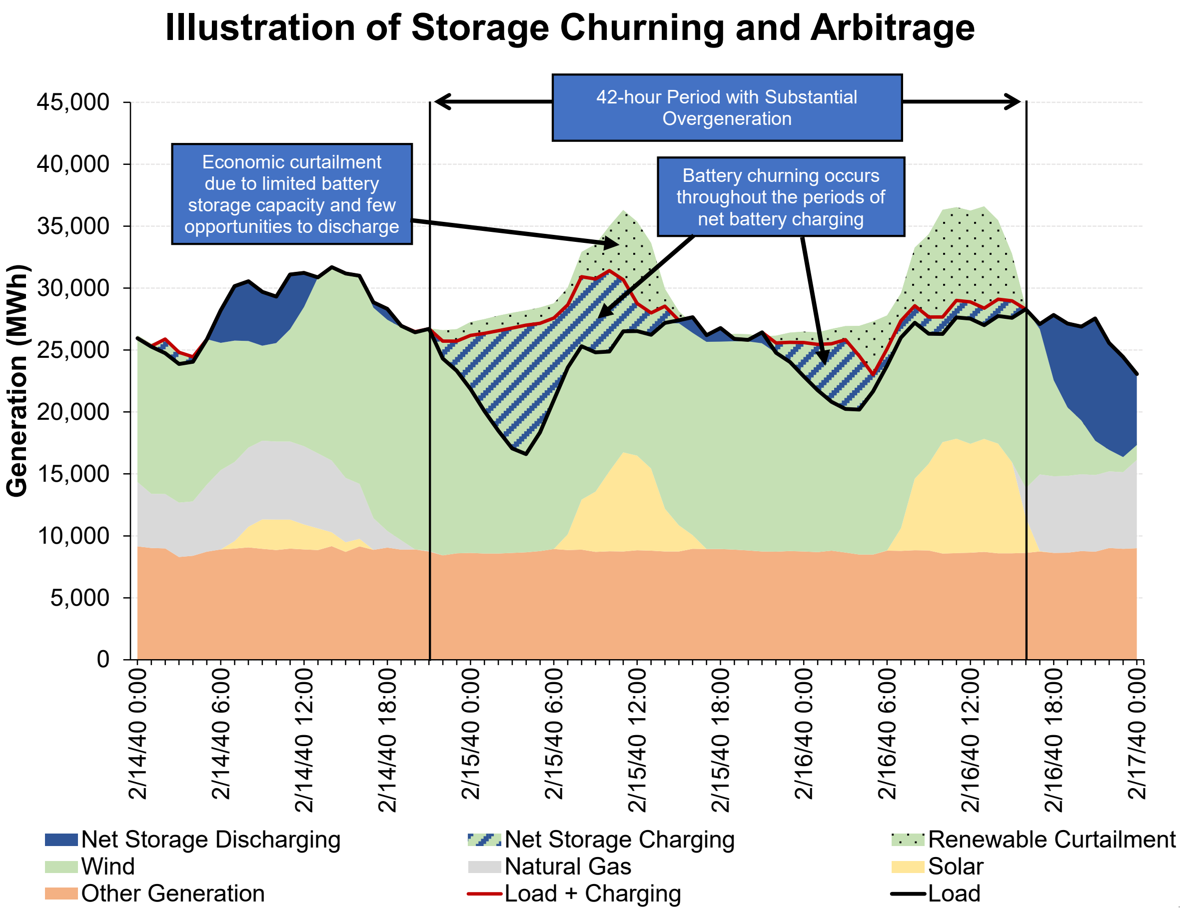
- **Storage “churning”** can occur during long-spells of negative prices (e.g., hours 0:00 to 9:00)
  - Pattern of charging and discharging differs from periods of storage LMP arbitrage
- **Storage LMP arbitrage** (shown on right hand side of figure, hours 10:00 to 20:00) shifts energy from periods of excess variable renewables to periods when discharge can displace fossil generation

Storage (Battery) "Churning" (3)

- Is churning likely to occur in practice under policy approaches that create profitable opportunities for churning (e.g., Status Quo and FCEM)?
- Churning does not appear to impose excess degradation (per MWh) on battery
  - "Shallow" charge/discharge may lead to less (rather than more) degradation than "full" charge/discharge
- Analysis indicates the potential for extended "spells" of negative pricing (given assumed loads and variable renewable patterns), which would be conducive to churning given ISO-NE market rules
- Competition from other technologies for negative LMPs
  - Storage resources are the only resources we consider able to take advantage of negative LMPs, but other technologies could become commercially available that would utilize this opportunity (e.g., production of "green hydrogen")

Storage (Battery) "Churning" (4)

Illustration of storage churning



- Illustration of extended period (42-hours) of overgeneration leading to storage churning
- Long spells with overgeneration (and negative pricing) makes execution of energy market offers to facilitate churning feasible and less risky
- Note that churning leads to CEC generation without corresponding emission reductions (by displacing fossil generation) and does not eliminate all economic curtailments

Clean, dispatchable generation

- Quantitative analysis does not include any clean energy dispatchable resources
  - Battery technologies are dispatchable resources that can shift clean energy from one period to another, but not produce clean energy *per se*
  - Potential technologies include combustion turbines or combined cycle powered by "green" hydrogen or renewable natural gas
- Centralized approaches provide incentives for these resources, if commercially available and cost-effective – no different than any other resource
- Status Quo would require some type of support (e.g., PPA) to compete with other fuels because the Status Quo provides no disincentives for operation of fossil fuel resources (e.g., natural gas)
  - Support would need to be sustained throughout the plant's lifetime because "missing money" to help these facilities compete reflects more costly fuel (capital costs may also be higher, but can be covered through a finite-term contract)
  - Design of support would be potentially complex, given need to provide sufficient (but not excessive) support to mitigate price gap for clean energy fuels relative to fossil fuels (e.g., natural gas)

