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Pathways Study

Evaluation of Pathways to a Future Grid

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Overview

- Purpose of today's presentation is to review our **proposed** modeling inputs and assumptions for the central analysis cases
  - The proposal reflects multiple considerations, including appropriate data and analysis regarding future market conditions (*e.g.*, input costs, loads, *etc.*) and technology (*e.g.*, costs, performance), and input received to date from stakeholders
- We encourage further stakeholder feedback to help ensure our assumptions are reasonable and reflect a range of viewpoints regarding future policies
- Future iterations on modeling inputs and assumptions will be shaped by this feedback
- Assumptions different from those in the central case will be evaluated through alternative scenarios, to the extent feasible

Agenda

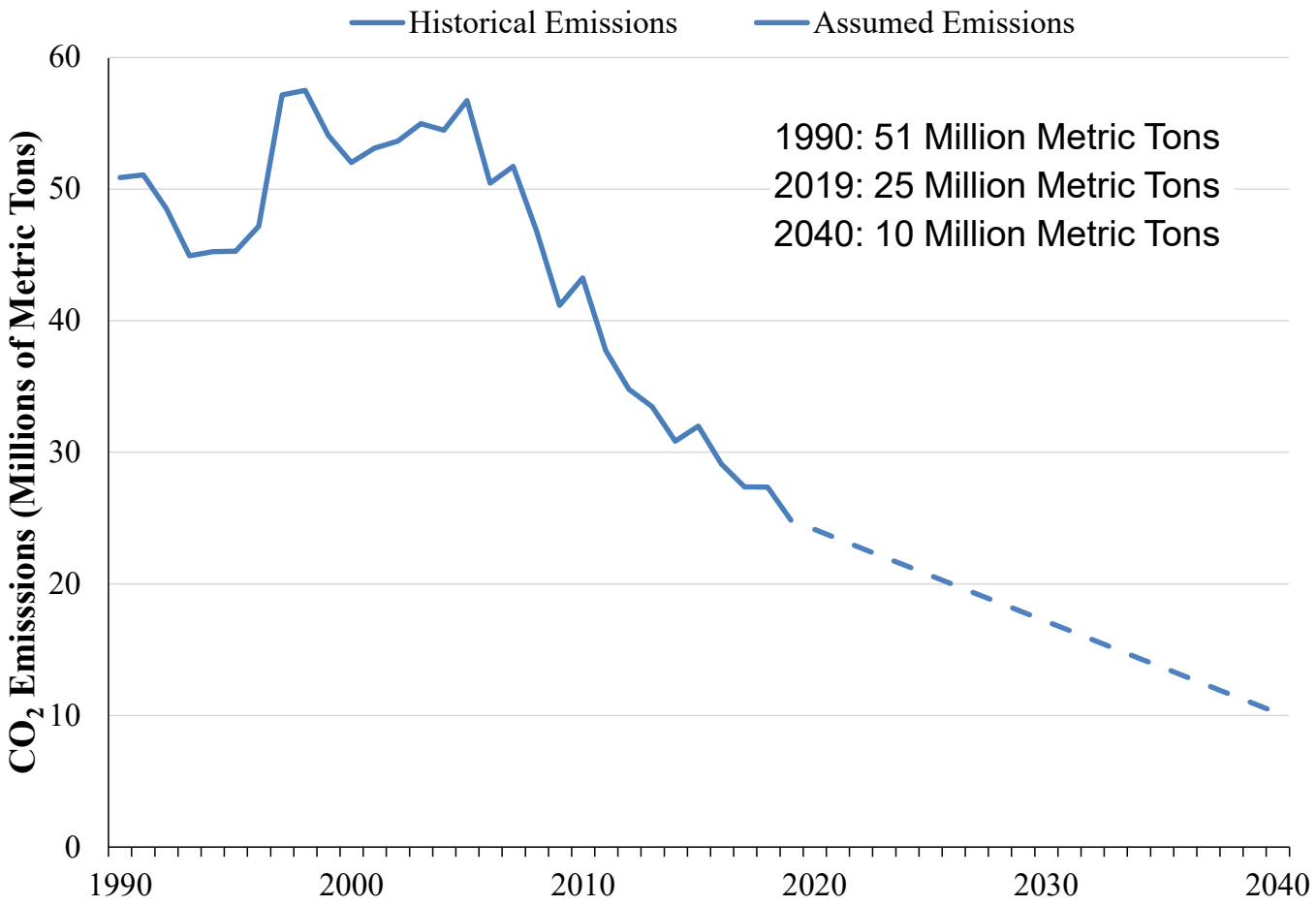
- Modeling Inputs and Assumptions
  - Study parameters
  - Resource characteristics, operating costs, and operating specifications
  - Entry, exit and going-forward costs
  - Load and electrification
- Case Assumptions
  - State policies
  - Status Quo
  - FCEM/ICCM
  - Net Carbon Pricing
- Proposed Outcomes

