From: Martin, Tim <timothy.martin@nationalgrid.com>
Sent: Friday, October 9, 2020 4:59 PM
To: Wasik-Gutierrez, Erin <ewasik-gutierrez@iso-ne.com>
Cc: Peter G Flynn (petergflynn@gmail.com) <petergflynn@gmail.com>; Runge, Eric K. <ekrunge@daypitney.com>; Grasse, Julia <Julia.Grasse@nationalgrid.com>; Klein, Alexander <Alexander.Klein@nationalgrid.com>; Perben, Marianne <Marianne.Perben@nationalgrid.com>
Subject: [EXT] Future Grid Study Scope

Erin,

National Grid would like to provide the following feedback with respect to the Future Grid Study's scope and on the appropriate criteria and metrics to be adopted in its conduct.

With respect to the scope of the study National Grid is currently working towards understanding the demand that widespread transportation electrification which we believe will have significant implications for the future grid. We suggest looking beyond the near-term electrification of light-duty vehicles to include the electrification of medium and heavy-duty vehicles and to particularly focus on two specific areas where EV charging loads could be significant: impact of highway ultra-fast charging and large-scale fleet electrification. While our work is at an early stage we suggest that the modeling of EVs and transportation electrification should be an integral consideration of the Future Grid study.

Further, National Grid's Market Fundamentals Team has identified what we believe are some of the key questions for the modeling of the electric system in the Northeast. If it would be beneficial to the Future Grid Study we could discuss the importance of properly characterizing key uncertainties when evaluating competing future pathways. I have attached some slides which provide an overview of our capabilities and some of the key questions we are exploring with respect to electric system modelling.

In addition, since it is our understanding that the study will now consider a number of 'condition-cases' book-ending the range of reasonably likely outcomes, we would like to re-iterate our previous offer to contribute the scenario and assumptions that have been developed with the ISO in support of National Grid's 2020 economic study request as the basis for, or element of, one of these book-ends. The draft scope of work for the study was recently reported to the Planning Advisory Committee (attached) and we would be happy to share more of the details.

We appreciate the opportunity to provide this feedback and look forward to the future discussions.

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Overview of National Grid's Market Fundamentals Team and Electric Sector Modeling Capabilities in the US Northeast

October 2020

nationalgrid

US Market Fundamentals: who we are & what we do

- Formed in January 2019
- Develop and maintain ‘central view’ of markets where NG does business, based on modeling and analysis
- Support long-term strategic decision making in the regulated and unregulated businesses, including renewables development
- Deliver insights on important sector & market developments and leading indicators

US Market Fundamentals: our core modeling capabilities

System Expansion

- What mix of generation resources may be required to reach policy targets? Cost of those resources?
- What market / sectoral developments could meaningfully impact the mix?
- What is the role for storage, imports?

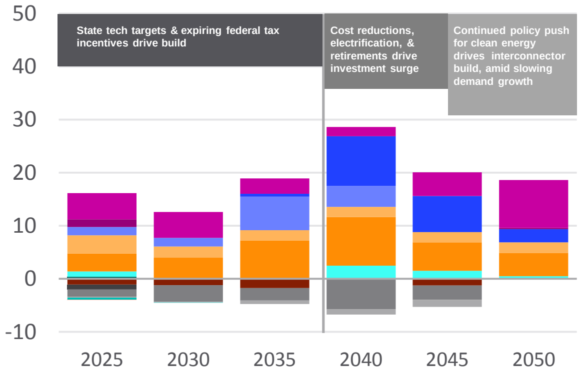
System Operations

- Can the system be reliably operated within resource and transmission limitations under contemplated future resource mixes?
- How will offshore wind development impact the transmission system?

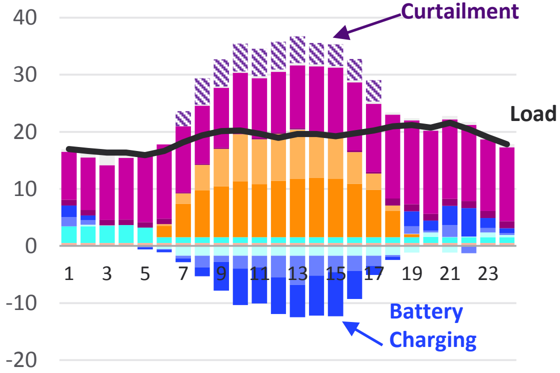
Supplemental Modeling & Analysis

- How might transport and heat electrification impact hourly load profiles in New York and New England?
- What are the non-electric sector costs of developments underlying expansion and operations scenarios?

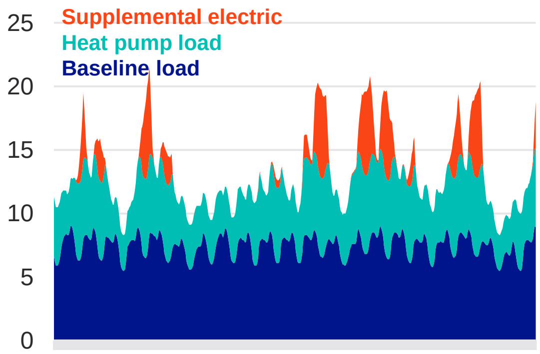
Ex: builds & retires over time



Ex: hourly system dispatch

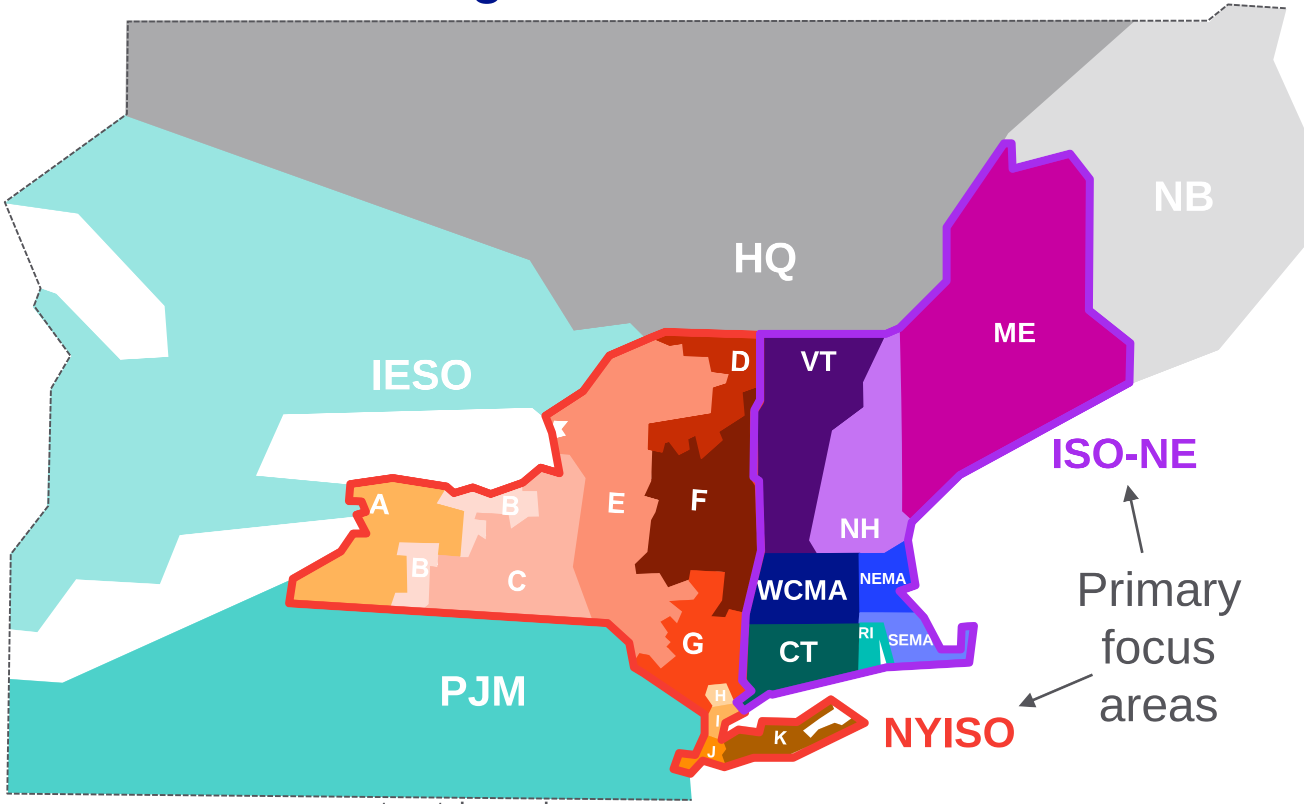


Ex: electrification impacts on load



Note: Enelytix is our primary modeling platform for system expansion and operations simulations. Other modeling and analysis conducted with purpose-built models.