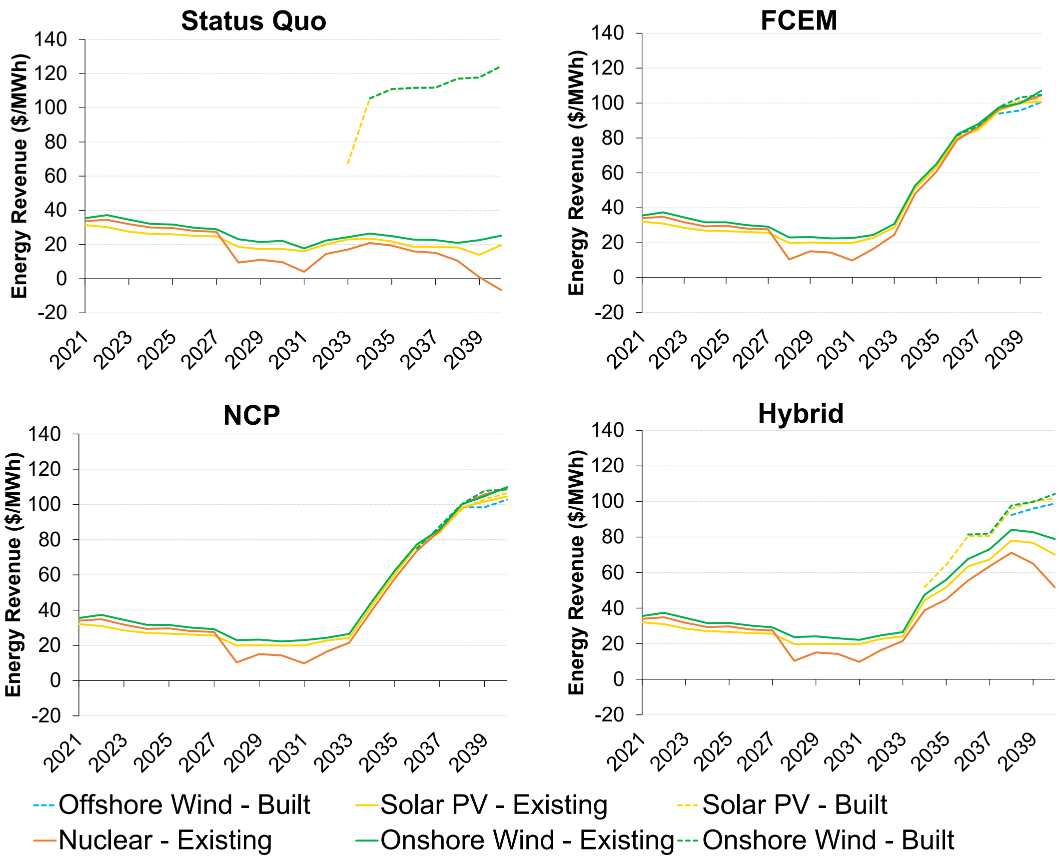
Price discrimination

- Policy approaches differ in the extent to which they offer compensation for similar "services" provided
  - FCEM and Net Carbon Pricing provide the same compensation for all resources supplying a similar service, including capacity, energy and environmental attributes
  - Status Quo and Hybrid Approach provide different compensation for similar services depending on the whether the resource is "new" or existing
- Compensating new resources at a higher rate than existing resources can produce unintended consequences
  - Economically inefficient capacity decisions, with more funds directed toward new, higher-compensated facilities relative to older, lower-compensated facilities (this effect is not measured in our quantitative analysis)
  - Differences in market outcomes across variable renewable resources – in particular, we expect economic curtailments to be greater for existing resources because their energy market offers are higher (less negative) than those from new resources (with higher PPA prices)

Price Discrimination

Degree of price discrimination varies across approaches

Comparison of Energy Revenues for Clean Energy Resources by Policy Approach



- **Status Quo.** Energy revenues for existing resources are substantially below new resources with some support (figure does not reflect payments for nuclear and existing renewables assumed in quantitative analysis)
- **Hybrid Approach.** In-market compensation for clean energy from existing resources is below in-market compensation for clean energy from new resources
- **FCEM, Net Carbon Pricing.** Same compensation for all clean energy

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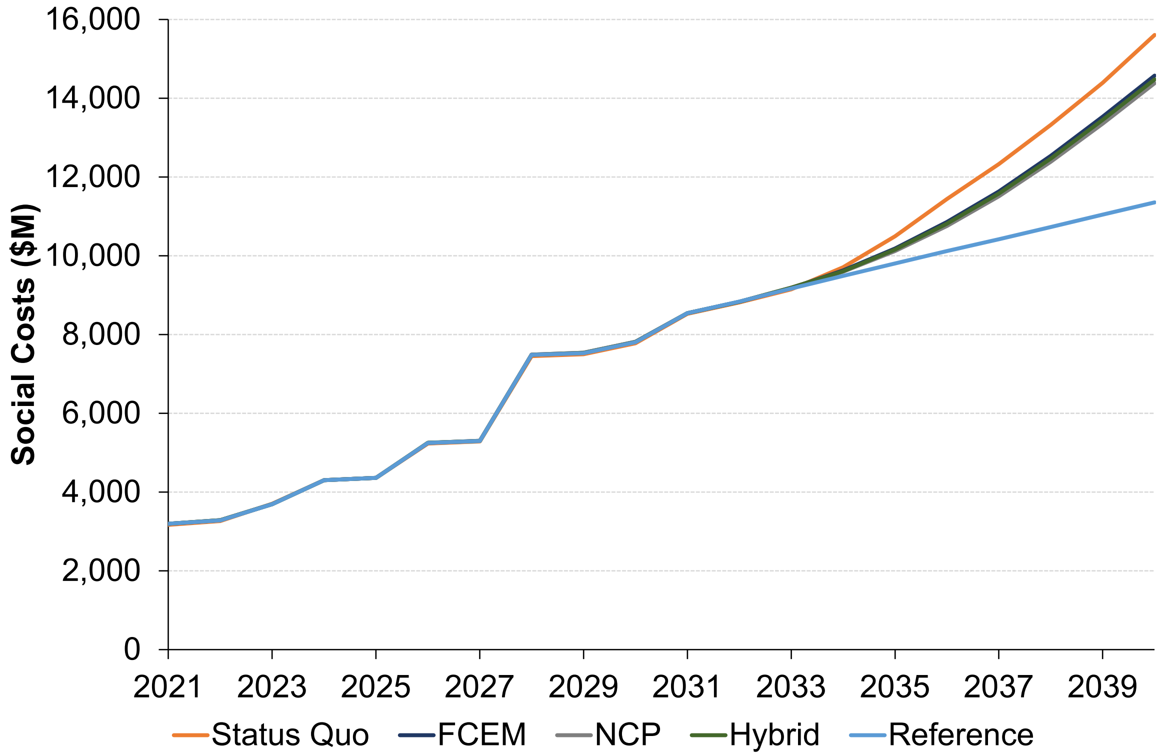
Assessment of Policy Approaches to Achieving Decarbonization: Social Costs (Section VI.D)

Social Costs

Social costs increase due to more stringent emission target

Annual Social Costs by Policy Approach, $2020 Million, 2021-2040



- **Reference Case:** Reference Case has same Central Case assumptions as other policy approaches except includes no 2040 emission target (emission reductions occur due to baseline state policies)
- **Incremental Costs:** Equals policy approach social costs minus Reference Case total social costs; reflects the incremental costs needed to achieve more stringent emission target
- **Provides appropriate metric** for evaluating relative costs across policy approaches

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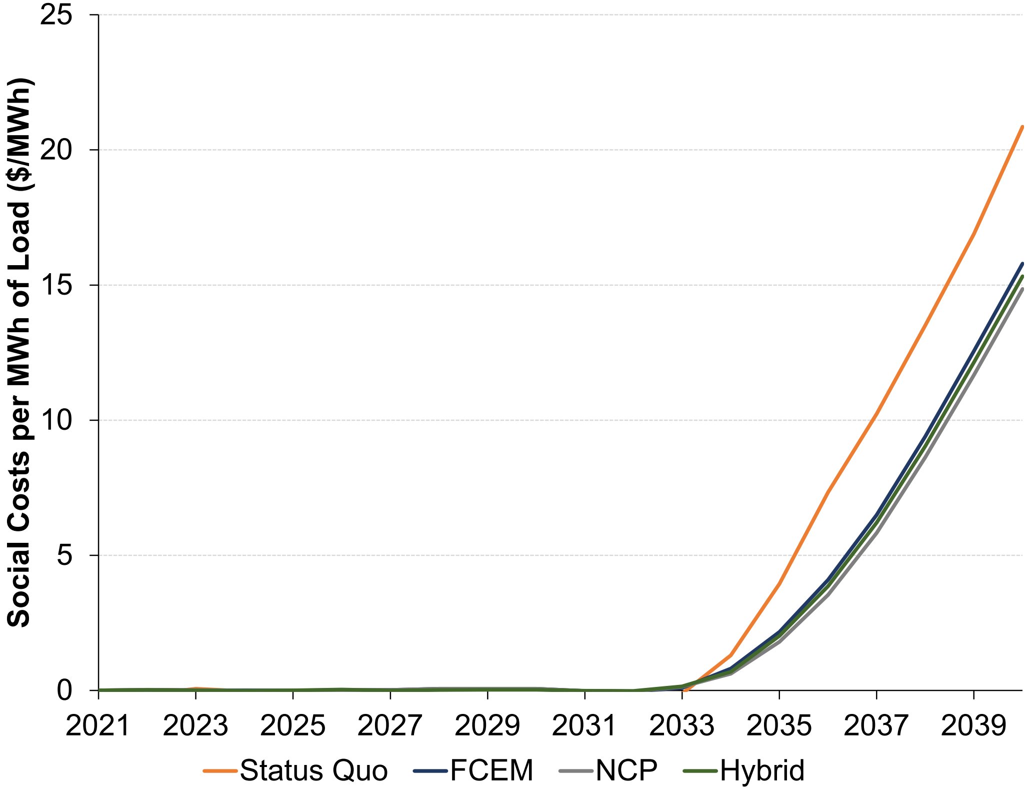
Social Costs (2)

