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Pathways Study

Evaluation of Pathways to a Future Grid

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October 25, 2021

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Overview

- Purpose of today's presentation is to summarize preliminary results and findings of the quantitative analysis of alternative Pathways to decarbonizing the New England grid
  - Four approaches: Status Quo, Forward Clean Energy Market (FCEM), Net Carbon Pricing (NPC), and Hybrid
  - Core Central Case results presented today; scenario results initially to be presented at December meeting
- Quantitative analysis is one element of our assessment of the alternative policy approaches
  - Discussion of qualitative aspects of our analysis to come in future presentations and report

- Status of analysis
  - Results presented today are ***preliminary***

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Summary of Key *Preliminary* Modeling Results

Preliminary findings regarding policy approaches include:

- Market prices and resulting incentives vary widely across approaches and have important consequences for market outcomes – for example:
  - Storage resource build out and utilization varies depending on energy market incentives created for non-carbon-emitting generation
  - Extent of available renewable energy that does not clear energy market ("economic curtailments") varies given market incentives for storage
  - Efficiency (and resulting carbon-intensity) of fossil (gas-fired) resources reflects incentives for clean energy versus carbon reduction
- Net Carbon Pricing approach produces the lowest production costs, with similar but somewhat higher costs for the FCEM and Hybrid approaches
  - The Status Quo approach leads to notably higher costs, reflecting multiple factors including absence of market incentives for clean energy/decarbonization and higher renewable curtailment
  - Assumed clean energy resource mixes reflecting state decarbonization "roadmaps" and plans

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Agenda

- Central Case Assumptions: A Brief Overview
- Quantitative Modelling: Achieving Decarbonization Targets
- Comparison of Outcomes Under Alternative Policy Approaches
  - Impact of Differences in Energy Market Incentives
  - Costs and Payments
- Proposed Set of Scenarios

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Central Case Assumptions: A Brief Overview

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Recap of Pathways Analysis

- Pathways analysis is evaluating alternative regulatory/policy approaches to decarbonizing the New England grid
  - Focus is on comparison of the implications of alternative regulatory approaches on economic outcomes, including the incentives for decarbonization
- **Four policy approaches:**
  - **Status Quo:** continued reliance on state-authorized procurements of multi-year contracts for renewable energy from new resources
  - **Forward Clean Energy Market:** market for clean energy, where "clean energy" is assumed to include electricity generated from nuclear, renewables, hydropower and biomass (but not storage)
  - **Net Carbon Pricing:** carbon pricing with generator payments for carbon emitted credited to load
  - **Hybrid:** combination of carbon pricing to cover existing clean energy "missing money" plus a forward clean energy market for not-yet-in-service resources

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Central Case Assumptions: Period, Targets

- **Central Case** assumptions are held constant across 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

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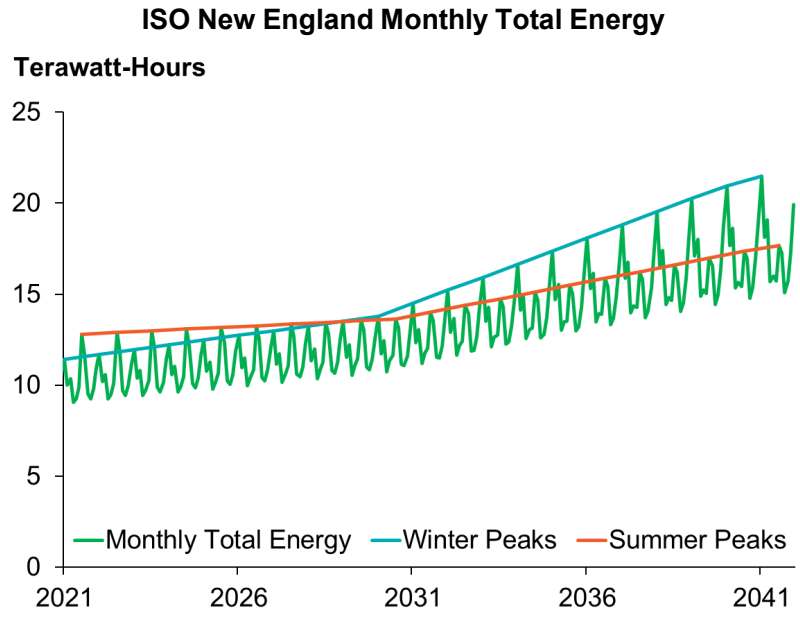
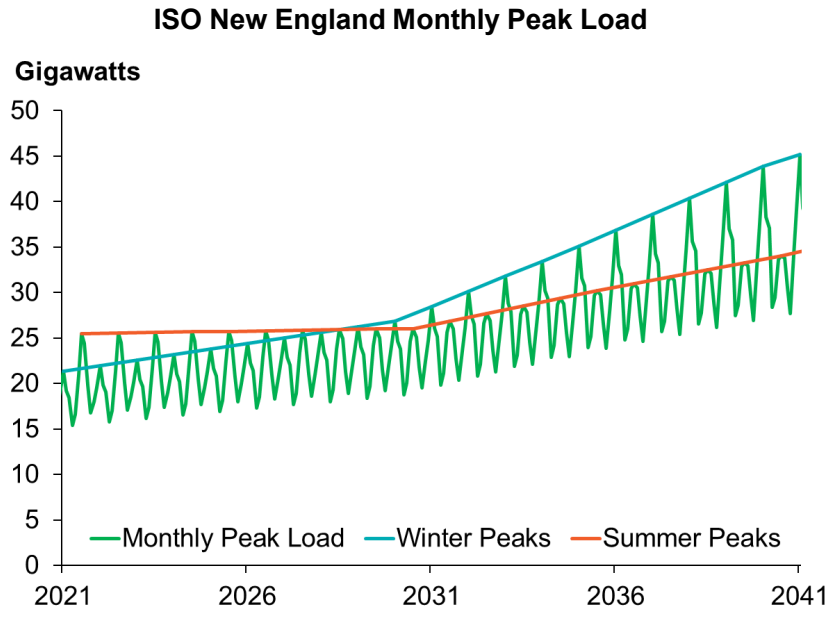
Central Case Assumptions: Loads

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





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Central Case Assumptions: Supply-Side

- Resource mix including 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
- ***Incremental resources***
  - All cases assume the same mix of potential new resources and associated costs
  - Only considers existing technologies, with assumed decreasing costs
  - ***Status Quo case***: assumes renewables from state Plans, Roadmaps, and studies
  - ***FCEM, NCP, Hybrid***: least-cost mix of solar, offshore wind, onshore wind to meet carbon target given policy-specific constraints
  - Dispatchable resources in all cases: 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 Modelling Results: Achieving Decarbonization Targets

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Central Case Results: Some Basics

System resources and energy evolve over time

- Start with an overview of a single case to show how the mix of energy and resources changes over the 20-year study period
  - Preliminary results for the Net Carbon Price case are provided below
  - Results are broadly similar for the other three cases because the key drivers of changes in resource/energy outcomes – decarbonization and growing loads – are the same across cases
- Review of results across years for one case will provide context for comparison of outcomes across cases

