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Energy Security Improvements Impact Analysis

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Agenda

- Analysis of Non-Winter Months
- Enhancement of Fuel Input Assumptions
- Modeling of Energy Imbalance Requirement (EIR)
- New Scenarios
- Other Enhancements
- Appendix: Model Input Assumptions

Analysis of Non-Winter Months

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Analysis of ESI Impacts in Non-Winter Months

Evaluation of non-winter months independent of winter months

- Analysis will evaluate impacts during non-winter months in Cases that are separate from winter month Cases
  - Do not plan to aggregate winter and non-winter months into a single annual Case
  - Separate analysis of winter months will allow continued focus on the energy security outcomes that are of greatest concern during the winter months
  - Separate analysis of non-winter months will facilitate assessment of outcomes in winter months vis-à-vis outcomes in non-winter months, particularly with respect to economic impacts

Analysis of ESI Impacts in Non-Winter Months

Non-winter Cases

- Current plan is to evaluate two non-winter Cases for a future year, 2024/25:
  - "Severe" Case – based on 2018 (March through November)
  - "Moderate" Case – based on 2017 (March through November)
  - Future hourly loads estimated using same adjustments as were used for winter months
- Choice of historical years reflects several factors:
  - 2018 summer was one of the hottest on record by several metrics (cumulative CDD, days with temperature > 90º Fahrenheit)
  - Recent years better reflect load shape changes occurring over time due to increased energy efficiency and growth in behind-the-meter solar
- These Cases occur immediately before and after the Extended Severity Case, which was based on Winter 2017-18

Approach to Modeling Non-Winter Months

Non-winter Cases

- Market simulation consistent with approach used in winter months
  - Same solution logic used to clear DA and RT markets
  - ESI market design the same, with the same DA ancillary service products
- Resource assumptions consistent with winter analysis
  - Energy offers reflect the marginal cost of supplying energy
  - Certain resources modeled based on historical supply (e.g., hydro, pumped storage)
- Fuel usage
  - Fuel system limits and constraints will remain in place, including limits on NG supply and on-site fuel oil storage, although we expect these not to be binding during non-winter months

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Enhancement of Fuel Input Assumptions

Fuel Input Assumptions

Modeling of fuel supply accounts for storage and delivery limitations

- Today, we'll discuss two items:
  - A refresher on how we model natural gas and oil delivery and storage
  - Enhancements to the model's fuel inputs and logic that are being considered

- The model includes fuel supply delivery and storage systems, which limit the ability of resources to supply DA and RT energy
  - Natural gas (NG) pipeline system, including liquefied natural gas (LNG) storage
  - On-site storage of fuel oil

On-Site Stored Fuel Oil Inventory

Fuel inventory reflects initial inventory level and replenishment logic

- For resources reliant on on-site fuel oil, energy supply is limited by available fuel in inventory
  - Tank size varies by resource based on actual tank size data
  - Inventory changes daily based on consumption for generation and, potentially, replenishment
  - Fuel replenishment occurs based on algorithm reflecting multiple factors, including current inventory, tank size and means of refueling
- These limitations affect energy market outcomes
  - Supply from resources with limited energy inventory is limited to their inventoried energy
  - DA and RT offers reflect opportunity cost of using fuel given resource-specific inventory limitations