Modeling Inputs and Assumptions: Study Parameters

Study Parameters

- Study year
  - Analysis will evaluate detailed outcomes in year **2040**
    - Consistent with Future Grid Reliability Study (FGRS)
  - Resource mix will be reported for (certain) intermediate years
  - Potential to include full results for other years or certain policies/scenarios, particularly if we determine that intermediate years provide meaningful information to assess differences between approaches
- Regional carbon target
  - Under all cases, region-wide emissions from the electricity sector will be **80% below 1990 levels** in 2040
    - *For example*, consistent with achieving target of 80% below 1990 levels by 2050 (e.g., MA Global Warming Solutions Act's economy-wide target) assuming faster decarbonization in the electricity sector compared to other sectors
  - Annual emissions target will be linear interpolation between 2021 and 2040 using a straight line annual target
  - This assumption will be met in all central cases, but may be modified in scenario analysis

Annual Historical and Assumed CO_2 Emissions



Source: EIA, Electricity, Detailed State Data, available at https://www.eia.gov/electricity/data/state/

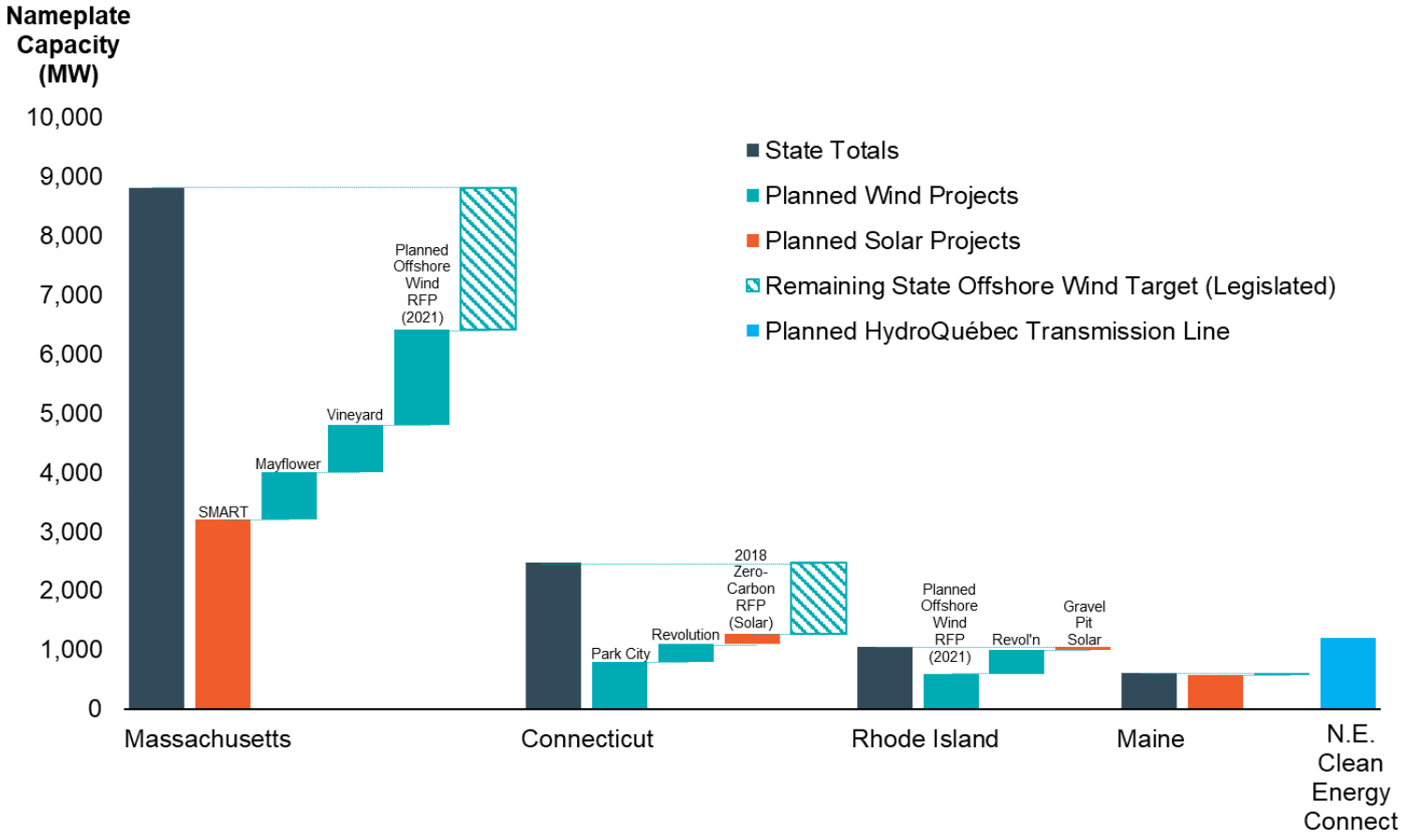
Modeling Inputs and Assumptions: Resource Characteristics, Operating Costs and Operating Specifications