Our modeling spans the Northeast US & neighboring regions and focuses on a range of net-zero-related issues



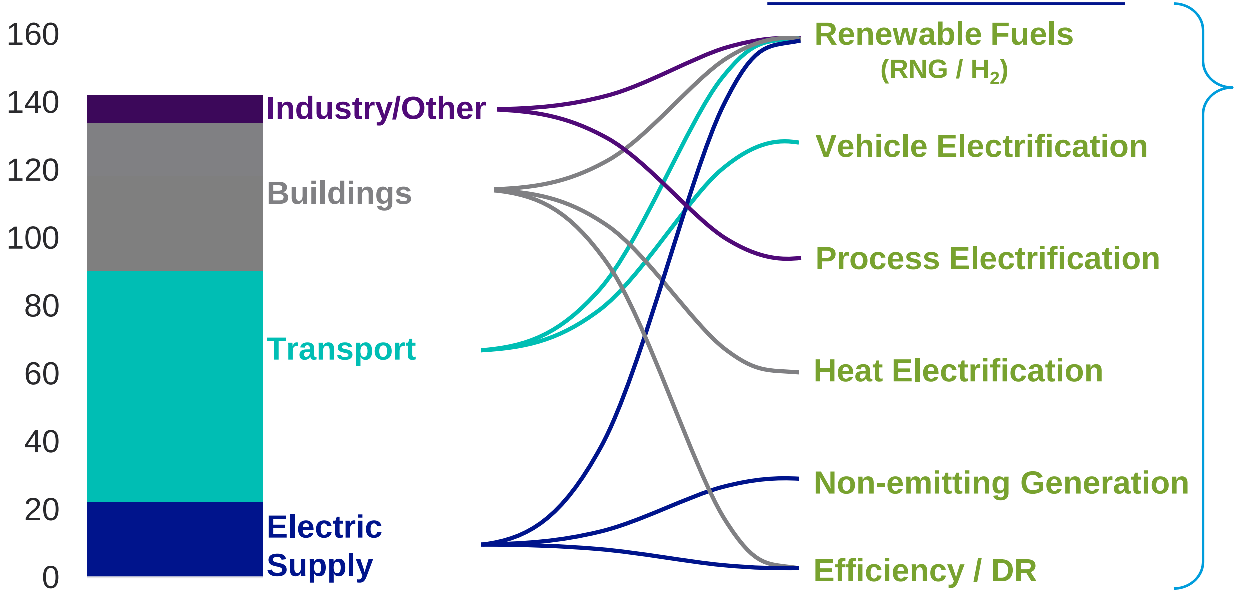
Key Factors Considered:

- State-level policies
  - CO_2 emissions
  - RPS / CES
  - technology targets
- Capacity needs / availability under an evolving gen mix
- Changes in end-use electric demand composition
- Intra-regional transmission capability to unlock renewables
- Availability of imports from HQ and other neighboring regions
- Cost trajectory for battery storage & other technologies
- Long-term market outlook

Broad consensus exists on need to reach net zero at the lowest cost to customers while preserving reliability, solutions analysis ongoing

ISONE CO_2 emissions by sector in 2017 (MMtons)

Decarbonization Solution Areas



- Studies progressing in a number of venues* **exploring solution pathways** that would enable region to attain net zero
- **Characterizing uncertainties** around solution cost, reliability, and emissions impacts are **key to developing viable pathways**

Source: EIA State Energy Data System, NG US Market Fundamentals
*E.g., EEA pathways analysis, ISONE Future Grid Study, RI 100% Renewables Study, various NYISO deep decarbonization studies

2020 Economic Study:

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

Planning Advisory Committee

Richard Kornitsky

ASSISTANT ENGINEER | RESOURCE STUDIES AND ASSESSMENTS

One Economic Study Request Was Received in 2020

- ISO New England (ISO) received one request for an Economic Study
  - Request made by National Grid and presented to the PAC on April 23, 2020
- The goal of the National Grid 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(1) and/or storage as needed"
  - Evaluate the potential economic benefits associated with the deployment of transmission(1) 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 scope of work and assumptions were presented to the PAC on May 20, 2020 (Part I of III) and June 17, 2020 (Part II of III)

(1) Bi-directional transmission capability with neighbors

Assumptions Previously Covered at the May and June PAC Meetings

May 20 PAC

- Modeling tools
- GridView Production Metrics
- EPECS Sub-Hourly Simulation Metrics
- Demand & EE for All Scenarios

June 17 PAC

- Transmission Interface limits
- Transmission Import and Export Capabilities
- Fuel Prices
- Environmental Allowance Prices & Marginal Emissions
- Exclusion of FCM outcome analysis from the study
- Reserve Requirements
- Active Demand Response
- Wind Data
- Energy Efficiency
- Electric Vehicles
- Storage

Assumptions Covered in Today's Presentation

- **Revised** study scenarios
- **Revised** threshold prices
- Bi-directional threshold prices
- Resource modeling assumptions
  - Wind resources
  - PV resources
  - Off-shore wind additions sufficient to exceed NICR
  - Heat pumps
- Fuel price forecast
- Modeling of battery storage

SCENARIOS AND THRESHOLD PRICES

A revision to prior assumptions based on comments received

Scenario Overview

- A set of *Incremental Resource Scenarios ('I' Series of cases)* will model two different amounts of offshore wind interconnections
  - Initial offshore wind interconnection mimics the 2019 NESCOE Economic Study 8,000_1 scenarios but with updated input assumptions
- The substantial focus of the study is on the *Bi-directional Scenarios ('B' Series of cases)*
  - These scenarios explore bi-directional use of existing and proposed external tie lines as well the use of Hydro Quebec as virtual storage
- These scenarios and threshold prices are a revision to the May PAC presentation based on feedback received
  - ***They replace*** *those scenarios and threshold prices*
- Sensitivities of resource location and quantities will be discussed in Q3 2020
  - OSW interconnections
  - Battery energy storage systems

2020 National Grid Economic Study Scenarios

<table>
<tr><th>Scenarios</th><th>Threshold Prices Used</th><th>Retirements</th><th>Must Run Units</th><th>Wind Additions (Nameplate)</th><th>Peak Demand from Heat Pumps</th><th>Peak Demand from Electric Vehicles</th><th>Nameplate Storage Additions</th><th>Bi-Directional External Tie(s)</th></tr>
<tr><td>Bi-Directional Reference (B)</td><td rowspan="4">REC-Inspired</td><td rowspan="4">FCA 14, Mystic 8&9, Millstone 2, NE Coal, + 75% of conventional NE oil including dual-fuel based on age</td><td rowspan="7">Nuclear, Municipal Solid Waste, Landfill Gas, Wood</td><td rowspan="7">1,330 MW Onshore

8,000 MW Offshore(2)</td><td rowspan="7">5,214 MW</td><td rowspan="7">1,817 MW (2.2 million vehicles)</td><td>2,000 MW Battery(2)</td><td>None</td></tr>
<tr><td>Bi-Directional Legacy (B_HQNB)</td><td rowspan="3">2,000 MW Battery(2) and Utilizing Hydro Quebec as Virtual Storage</td><td>HQ PHII and NB</td></tr>
<tr><td>Bi-Directional New Transmission 1 (B_HQNB_1T)</td><td>HQ PHII, NB, One New 1,200 MW Tie(4)</td></tr>
<tr><td>Bi-Directional New Transmission 2(3) (B_HQNB_2T)</td><td>HQ PHII, NB, Two New 1,200 MW Ties(4)</td></tr>
<tr><td>Incremental_8000 (I)</td><td rowspan="3">Positive Threshold Prices</td><td>FCA 14, Mystic 8&9, Millstone 2, NE Coal</td><td rowspan="3">2,000 MW Battery(2)</td><td rowspan="3">None</td></tr>
<tr><td>Incremental_8000 with Oil retirements (I_Oil)</td><td>Same as (I) plus the rest of the oil units</td></tr>
<tr><td>Incremental_8000 Oil and NG Retirements (I_Oil_NG)</td><td>Same as (I_Oil) plus 50% of the remaining NG units including dual-fuel units</td></tr>
</table>

(2) Other magnitudes of these resources may be considered as sensitivities

*(3) **May** be performed depending on utilization of the scenario where a single 1,200 MW transmission line is added*

Threshold Prices Will Be Used to Decrease Production of $0/MWh Resources When There is Oversupply

- The ***Incremental Resource Scenarios*** will use a different threshold price and order as requested by National Grid than what has been used in recent Economic Studies

Price-Taking Resource	Threshold Price ($/MWh)
Behind-the-Meter PV	1.00
NECEC (1090 MW)	2.00
Imports from HQ on Ph. II	5.00
Imports from NB	10.00
Utility Scale PV	11.00
Onshore Wind	12.00
Offshore Wind	13.00

- New England hydro is no longer modeled with a profile and therefore does not need a threshold price
- These threshold prices are used to facilitate the analysis of load levels where the amount of $0/MWh resources exceeds the system load
  - They are not indicative of "true" cost, expected bidding behavior or the preference for one type of resource over an other
  - Use of different threshold prices than indicated will produce different outcomes, particularly spillage by resource

Bi-Directional Scenario Requires a New Threshold Pricing Order

- In the goal of the study, which is to investigate the concept of reducing spillage of renewable energy, an explicit recognition of zero-carbon renewable energy credits (RECs) in the threshold prices seems necessary
- Imports would continue to be modeled with their current threshold prices, which may not earn RECs but would reduce carbon emissions in New England
- In order to have a rational export model, there needs to be a cessation of non-firm contracted imports from Quebec, and New Brunswick before exports can be made
  - The proposed threshold prices need to drive these exports

Hydro Quebec as Virtual Storage

Study Shared by National Grid with ISO-NE

- MIT's "Deep Decarbonization of the Northeastern U.S. and the Role of Canadian Hydropower" 2020 study demonstrated bi-directional transmission with Quebec complements high intermittent resource mixes in New England
  - This study further explores this concept
- HQ can function as virtual storage (aka "energy banking") in which HQ it would curtail its hydro production during times of New England renewable overproduction with the possibility of transmitting that energy back at a later time
  - This virtual storage might be accomplished through bilateral contracts or other market mechanisms; this is outside the scope of this study
- For the 2020 National Grid Economic Study: The new transmission tie(s) with HQ will be connected into NEMA

Effect of Renewable Energy Credits on Threshold Prices

- States have:
  - Multiple layers of requirements for RECs
  - Varying policies regarding which resources qualify for RECs
- Each requirement is associated with:
  - A supply from producers
  - A demand from Load Serving Entities which needs to show compliance with state requirements
- No single value for a REC will accurately represent all the various layers and tranches
- Because resources garner monetizeable RECs that are additive to energy revenues, negative threshold prices would be a rational economic strategy (e.g., profitable)

Effect of Renewable Energy Credits on Threshold Prices, cont.