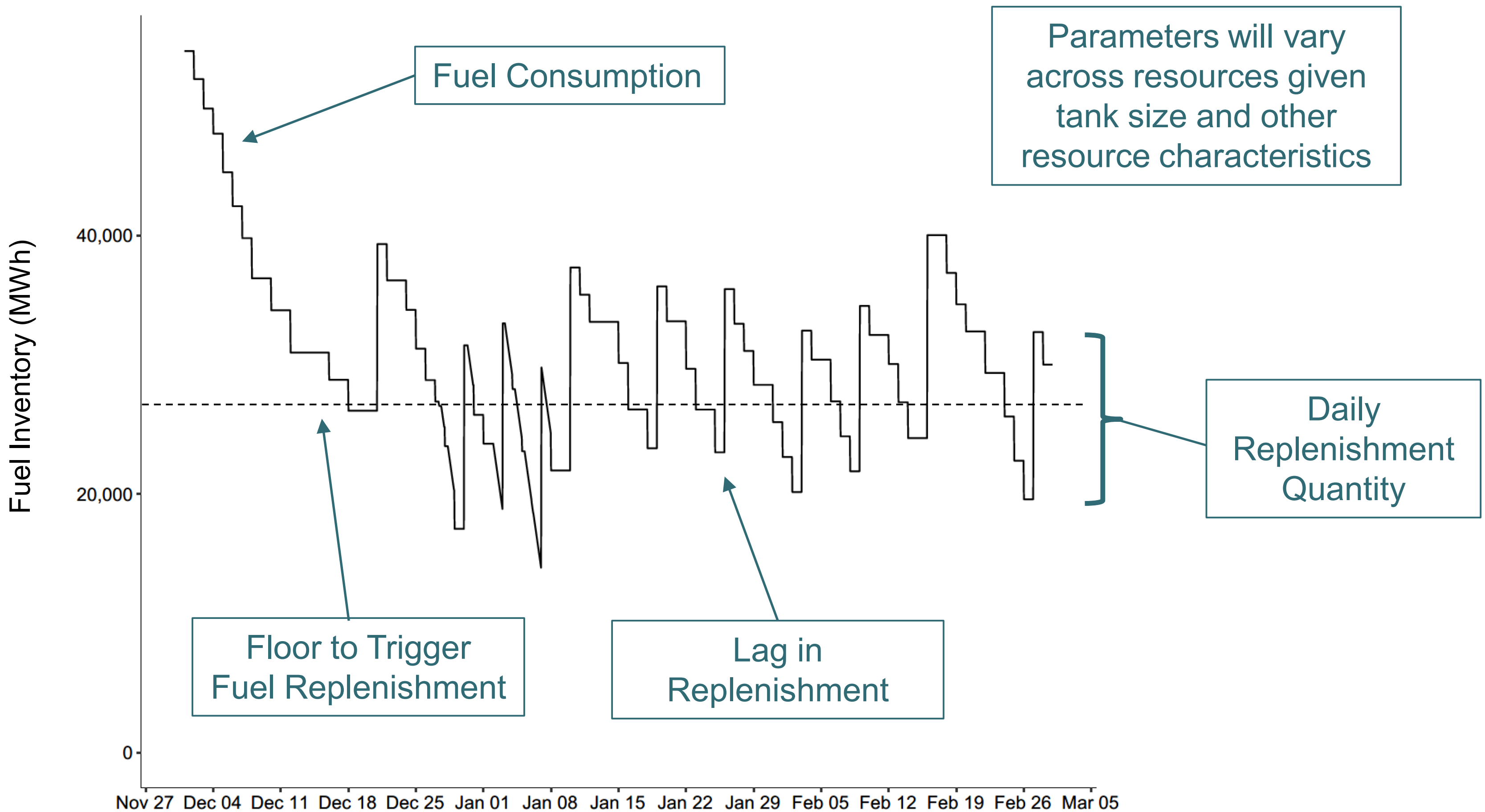
On-Site Stored Fuel Oil Inventory

Model of resource-level fuel inventory

- Model captures resource-level fuel inventory based on multiple parameters:
  - Initial (beginning of winter) inventory levels, with levels varying at the resource-level
    - With CMR, assumes initial inventory based on levels without Winter Fuel Program (2018/19)
    - With ESI, assumed initial inventory based on levels during Winter Fuel Program (2014/15 to 2017/18), generally higher than without Winter Fuel Program
    - ESI initial inventories are assumed to be at least as high as CMR initial inventories
  - Trigger level
    - Based on reasonable expectations that balance costs of refilling too frequently (given holding costs) and costs of refilling too infrequently (lost revenues)
  - Replenishment lag
    - 1 day for trucks and 4 days for barges
    - Replenishment continues until actual inventory exceeds the trigger level
  - Replenishment rate
    - Different replenishment rate for resources relying on trucks and barges (with uniform value for those relying on trucks and barges, respectively); 33% higher replenishment rate with ESI