Resource Mix

- Existing resources will include:
  - Resources (from most-recent CELT report) and resources that were awarded capacity obligations in FCA 15, adjusted for announced additions/retirements
  - Resources procured through legislated renewable procurements and announced contracts entered into by New England states (see next slide)
- Future changes in resource mix
  - New entry
    - Depending on the case, will reflect both resources prescribed through assumed state policies (e.g., Status Quo) and resources that are most economical/least-cost given incentives from FCEM and net carbon pricing
  - Retirements
    - Reflect resources that are not economical given assumed and/or economic entry
- *More detail on new entry and retirements provided in next section*

Assumed State Targets and Procurements

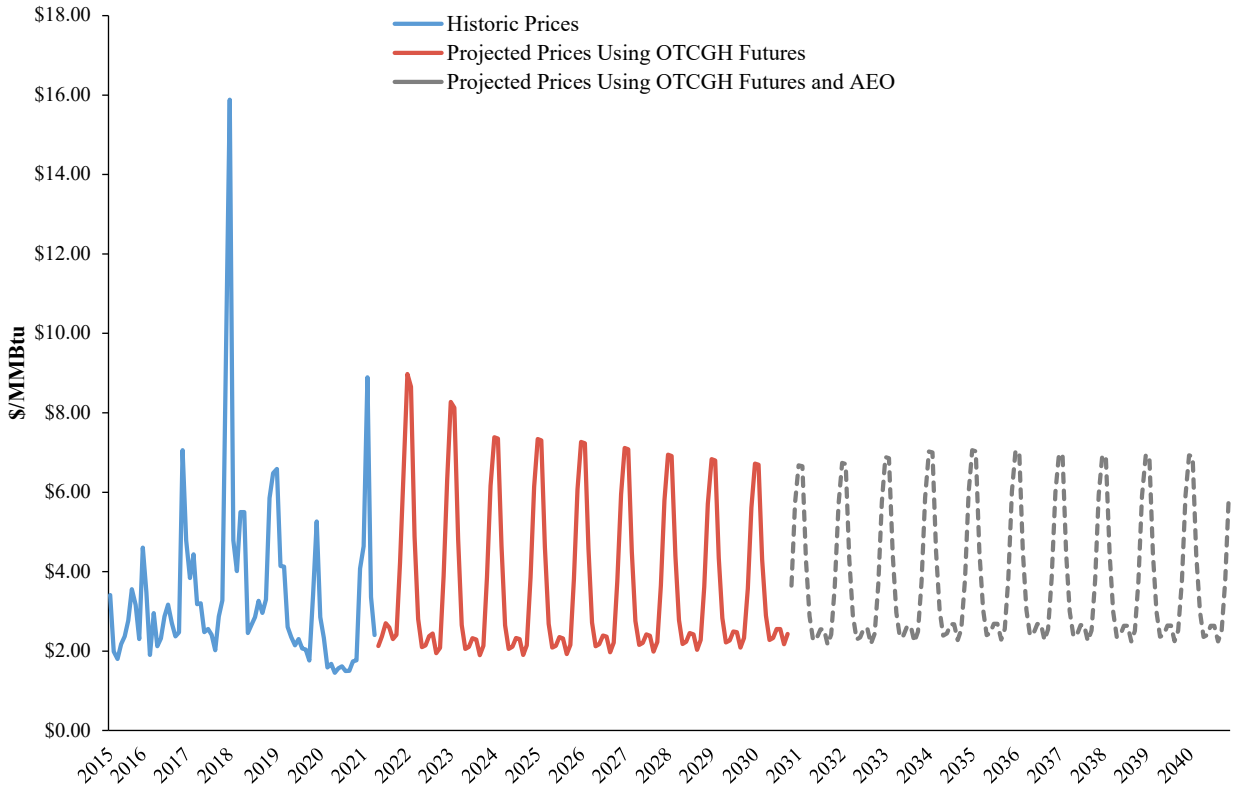
- The resources listed below will be included in addition to the resources in the CELT report and that were awarded capacity obligations in FCA 15