- State and Federal Policy initiatives have created monetizeable RECs
  - RECs have a value that provides a revenue stream to renewable energy producers
    - Solar (assumed to be most valuable)
    - Wind
    - Biomass
    - Qualified imports
    - Other technologies (MSW / LFG / Other)
- Threshold prices are assumed to be:
  - $0/MWh (energy) minus value of associated technology-based REC
  - Threshold price hierarchy is more important than its magnitude
    - Onshore and off-shore wind threshold prices assumed different to allow insights into spillage between these resources
- Magnitude of threshold price has no impact until the resource becomes “marginal”
- Negative $ -25/MWh “Trigger for Exports” provides observability

Bi-Directional Threshold Prices Reflect RECs and Make the Export Model Function

- The ***Bi-Directional Threshold Prices*** assumed to reflect the value of RECs: curtail imports first, then trigger exports, and only curtail renewables when export capability is exhausted.

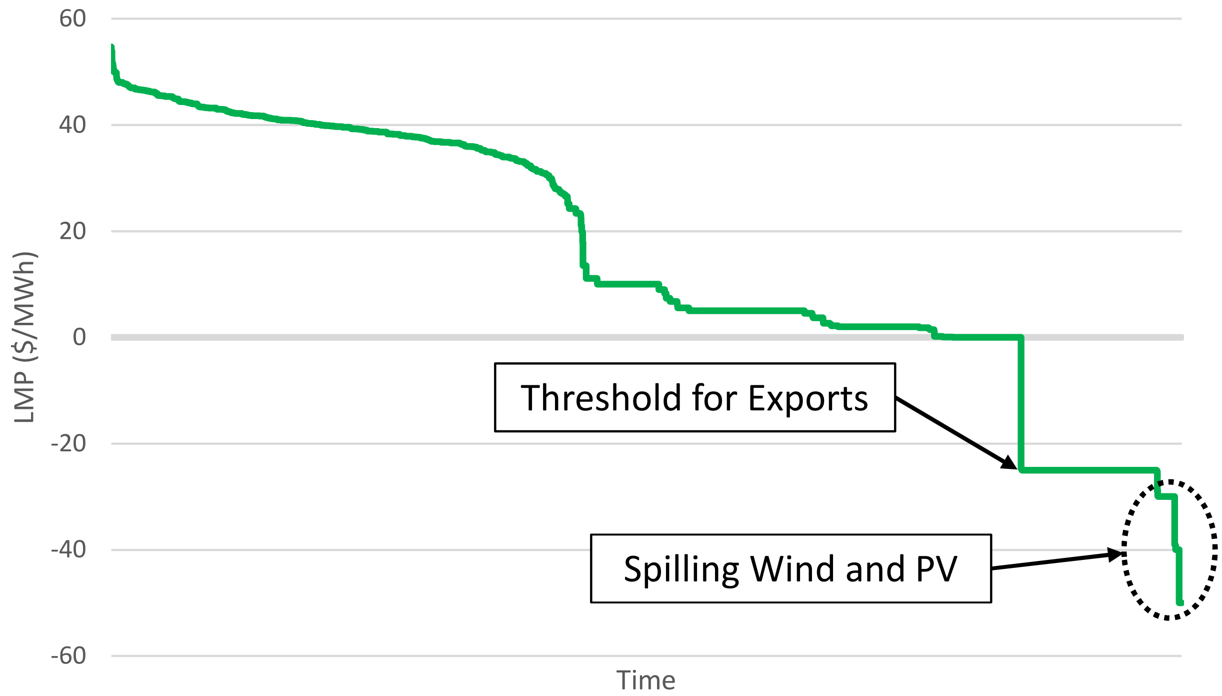
Price-Taking Resource	Threshold Price ($/MWh)
Behind-the-Meter PV	-100.00
Highgate	-99.00
FCM and Energy-only PV	-50.00
Offshore Wind	-40.00
Onshore Wind	-30.00
Trigger for Exports	-25.00
NECEC (1090 MW)	2.00
Imports from HQ on Ph. II	5.00
Imports from NB	10.00

- New England hydro is no longer modeled with a profile and therefore does not need a threshold price
- These threshold prices are used to facilitate the analysis of load levels where the amount of $0/MWh resources exceeds the system load
  - They are not indicative of "true" cost, expected bidding behavior or the preference for one type of resource over an other
  - Use of a different order for threshold prices than indicated will produce different outcomes, particularly spillage by resource

Negative Threshold Prices

- GridView is driven by a cost-minimization objective function
  - Threshold prices are not “costs”
  - Negative threshold prices may cause second-order effects
    - Energy storage is primarily driven by production cost minimization
    - Possible change in unit commitment
- Effect of negative threshold price magnitude on metrics
  - Mostly unaffected
    - Production cost
    - Emissions
    - Spillage
  - Affected
    - LMPs
    - LSE Energy Expense
    - Resource energy market revenues

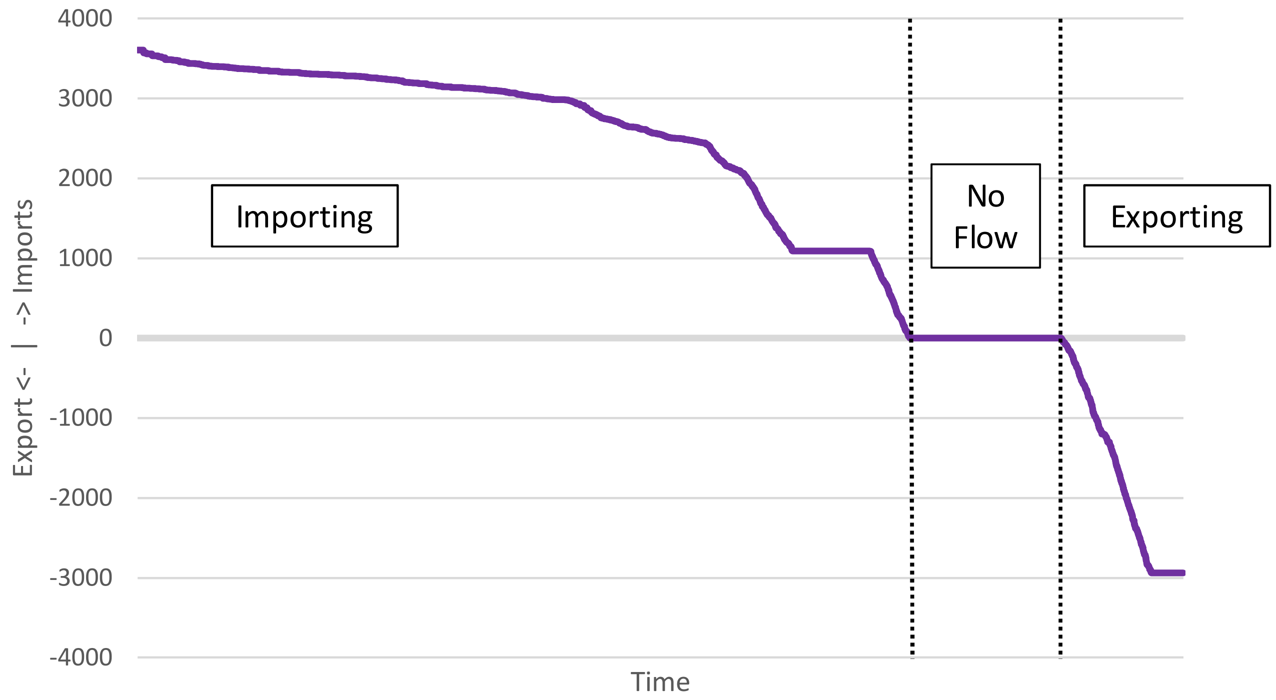
Conceptual LMPs with Negative Threshold Prices



- Example: Average LMP of $14.93/MWh and median LMP of $10/MWh
- Example: 7,022 hours of positive LMP, 153 hours of $0/MWh LMP, and 1,585 hours of negative LMP

Note: This example is for illustrative purposes only, results for the 2020 Economic Study will differ

Conceptual Imports and Exports with Negative Threshold Prices (MW)