Operational Constraints

Fuel Replenishment – Illustrative Resource-Level Examples



On-Site Stored Fuel Oil Inventory

On-going Work

- We are re-evaluating the model parameters and may revise Central Case assumptions – adjustments we are contemplating include:
  - Adjustments so that inventory decisions are consistent with profit-maximizing responses by market participants
    - Initial results suggest certain modifications to replenishment assumptions are appropriate; for example, in initial results, increased fuel inventory levels under ESI did not, on average, result in positive net revenues for resources with large tanks
    - Model inputs may be refined through a process of iteratively adjusting model parameters given intermediate results, with adjustments focusing on certain parameters that resources can more easily control (e.g., trigger levels and initial inventory)
  - Adjustments so that delivery better reflects varying market conditions
    - For example, increase fuel delivery lag during cold snaps to account for potential constraints in fuel delivery system during these periods

On-Site Stored Fuel Oil Inventory

On-going Work

- Sensitivity analyses are being contemplated regarding these fuel inventory and refueling parameter values
  - For example, test sensitivity of results to initial resource-specific inventory level – e.g., assume that initial inventory levels is set at the average of current ESI and CMR levels
- Sensitivity analyses are being contemplated regarding whether parameter values should be modified in certain scenarios to more fully reflect appropriate levels given incremental incentives provided by ESI, which may differ across scenarios

Enhancing Fuel Input Assumptions

Summary

- Re-evaluation of fuel parameters will allow the model to better represent potential market and reliability impacts associated with ESI
  - Refining model to align more closely with profit maximizing behavior will provide a better indication of the level of potential economic and energy security impacts, along with demonstrating the incentives for resources to take action to improve energy inventory
  - Refinements will also provide more information regarding how ESI would be expected to affect economic outcomes and energy inventory across different types of resources in the New England fleet
- Sensitivity analysis may provide additional information on the robustness of results to different assumptions regarding individual parameters

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Modeling of Energy Imbalance Requirement (EIR)

EIR

Current approach to the Energy Imbalance Reserves (EIR)

- The EIR ensures that there is sufficient energy available to meet the forecast energy level in each hour
- In the initial model, the EIR was set at a fixed, static value for each hour:

  EIR = max(0, forecast load – cleared DA energy)

  - The fixed EIR value was based on historical levels of the gap between the forecast load and cleared DA generation
- This methodology does not account for the interaction between the quantity of energy procured and the EIR quantity, with the ESI design:

  EIR = max(0, forecast load – cleared DA energy)

  - Additional DA energy reduces the quantity of EIR that needs to be procured to meet forecast load (so long as DA energy is less than forecast load)
  - By contrast, with other ESI products (RER and GCR) the quantity of service procured is generally independent of the quantity of energy procured

Interaction Between DA Energy and EIR

DA optimization accounts for substitution between energy and EIR

- The optimization accounts for the tradeoff posed by procuring additional energy given the interaction between DA energy and EIR
  - If day-ahead optimization clears 1 more MW energy, it will require 1 less MW EIR
  - To see the tradeoff, consider the impact of a 1 MW increase in demand (physical or virtual):

Cleared Energy Supply = Demand + 1 MW

➔ Energy quantity *increases* (by 1 MW) and cost (and price) *increases*

EIR = max(0, Forecast Load – (Cleared Energy Supply + 1 MW))

➔ EIR quantity *decreases* (by 1 MW) and cost (and price) *decreases*

- By accounting for this substitution, the ESI design may award more DA energy than under current market rules
  - Solution with higher DA energy may increase social surplus, reflecting optimal tradeoff between the energy and EIR quantities