Fuel Prices

- Fuel price assumptions based on reasonable estimates of likely market clearing prices, recognizing that such assumptions are subject to uncertainty
- Natural gas
  - One natural gas price, based on Algonquin City Gates pricing
  - Source: OTC Global Holdings (OTCGH) future prices plus U.S. Energy Information Administration Annual Energy Outlook (EIA AEO) growth rates
  - As electrification in the heating sector increases, consider potential impact of medium/long-run changes in total winter and summer gas demand on winter and summer basis
- Oil prices
  - Source: OTCGH future prices plus EIA AEO growth rates
- Coal prices
  - Source: EIA AEO

Natural Gas Algonquin City Gates Monthly Price Series (April 2015-December 2040)



Sources:
[A] "SNL Day-Ahead Natural Gas Prices" (Algon Gates), S&P Global Market Intelligence.
[B] "Natural Gas Forwards & Futures" (As of 4/30/2021), S&P Global Market Intelligence.
[C] "Table 3: Energy Prices by Sector and Source," EIA Annual Energy Outlook 2021.

Variable Operating Costs

- Variable operations and maintenance costs ("Variable O&M") for existing generation will be based on recent historical Variable O&M
  - FERC Form 1 or RUS 12 annual filings as reported by SNL
  - For new generation, we will rely on historical Variable O&M costs from comparable existing resources, by technology type
  - We will assume that Variable O&M costs are constant over time

- Emission costs
  - Only CO_2 emissions under RGGI will be quantified and costed
  - NO_X and SO_2 emissions do not impose incremental costs in New England under current federal regulations