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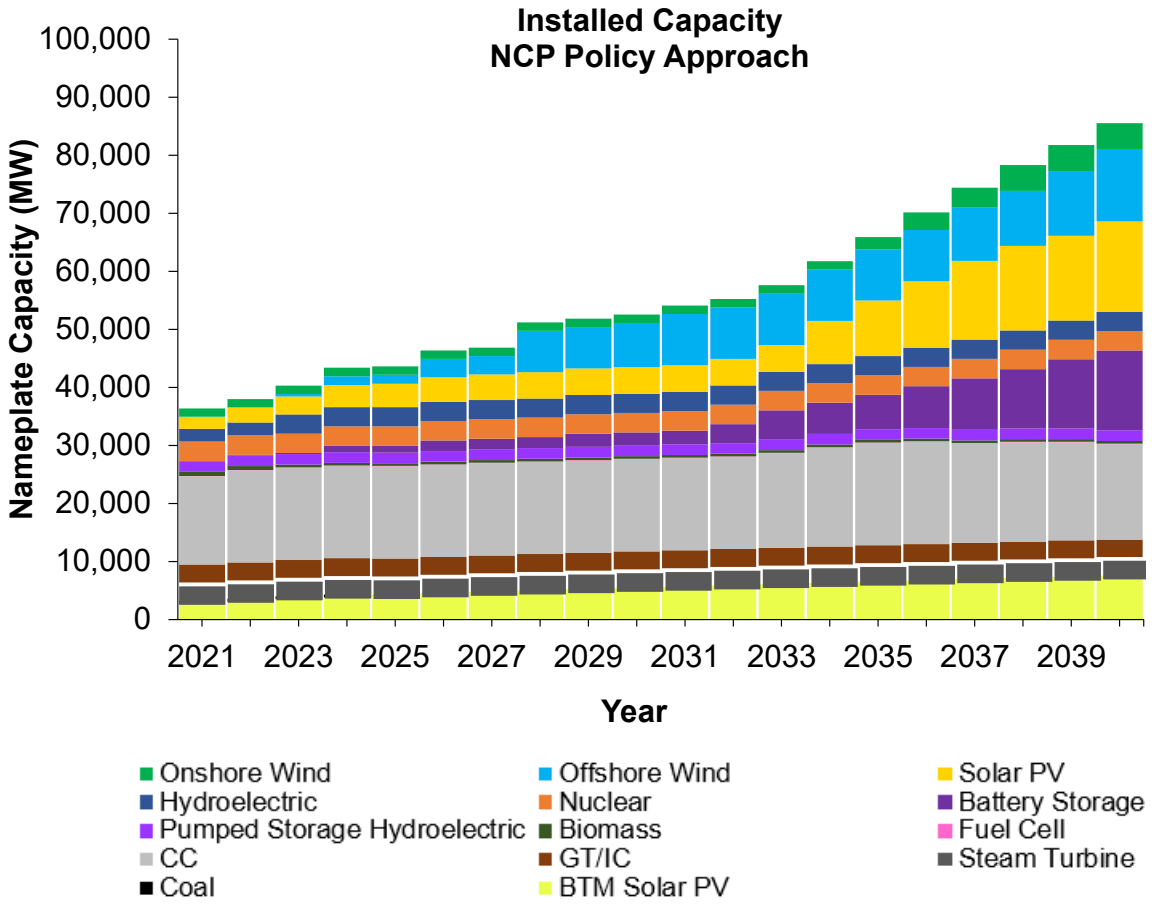
Central Case Results: Resource Mix

Decarbonization target and load growth drive increases in resources



Mix of resources reflects:

- Renewable build to achieve decarbonization target
- New dispatchable resources, particularly batteries, to supply energy when renewables are not available to meet load
- Existing resources needed to maintain resource adequacy and supply energy needs

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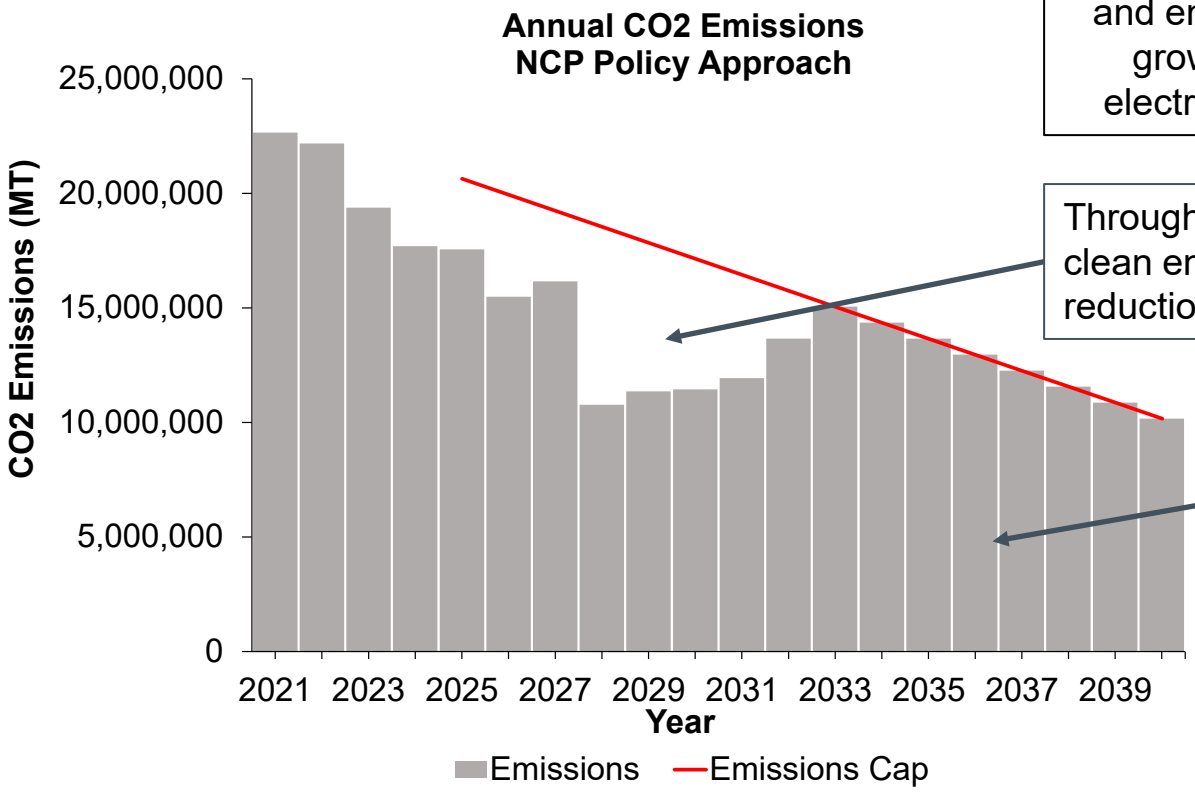
Central Case Results: Carbon Emissions

Alternative policy approaches bind starting in 2033



But-for assumed state baseline policies and emission targets, annual emissions grow as transportation and heating electrification increase customer loads

Through 2032, assumed baseline state clean energy policies produce sufficient reductions to meet decarbonization target

As of 2033, additional clean energy resources are required to achieve emissions target