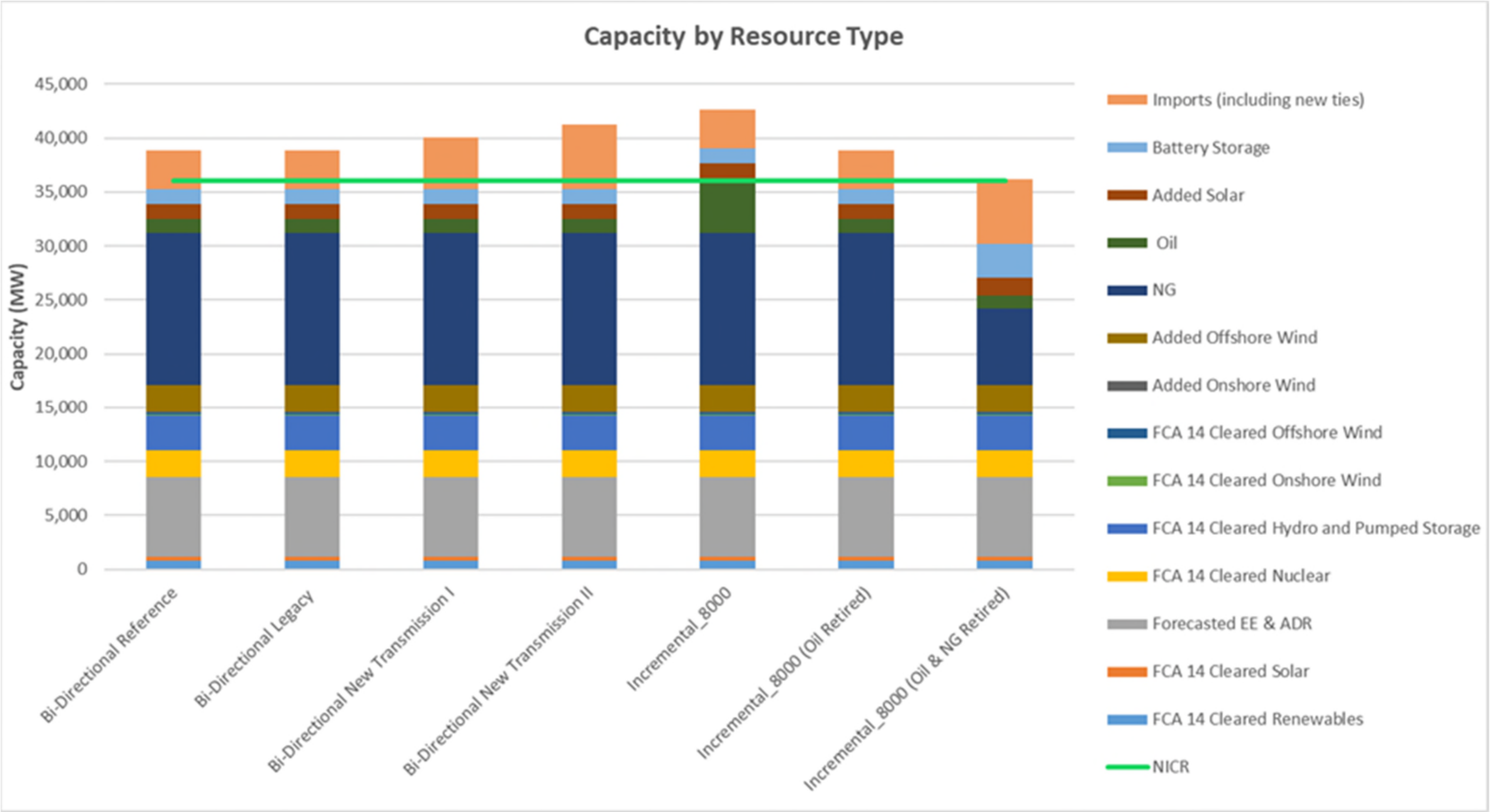


- Example: 17,057 GWh of imports and 1,802 GWh of exports
- Example: 6,471 hours importing, 1,266 hours exporting, and 1,023 hours of no exchange

Note: This example is for illustrative purposes only, results for the 2020 Economic Study will differ

RESOURCE MODELING ASSUMPTIONS

Capacity vs NICR for All Scenarios (MW)



- See the appendix for this data in tabular format.

Changes to Modeling of Select Resources

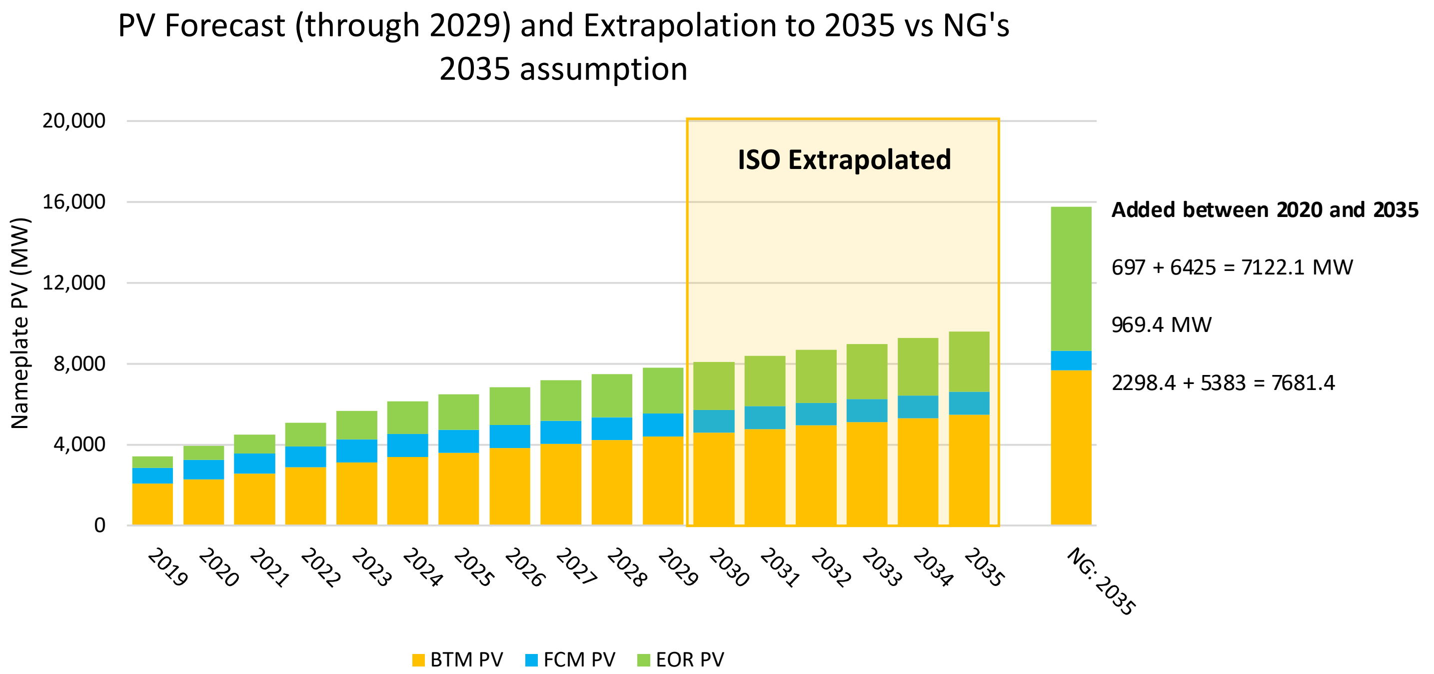
- Nuclear resources will continue to be must run
- Municipal Solid Waste (MSW), Landfill Gas (LFG), and Wood resources will be modeled as must run
  - Previously these units were modeled as dispatchable with a low price. However, these derive a large amount of their income outside of the ISO markets and do not appears sensitive to price changes in the ISO markets
  - This change will result in more spillage of profiled resources
- New England hydro resources now dispatched internally

Wind Resources

- All scenarios will include a 1,330 MW increase in onshore wind in service of meeting state renewable goals
  - Onshore wind will be distributed proportional to ISO-NE's queue requests for onshore wind
- The initial scenarios will use the NESCOE 8,000_1 deployment of offshore wind
  - Other wind levels may be evaluated and will be discussed at a future presentation on sensitivities

Interconnection Points (RSP Area)	Block Island (RI)	Montville (CT)	Kent County (RI)	Brayton Point (SEMA)	Barnstable (SEMA)	Mystic (Boston)	Total
Nameplate (MW)	29	800	1,000	1,600	2,400	2,200	**8,029**

PV Resources



- Provided by National Grid to meet state mandates
  - Additional sensitivities may be explored in future presentations

Behind the Meter Photovoltaic (BTM PV) Reductions in Peak Load and Energy

New England	2035
BTM PV - Nameplate (MW)	7,681
Energy Production (GWh)	8,579
Estimated Peak Load Reduction (MW)	1,774
Estimated % of Peak Load Reduction	23.1%