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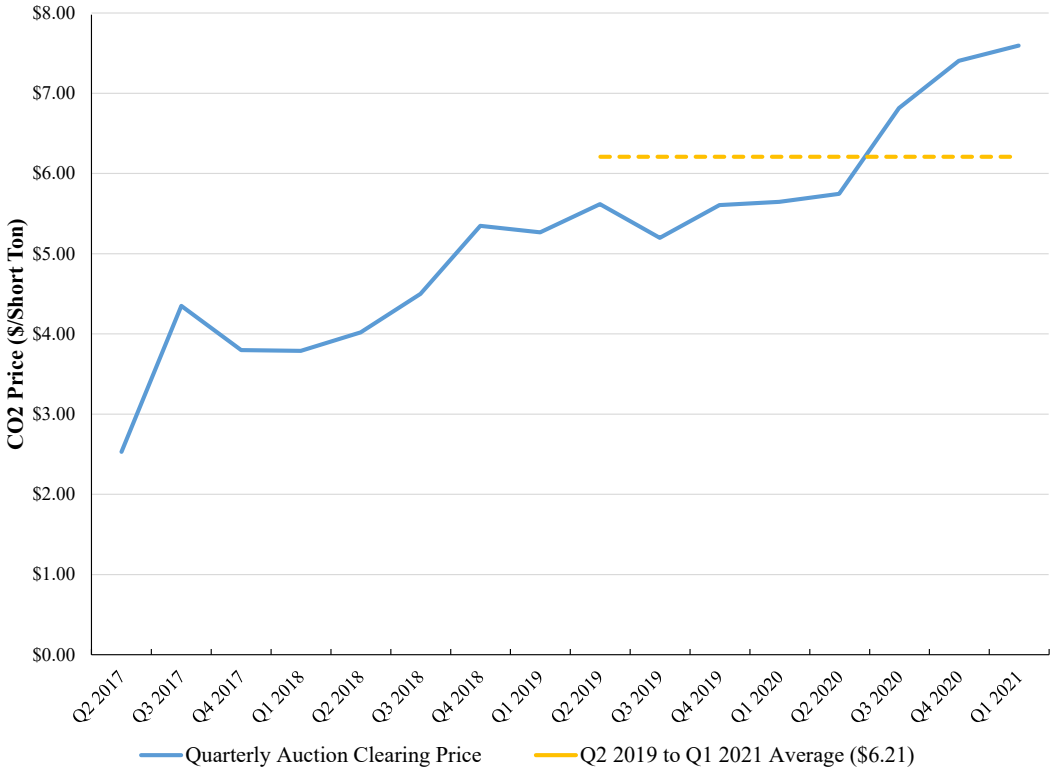
Emissions Prices

- We will assume that RGGI still exists. The RGGI price will be set at the average of the price from recent auctions (e.g., the last two years)

RGGI CO_2 Auction Clearing Price (Q2 2017 – Q1 2021)



Non-Fossil Fuel Resource Assumptions

- Renewable Hourly Resource Profiles
  - For existing and new generation, rely on DNV profiles
- Battery Storage
  - Will earn net energy market revenues by charging when prices are low and discharging when prices are high (*i.e.*, price arbitrage)
  - Gains to charging and discharging must exceed hurdle rate reflecting roundtrip efficiency of 85% and other opportunity costs
  - Can also supply ancillary services, subject to ISO-NE rules
  - Co-located solar + battery resources modeled as separate solar and battery resources
- Imports/Exports
  - Imports from Canada will be modeled using an hourly profile
  - NYISO will be modeled concurrently

Modeling Inputs and Assumptions: Entry, Exit and Going-Forward Costs

Going-Forward Costs for Existing Resources

- Consistent with market rules, Going-Forward Costs (GFC) for existing resources will reflect the expected avoidable costs from suspension of operations
  - The GFC will take into account fixed operations and maintenance costs ("Fixed O&M") as well as expected energy and ancillary service ("EAS") market net revenues, consistent with current market rules
  - Fixed O&M for existing resources will be based on data from SNL
  - Expected EAS net revenues will be estimated within the simulation model

Potential Resource Additions

- Consider resource additions for commercially available technologies with costs that potentially support economic entry and meaningful new resource potential
- Certain technologies not evaluated due to cost considerations (e.g., fuel cells) or limited resource opportunities (e.g., non-Canadian hydro)

Technology	Modeled for Potential New Entry?
Onshore wind	✓
Offshore wind	✓
Utility-scale solar	✓
Canadian hydro	✓
Run-of-river hydro	×
Pondage hydro	×
Pumped storage	×
Nuclear	×
Battery storage	✓
Solar + storage	✓
Municipal solid waste	×
Biomass	✓
Natural gas combined cycle	✓
Fuel cells	×

New Entry Capital Costs

- Costs of new entry (capital costs) will be based on independent, reliable and representative estimates of current costs – such estimates need to reflect, among other things:
  - Region-specific cost factors (*e.g.*, labor costs, project requirements, etc.)
  - Full scope of installed costs (*e.g.*, transmission)
  - Forward looking time period (*i.e.,* present to 2040)
- Costs are assumed only for the purpose of evaluating alternative approaches to achieving decarbonization targets
  - Rely on publicly available sources
  - Rely on sources with information for multiple resource types of technologies to best characterize the relative costs across resource types given common assumptions regarding underlying cost factors
  - May combine information from different sources regarding different components of costs (*e.g.*, cost trajectories, region-specific cost factors, transmission costs, *etc*.)