Analysis does not account for banking in FCEM and NCP, which can lower costs

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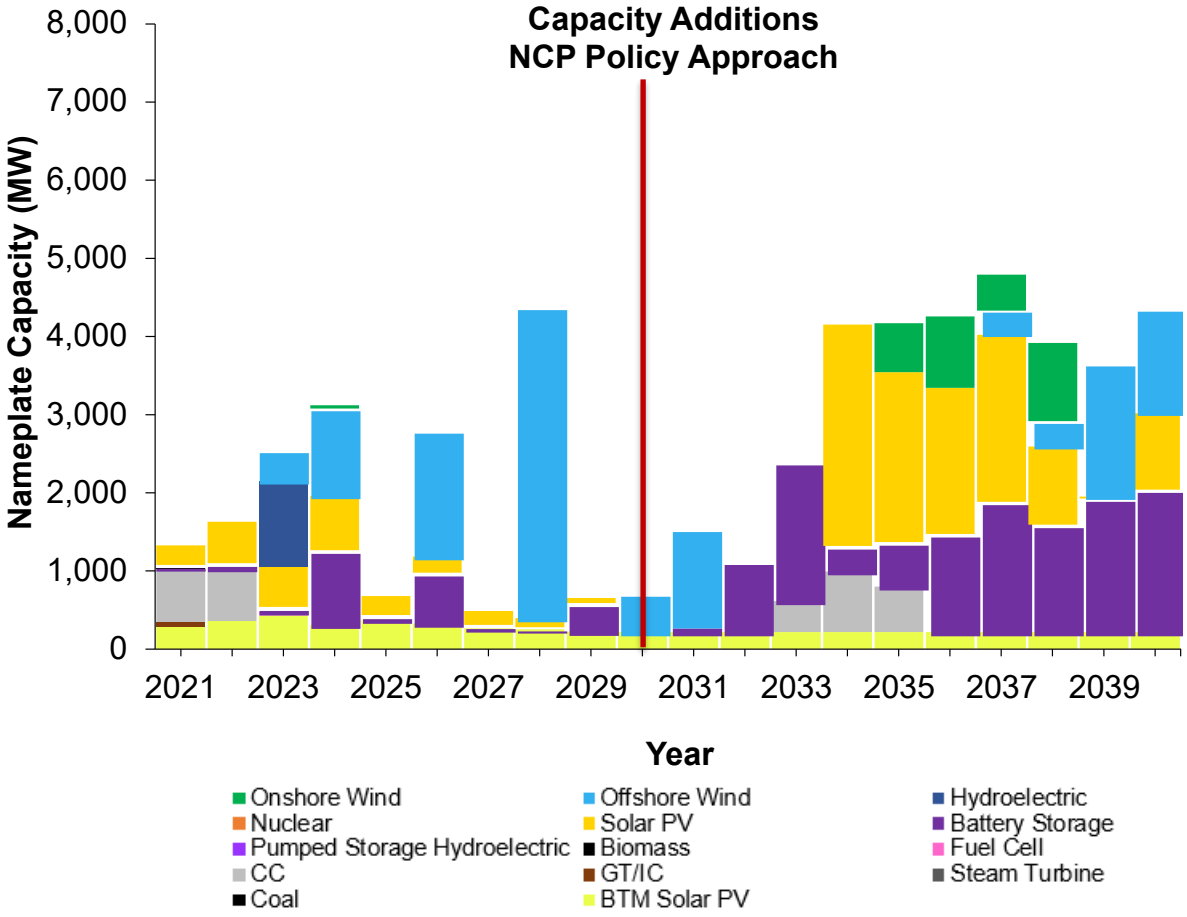
Central Case Results: Resource Additions

Resource additions reflect assumed and modelled resources



New capacity includes a wide mix of resources:

- In first decade, resource builds largely reflects baseline assumed state policies
- Second decade reflects resources needed to meet resource adequacy and clean energy requirements, including incremental renewable and dispatchable builds

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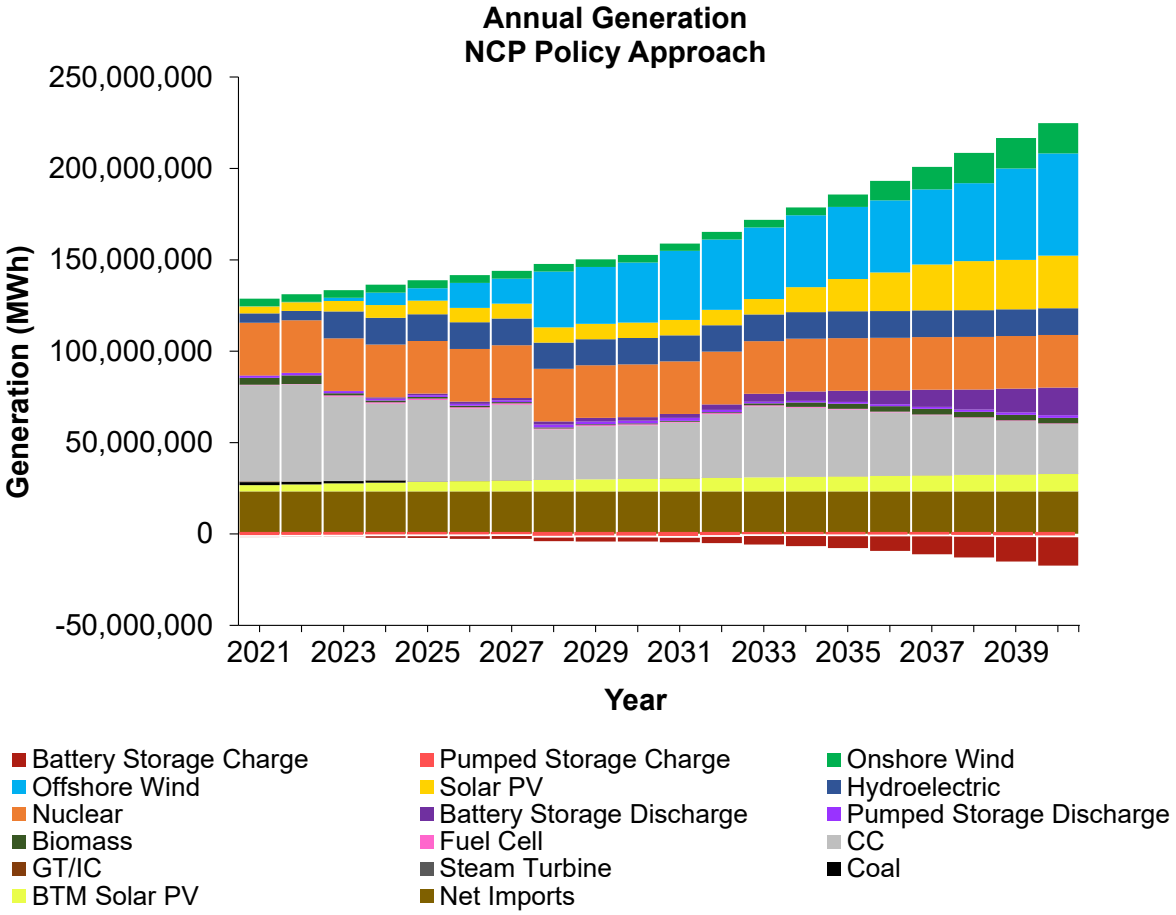
Central Case Results: Energy Mix

Energy mix driven by growing clean energy share and market dynamics



Changes in energy mix reflects evolving resource mix:

- Renewables: Increasing supply consistent with increased capacity (with some curtailed energy)
- Fossil resources: Reduced energy (and capacity factors) as non-emitting sources increase as share of load
- Batteries: Charging and discharging a small share of energy compared to battery's share of capacity
- Nuclear, imports: Assumed to be constant