Incremental social costs vary across approaches

Average Incremental Social Costs by Policy Approach (Relative to the Reference Case), 2021-2040 ($2020/MWh)



- **Incremental costs start in 2033** – no meaningful differences in earlier periods because of baseline state policies
- **Incremental costs increase annually** as emission target becomes more stringent

Social Costs (3)

Social costs similar between FCEM and NCP, higher for Status Quo

Incremental Social Costs by Policy Approach, 2040 and Present Value

	2040			2021-2040	
Policy Approach	**Incremental Social Cost ($2020 M)**	**Incremental Social Cost ($2020/MWh)**	**Percent Change from Status Quo**	**Present Value of Incremental Social Cost ($2020 M)**	**Percent Change from Status Quo**
Status Quo	4,256	20.86	-	6,027	-
FCEM	3,222	15.79	-24.3%	4,296	-28.7%
NCP	3,031	14.86	-28.8%	3,935	-34.7%
Hybrid	3,126	15.32	-26.5%	4,119	-31.7%

- Costs in 2040 reflect nominal values (in $2020)
- Present value as of 2021 (in $2020), assuming a 5% discount rate

Social Costs (4)

Social costs similar between FCEM and NCP, higher for Status Quo

- Centralized approaches (FCEM, Net Carbon Pricing, Hybrid Approach)
  - In present value terms, Net Carbon Pricing has the lowest social costs; FCEM and Hybrid Approach are 9% ($361 million) and 5% ($184 million) higher than Net Carbon Pricing, respectively
- Status Quo
  - In present value terms, Status Quo has the highest social costs – costs over study period are $2.1 billion (53%) higher than lowest-cost policy approach (Net Carbon Pricing)
  - Higher costs reflect a combination of factors, including differences in in-market incentives for emission reductions and assumed resource mix given current state studies and roadmaps
- Conclusions are similar for final year of study, 2040 (with values reported in nominal terms)
  - In 2040, FCEM and Hybrid Approach are 6% ($191 million) and 3% ($95 million) higher than Net Carbon Pricing, respectively
  - In 2040, Status Quo costs are $1.2 billion greater than Net Carbon Pricing (in $2020)

Assessment of Policy Approaches to Achieving Decarbonization: Prices and Customer Payments (Section IV.E)

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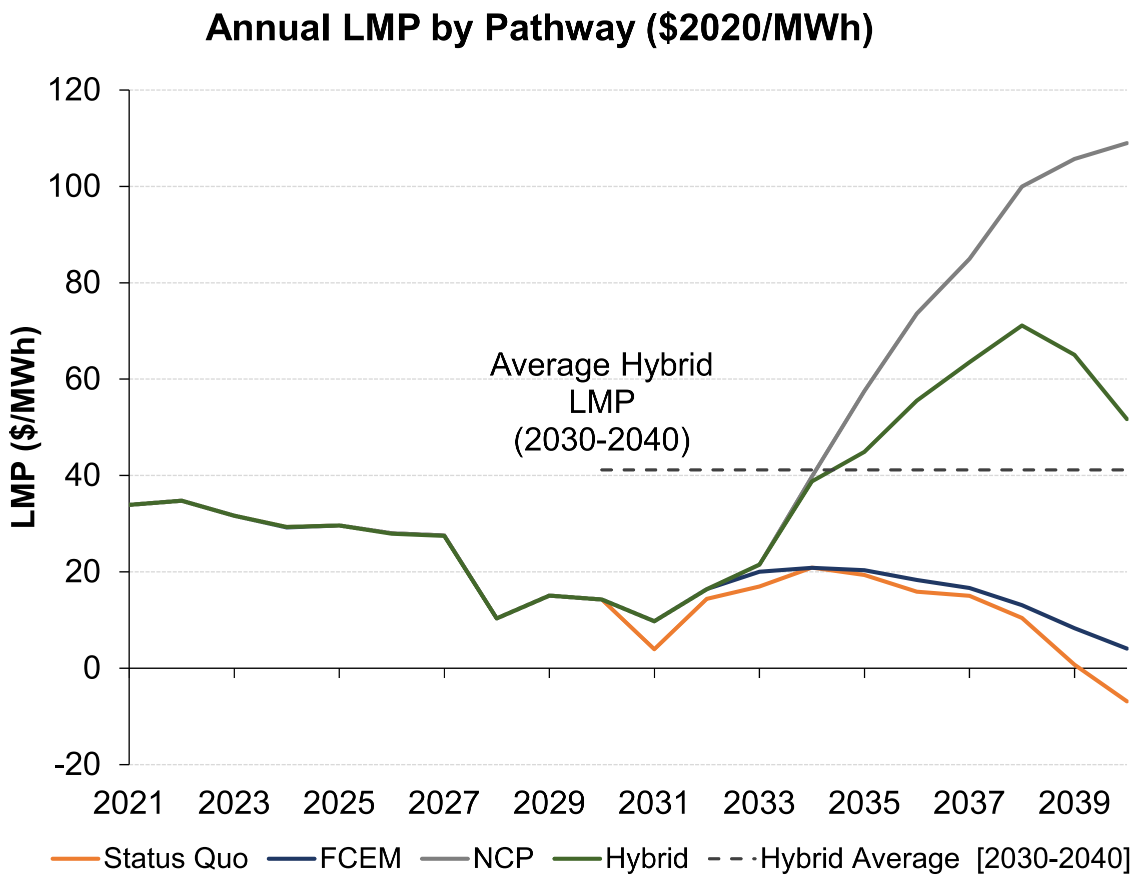
LMPs

LMPs vary widely across policy approaches



Difference in LMPs among the approaches grows over time

- **Limited differences in LMPs prior to 2033**, when incremental emission reductions needed to meet 2040 emission target (given baseline state policies)
- **LMPs begin to diverge more dramatically** when the environmental constraints begin to bind
- Hybrid LMP is ~$41 on average starting in 2030 (relevant as benchmark compensation for existing clean energy resources)