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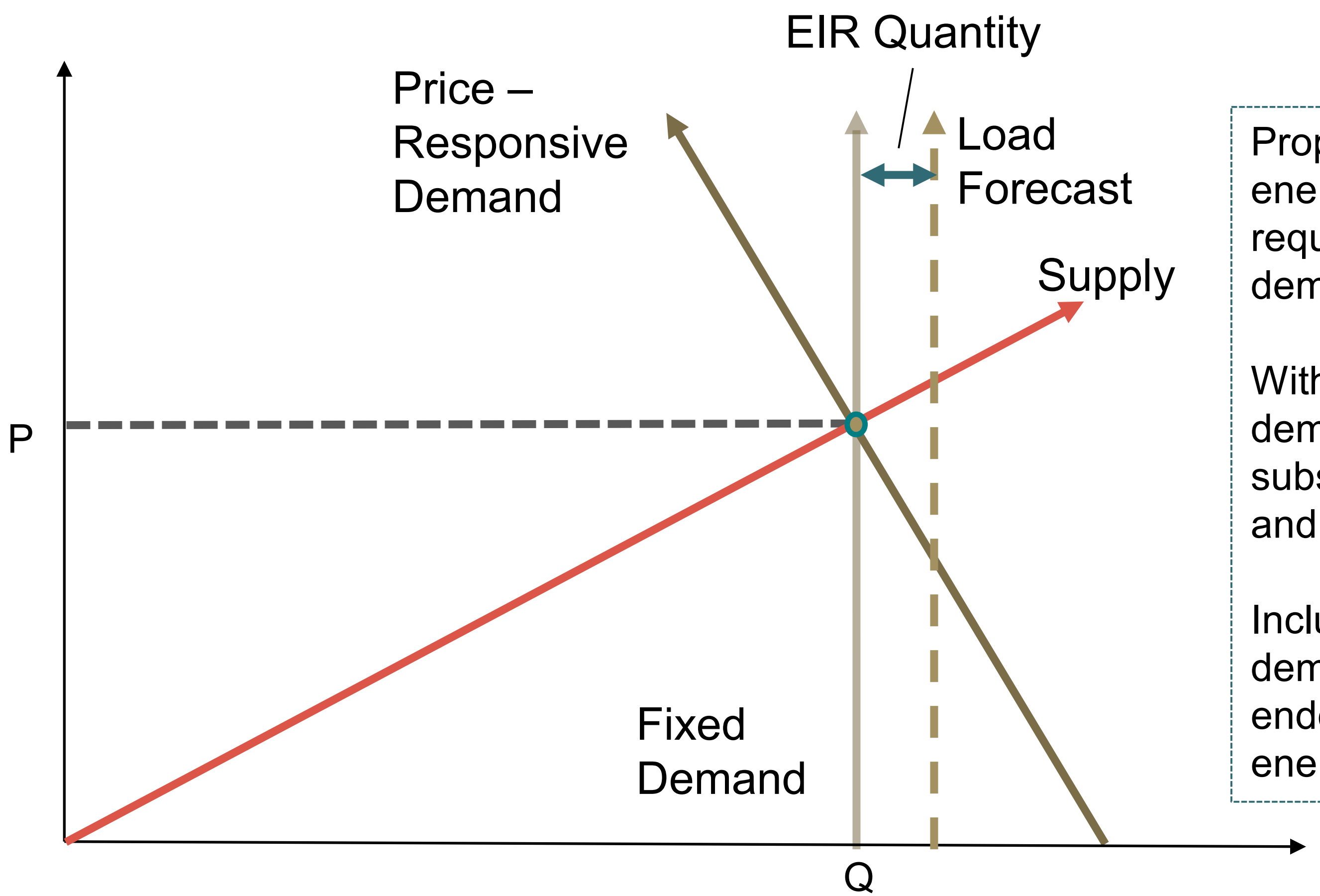
Price-Responsive Demand

Properly accounting for interactions requires price-responsive demand

Illustrative Fixed Demand



Properly accounting for DA energy and EIR interactions requires price-responsive demand

Without price-responsive demand, the model cannot substitute between energy and EIR

Including price-responsive demand allows the model to endogenously solve for energy and EIR quantities