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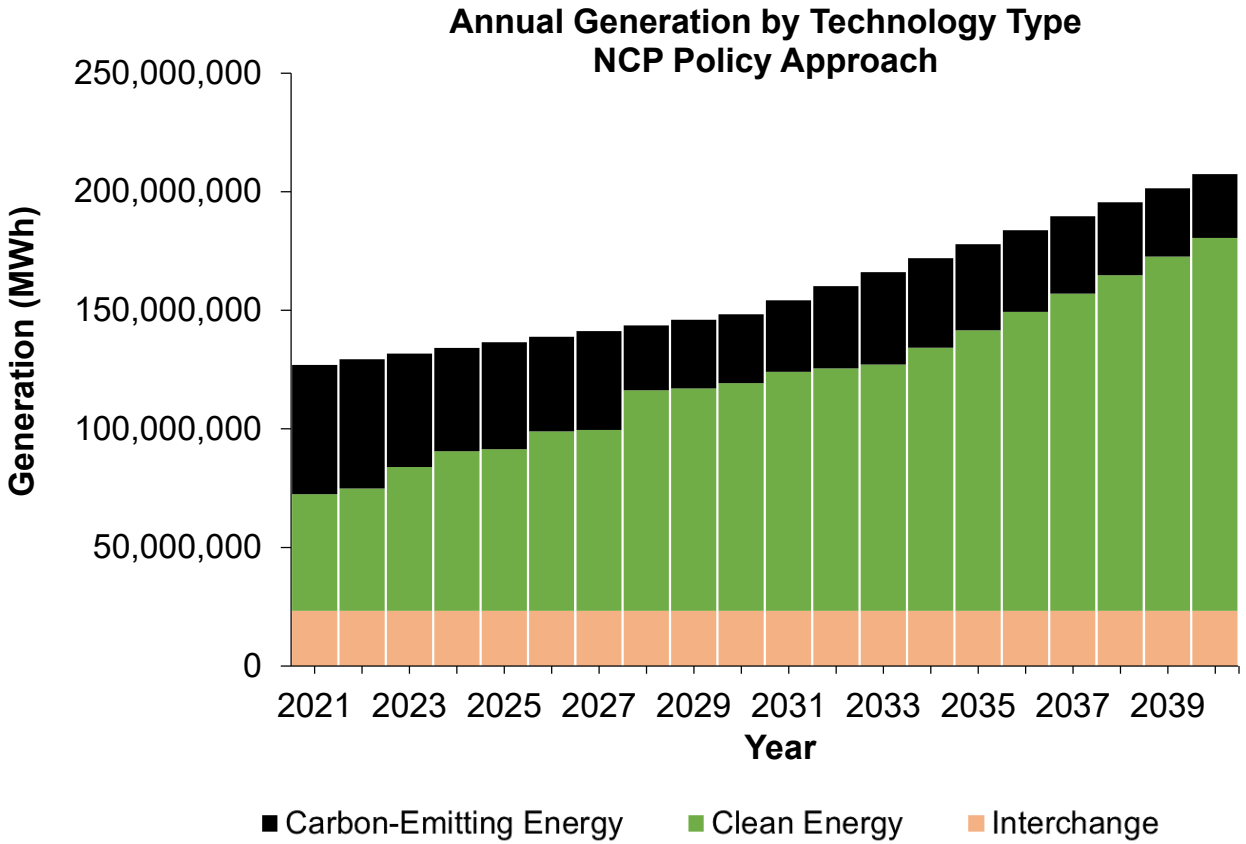
Central Case Results: Clean Energy

Clean energy share increases gradually to reflect assumed targets



- Clean energy's share of total energy increases over study period to achieve decarbonization goals
- "Clean energy" assumed to include:
  - Solar
  - Wind
  - Biomass
  - Nuclear
  - Hydroelectric

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Comparison of Outcomes Under Alternative Policy Approaches: Impact of Differences in Energy Market Incentives

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Central Case Results: Differences in Resource Mix and Utilization

System resources and energy evolve over time

- Policy and economic outcomes reflect the mix of resources arising under each approach and the use of resources given market incentives
- Policy approaches differ in terms of the resources that emerge and how they are used, reflecting a combination of factors and interactions
  - In the Status Quo, the absence of energy market incentives for clean energy reduces incentives for storage, leading to greater reliance on gas-fired capacity for resource adequacy and higher market curtailments of renewable resource supply
  - Net Carbon Pricing drives a more efficient mix of resources relative to FCEM by accounting for carbon-intensity of generation, rather than only rewarding clean energy (irrespective of the carbon-intensity of displaced energy)
  - FCEM creates energy market incentives for storage resources (even without rewarding storage with clean energy credits), but creates some inefficiencies by failing to account for carbon-intensity and through “pumping” of negative-LMP energy

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Central Case Results: Differences in Resource Mix and Utilization

System resources and energy evolve over time

- Hybrid approach blends tradeoffs between Net Carbon Pricing and FCEM
  - Under Hybrid approach, sensitivity of LMPs to a new-resource FCEM may create challenges for setting carbon price to reliably cover existing clean energy costs

- Differences in payments can affect market participation
  - Status Quo and Hybrid approaches result in differential payments to resources that provide otherwise similar services; potential consequences for resource retention and participation in ISO-NE markets

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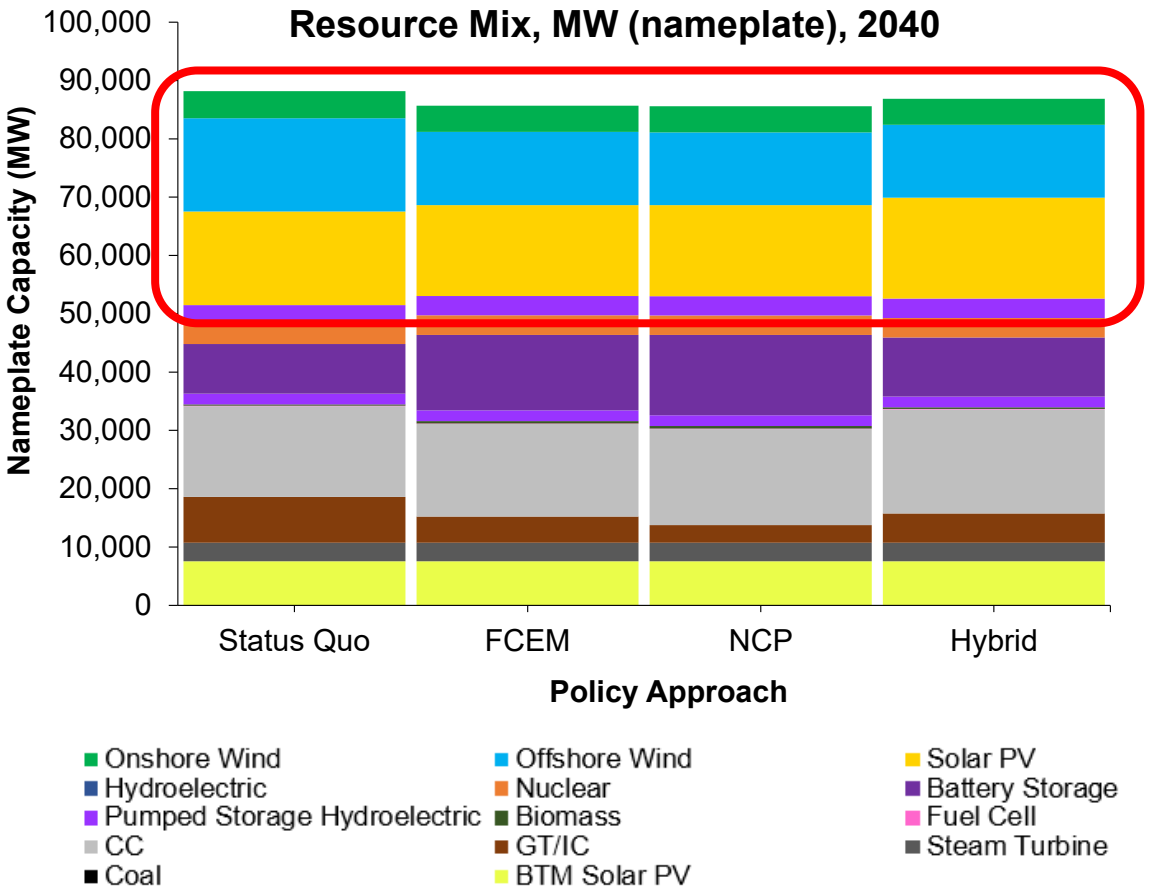
Central Case Results: Resources Mix