Utility Scale PV Reductions in Peak Load and Energy

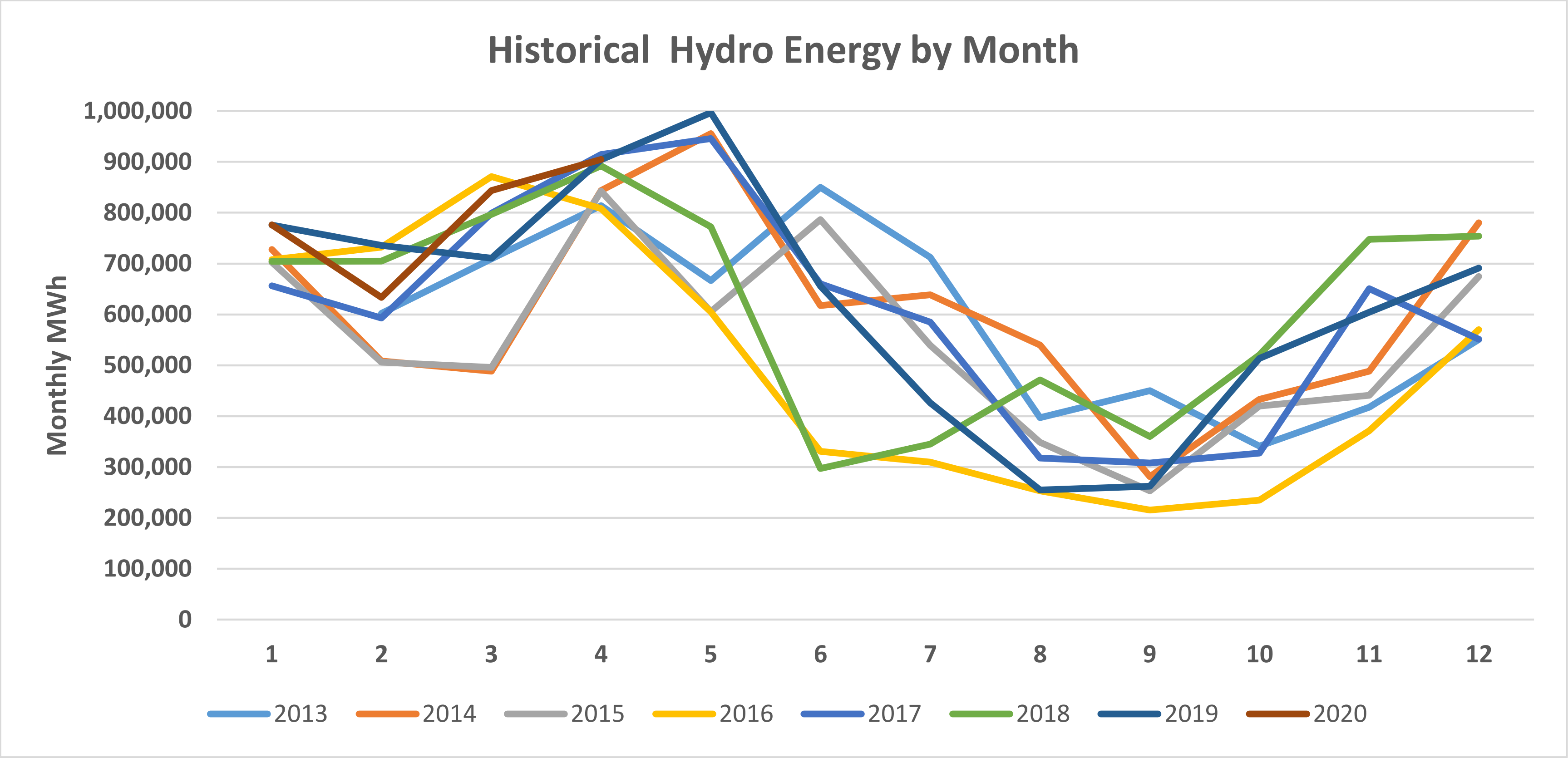
New England	2035
FCM PV - Nameplate (MW)	969
	7,122

- In-front-of-the-meter or utility scale PV includes FCM PV and energy-only PV

Revised Hydro Model: Internal GridView Model

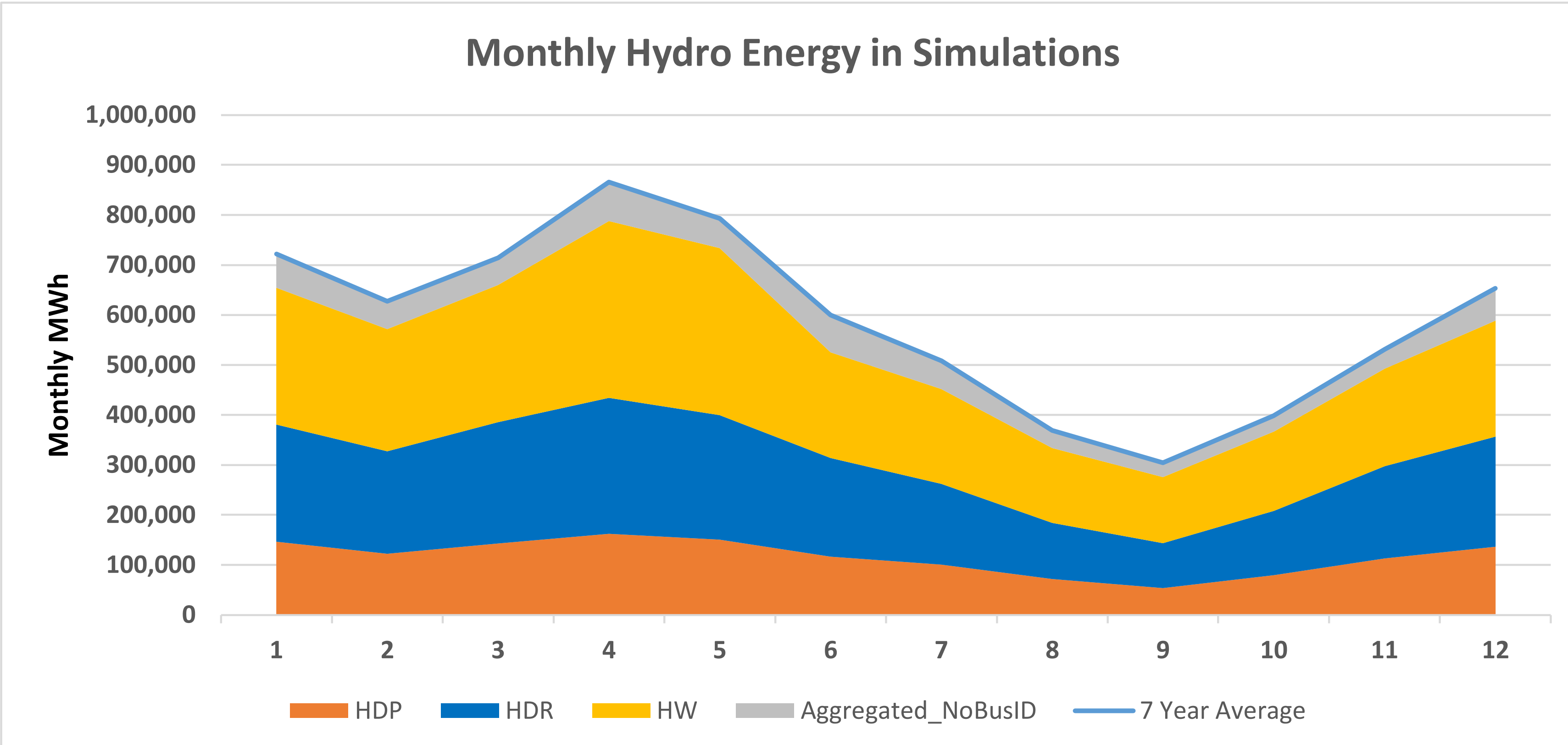
- GridView internal hydro simulation model to be used
  - Replaces manual method of creating an aggregate New England hydro generation model used in prior economic studies
    - Threshold pricing would no longer be necessary for New England hydro
  - More responsive to high penetrations of variable energy resources
- Hydro resource data developed based on asset level statistics
  - Seven years of historical generation (February 2013 - April 2020)
  - Monthly MWh (Average)
  - Operating Range
    - Average of asset minimum output by month
    - Average of asset maximum output by month
    - Unconstrained range between minimum and maximum allowed
  - Aggregated small hydro units
    - Many not assigned to a bus in the network model
    - Approximately 180 MW (~10% of the hydro capacity)
- Modeling Notes
  - Some hydro resources may be scheduled for reasons other than LMPs
  - Operating flexibility may be overstated