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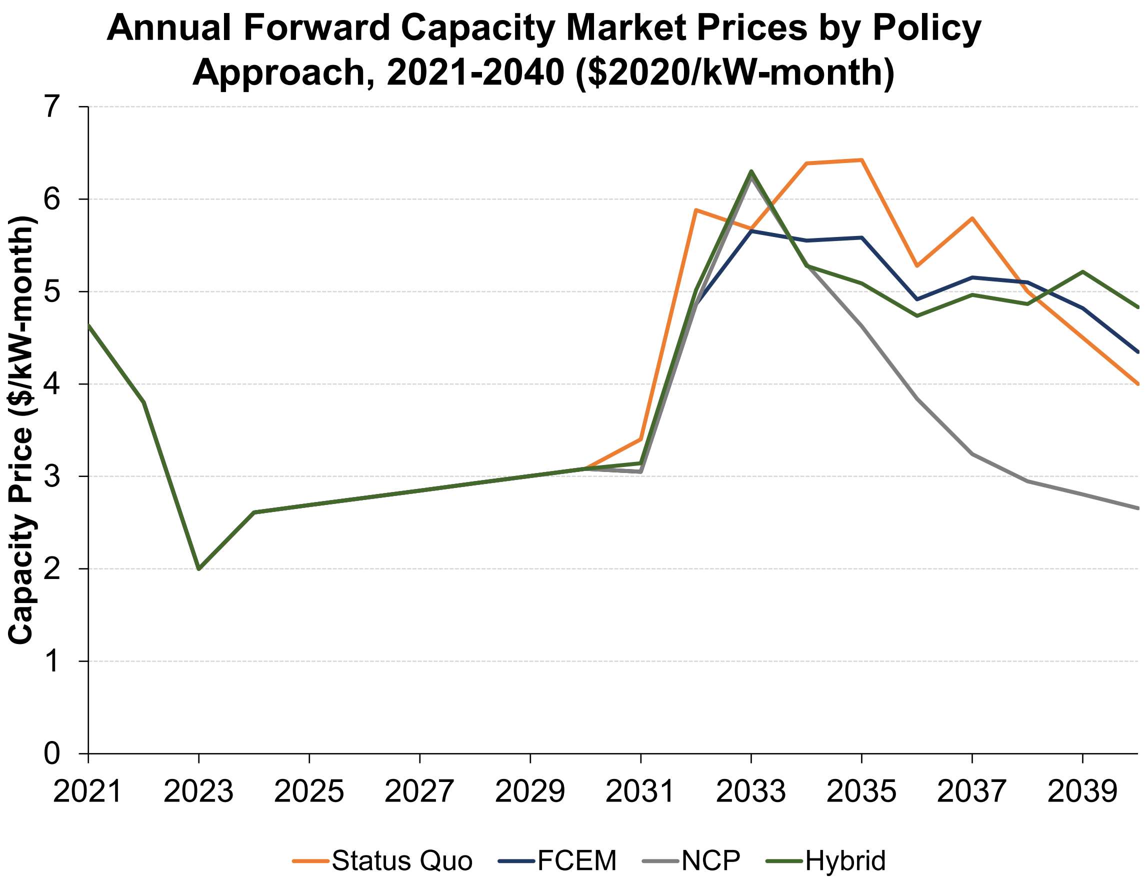
Capacity Market Prices

Capacity market prices follow a similar pattern across policy approaches



- Capacity market prices follow a similar pattern across approaches
  - **Prices increase when the environmental constraints begin to bind,** as these lower gas-fired energy market revenues
  - **Prices decrease over time,** as battery resources become the cost-effective resource supplying capacity and greater overgeneration increases energy market arbitrage opportunities

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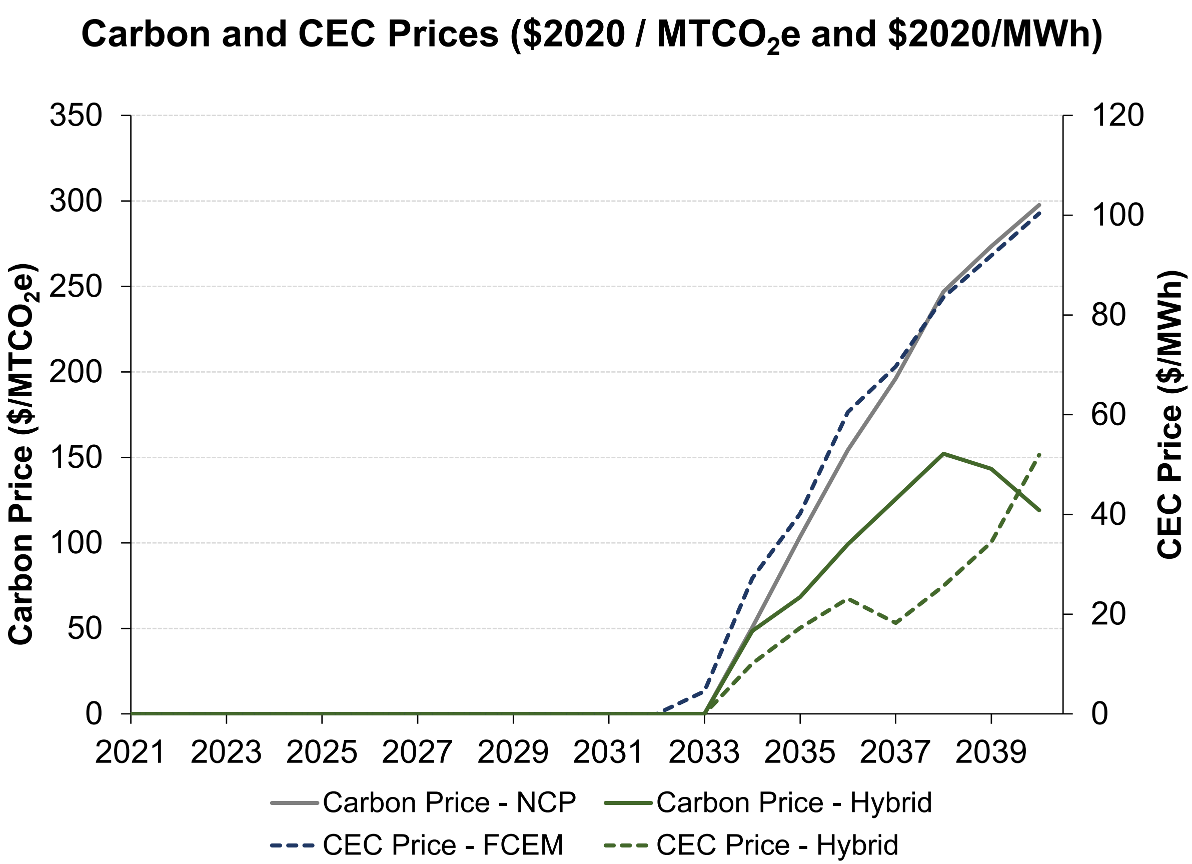
Environmental Prices

CEC and carbon prices grow with increasing target stringency



- **CEC and carbon prices rise over time with increasing stringency**
  - "Kink" in Hybrid Approach carbon price reflects assumption of annual targets and complex interaction between model constraints (CEC, emission, etc.)
- **Carbon prices reflect the cost of marginal abatement** in each year, while **CEC price reflects the "missing money"** needed for new clean energy entry
- CEC and allowance banking would flatten CEC and carbon prices – higher in earlier years, lower in later years

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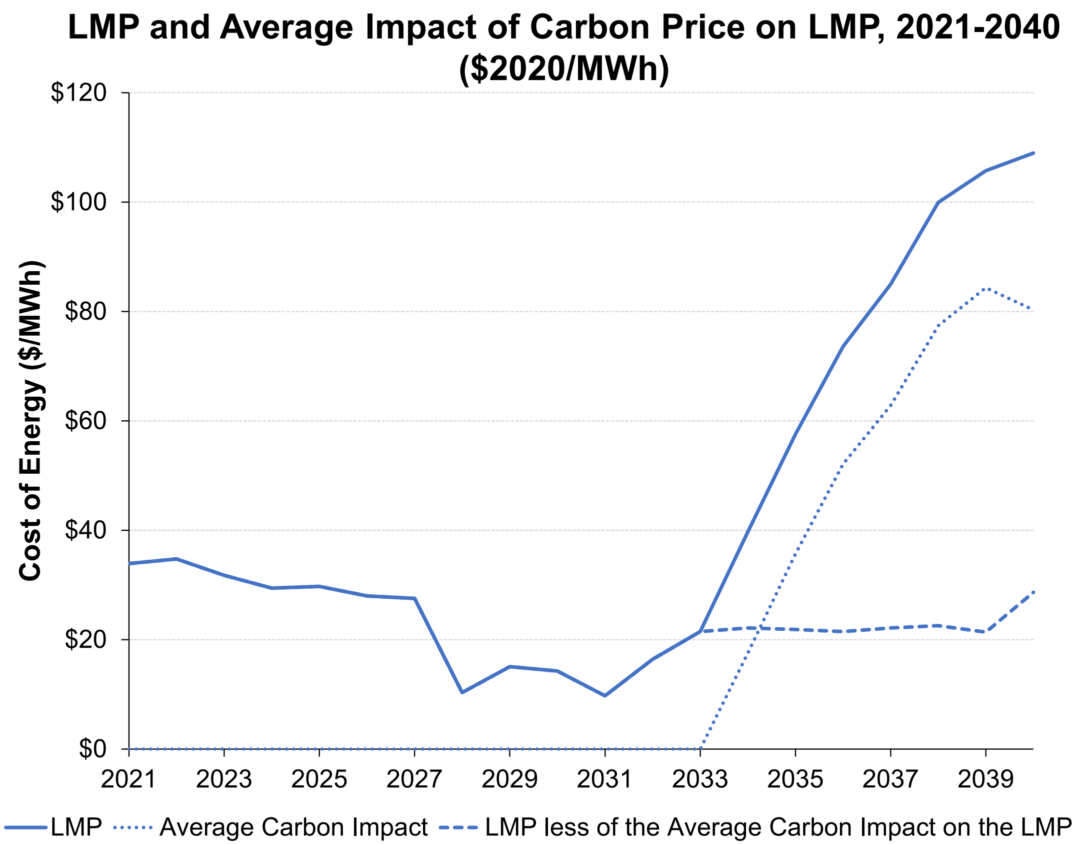
Central Case Results: Net Carbon Price