Policy approach affects renewable resource mix



- Renewable resource mix similar across approaches
  - Analysis assumes least-cost projects developed for each technology type (as defined by policy approach)
  - Total quantity of resources varies reflecting economic curtailments given battery storage incented by policy approach
  - Mix of technologies is roughly proportional across approaches, with differences reflecting resource preferences (in Status Quo), storage resources incented by approach, and accounting for carbon-intensity (between FCEM and NCP)

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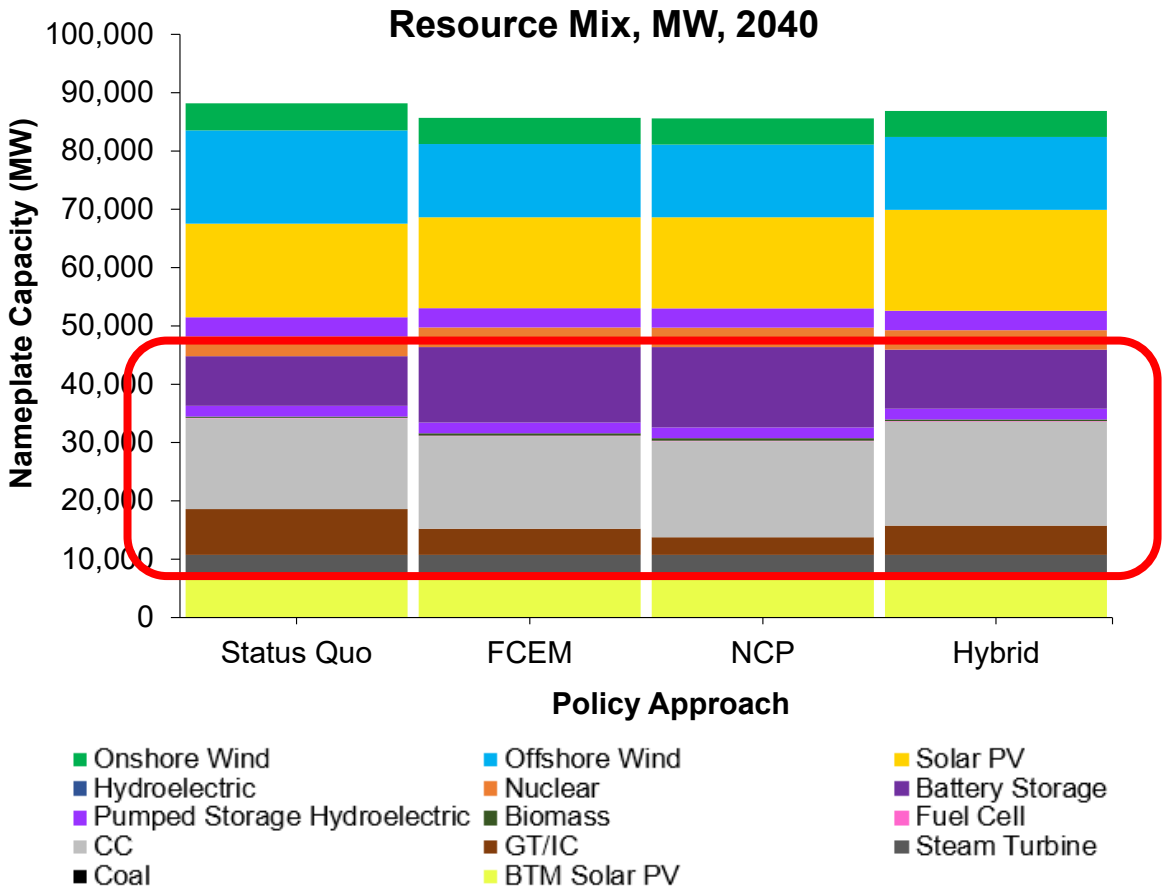
Central Case Results: Resources Mix

Policy approach affects dispatchable resource mix



- Dispatchable resources differ by policy approach depending on:
  - If the approach is sensitive to differences in emissions-intensity (true for Net Carbon Pricing, not for FCEM or Status Quo)
  - Incents storage capacity because environmental value is priced into EAS market (not the case for Status Quo) (more on this in subsequent slides)
- As a result, for example:
  - More CTs and less storage in Status Quo
  - More CCs (most efficient fossil unit) in Net Carbon Pricing

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Central Case Results: Prices

Prices vary widely across policy approaches

LMP, Environmental and Capacity Prices by Policy Approach, 2040

	SQ	FCEM	NCP	Hybrid
	[1]	[2]	[3]	[4]
Load-Weighted LMP ($/MWh)	19	10	106	39
Standard Deviation ($/MWh)	17	40	59	54
Maximum LMP ($/MWh)	63	63	249	116
Minimum LMP ($/MWh)	0	-75	0	-77
% Hours with $0 LMP	24%	0%	9%	1%
% Hours with Negative LMP	0%	26%	0%	22%

Note: All values are in $2020

Distribution of prices – levels, variation and range – differ widely across policy approaches:

- ***Average LMPs*** range from $10 to $106 / MWh due to differences in how environmental attribute is priced into energy markets
- ***Price variation*** (Std Dev, min/max) lower in Status Quo compared to market-based approaches
- Large fraction of zero or negative prices under all approaches, reflecting renewable build-out

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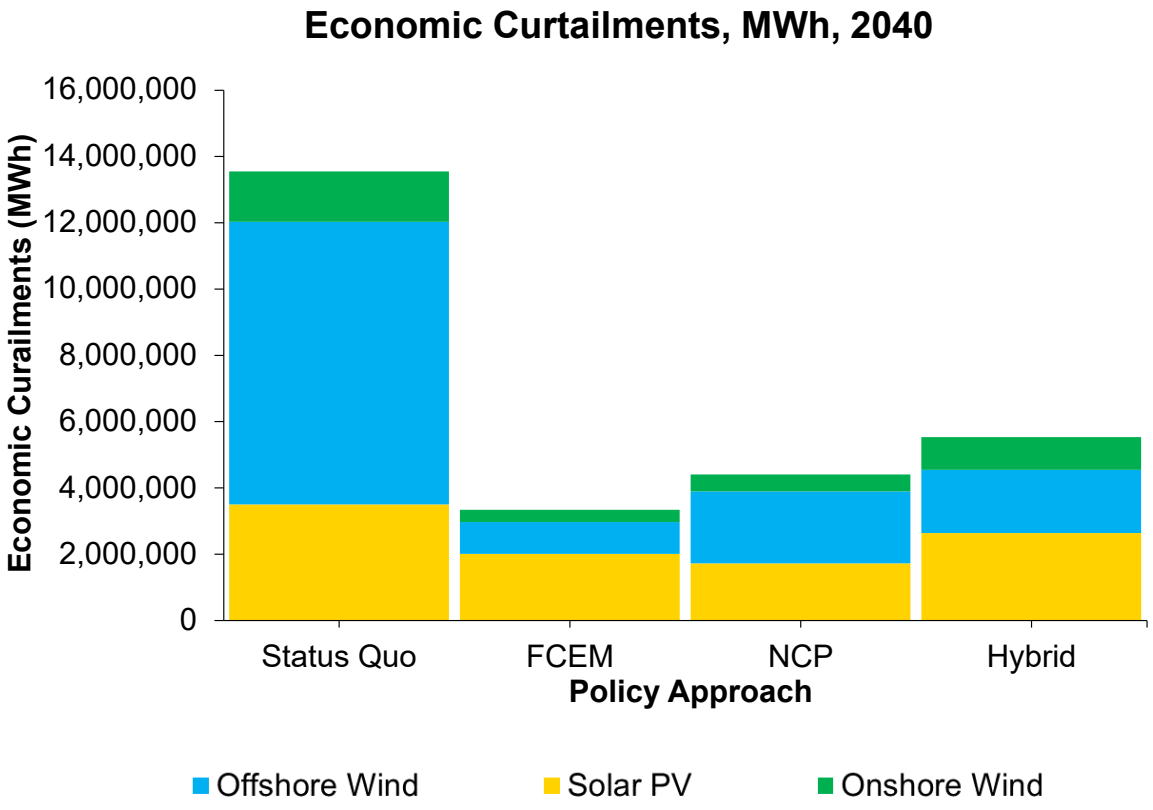
Central Case Results: Market Curtailments