Price-Responsive Demand

Approach to constructing price-responsive demand

- Model will include hourly demand offer curve based on historical physical and virtual offers
- Historical offer quantities will be scaled based on the 2025/2026 projections of load levels
  - Same approach as was used in initial analysis to scale fixed loads
- Historical offer prices will be adjusted to calibrate with modeled LMPs and economic factors (e.g., equilibrium between DA and RT prices)

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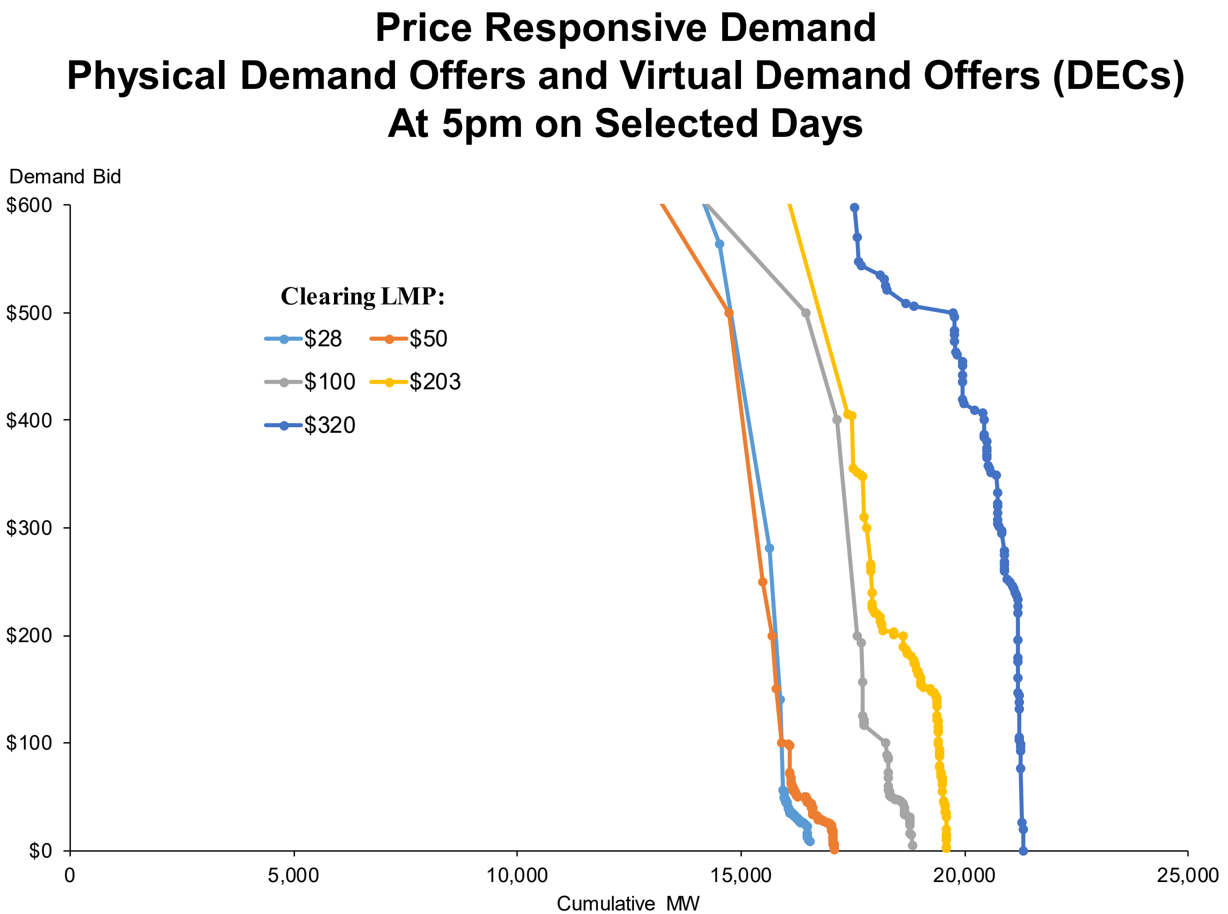
Price-Responsive Demand