Credit of carbon prices lowers effective LMP charged to customers



- LMPs can be decomposed into two components
  - Average variable costs (variable O&M and fuel)
  - Average impacts of carbon pricing
- Average variable costs remain relatively constant over time (consistent with relatively flat natural gas price forecast)
- Impact of carbon pricing grows over time with more stringent target

Customer Payments

- From an economic perspective, social costs provides the best metric for evaluating the (opportunity) costs to society of achieving decarbonization targets
- However, we recognize that there is interest in comparing customer payments, which reflects gains to consumers (i.e., consumer surplus) and does not reflect consequences to producers (i.e., producer surplus)
- For each policy approach, total payments by customers reflects four components:
  - Energy market payments, including PPA contracts and LMPs (which reflect competitive offers including carbon prices)
  - Forward Capacity Market payments
  - CEC payments in FCEM and Hybrid Approach
  - Credit to customers for carbon tax payments (by generators) in Net Carbon Pricing and Hybrid Approach
- For the FCEM, Net Carbon Pricing and Hybrid Approach, the payments reflect in-market payments at market prices, in addition to the PPA contracts for currently legislated procurements assumed in all cases

Customer Payments – Status Quo Assumptions

- Total payments under the Status Quo approach reflect out-of-market purchases of energy through PPAs
  - Total energy market payments are calculated assuming energy procured through PPAs is paid for at the PPA price, not the market-clearing LMP
  - PPA contract prices reflect levelized cost of supplying energy (net of FCM revenues) given changes in underlying costs (technological change, transmission), escalating curtailments, and market-clearing prices in PPA procurements

Customer Payments – Status Quo Assumptions

- Total payments for the Status Quo approach are sensitive to whether existing clean energy resources are provided with payments for "clean energy" services in additional to energy market and FCM revenues
  - Absent payments for clean energy, revenues decline over time for existing clean energy resources with the increased procurement of renewable energy
- We assume that existing clean energy resources receive supplemental payments for clean energy in light of retirement risks and potential for sales to other regions
  - Existing nuclear receives $41/MWh (e.g., through an extended PPA)
  - Existing renewables (but not nuclear) receive an escalating REC payment, given "outside" options (e.g., sale of clean energy to New York or other region) – RECs rise from $0/MWh in 2030 to $60/MWh in 2040
  - We believe these assumptions are toward the *lower* end of reasonable assumptions about compensation for existing renewables

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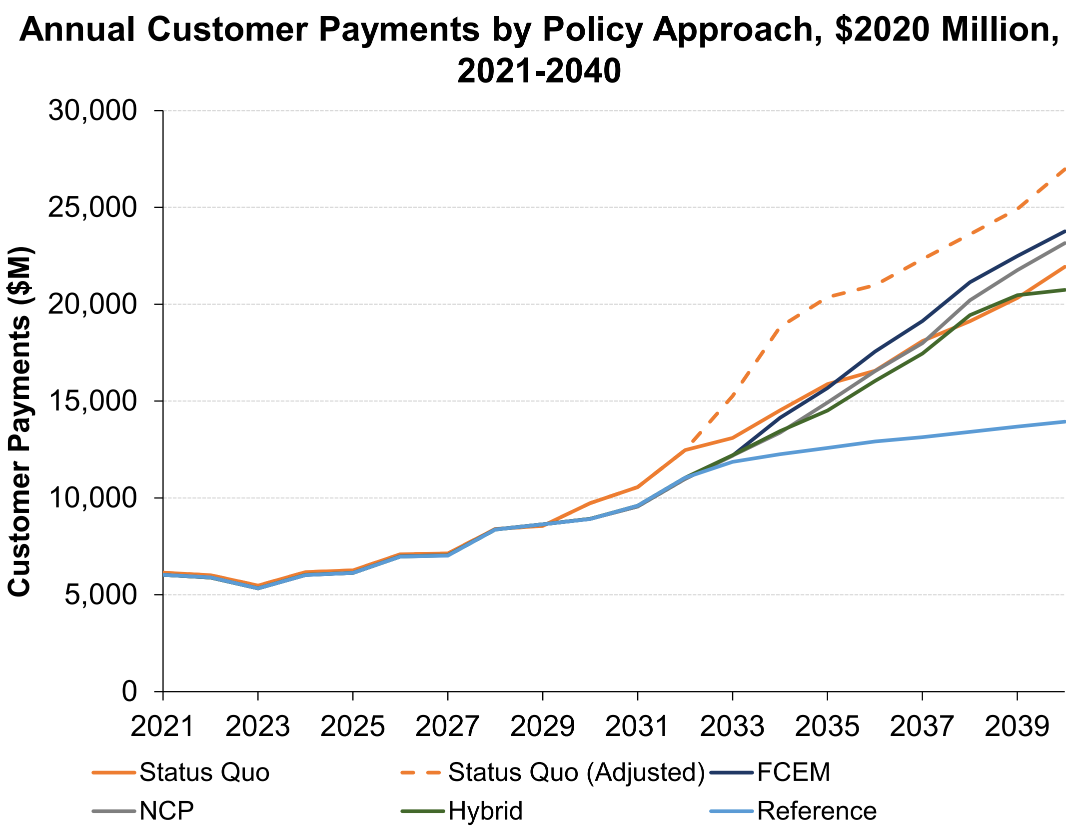
Customer Payments: Results

Customer payments increase due to more stringent emission target



- **Like social costs, customer payments are evaluated relative to customer payments in Reference Case**
- **Incremental Payments:** Equals policy approach payments minus Reference Case total payments; reflects the incremental payments needed to achieve more stringent emission target
- **Provides appropriate metric** for evaluating relative payments across policy approaches

Customer Payments – Alternative Status Quo Assumptions

- Status Quo assumptions in prior slide reflect payments to existing clean energy at lower rates than received by new clean resources (via PPAs)
- In alternative Status Quo assumptions, existing clean energy is compensated at same level as new clean energy (via PPAs)
  - Total payments increase compared to Central Case assumption
- Payments that assume existing clean energy is compensated at the same level as new clean energy reflects an upper bound on plausible payments