Market curtailment of renewable energy varies across policy approach



- "Curtailments" reflect energy that does not clear the market given market-clearing prices
- The curtailments vary across cases depending on both storage capacity and energy market pricing
  - Market curtailments are highest in Status Quo because of lower storage capacity. With less storage, there is less capability to shift renewable supply from hours when it does not clear the market to hours when it will clear
  - Lower storage reflects diminished arbitrage opportunities given absence of pricing of environmental attributes (as discussed in following slides)

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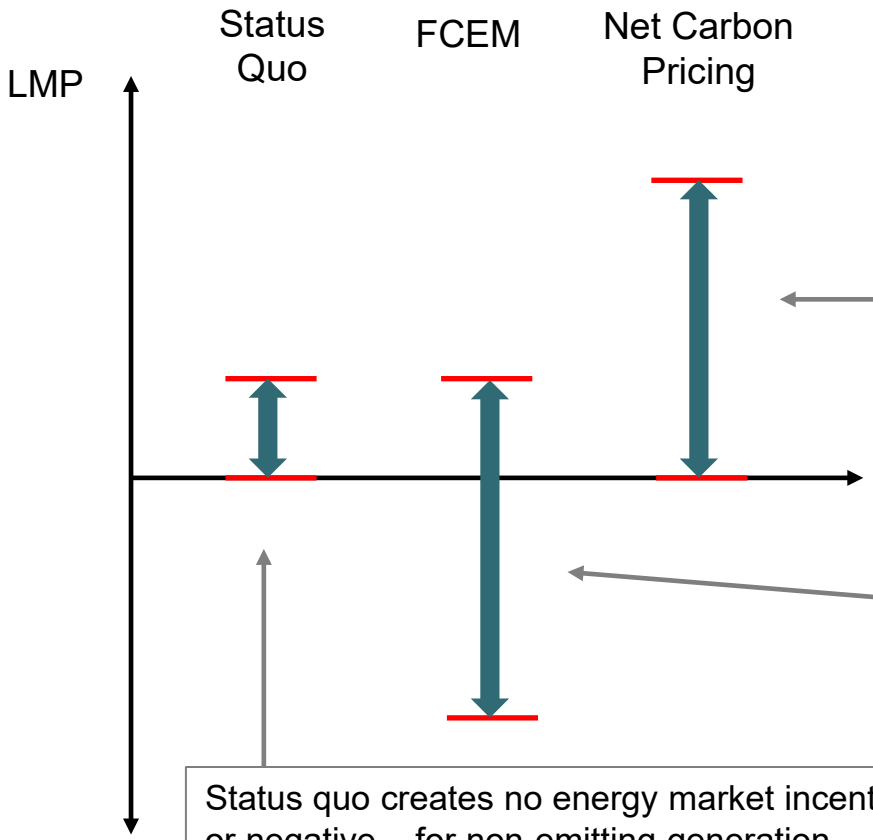
Incentives for Energy Storage Vary with Policy Approach

Energy market spreads larger with carbon pricing or CECs



Financial viability of storage resources depends on opportunities to arbitrage LMPs at different points in time

With Net Carbon Pricing, carbon price increases LMPs when gas-fired resources are price-setting because cost of carbon is included in offers
– provides a larger spread for storage resources to arbitrage

With FCEM, CEC values leads to negative LMPs when renewable resources are price-setting because they submit negative-priced offers due to CEC subsidy
– also, provides a larger spread for storage resources to arbitrage

Status quo creates no energy market incentives – positive or negative – for non-emitting generation

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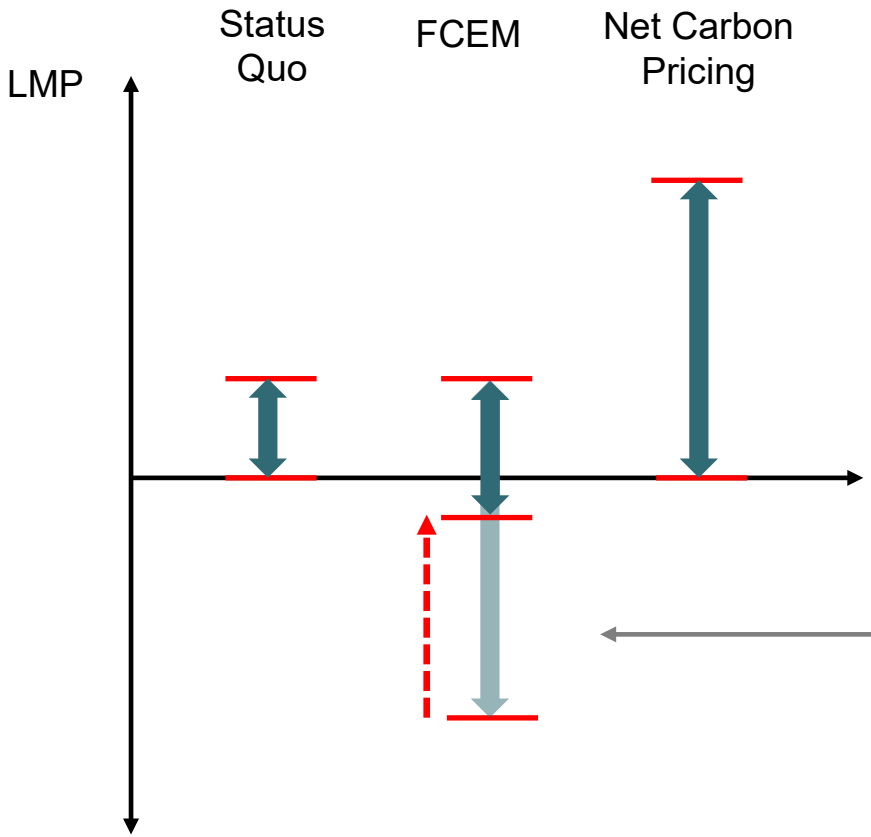
Incentives for Energy Storage Vary with Policy Approach

Negative pricing creates incentives for storage



Negative prices provide an opportunity for storage resources to earn money simply by charging and then discharging a smaller quantity due to energy loses:

- With negative prices, storage resource is ***paid*** to charge and ***pays*** to discharge
- Payments received for charging exceed payments made for discharging because a smaller quantity of energy is discharged than charged due to energy losses

Equilibrium negative prices are greater (less negative) due to this storage activity – that is, storage resource tends to reduce frequency of negative prices

