2020 Economic Study:

Draft Scope of Work and High-Level Assumptions for Production Simulations - Part II of III

Planning Advisory Committee

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One Economic Study Request Was Received in 2020

- ISO New England (ISO) received one request for an Economic Study
  - Request made by National Grid (NGRID) and presented to the PAC on April 23, 2020
- The goal of the NGRID request is to "Provide stakeholders analyses of potential pathways to best use the MWh of clean energy resources to meet state goals cost-effectively, leveraging transmission* and/or storage as needed"
  - Evaluate the potential economic benefits associated with the deployment of transmission* and/or storage under a range of assumed future resource portfolios
  - Assess changes to thermal unit capacity factors, spillage and emissions as related to different resource and dispatch scenarios
  - The request is for a one-year study focusing on 2035
- A high-level draft of work and assumptions were presented to the PAC on May 21, 2020 (Part I of III)
  - A third presentation regarding assumptions will be made in July

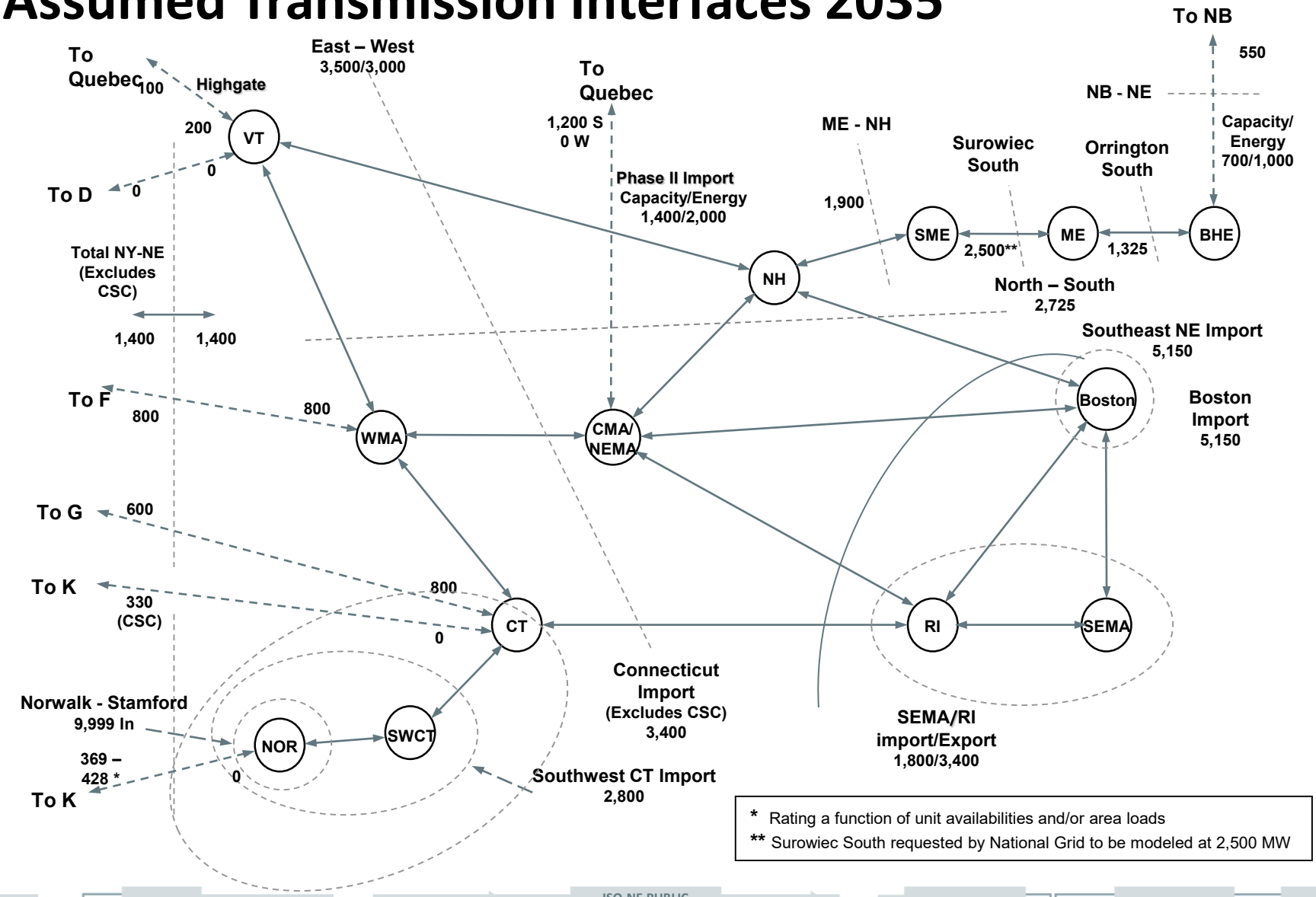
*Bi-directional transmission capability with neighbors