Historical Data Variability During 2013-2020



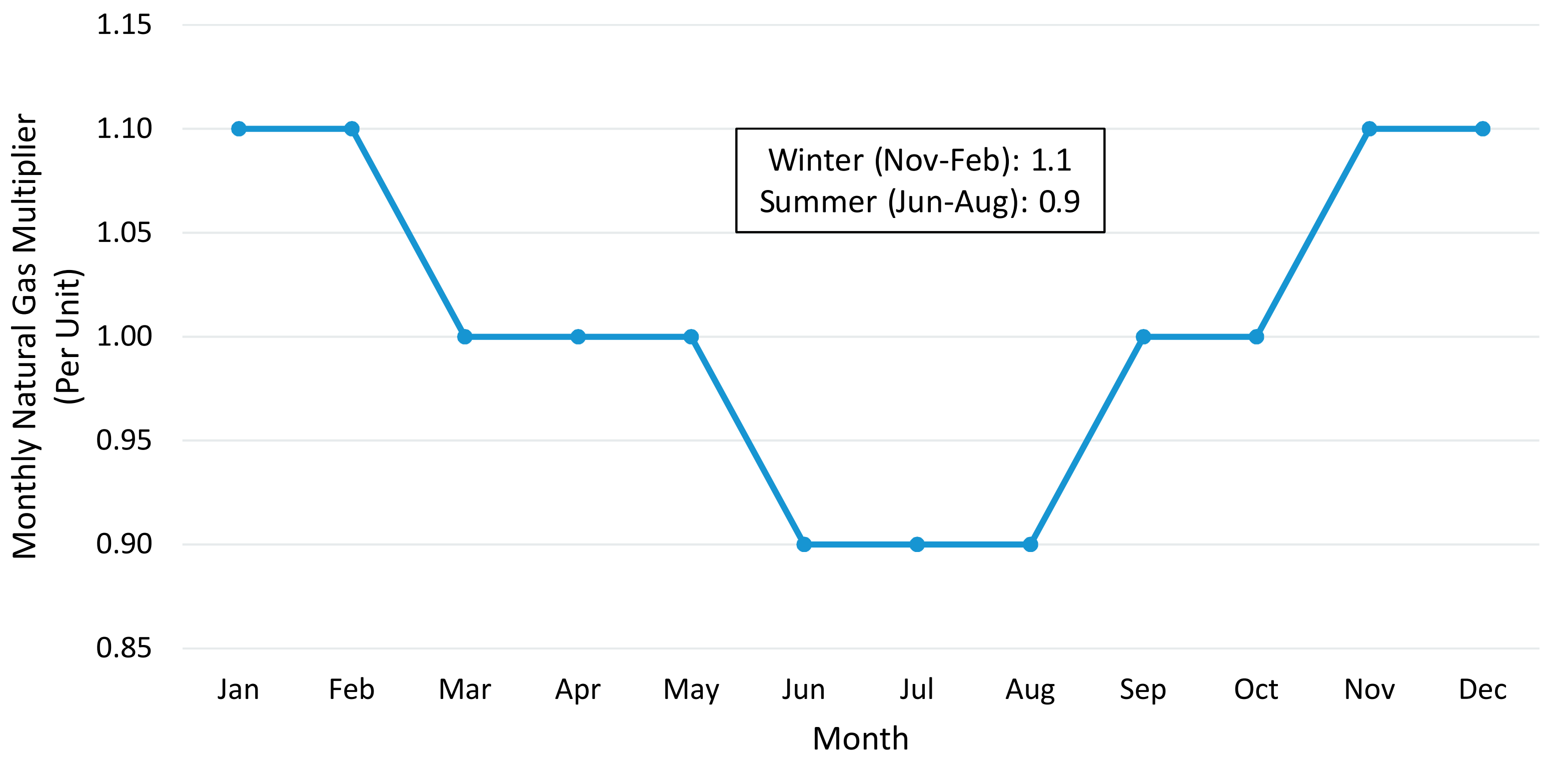
- Historical hydro energy is highly variable between years

Monthly Breakdown by Hydro Type



- About 40% of the energy is "Weekly Cycle" (HW) with the remainder (HDP, HDR and unassigned) treated as peak shaving
  - HDR – Daily cycle – Run of river
  - HDP – Daily Cycle – Pondage

Fuel Price Forecast: Per Unit Multiplier for Monthly Natural Gas Price Assumptions



ISO-NE will use the same seasonal multiplier as it has it recent Economic Studies. This multiplier shows that natural gas prices increase during heating season when there is competition for natural gas and decrease in the summer. While the demand for gas will change between now and a high-renewable grid in 2035, we assume this basic seasonal demand shift is reasonable.

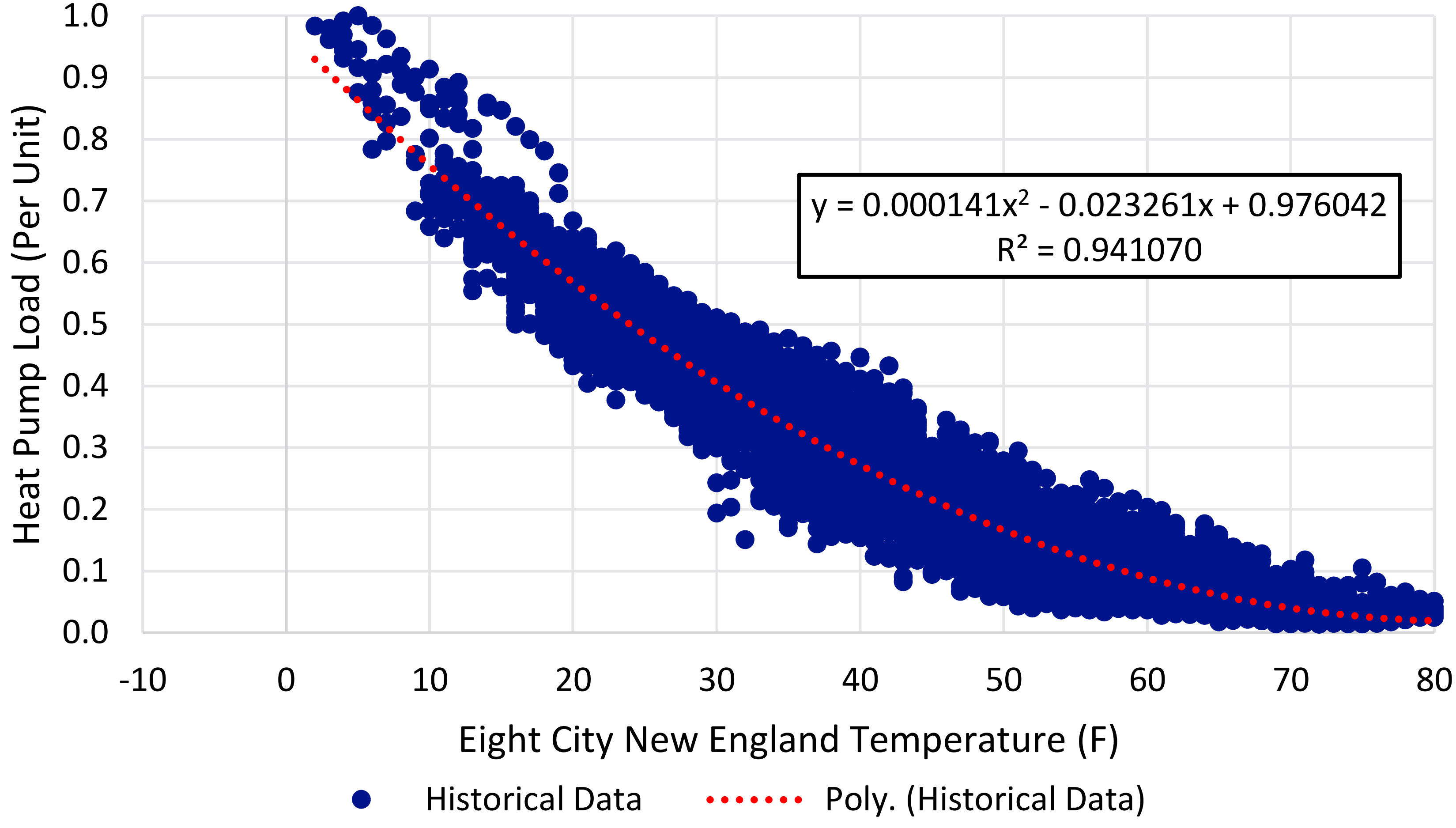
Modeling of Forced Outages of Resources

- In the 2020 economic study, we model forced outages of resources by derating their capacities to reflect the resources' Equivalent Forced Outage Rate demand (EFORd)
  - EFORd from the most recent five-year, 2016-2019, is used