Price-responsive demand varies by hour



Five different price responsive demand curves are shown for selected days

Price responsive demand is relatively inelastic – i.e., small changes in cleared energy quantity may be associated with large changes in price

The model will trade off the value of cleared energy (as reflected by demand offers) with value of EIR

Implications of Price-Responsive Demand

Implications of adding price-responsive demand

- With these adjustments, the analysis will better capture all substitutions in DA market-clearing under the new ESI design
- Estimates will better reflect impacts expected under the ESI proposal – all else equal:
  - Increases DA energy quantity, LMPs and total payments for DA energy
  - Reduces EIR quantity, prices, and total payments for EIR
  - Reduces total production costs (including DA option costs)

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New Scenarios

Scenario Analysis

Set of Scenarios evaluated will include additional scenarios

- Initial analysis included a set of 12 scenarios
  - August 2019 MC presentations summarize these scenarios (and initial results)
- Additional scenarios will be evaluated in response to stakeholder requests
- Our current thinking is to evaluate the following additional scenarios:
  - Nuclear retirements
  - Alternative DA energy option quantities, including scenarios excluding particular DA ancillary service products (while retaining others)
  - ESI case with no changes to fuel/energy inventory assumptions

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Scenario Analysis

NESCOE October 15, 2019 Letter

- NESCOE provided ISO-NE with a letter identifying “Extension Priorities”, including particular Scenarios NESCOE would like performed
- We believe that a number of Scenarios identified are addressed through Scenarios that have or will be performed – for example:
  - Quantity of ancillary services procured (see planned scenarios on prior slide)
  - Fuel oil inventory and refueling schedule (see earlier discussion of fuel input assumptions)
  - At-risk Resource Retirements.
    - At-risk resource retirements addressed by Oil Retirement Scenarios
    - Oil Retirement Scenario assumes an additional ~1,400 MW of oil-fired resource retirements, including “at-risk” resources identified by ISO-NE

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Scenario Analysis

NESCOE October 15, 2019 Letter (continued)

- ***Load forecast error and real time volatility.*** At present, we do not plan to undertake a separate Scenario to address these issues for several reasons:
  - The current Cases include load forecast error and RT volatility based on historical differences between forecast load and RT load – these Cases capture impacts associated with periods of high forecast error and RT volatility
  - We are evaluating Scenarios with 1- and 5-day supply disruptions (interruption of supply from Hydro Quebec)
    - These supply shocks create unexpected differences between DA expectation and RT dispatch that require additional inventoried energy, similar to the need for inventoried energy created by a load forecast error.
    - Thus, these scenarios allow us to evaluate how impacts from unexpected deviations between DA and RT differ under ESI and current market rules

Scenario Analysis

NESCOE October 15, 2019 Letter (continued)

- ***LNG Costs.*** Request related to impact of changes in global LNG prices
  - Given the model's assumptions, a change in the global LNG prices would not meaningfully change estimated outcomes in either the CMR or ESI runs
  - Potential impact on LNG supplies
    - In principle, global LNG prices can affect LNG terminal storage decisions (and eventual in-winter supply) given the resulting risk of forward-committing to LNG supplies (at potentially lower prices than in-season supplies)
    - But, the analysis assumes LNG terminal (Repsol) is able to supply at full sendout capacity with and without contract, independent of global LNG prices
  - Potential impact on forward LNG contract
    - Forward LNG contract prices are driven largely by the expected NG prices (and particularly volatility in NG prices), not LNG prices
    - Changes in forward LNG prices would only affect the returns and dispatch cost (SRMC) of gas-only capacity with the contract; but, forward LNG contract supply is limited to ~600 MW of capacity, thus limiting any broader impact

Other Enhancements

Changes in EIR Eligibility

Analysis will integrate new EIR eligibility requirements

- ISO-NE has proposed new eligibility requirements for the EIR to include:
  - Offline fast-start resources (with Claim10 and Claim30 capability)
  - Ramp capability from on-line resources
- Model will incorporate these eligibility constraints into the analysis
- Nature of the constraints is very similar to the modeling of GCR eligibility