Other Market Rule-Related Issues

- MOPR
  - A process to remove the MOPR has been proposed (*Updated 2021 Annual Work Plan*), although specific rules to replace the MOPR are yet known
  - In light of this proposal and other factors (e.g., FERC identification of this as a priority), assume no MOPR in the central case for modeling simplicity
  - Assumption made only for modeling purposes of the Pathways project
- Capacity credits for variable renewable
  - Analysis will need to account for capacity credits for renewable resources
  - The analysis will assume current rules regarding capacity credits to variable renewables
    - ISO-NE is currently working to assess if the existing methodology to determine resource capacity contributions should be modified to account for the increase in variable renewables such as wind and solar
    - However, this work is just beginning, and we do not expect any changes would be determined in time to be considered as part of this modeling effort

Modeling Inputs and Assumptions: Load Assumptions

Load Shape

- Assume FGRS Load Scenario 3 in our central case
  - Reflects (MA) goal to achieve 80% economy-wide carbon reduction by 2050
  - Assumes:
    - Investment in energy efficiency
    - Heating and transportation electrification that reduces emissions from these sources by two-thirds relative to 2020 levels
      - Heating: 38.9 TWh
      - Transportation: 40.0 TWh
  - Total energy: 198.5 TWh (excluding Behind-the-Meter (BTM) solar)
  - Based on 2019 load shape, modified for the future changes described above
  - We will test modifications to the load shape in scenario analysis
- BTM solar will be based either on the most recent CELT report or FGRS assumptions
  - If CELT, growth from 2031-2040 will be based on 3-year compound annual growth rate

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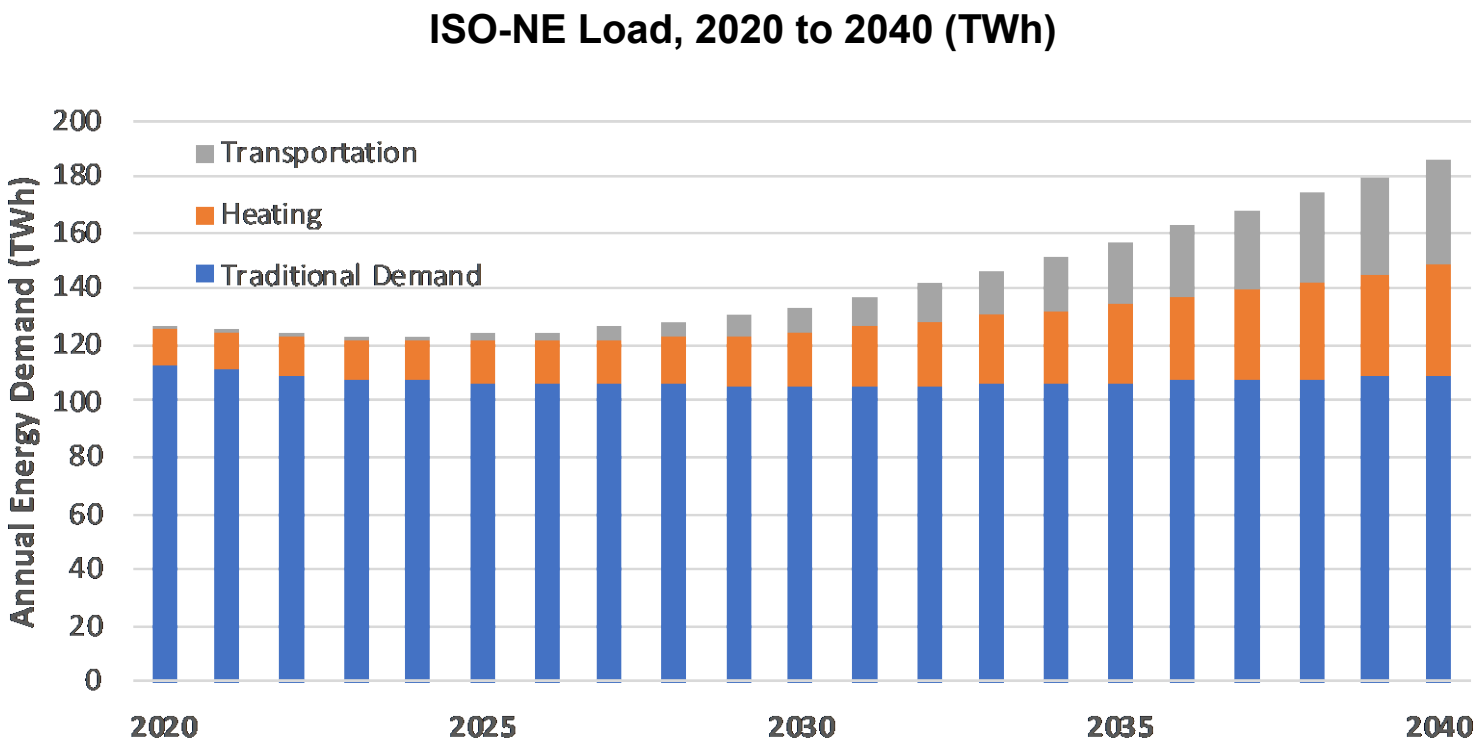
FGRS Scenario 3 Load Growth