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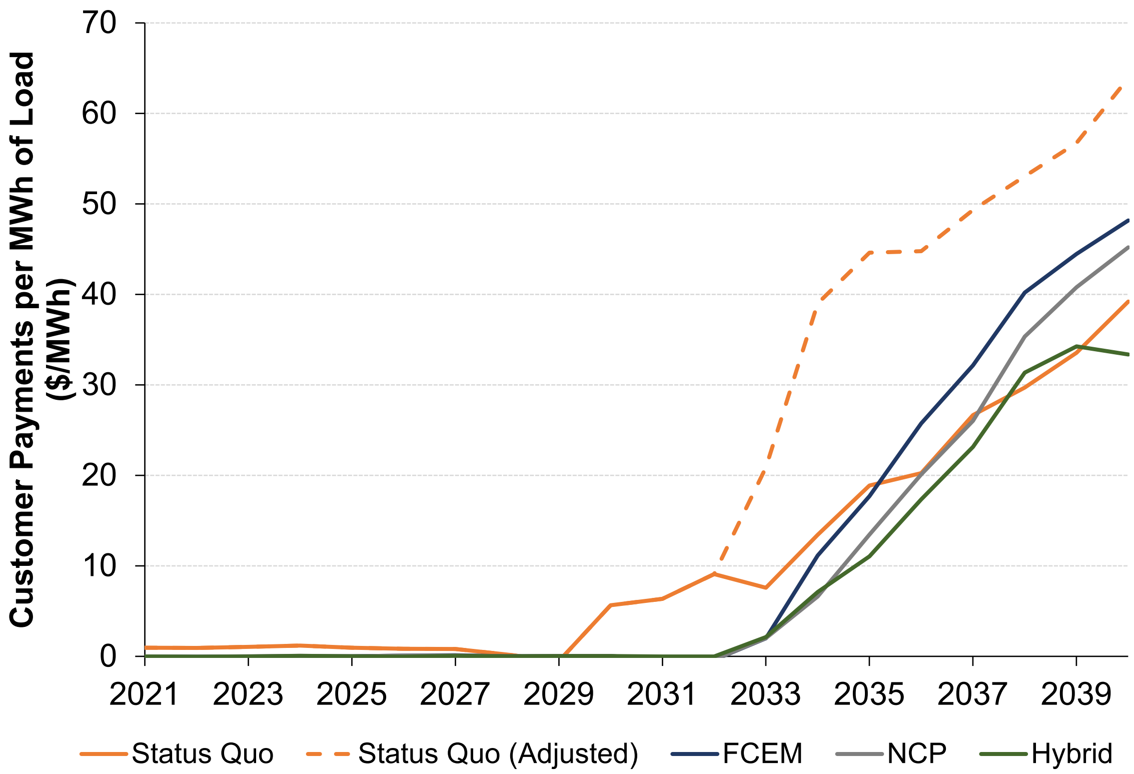
Customer Payments: Results (1)

Incremental customer payments differences reflect multiple factors

Average Incremental Customer Payments by Policy Approach (Relative to the Reference Case), 2021-2040 ($2020/MWh)



- **Incremental payments follow similar pattern across policy approaches** – with all approaches, payments increase with increased emission stringency
- **Differences across approaches reflect multiple factors:**
  - **Cost of emission reductions**
  - **Price discrimination**
  - **Market interactions**, particularly between energy and environmental market outcomes and capacity market outcomes, reflecting multi-year revenue recovery

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Customer Payments: Results (2)

Customer payments similar between FCEM and NCP, higher for Status Quo

Incremental Customer Payments by Policy Approach, 2040 and Present Value

	2040			2021-2040	
Policy Approach	**Incremental Payments ($2020 M)**	**Incremental Payments ($2020/MWh)**	**Percent Change from Status Quo**	**Present Value of Incremental Payments ($2020 M)**	**Percent Change from Status Quo**
Status Quo	7,997	39.20	-	18,692	-
Status Quo (Adjusted)	13,034	63.89	63.0%	34,368	83.9%
FCEM	9,828	48.18	22.9%	18,600	-0.5%
NCP	9,222	45.20	15.3%	15,872	-15.1%
Hybrid	6,806	33.36	-14.9%	13,442	-28.1%

- Payments in 2040 reflect nominal values (in $2020)
- Present value as of 2021 (in $2020), assuming a 5% discount rate

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Customer Payments (3)

Customer payments across policy approaches reflects multiple factors

- Hybrid Approach has lowest payments, reflecting combination of in-market incentives and price discrimination
- Net Carbon Pricing has higher payments than the Hybrid Approach – 18% ($2.4 billion) in present value terms, reflecting the low social costs
- Status Quo and FCEM have similar payments, higher payments than the Hybrid Approach
  - Status Quo is 39% ($5.3 billion) higher than the Hybrid Approach in present value terms, reflecting combination of price discrimination (which lowers payments) and higher costs
  - FCEM is higher by 38% ($5.2 billion) in present value terms; FCEM is less cost-effective than Net Carbon Pricing, thus leading to higher payments than Net Carbon Pricing
- Alternative Status Quo – Most costly, given higher social costs and no price discrimination
- Conclusions are similar for final year of study, 2040 (with values reported in nominal terms)
  - In 2040, Net Carbon Pricing payments are 35% ($9.2 billion) higher than Hybrid Approach
  - In 2040, Status Quo and FCEM payments are 17% ($1.2 billion) and 44% ($3.0 billion) higher than the Hybrid Approach, respectively

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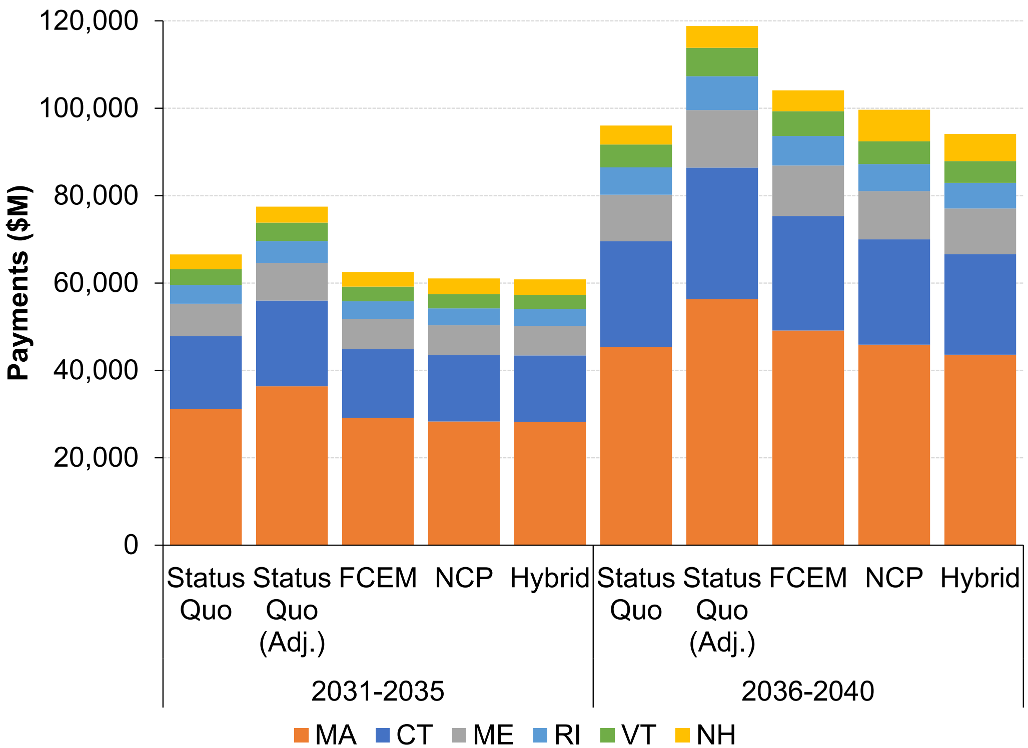
Customer Payments by State

Payments vary by state, largely due to load differences

Allocation of Total Payments by State and Policy Approach, 2031-2040 ($2020 Million)



- **States with more ambitious emission reduction goals bear a larger fraction of total payments** in the Status Quo and FCEM
- **Payments are spread more evenly across states, in proportion to load** when approach includes carbon prices; Hybrid Approach (combining carbon pricing and CECs) shares payments proportionately, but to a lesser degree