DA Energy Option Offers

Potential enhancements being considered

- Potential enhancements to methodology for estimating DA energy options
  - More explicit accounting for operational/intertemporal limitations when calculating risk premium
  - Modifications to risk premium parameters
- Potential Scenarios
  - Introduce variation across offers to component of DA energy option offers reflecting expected closeout costs, which is currently equal across all offers
  - Adjustment to level of risk premiums (e.g., scale up all premiums)

Next Steps

Current plan for providing stakeholders with findings

- December
  - Preliminary results of Central Case with EIR enhancements and revised refueling assumptions
- January
  - Preliminary results of Cases for non-Winter Months
  - Preliminary results of Winter Scenarios
- February
  - Draft Report

Contact

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Energy Security Improvements Impact Analysis

Inputs and Assumptions

Analysis Group, Inc.

November 2019

Key Inputs and Assumptions

Input	Assumption
ESI Rules	Day-Ahead Energy Options: GCR10, GCR 30, EIR, and RER. GCR10: 1,600 MW GCR30: 2,400 MW RER: 1,200 MW No Multi-Day Ahead [Energy] Markets (MDAM).
Opportunity Cost	Opportunity cost modeled to account for energy opportunity costs of limited energy inventory in day-ahead and real-time.
Gas Assumptions	DOMAC retired both with and without ESI.
LNG Forward Contracts	610 MW of LNG Forward Contracts with ESI.
ESI DA Option Bids	Expected closeout costs and risk premium.
Resources	Resource mix based on FCA 13 with retirements based on de-list bids by FCA 14.
Load	Load levels based on 2025/2026 projections.
Natural Gas Prices	Historical Algonquin Winter Spot Prices. Prices based on historical years: Frequent Stressed Conditions - 2013/2014; Extended Stressed Conditions - 2017/2018; Infrequent Stressed Conditions - 2016/2017.
Fuel Oil Prices[1]	December 2021 Forwards prices from NYMEX and CME Group, S&P Global Market Intelligence: DFO - $81.27/bbl or $14.07/MMBtu; RFO - $60.58/bbl or $9.64/MMBtu; Jet Fuel - $82.29/bbl or $14.51/MMBtu.
Coal Prices	Energy Intelligence Agency, Table 55.5. Coal price: $22.95/ton.
Emissions Prices	RGGI CO_2 - Based on most recent Auction: $5.27/ton. Massachusetts CO_2 - Based on most recent Auction as reported by Potomac Economics: $8.77/ton. Acid Rain Program as reported by S&P Global Market Intelligence: $0.32/lb, annual allowance.

Note:
[1] Barrels are converted to million Btu per barrel at the following heat content conversion factors, 5.67 for jet fuel, 5.778 for residual fuel oil (RFO), and 6.287 for distillate fuel oil (DFO).

Source:
[1] U.S. Energy Information Administration, *Annual Energy Outlook 2016* , https://www.eia.gov/outlooks/aeo/pdf/appg.pdf.

Future Resource Mix Scenarios
Nameplate Capacity (MW)

	Current Market Rules	ESI
Natural Gas Fired Resources		
Natural Gas with Oil Dual Fuel	8,320	8,320
Natural Gas Only	8,582	7,989
Natural Gas with LNG Forward Contract	0	593
Natural Gas Fuel Cell	27	27
Oil Only	6,601	6,601
Coal	549	549
Nuclear	3,472	3,472
Hydroelectric Resources		
Hydro: Pondage	1,241	1,241
Hydro: Run-of-River	749	749
Pumped Storage	1,778	1,778
Wind Resource		
Land Based Wind	1,401	1,401
Offshore Wind	832	832
Solar	1,671	1,671
Biomass/Refuse	830	830
Battery Storage	458	458
Price Responsive DR	167	167
Total	**36,677**	**36,677**