Source: Scenario 3 Load Assumptions, NESCOE

Case Assumptions: State Policies

Existing State Policies

- For all central cases, assume existing RPS remain in place
- Analysis will assume RPS targets, but measures/instruments used to achieve those targets will vary across cases

	2040 Requirement Quantity (% of Load)
State	**RPS Only**
Connecticut	48%
Maine	80%
Massachusetts	57%
New Hampshire	25%
Rhode Island	39%
Vermont	75%
Total (load weighted)	54%

Note: Estimates by AG based on review of state legislative mandates. Load weighting based on ISO-NE's 2029 load forecast, net of behind the meter solar and energy efficiency.

Meeting Decarbonization (and RPS) Target

- Resources used to meet 80% decarbonization target (and RPS) will differ across cases
- Status Quo:
  - New clean energy resource entry assumed reflecting recent procurements, state policy plans, and other policy indications
  - Resources will be financed through long-term contracts
- FCEM/ICCM and Net Carbon Pricing
  - Entry (and exit) will occur to minimize costs of meeting decarbonization target (and RPS) given the different ways in which the policy mechanisms incent decarbonization:
    - FCEM/ICCM – provides additional revenues to “clean” resources that do not emit carbon
    - Net Carbon Pricing – imposes a direct cost on all carbon emissions (which makes clean resources more competitive)
  - No long-term contracts beyond what are currently in place or legislated to be procured

Case Assumptions: Status Quo

Approach and Resource Mix

- States have indicated that they plan to meet their environmental goals primarily via procurement of multi-year contracts with wind, solar, and hydro resources
  - States have not specified binding procurement plan
  - State policy analysis suggest different preferences for mix of technical approaches and resources to achieve decarbonization
- Analysis will assume:
  - Resource mix consistent with New England State's policy assessments (we will provide a proposed mix at a future meeting)
  - Incenting of resource finance through long-term contracts
- Additional information on approach to resource procurement under the Status Quo will be presented at the next PC meeting

Case Assumptions: FCEM/ICCM

FCEM Assumptions

- Model will determine capacity and CEC awards simultaneously
  - This approach is consistent with an ICCM
  - ICCM outcomes are similar those of an FCEM in which resources have perfect foresight about FCM outcomes (assuming the FCEM goes first)
  - Thus, from a modeling standpoint, these approaches result in identical outcomes (absent introduction of assumptions regarding differences between expected and actual outcomes of the FCM)
- Proposed resource types eligible for CECs include wind, solar, nuclear, and all hydro
  - Only criteria for eligibility is technology type
- Storage will not be eligible, but we expect it to benefit
  - More detail is provided in ISO-NE's materials
- CECs imports
  - Imports will be eligible for CECs, including Hydro Quebec imports
  - Other out of state resources will need to bundle CECs and RECs to avoid double payment