BACKGROUND AND GENERAL ASSUMPTIONS

Modeling Software Used to Conduct Study

- Production cost simulation runs will be performed using the ABB GridView Production Simulation Model
  - Generation production simulation using pipe and bubble format
- ISO will conduct sub-hourly production simulations associated with these scenarios using the Dartmouth Electric Power Enterprise Control System (EPECS) software to investigate ancillary reserve needs

New England Pipe and Bubble Representation (MW) Assumed Transmission Interfaces 2035



* Rating a function of unit availabilities and/or area loads

** Surowiec South requested by National Grid to be modeled at 2,500 MW

Internal Transmission Interface Limits (MW)

Single-Value, Summer Peak,[a] Non-Firm, Transmission Interface Limits for Use in Subarea Transportation Models

Interface	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Orrington South Export	1325	1325	1325	1325	1325	1325	1325	1325	1325	1325
Surowiec South	1500	1500	1500	1500	1500	1500	1500	1500	1500	2500*
Maine-New Hampshire	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Northern New England-Scobie + 394	3450	3450	3450	3450	3450	3450	3450	3450	3450	3450
North-South	2725	2725	2725	2725	2725	2725	2725	2725	2725	2725
East-West	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
West-East	2200	2200	2200	3000[e]	3000	3000	3000	3000	3000	3000
Boston Import (N-1)	5400	5700[b]	5700	5700	5150[f]	5150	5150	5150	5150	5150
Boston Import (N-1-1)	4500	4600[b]	4600	4600	4300[f]	4300	4300	4300	4300	4300
SEMA/RI Export	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400
SEMA/RI Import (N-1)	1280	1280	1280	1800[e]	1800	1800	1800	1800	1800	1800
SEMA/RI Import (N-1-1)	720	720	720	800[e]	800	800	800	800	800	800
Southeast New England Import (N-1)	5400	5700[b]	5700	5700	5150[f]	5150	5150	5150	5150	5150
Southeast New England Import (N-1-1)	4500	4600[b]	4600	4600	4300[f]	4300	4300	4300	4300	4300
Connecticut Import (N-1)	3400[c]	3400	3400	3400	3400	3400	3400	3400	3400	3400
Connecticut Import (N-1-1)	2200[c]	2200	2200	2200	2200	2200	2200	2200	2200	2200
SW Connecticut Import (N-1)	2500	2800[d]	2800	2800	2800	2800	2800	2800	2800	2800
SW Connecticut Import (N-1-1)	1750	1900[d]	1900	1900	1900	1900	1900	1900	1900	1900

**2,500 MW limit requested at the Surowiec South Interface by National Grid, FCA 15 internal transfer capability of Surowiec South is 1,500 MW for the year 2029*

- The internal transmission interface limits for 2029 will also be used for 2035
- N-1 limits will be used in the 2020 Economic Studies
- The table notes are shown in Appendix I
- Source: https://www.iso-ne.com/static-assets/documents/2020/03/a08.0_rc_2020_03_17_presentation.pdf

External Interface Import Capability (MW)

Single-Value, Summer Peak,[1] Non-Firm, Transmission Interface Limits for Use in Subarea Transportation Models