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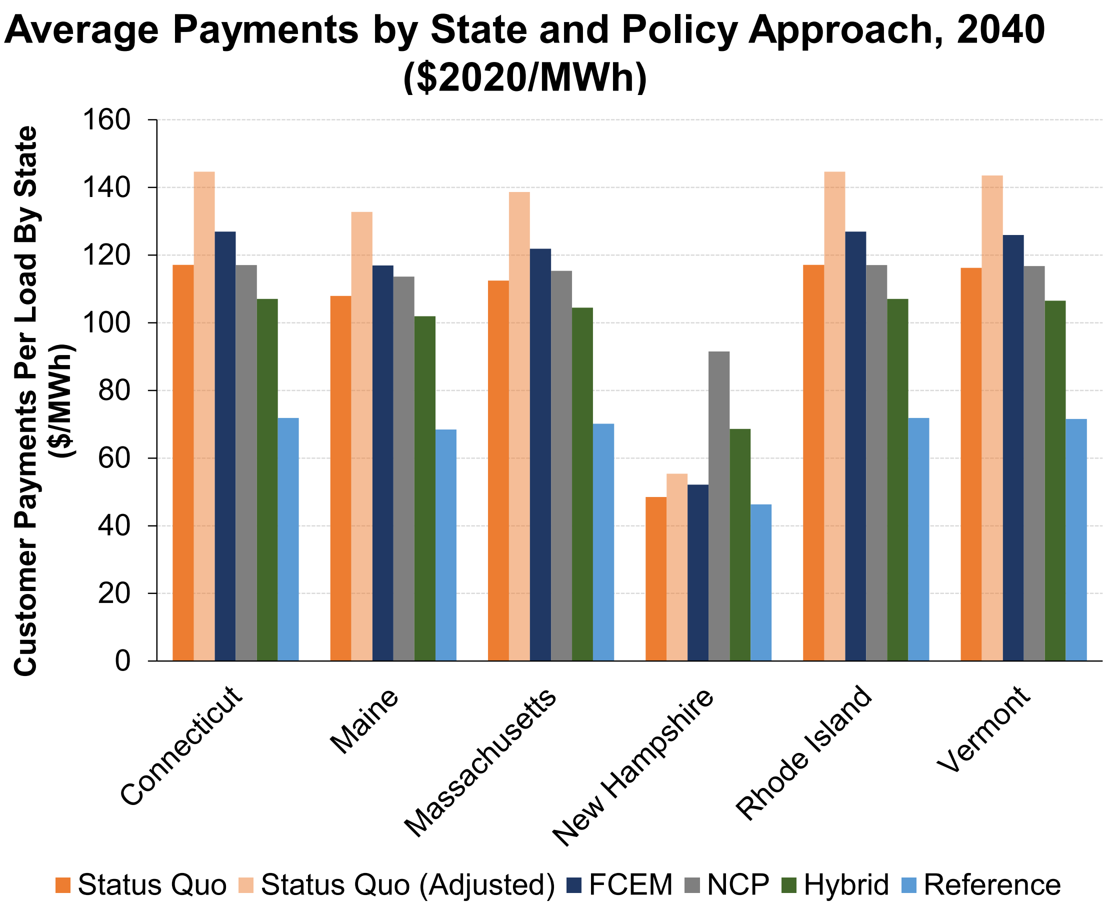
Customer Payments by State

Payments vary by state, largely due to load differences



- Incremental impact of ambitious emission reduction goals can be assessed by comparing to the Reference Case (which does reflect differences in state decarbonization commitments)

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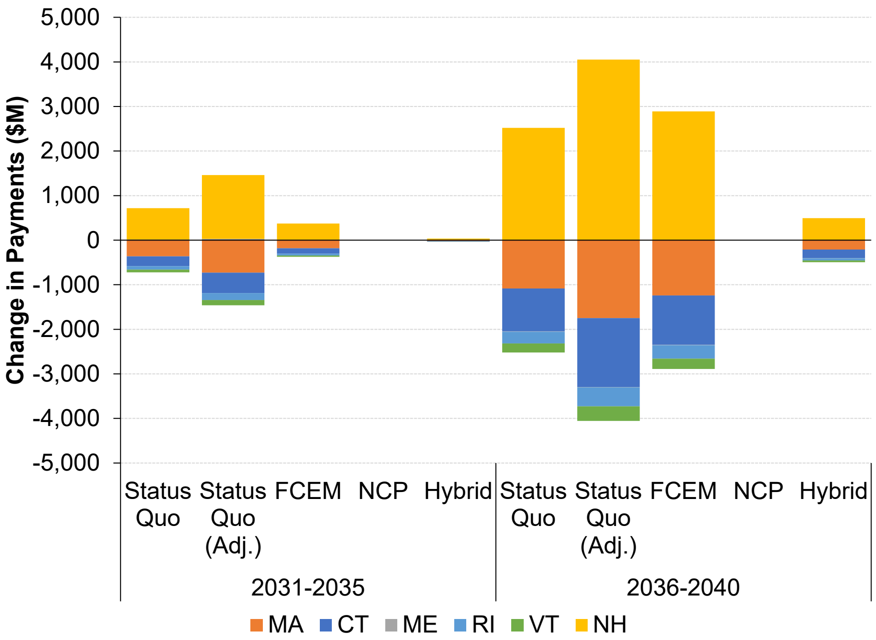
Scenario: Alternative Payments by State

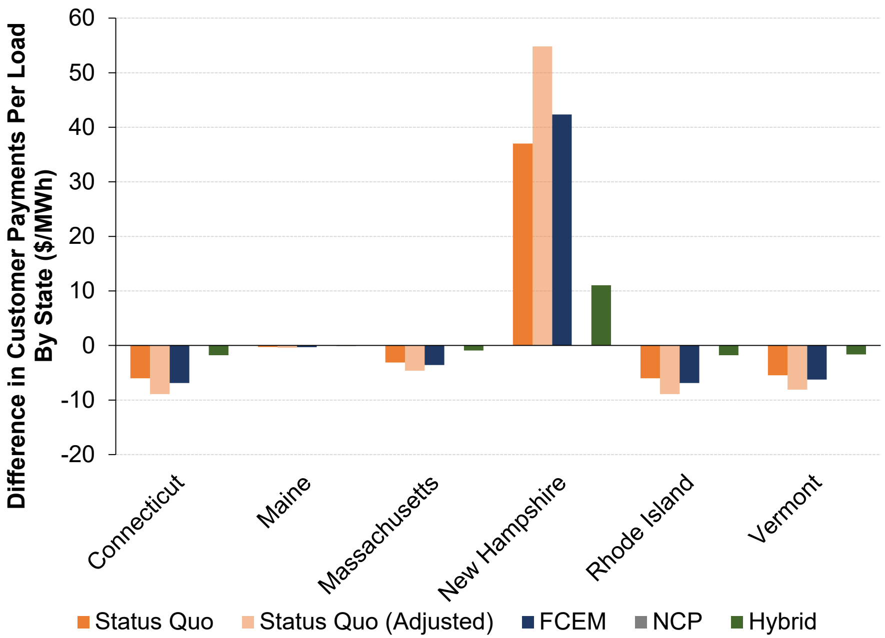
All payments weighted by electricity demand

- Allocation of all payments (including clean energy payments) by load rather than state commitments to decarbonization shifts payments from states with greater than average commitments to states with less than average commitments

Change in Payments from Alternative Payment Allocation for Each State by Policy Approach, 2031-2040 ($2020 Million)



Change in Payments from Alternative Payment Allocation for Each State by Policy Approach, 2040 ($2020/MWh)



Assessment of Policy Approaches to Achieving Decarbonization: Other Environmental, Economic and Market Consequences (Section IV.F)

Other Environmental, Economic and Market Consequences

- Several potential consequences for ISO-NE markets that may vary across policy approaches
- Negative LMPs
  - Potential consequence associated with certain policy approaches (e.g., Status Quo and FCEM, and, to a less degree, Hybrid Approach), but not others (i.e., Net Carbon Pricing)
  - The full consequences of frequent, large negative price for ISO-NE markets is not evaluated, but have potential consequences that merit further research
  - Negative prices could increase uplift payments, particularly for less-flexible resources with intertemporal constraints (e.g., minimum run times, start up costs, etc.)
- Resource adequacy construct and outcomes
  - Broader implications not evaluated, including implications for orderly transition in resources, including exit and entry