CEC Resource Eligibility

- Proposed CEC eligibility reflects stakeholder input and certain market design considerations
- Combined solar + storage resource eligibility to reflect solar capacity only
- Look forward to further stakeholder feedback before determining study assumptions

Technology	Eligible for CECs?
Onshore wind	✓
Offshore wind	✓
Utility-scale solar	✓
Canadian hydro	✓
Run-of-river hydro	✓
Pondage hydro	✓
Pumped storage	×
Nuclear	✓
Battery storage	×
Solar + storage	✓
Municipal solid waste	?
Other biomass	?
Natural gas combined cycle	×
Fuel cells	×

Clean Energy Credit Assumptions

FCEM / ICCM will assume:

- No partial CECs for efficient gas-fired resources
- CEC banking
- Static CEC value based on the results of the FCEM / ICCM
  - The process for studying dynamic credits is still under development and will be studied separately
- New England states demand the necessary quantity of CECs to meet the regional decarbonization target
  - We will assume that individual States' demand is proportional to their current RPS/clean energy policy requirements, not exceeding their load

CEC Offers and Settlement

- Resource CEC offer quantity
  - Existing dispatchable resources will offer an amount of clean energy consistent with recent performance
  - Existing wind, solar, and hydro will offer based on 2019 performance
  - Wind and solar added through the capacity expansion model will offer based on 2019 performance of a similar existing resource or DNV profiles
- Compliance penalty
  - Resources can fulfill CEC obligations through generation or purchase of CECs
  - Compliance penalty, in effect, reflects a price at which resources can purchase CEC's in lieu of generating or purchasing CEC's
    - Like an Alternative Compliance Payment in state RPS programs
  - Thus, in effect, the compliance penalty acts as a price cap on CECs
  - In the central cases, we will not assume any compliance penalty

Case Assumptions: Net Carbon Pricing

Net Carbon Pricing

- Carbon price will be set to achieve the 80% electricity sector decarbonization target
  - In practice, carbon price could be set through a fixed carbon price or through a quantity-based approach
    - Under a fixed carbon price, the price would be fixed and the resulting emissions would be uncertain
    - Under a quantity-based approach (e.g., a cap-and-trade system), the quantity would be fixed (at the policy target), and the price would be uncertain
  - Analysis will encompass both price-based and quantity-based carbon pricing, as it will not evaluate the distribution of outcomes given price/quantity uncertainty
  - Analysis will equalize emissions across approaches to facilitate comparison of carbon pricing, FCEM and status quo
- Carbon revenues will be credited against EAS costs
  - The specific method for allocating costs by load is under consideration
- To offset leakage, we will include a cost adder for imports when the marginal generator in the exporting region is an emitting resource.

Outcomes

Proposed Study Outcomes

- This study will focus on differences in outcomes across approaches to give insight into how outcomes may differ under each approach.
  - This will be assessed by holding relevant central case assumptions constant across approaches: total emissions, existing state policies and procurements, load, fuel prices, etc.
- Potential quantitative outcomes include:
  - Customer payments
  - Total production costs, by technology type
  - Changes in net revenues, by technology type, relative to status quo case
  - Wholesale energy and reserve prices (LMPs)
  - Capacity prices
  - Environmental prices (carbon, CEC)
  - Total CEC payments by states
  - Total carbon price payments by resources
  - Emissions, by technology type
  - Resource mix, by technology type (MW, MWh)

Proposed Study Outcomes

- Qualitative analysis
  - Quantitative analysis will capture some but not all differences in approaches, while qualitative analysis will aim to identify and evaluate other consequential differences in outcomes across approaches
- As with feedback on input and modeling assumptions, we encourage stakeholder feedback on additional outcomes of interest

Next Steps

- June
  - Review any additional feedback from stakeholders
  - Present finalized assumptions and inputs
  - Present initial set of proposed scenarios

- Summer
  - As needed, additional meetings to discuss further detail on inputs, assumptions and methodologies

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