Interface	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
New Brunswick-New England (energy import capability)[2]	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
New Brunswick-New England (capacity import capability)	700	700	700	700	700	700	700	700	700	700
HQ-New England (Highgate) (energy import capability)[3]	217	217	217	217	217	217	217	217	217	217
HQ-New England (Highgate) (capacity import capability)	200	200	200	200	200	200	200	200	200	200
HQ-New England (Phase II) (energy import capability)[4]	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
HQ-New England (Phase II) (capacity import capability)	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
Cross-Sound Cable (CSC) (energy import capability)[5]	330	330	330	330	330	330	330	330	330	330
Cross-Sound Cable (CSC) (capacity import capability)	0	0	0	0	0	0	0	0	0	0
New York-New England (energy transfer capability)[6]	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
New York-New England (capacity transfer capability)	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400

- The external interface import capability for 2029 will also be used for 2035
- The table notes are shown in Appendix I
- Source: https://www.iso-ne.com/static-assets/documents/2020/03/a08.0_rc_2020_03_17_presentation.pdf

External Interface Energy Transfer Capability for Economic Studies

Single-Value, Summer Peak,[1] Non-Firm, Transmission Interface Limits for Use in Subarea Transportation Models

Interface	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
New Brunswick-New England										
(energy import capability)[2]	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
(energy export capability)	550	550	550	550	550	550	550	550	550	550
HQ-New England (Highgate)										
(energy import capability)[3]	217	217	217	217	217	217	217	217	217	217
(energy export capability)	100	100	100	100	100	100	100	100	100	100
HQ-New England (Phase II)										
(energy import capability)[4]	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
(energy export capability)	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Norwalk Harbor - Northport Cable (NNC)										
(energy import capability)[5]	200	200	200	200	200	200	200	200	200	200
(energy export capability)	200	200	200	200	200	200	200	200	200	200
Cross-Sound Cable (CSC)										
(energy import capability)[5]	330	330	330	330	330	330	330	330	330	330
(energy export capability)	346	346	346	346	346	346	346	346	346	346
New York-New England										
(energy import capability)[6]	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
(energy export capability)	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200

Notes are discussed on the following pages

- The internal transmission interface limits for 2029 will also be used for 2035
- N-1 limits will be used in the 2020 Economic Studies

Source: https://www.iso-ne.com/static-assets/documents/2020/03/a08.0_rc_2020_03_17_presentation.pdf

GENERIC PRODUCTION COST ASSUMPTIONS

Common Production Simulation Assumptions

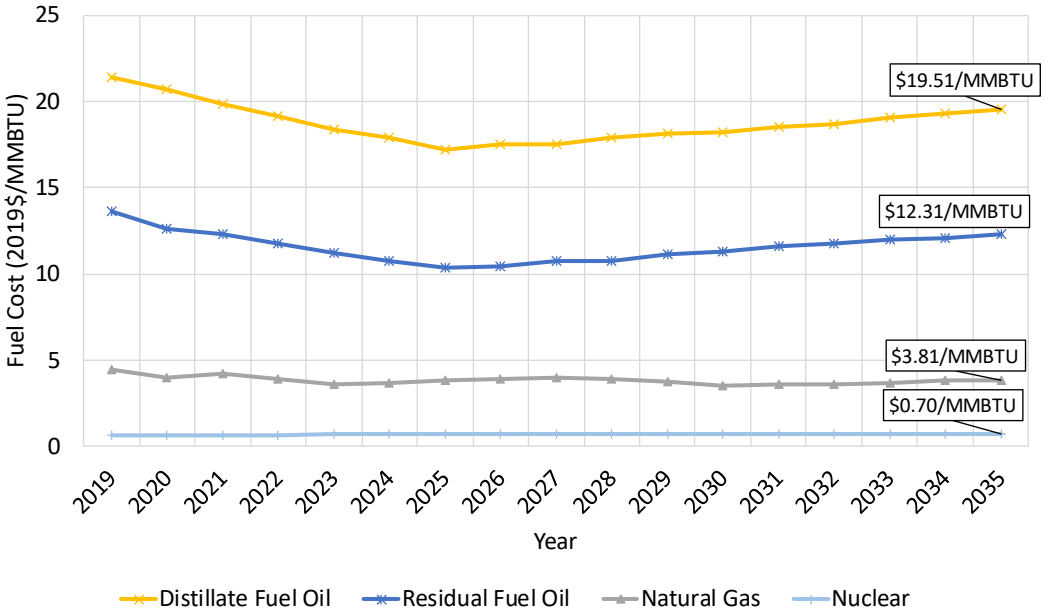
- Resources that have a Forward Capacity Market (FCM) Capacity Supply Obligation (CSO) through Capacity Commitment Period 2023-2024 and energy-only generators will be modeled at their Seasonal Claimed Capability (Based on the 2019 SCC)
  - As reflected in the 2019 Capacity, Energy, Loads, and Transmission (CELT)
  - Resources without a SCC value will be modeled at their CSO, including new resources
  - These capabilities will be reduced to reflect potential forced outages
  - All other demand and supply variables will be modeled through the use of specific profiles provided by NGRID or developed by ISO
- Fuel prices for coal, oil, and natural gas will be based on 2020 forecasts from the Energy Information Administration (EIA) for New England
- Emission allowance prices for carbon dioxide, nitrous oxide, and sulfur oxide will be reflected for fossil-burning generation units