Heat Pumps Will Be Included in All Scenarios

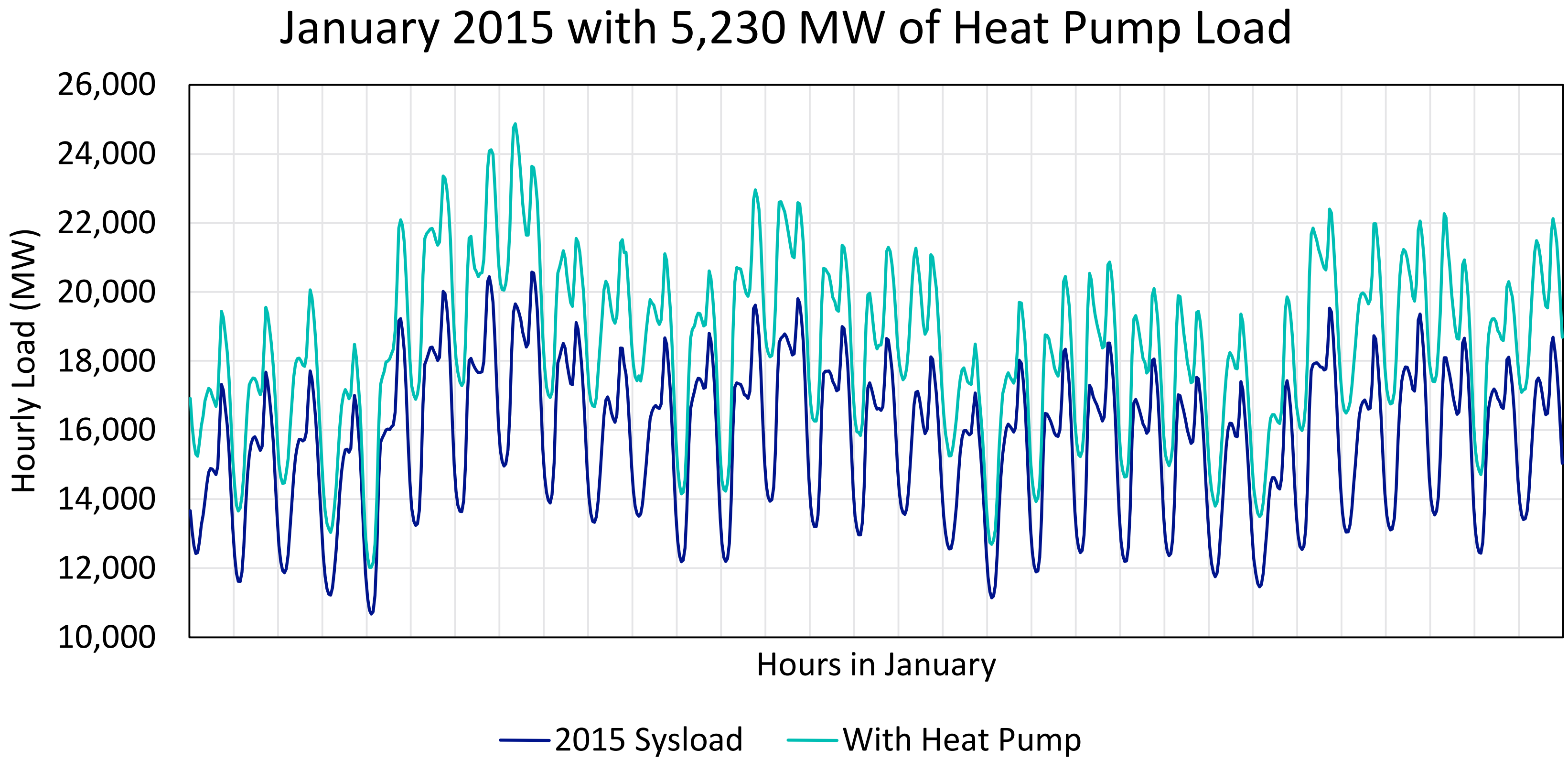
Load Zone	Nominal Annual Energy (GWh)	Effective Installed Heat Pumps (MW)
CT	2,308	1,297
ME	1,741	982
NH	907	505
NMABO	1,473	736
RI	712	408
SEMA	995	515
VT	443	252
WCMA	984	535
ISO-NE	**9,564**	**5,214**

Correlation of 2008 New England Temperatures and National Grid Heat Pump Demand



Note: At temperatures below -1 degree F, heat pump load continues to rise and exceeds the nominal MW value

Increase in Winter Loads Due to Heat Pumps
Winter Peak Becomes Comparable to Summer Peak



BATTERY ENERGY STORAGE SYSTEMS

Overview and Modeling in Gridview

Battery Energy Storage Systems

- Energy Storage is a central focus in the 2020 Economic Study
  - Pumped Storage
  - Battery Energy Storage Systems (BESS)
- BESS
  - Relatively novel technology for the electric Power Grid
  - Flexible BESS siting and operating characteristics provide incentive for use in the electric power sector
  - BESS can help facilitate the integration of renewable resources
    - Solar
    - Wind
  - Evolving costs and operating characteristics are a focus of research

BESS Opportunities

- Distinct opportunities exist for BESS
  - Co-located with variable energy resource behind an interconnection
    - May respond to LMP – subject to interconnection capability
    - Augments “Capacity” attribute of the co-located variable energy resource
    - Enhances regulation and reserve capability of the co-located variable energy resource
  - Co-located with customer load
    - Primary function is to manage energy interaction with an energy supplier
    - May respond to LMP if beneficial to customer
    - May decrease customer’s “capacity” cost (e.g., demand charge)
    - Providing regulation and reserves may be in conflict with customer’s cost management objective
- For the 2020 Economic Study, will use a Grid-focused approach where the BESS
    - Responds to LMP
    - Provides “System Capacity”
    - Provides regulation and reserves

Operating Characteristics

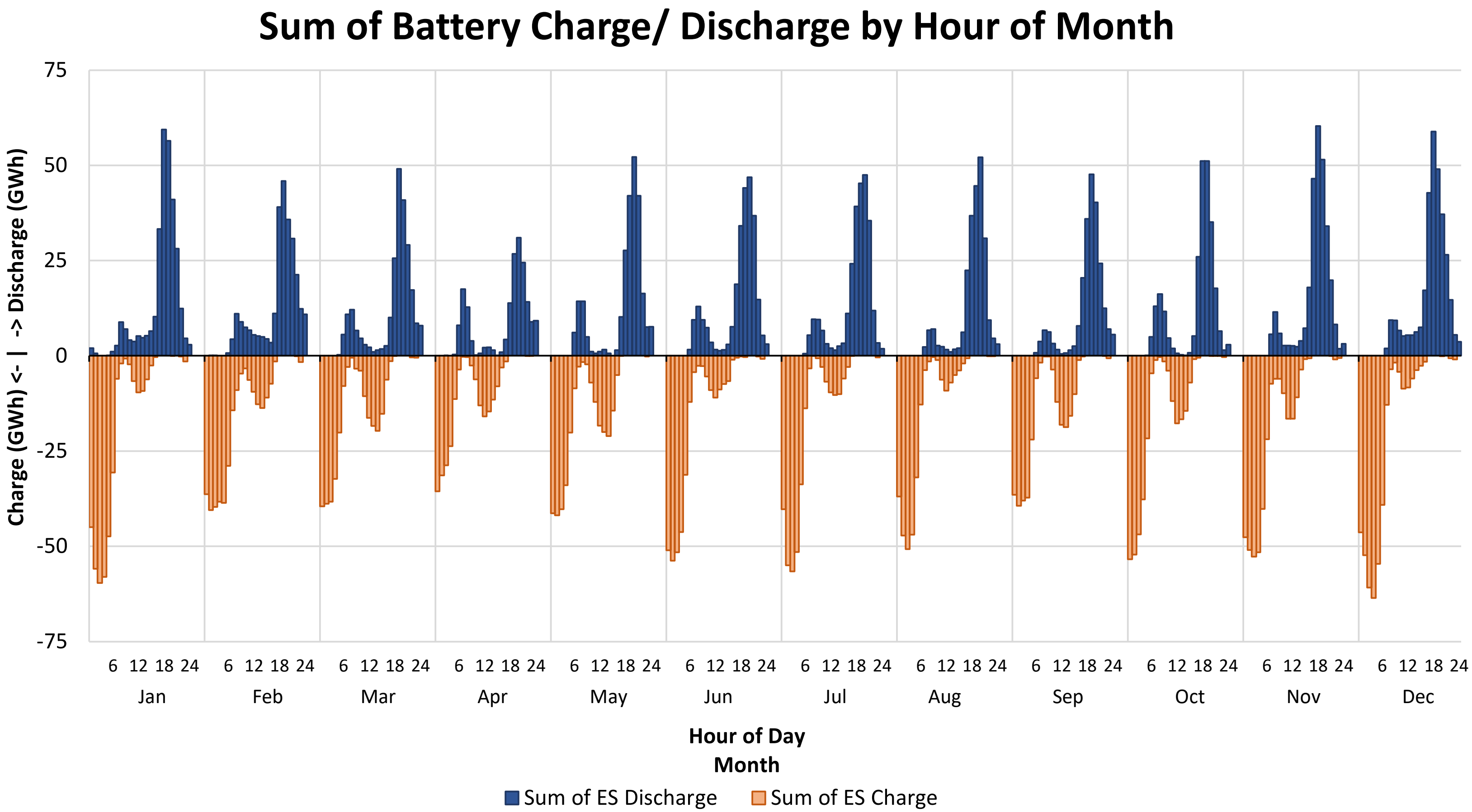
- Major operating characteristics
  - Round-trip efficiency of 86 percent to be modeled in the 2020 Economic Study
  - Number of lifetime charge / discharge cycles
    - Not addressed in the literature as a quantified constraint
    - Li-ion degradation affected by high and low states-of-charge, not cycles
    - Example: Tesla warrantee for Powerwall (2017 contract)
      - Unlimited cycling in household applications
      - Specific MWh throughput for other applications
    - Therefore, in the 2020 Economic Study, no specific number of charging/discharging states will be used
  - Variable O&M
    - Literature supports various allocations of O&M to variable production
    - NREL uses zero for the variable O&M component
    - Assumed that participants will bid-in to avoid unacceptable wear-and-tear
    - Thus, in the 2020 Economic Study, O&M costs will not be considered
- Capital cost and Fixed O&M
  - Not considered in ISO-NE Economic Studies

Simulating Battery Energy Storage Systems (BESS) in GridView for the 2020 Economic Study

- Grid-level batteries models are aggregates of:
  - Many battery facilities under many participants
  - Each facility may have multiple battery stacks that can be dispatched separately
  - Assumed that each participant will manage their facilities to minimize degradation
  - Aggregated by RSP Zone based on BESS in the ISO-NE queue
- Assumed Operations / Dispatch
  - Each facility will receive a day-ahead schedule
  - Each facility will endeavor to satisfy the awarded schedule
  - Each facility may elect, in real time, to respond to real time market signals
- Dispatch of a fleet of batteries is likely to behave smoothly
  - Owners of specific battery stacks may elect to operate differently
  - Dominate mode has primary discharge peak in the evening