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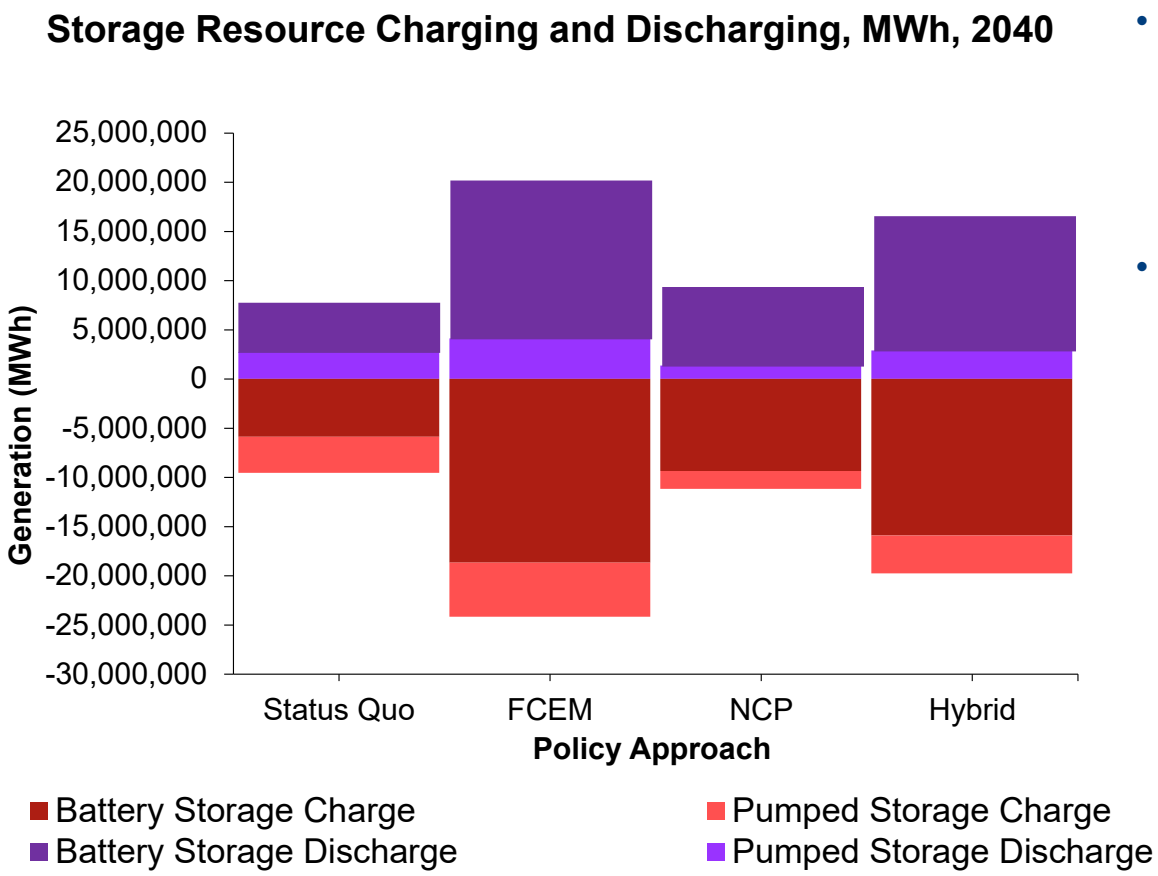
Central Case Results: Storage Charging/Discharging

Market incentives affect opportunities for storage



- Negative pricing with FCEM incents increased storage charging and discharging
- NCP provides large spread and opportunities for arbitrage, but fewer $0 hours than SQ.

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Comparison of Outcomes Under Alternative Policy Approaches: Costs and Payments

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Central Case Results: Costs and Payments

Status of Analysis of Costs and Payments

- Presentation today includes estimated total costs of each approach

- Analysis of payments is on-going but not yet complete
  - Results will be included in the December presentation and the report
  - Analysis of payments is complex given the need to determine terms of future PPAs (entered into at different points in time), compensation to existing resources in the market (e.g., nuclear plants), outcomes of others ISO-NE markets (e.g., FCM), etc.

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Central Case Results: Differences in Costs

Economic outcomes reflect efficiencies in achieving carbon target

- Economic outcomes reflect the mix of resources arising under each approach and the use of resources given market incentives
- Important differences in prices, costs and payments emerge because of a combination of factors affecting quantity, type and utilization of resources under each policy approach
  - In the Status Quo, costs reflect mix of resources assumed under state policies, the absence of energy market incentives for clean energy or carbon reduction, and the greater quantity of renewable resources required given the diminished incentives for storage
  - Net Carbon Pricing drives more efficient resources investment and operation, producing the lowest social costs
  - FCEM costs are slightly higher than Net Carbon Pricing because of increased resource investment because of less-efficient price signals to incent optimal storage development and use, investment in less efficient gas-fired generation, and a less-efficient mix of renewable resources
  - Hybrid approach blends tradeoffs between Net Carbon Pricing and FCEM

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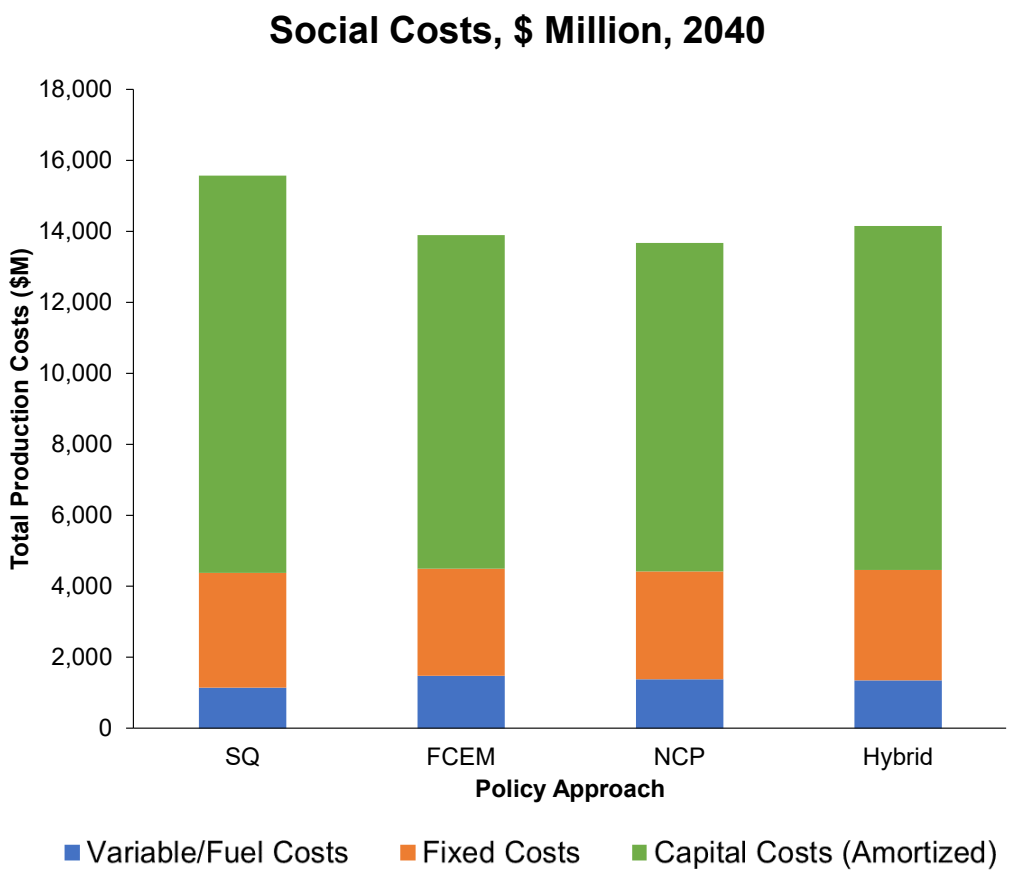
Central Case Results: Social Costs