Resource Retirements – All Scenarios

- Cleared Existing Capacity Resource retirements known through Capacity Commitment Period 2023-2024 (Forward Capacity Auction (FCA 14)) and the assumed retirement of:
  - Mystic 8 & 9
  - New England coal units
  - Millstone 2
  - 75% of the conventional New England oil, including dual-fuel units, based on age*
- A sensitivity that includes the retirement of 50% of the remaining New England natural gas units based on age*

*Of Units Qualified for FCA 14

Annual Fuel Price Forecast: EIA's 2020 AEO Base Forecast



- Based on 2020 EIA Annual Energy Outlook fuel price forecast for New England
  - Same method as prior Economic Study models
  - Reflect the EIA Appendix prices for New England oil and natural gas

Environmental Emissions Allowances Assumptions

- Future Environmental Air Emission Allowances Prices
  - 2035
    - NOX = $ 4.00 /ton
    - SO_2 = $ 2.00 /ton
    - CO_2 = $33.52 /ton

- CO_2 emissions for Massachusetts affected fossil fuel generators will also be monitored exogenously to confirm that they meet the Massachusetts Global Warming Solutions Act (GWSA) cap

Emissions Allowance Prices Sourced from NYISO Congestion Resource and Integration Study (CARIS)

Production Cost Operating Reserve Modeling

- GridView production cost analysis models operating reserve requirement
  - Modeled similar to previous Economic Studies
    - 120% of the first contingency in ten minutes split between
      - Ten-Minute Spinning Reserve (TMSR) = 50%
      - Ten-Minute Non-Spinning Reserve (TMNSR) = 50%
- Offshore wind interconnections respect 1,200 MW loss of source limit
  - Individual transmission interconnections to shore have a maximum value of 1,200 MW

Active Demand Resources (DR)

- Active DR (Active Demand Capacity Resources (ADCR)) assumptions are based on FCA 14 results, totaling 592 MW
- The active DR will be modeled dispatchable, as was done in prior Economic Studies
  - First 100 MW dispatched at $50/MWh
  - Remainder at $500/MWh