Other Environmental, Economic and Market Consequences

- Economic Consequences of Multi-year Contracts
  - Multi-year contracts pose tradeoffs between impacts to project financing costs and utility and customer financial risk
  - Report discusses and provides evidence for economic tradeoffs
    - Multiyear contracts may lower project financing costs (e.g., lower debt costs)
    - Multiyear contracts transfers financial risk to utilities and/or customers (e.g., debt equivalency)
  - Quantitative analysis does not account for potential impact on project financing costs given uncertainty over corresponding economic cost associated with increased customer financial risk

Other Environmental, Economic and Market Consequences

- Many challenges for implementation – for example:
  - FCEM
    - Forward structure of FCEM is novel
    - Various questions about how CECs interact with existing state RECs
    - Potential integration with FCM (into ICCM) would raise many technical challenges
  - Hybrid Approach
    - Challenges to administratively and computationally "calibrate" carbon prices and CEC quantities to achieve LMP and emission targets given interactions between carbon prices, CEC quantities and energy markets
    - Uncertainty associated with Hybrid Approach would not necessarily guarantee that largest clean energy resources (or other clean energy resources) would remain in the market
      - The Hybrid Approach presents large clean energy resources currently with PPAs with a financial riskier position, given uncertainty in LMPs (despite the intent of the Hybrid Approach) and capacity market prices
      - Existing PPAs for nuclear plants provide a (relatively) sure energy market revenue stream (for large portions of the plant's output)

Comparison of Scenarios (Section VII)

Quantitative Scenarios

- Robustness of Central Case findings are tested through scenario analysis that modifies certain Central Case assumptions
- The following scenarios are evaluated:
  - Alternative regional carbon target – 85% below 1990 emissions by 2040
  - Alternative levelized costs of new entry for renewable resources
  - Additional retirements
  - Transmission and congestion (not discussed in December)
  - Hybrid only: alternative LMP targets for existing renewables (not discussed in December)
  - Alternative distribution of costs amongst states (address above in analysis of customer payments)
  - Adjusted Status Quo payments to existing clean energy (address above in analysis of customer payments)
- Discuss Transmission and Alternative Hybrid Policy scenarios, not discussed in December

Transmission Scenario

- Transmission scenario introduces a simplified set of transmission constraints for New England system
  - Includes regional transmission interfaces, but not detailed constraints or contingencies
  - Not intended as a full representation of potential transmission needs
- Impact on system outcomes
  - Introduces congestion along several key interfaces, including SEMA/RI, and NE/ME
  - Congestion increasing with higher levels of decarbonization
- Key outcomes (e.g., resource mix, social costs) do not change meaningfully with addition of transmission constraints
  - Modest shifts in resource mix, costs, prices, etc.

Alternative Hybrid Approach Scenario

- Alternative Hybrid Approach scenario assumes a higher target LMP for existing renewable resources:
  - LMP target increases from $41/MWh to $51/MWh (25% increase)
  - Achieving higher average LMP (to existing resources) while attaining the same target emissions requires both higher carbon prices and reduced CEC quantities
- Higher target LMP results in:
  - Modest shifts in the resource mix, including less total variable renewable resources (mostly from a 350 MW reduction in solar PV), reduced battery storage and increased combined cycle capacity
  - Modest reduction in social costs (e.g., $20 million present value, 2021-2040, or 0.5% reduction)
  - Increase in customer payments (e.g., $2.1 billion present value, 2021-2040, or 14% increase)
  - These outcomes are consistent with expectations: (1) social costs decrease with greater reliance on the more cost-effective carbon prices to achieve emission reductions, and (2) payments increase because higher carbon prices reduces the degree of price discrimination

Quantitative Scenarios: Overview of Findings

Several conclusions can be from the scenario analysis

1. Changes in economic and resource outcomes (relative to the Central Case) were consistent with expectations given the nature of changes in Central Case assumptions – for example:
   - Social costs increase with a more stringent decarbonization target and additional retirements, and decrease with alternative (lower) cost assumptions
   - Shifts in resource/technology mix reflect relevant factors, including stringency of emission target (e.g., more variable renewables and storage, less fossil) and alternative costs (e.g., reflecting a shift toward technologies with lower relative costs)

Quantitative Scenarios: Overview of Findings (2)

2. With respect to social costs, the relative ranking of policy approaches does not vary across scenarios
   - Social costs (from lowest to highest) generally: Net Carbon Pricing, Hybrid Approach, FCEM, Status Quo

Present Value of Incremental Social Costs by Policy Approach and Scenario, 2021-2040 ($2020 Million)

	Central Case		Alternative Emissions		Alternative Costs		Additional Retirements		Transmission	
Policy Approach	Present Value of Incremental Social Cost ($2020 M)	Percent Change from Status Quo	Present Value of Incremental Social Cost ($2020 M)	Percent Change from Status Quo	Present Value of Incremental Social Cost ($2020 M)	Percent Change from Status Quo	Present Value of Incremental Social Cost ($2020 M)	Percent Change from Status Quo	Present Value of Incremental Social Cost ($2020 M)	Percent Change from Status Quo
Reference	-		-		-		-		-	
Status Quo	6,027	-	9,249	-	4,125	-	5,983	-	5,993	-
FCEM	4,296	-28.7%	5,798	-37.3%	3,148	-23.7%	4,296	-28.2%	4,333	-27.7%
NCP	3,935	-34.7%	5,613	-39.3%	2,922	-29.2%	3,900	-34.8%	3,938	-34.3%
Hybrid	4,119	-31.7%	5,888	-36.3%	3,026	-26.6%	4,018	-32.9%	4,145	-30.8%

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Quantitative Scenarios: Overview of Findings (3)

3. With respect to customer payments, the relative ranking of policy approaches varies across scenarios reflecting differences in price discrimination
   - Relative impact of price discrimination varies across approaches
   - In higher cost scenarios, impact of price discrimination is proportionately greater
   - Outcome reflects assumptions in scenario analysis that any support to existing resources does not change with policy stringency/costs

Present Value of Incremental Customer Payments by Policy Approach and Scenario, 2021-2040 ($2020 Million)

	Central Case		Alternative Emissions		Alternative Costs		Additional Retirements		Transmission	
Policy Approach	Present Value of Incremental Payments ($2020 M)	Percent Change from Status Quo	Present Value of Incremental Payments ($2020 M)	Percent Change from Status Quo	Present Value of Incremental Payments ($2020 M)	Percent Change from Status Quo	Present Value of Incremental Payments ($2020 M)	Percent Change from Status Quo	Present Value of Incremental Payments ($2020 M)	Percent Change from Status Quo
Status Quo	18,692	-	17,681	-	16,984	-	18,424	-	19,865	-
Status Quo (Adjusted)	34,368	83.9%	39,514	123.5%	25,868	52.3%	33,898	84.0%	36,033	81.4%
FCEM	18,600	-0.5%	21,420	21.2%	14,030	-17.4%	19,329	4.9%	19,179	-3.5%
NCP	15,872	-15.1%	20,133	13.9%	11,892	-30.0%	17,014	-7.7%	16,792	-15.5%
Hybrid	13,442	-28.1%	13,961	-21.0%	10,945	-35.6%	14,031	-23.8%	13,980	-29.6%

Next Steps

- Feedback on Draft Report
  - Receive feedback from NEPOOL Stakeholders and the New England States regarding the Draft Pathways Report
  - Please submit any written feedback on the Draft Pathways Report no later than March 15th to allow us time to consider it for the Final Pathways Report
  - Perform modifications to the Pathways analysis and Report
  - Post Final Pathways Report
- Presentation of Final Pathways Report in April