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



- Social costs reflect gains to producers and consumers (i.e., consumer and producer surplus)
- Analysis measures social cost as production costs including fuel, variable O&M, fixed O&M, and (amortized) capital costs
  - Social costs are highest for Status Quo
  - Costs are lowest for NCP, and similar but somewhat higher for FCEM and Hybrid
  - Cost differences reflect a combination of factors, particularly the differences in energy market incentives for each approach
  - All approaches include the least-cost resources, subject to different constraints
- Analysis does not account for all expected effects (e.g., changes in demand given differences in marginal prices)

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Central Case Results: Prices

Prices vary widely across policy approaches

LMP, Environmental and Capacity Prices by Policy Approach, 2040

	SQ	FCEM	NCP	Hybrid
	[1]	[2]	[3]	[4]
LMP ($/MWh)				
Load-Weighted LMP	19	10	106	39
Environmental Attributes				
Clean Energy Credit ($/MWh)		75		76
Carbon Price ($/MT)			280	101

Note: All values are in $2020

LMPs and prices for environmental attributes vary across cases

- *Results are preliminary*
- LMPs vary due to impact of CEC revenues and carbon prices on resource offers
- Prices are an element of the estimated payments

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Central Case Results: Differences in Payments to Resources

Results to be presented in future meetings

- Future presentations and the report will include comparisons of differences in payments
  - Results will include total payments, payments by state, and payments to different types of resources
  - Differences across approaches will reflect the different ways in which clean resources are incented (Status Quo PPA's versus in-market compensation) and the different market prices providing in-market compensation
  - Assessment will also include qualitative assessment of other differences between approaches with consequences for payments to customers
- Compensation will differ by states depending on state-level targets/contributions

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Central Case Results: Differences in Payments to Resources

Approaches differ in compensation to similarly situated resources

- The NCP and FCEM provide uniform compensation and impose costs uniformly across resources
  - FCEM provides resources generating clean energy with CECs
  - NCP imposes same carbon price on carbon-emitting resources
- Status Quo and Hybrid provide compensation that differs across resources
  - Status Quo offers PPA contracts for new resources, but no other compensation mechanism for existing resources other than energy and capacity market
    - Absent other arrangements, this compensation scheme would be expected to cause, to some degree, resources to retire early and/or sell energy in other markets (e.g., NYISO)
  - Hybrid offers differential compensation to new and existing resources providing otherwise identical services
- Future presentations and the report will include comparisons of differences in compensation

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Proposed Set of Scenarios

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Scenarios

- As discussed previously, assumptions different from those in the central case are being evaluated quantitatively through alternative scenarios, to the extent feasible
- The list of scenarios presented today reflects our current thinking and review of all submitted feedback and stakeholder discussion to date, plus the removal of some scenarios given the addition of the hybrid approach
  - We look forward to stakeholder feedback on this proposed list of scenarios, particularly in light of these changes and preliminary central case results being presented today
- We appreciate all the feedback, discussion, and continued interaction from stakeholders to date

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Potential Quantitative Scenarios

- Preliminary results to be provided in 2021
  - Across approaches:
    - Alternative regional carbon target
    - Alternative levelized costs of new entry for renewable resources
    - Alternative distribution of costs amongst states
    - Additional retirements
  - Status Quo
    - Alternative costs of long-term renewable contract procurement
- Preliminary results to be provided in 2022
  - Across approaches
    - Inclusion of basic transmission congestion (to support qualitative assessment of approach differences)
  - Hybrid
    - Alternative carbon price levels

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Next Steps

- December
  - Present updates to central cases, if any, based on stakeholder feedback and on-going research
  - Present initial set of scenario results, and take feedback on scenario results

- Next Steps
  - Present draft report with central case and updated scenario results
  - Take feedback on additional scenario results and draft report
  - Present on final report

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Appendix

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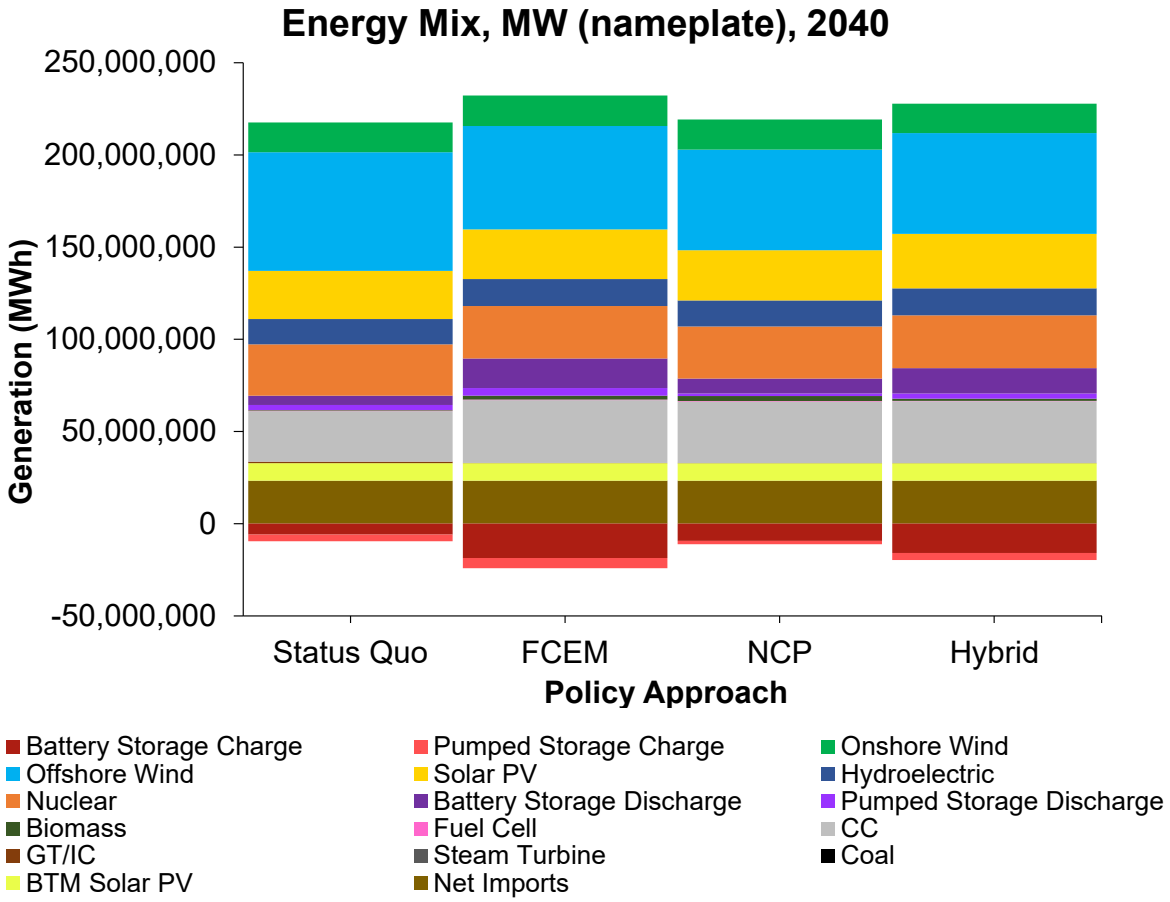
Central Case Results: Generation Quantities

Generation mix reflects a variety of factors



Energy mix varies across policy approaches

- Total generation highest in FCEM and Hybrid due higher storage utilization; lower generation in Status Quo and NCP due to lower storage utilization
- Smaller differences in other resource use given market incentives (e.g., CCs, biomass)