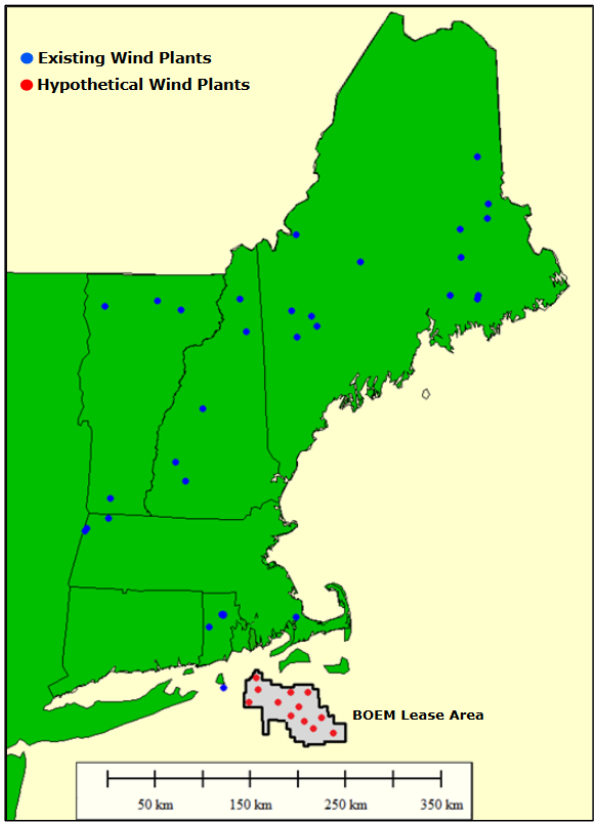
PROFILES-BASED ASSUMPTIONS

Many Resources May Be Represented by Profiles

- Many resources cannot be dispatched using production cost
  - Some technologies have zero or “indeterminate” production cost
  - Can be “curtailed” using assumed “threshold” prices
- 2015 weather year for onshore wind, offshore wind, and PV will use profiles
- Electric vehicles (EVs) and heatpumps will be modeled based on information provided by National Grid
- A profile for local New England hydroelectric generation (not pumped storage) will be developed that shifts their energy production to the higher net load hours
- The GridView storage functionality will be used rather than a profile based approach
  - Storage will be dispatched to minimize production cost

Onshore and Offshore Wind Data

- Magnitude and location of onshore and offshore wind will be presented during the July PAC meeting
  - Interconnection of offshore wind will be built off of findings from the 2019 NESCOE Economic Study
- Wind data is from the ISO's Wind and Power Time Series Model developed by DNV-GL (available on the ISO-NE PAC website)
  - 2015 weather year will be used



Source: DNV-GL

2035 Gross Load, EE, and BTM PV Forecasts

- The model will reflect separate MW values for gross peak load, EE, and Behind the Meter (BTM) PV with locations that are consistent with the 2020 CELT
- Quantities for 2035 can be determined using previous methodologies described below and 2020 CELT quantities
  - 2035 values (peak, EE, and BTM PV) can be calculated using the 2020 CELT values for 2029 and growing them to the year 2035 using data from 2028 and 2029
    - Example: For 2035 Peak Load: the 50-50 gross peak of 2029 x [(50-50 gross peak of 2029/50-50 gross peak of 2028)[6]]
    - Example: For 2035 EE and PV: total value for the year 2029 + [incremental growth for the year 2029 x 6]

Gross New England 50/50 Peak and Annual Energy Demand

New England	2035
Peak (MW)	33,112 (a)
Annual Energy (GWh)	177,762 (b)

(a) Gross 50/50 Peak calculation for 2035 = 31,550 MW x (31,550 MW / 31,297 MW)^6 = 33,112 MW
(b) Gross Annual Energy calculation for 2035 = 165,603 x (165,603 GWh / 163,659 GWh)^6 = 177,762 GWh

Source: 2020 CELT

Energy Efficiency
Reductions in Peak Load and Energy

- The same amounts of Energy Efficiency added in 2029 (174 MW of peak load reduction and 791 GWh of energy reduction) are assumed to be added annually through 2035
  - Capacity value for the year 2035 = 5,733 MW + [174 MW x 6] = 6,777 MW
  - Energy value for the year 2030 = 31,284 GWh + [791 GWh x 6] = 36,030 GWh