BESS Charging/Discharging Characteristics

NESCOE_8000_1 Scenario from 2019 Economic Study



- For all months morning charging peaks and evening discharging peaks are observed

NEXT STEPS

Next Steps of the Economic Studies

- Third Quarter 2020
  - Present draft production simulations results
  - Identify sensitivity scenario(s) and assumptions
  - Present assumptions for ancillary services analysis
- 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

Metrics for 2020 Economic Study and BESS Associated Costs

Capacity vs NICR for All Scenarios (MW)

Scenario	Bi-Directional Reference (B)	Bi-Directional Legacy (B_HQNB)	Bi-Directional New Transmission I (B_HQNB_1T)	Bi-Directional New Transmission II (B_HQNB_2T)	Incremental_8000 (I)	Incremental_8000 with Oil Retirement (I_Oil)	Incremental_8000 Oil and NG Retirements (I_Oil_NG)
Year	2035	2035	2035	2035	2035	2035	2035
FCA 14 Cleared Renewables (biofuels, landfill gas, etc.)	779	779	779	779	779	779	779
FCA 14 Cleared Solar	402	402	402	402	402	402	402
Forecasted EE & Active Demand Resources without Real-time Emergency Generation (RTEG)	7,372	7,372	7,372	7,372	7,372	7,372	7,372
FCA 14 Cleared Nuclear (with retirement of Millstone 2&3)	2,474	2,474	2,474	2,474	2,474	2,474	2,474
FCA 14 Cleared Hydro and Pumped Storage	3,218	3,218	3,218	3,218	3,218	3,218	3,218
Imports(5)	3,518	3,518	4,781	5,981	3,581	3,581	5,981
FCA 14 Cleared Onshore Wind (CSO)	109	109	109	109	109	109	109
FCA 14 Cleared Offshore Wind (CSO)(6)	161	161	161	161	161	161	161
FCA 14 Cleared Gas (without Mystic 8 & 9)	14,116	14,116	14,116	14,116	14,116	14,116	7,058(d)
FCA 14 Cleared Oil (75% oil and dual fuel legacy units retired)	1,247	1,247	1,247	1,247	4,988	1,247	1,247
Coal Retired (CSO)	0	0	0	0	0	0	0
Total Capacity for Existing Resource After Retirements	33,458	33,458	34,658	35,858	37,199	33,458	28,801
Added Solar Capacity Value	1,393	1,393	1,393	1,393	1,393	1,393	1,593
Added Onshore Wind Capacity Value	120	120	120	120	120	120	120
Added Offshore Wind Capacity Value	2,498	2,498	2,498	2,498	2,498	2,498	2,498
Battery Storage	1,400	1,400	1,400	1,400	1,400	1,400	3,150
Total Capacity After Retirement Plus Addition	38,870	38,870	40,070	41,270	42,610	38,870	36,162
Net Installed Capacity Requirement(7)	36,094	36,094	36,094	36,094	36,094	36,094	36,094
Capacity vs. NICR (+ Excess; - Insufficiency)	**2,776**	**2,776**	**3,979**	**5,176**	**6,516**	**2,776**	**68**

Green = Capacity meets or exceeds NICR **Red** = Capacity does not meet NICR

(5) Import capacity includes New York Power Authority Imports under a long-term contract plus the average capacity supply obligations from New Brunswick, Highgate, and Phase II cleared in FCA 12, FCA 13, and FCA 14 plus new transmission
(6) FCA 14 cleared offshore wind includes Deepwater Block Island and Vineyard
(7) The NICR calculation was based on assuming 1,127% of the net 50/50 peak load and rounding to the nearest 100 MW
(8) Assumed retirement of half of the natural gas resources

GridView Production Simulation Metrics

- System-wide energy production by resource/fuel type
- System-wide production costs
- Locational Marginal Prices (average annual, monthly, on/off peak, etc.)
- Load-serving entity energy expense and uplift
- Congestion by interface (internal and external) and key lines of interest
- Native New England Resource CO_2 emissions, including marginal emissions
- Spillage
- Energy exports to neighboring systems
- Storage utilization

Disclaimer: All results use the 2015 weather year to create the shape of load, solar, and wind profiles (scaled to 2030 forecasted values). The results are specific to this weather year. If a different weather year is used for profile shapes the results will differ – the trends would be similar but specific numeric results will change.

EPECS Sub-hourly Simulation Metrics

- Load-Following/Ramping
- Regulation/AGC
- Operating Reserves
  - Ten-Minute Synchronized
  - Thirty-Minute Operating
- Curtailment Performance
- Interface and New York Synchronous AC Tie-Line Performance
- Additional metric(s) to be determined

NREL Allocated Battery Replacement / Renewal / Cycling Expense as Fixed O&M

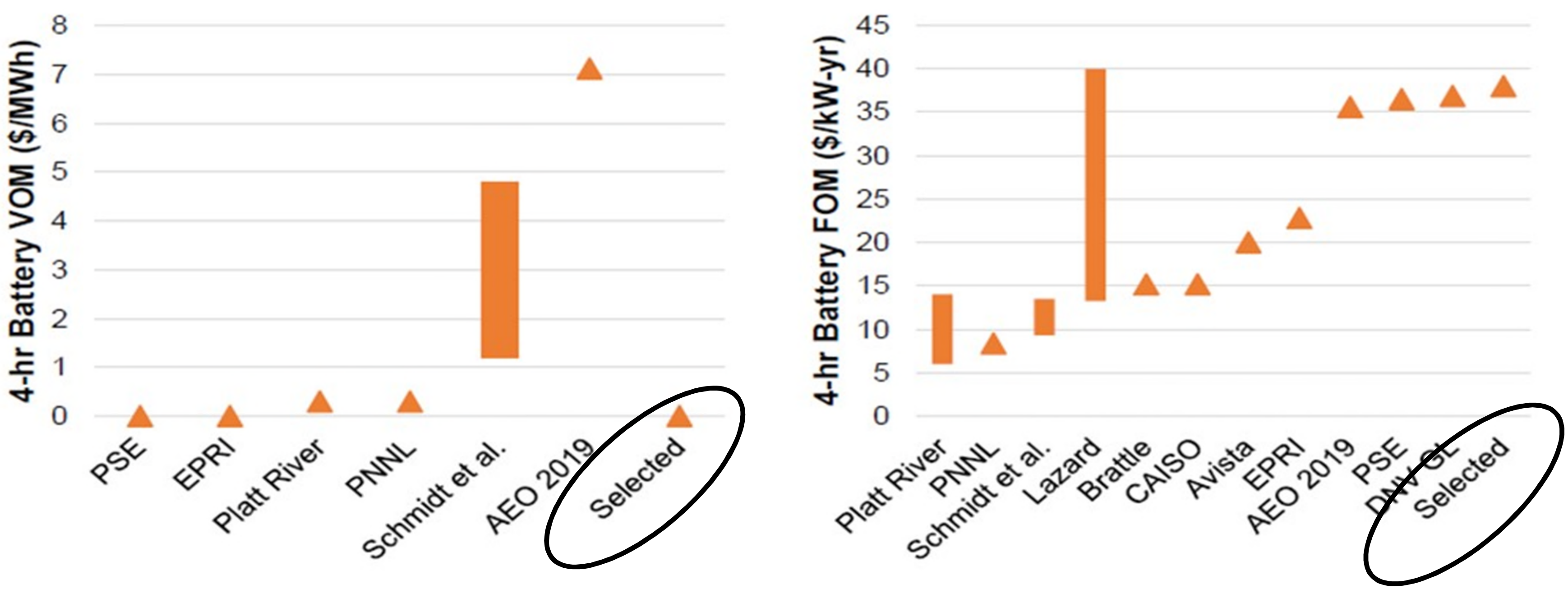


Figure 7. Variable O&M (top right) and fixed O&M (top left) from various published sources. The values selected for this study are the right-most values shown.

Source: *Cost Projections for Utility-Scale Battery Storage,* Wesley Cole and A. Will Frazier, June 2019, National Renewable Energy Laboratory, NREL/TP-6A20-73222, https://www.nrel.gov/docs/fy19osti/73222.pdf

APPENDIX II

Acronyms

Acronyms

- ACDR – Active Demand Capacity Resource
- ACP – Alternative Compliance Payments
- AGC – Automatic Generator Control
- BESS – Battery Energy Storage Systems
- 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
- EFORd – Equivalent Forced Outage Rate demand
- EIA – U.S. Energy Information Administration
- EPECS – Electric Power Enterprise Control System
- FCA – Forward Capacity Auction

Acronyms, cont.

- FCM – Forward Capacity Market
- FOM – Fixed Operation and Maintenance Costs
- HDR – Hydro Daily, Run of River
- HDP – Hydro Daily, Pondage
- HQ – Hydro-Québec
- HY – Hydro Weekly Cycle
- LFR – Load Following Reserve
- 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

Acronyms, cont.

- O&M – Operation and Maintenance
- PHEV – Plug-in Hybrid Electric Vehicle
- PHII – Phase II line between Radisson and Sandy Pond
- PV – Photovoltaic
- RECs – Renewable Energy Credits
- RFP – Request for Proposals
- RGGI – Regional Greenhouse Gas Initiative
- 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

Acronyms, cont.

- VOM – Variable Operation and Maintenance Costs