New England	2035
Capacity (MW)	6,777
Energy (GWh)	36,030

Source: 2020 CELT

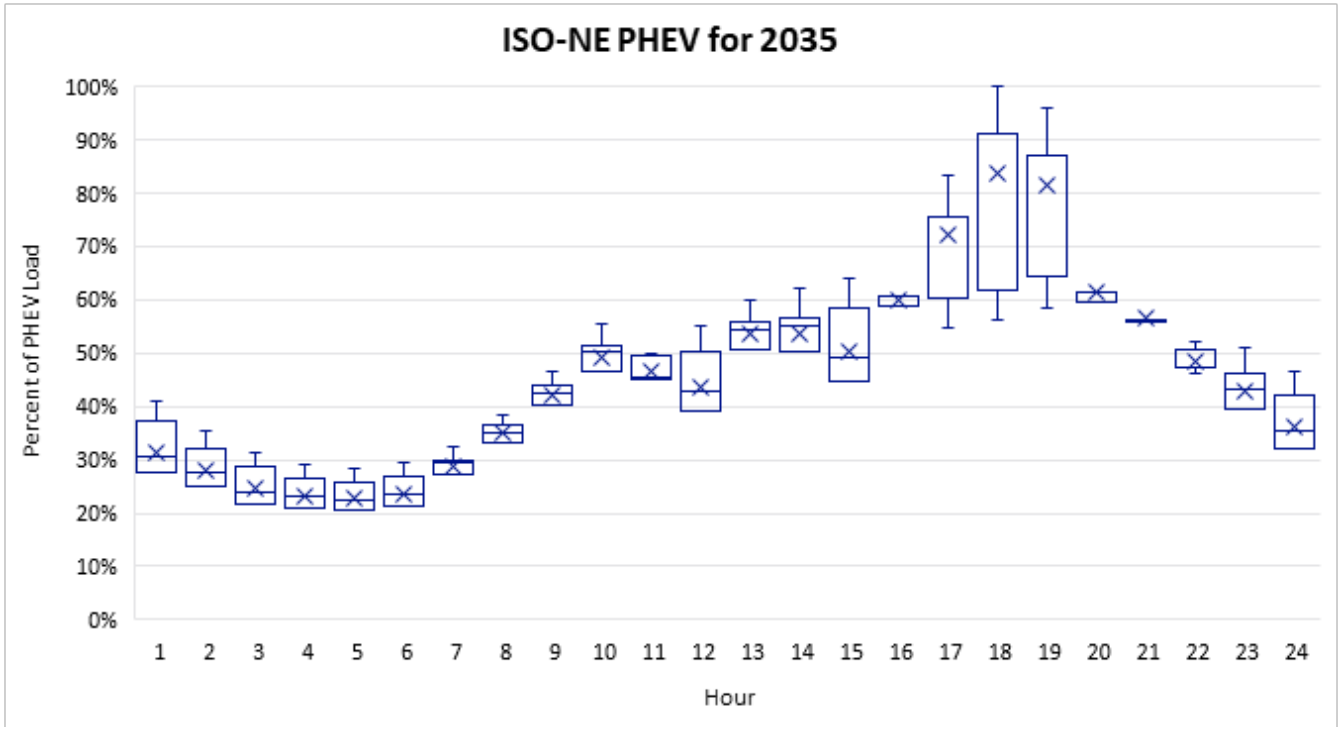
Distribution of Electric Vehicles (EV)

- A total of 2.2 million EVs will be modeled in the scenarios
  - Locations will be distributed by state, utilizing the same distribution that was used in the 2016 Economic Study
    - 43% in MA
    - 23% in CT
    - 12% in ME
    - 11% in NH
    - 6% in RI
    - 5% in VT
  - No discharge/generation back into the grid will be assumed

State	Percent of Load	Number of Vehicles
Massachusetts	43	946,000
Connecticut	23	506,000
Maine	12	264,000
New Hampshire	11	242,000
Rhode Island	6	132,000
Vermont	5	110,000
New England	100	2,200,000

Electric Vehicle Characteristics

- EV data is provided by National Grid
  - Hourly shapes were provided broken down by subarea
  - Generally charging is lowest in the morning and peaks at hour ending 18:00



Storage Will be Modeled to Minimize Production Cost

- For this economic study, the ISO will be using GridView's storage functionality which seeks to dispatch storage to minimize production cost
- Battery storage and pump storage will be modeled with different efficiencies
  - 74% efficiency for pump storage
  - 86% efficiency for battery storage
- Battery Capability: Four MWh per MW of inverter capability enables four hours of battery output at full load

NEXT STEPS

Next Steps of the Economic Studies

- July 2020 PAC Meeting
  - Present the rest of the detailed assumptions (Part III of III)
- Third Quarter 2020
  - Present draft production simulations results
  - Identify sensitivity scenario(s) and assumptions
- Fourth Quarter 2020
  - Present sensitivity scenario(s) simulation results
  - Present draft ancillary services (EPECS) results
- First Quarter 2021
  - Present draft and final reports

APPENDIX I

INTERNAL TRANSMISSION INTERFACE LIMIT NOTES

FCA 15 Internal Interface Transfer Capability (Notes)

a) Limits are for the summer period, except where noted to be winter
   - The limits may not include possible simultaneous impacts, and should not be considered as “firm”
   - For the years within the FCM horizon (CCP 2024-2025 and sooner), only accepted certified transmission projects are included when identifying transfer limits
   - For the years beyond the FCM horizon (CCP 2025-2026 and later), proposed plan approved transmission upgrades are included according to their expected in-service dates

b) Increase associated with the Greater Boston upgrades, with the Wakefield – Woburn 345 kV line in service (CCP 2021-2022 and later)

c) Increase associated with the Greater Hartford/Central Connecticut upgrades

d) Increase associated with the Southwest Connecticut (SWCT) upgrades

e) Increase associated with the Southeast Massachusetts/Rhode Island (SEMA/RI) Reliability project upgrades

f) Decrease associated with the updated load assumptions, updated Northern New England (NNE)-Scobietransfer capability and retirement of Mystic 7, 8 & 9

External Interface Energy Transfer Capability (Notes)

1. Limits are for the summer period
   - The limits may not include possible simultaneous impacts, and should not be considered as “firm” (the bases for these limits are subject to more detailed review in the future)
2. The electrical limit of the New Brunswick (NB)-New England (NE) Tie is 1,000 MW
   - When exporting, the NE-NB transfer limit is 550 MW
3. The capability for the Highgate facility is listed at the New England AC side of the Highgate terminal
4. The Hydro-Quebec Phase II interconnection is a DC tie with equipment ratings of 2,000 MW. Due to the lack of

External Interface Energy Transfer Capability, Cont.

coordinated analyses between New England, Hydro Quebec, New York, and PJM controlled areas, ISO-NE has assumed its export transfer capability to be 1,200 MW

5. Import capability on the Cross Sound Cable (CSC) is dependent on the level of local generation
6. NY interface limits
   - NY interface limit is 1,400 MW without CSC and with the Northport Norwalk Cable at 0 MW flow
   - Simultaneously importing into NE and SWCT or Connecticut can lower the NY-NE capability (very rough decrease = 200 MW)

APPENDIX II

Acronyms

Acronyms

- ACDR – Active Demand Capacity Resource
- ACP – Alternative Compliance Payments
- AGC – Automatic Generator Control
- BTM PV – Behind the Meter Photovoltaic
- BOEM – Bureau of Ocean Energy Management
- CCP – Capacity Commitment Period
- CELT – Capacity, Energy, Load, and Transmission Report
- CSO – Capacity Supply Obligation
- Cstr. – Constrained
- DR – Demand-Response
- EE – Energy Efficiency
- EIA – U.S. Energy Information Administration
- EPECS – Electric Power Enterprise Control System
- FCA – Forward Capacity Auction
- FCM – Forward Capacity Market
- LFR – Load Following Reserve

Acronyms, cont.

- LMP – Locational Marginal Price
- LSE – Load-Serving Entity
- MSW – Municipal Solid Waste
- NECEC – New England Clean Energy Connect
- NESCOE – New England States Committee on Electricity
- NG – Natural Gas
- NICR – Net Installed Capacity Requirement
- NREL – National Renewable Energy Laboratory
- OSW – Offshore Wind
- PHEV – Plug-in Hybrid Electric Vehicle
- PV – Photovoltaic
- RFP – Request for Proposals
- RGGI – Regional Greenhouse Gas Initiative

Acronyms, cont.

- RPS – Renewables Portfolio Standards
- RTUC – Real-Time Unit Commitment
- SCC – Seasonal Claimed Capability
- SCED – Security Constrained Economic Dispatch
- SCUC – Security Constrained Unit Commitment
- SOARES – System Operational Analysis and Renewable Energy Integration Study
- TMOR – Ten Minute Spinning Reserve
- TMSR – Ten Minute Spinning Reserve
- Uncstr. – Unconstrained