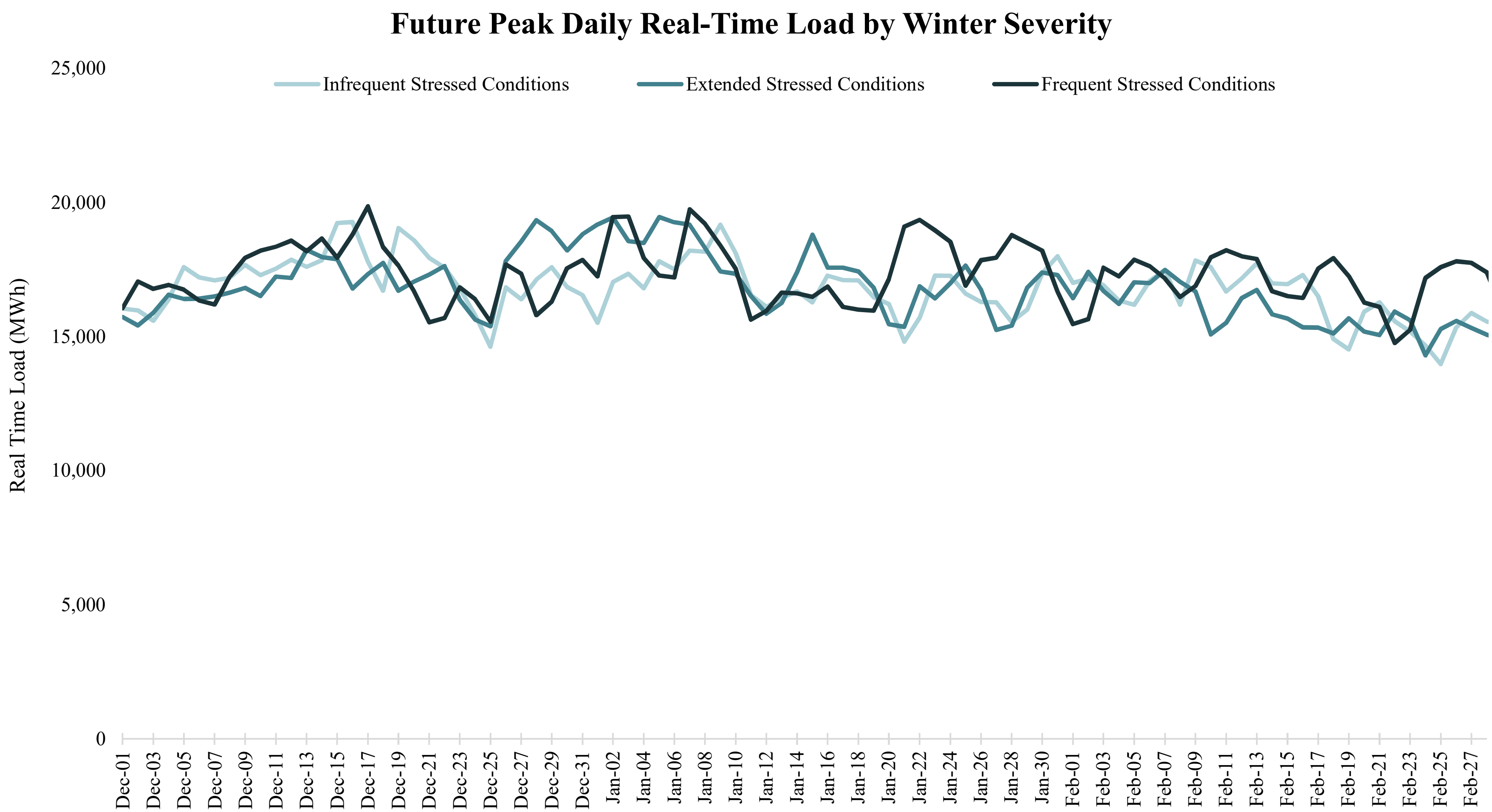
Notes:
[1] Capacity based on FCA 13 results and the 2019 CELT Report.
[2] Retirement assumptions shown on next page.

Assumed Retirements

Resource	Summer Capacity (MW)	Winter Capacity (MW)
Gas Combined Cycle	1,413	1,700
Nuclear Steam	677	683
Gas/Oil Steam	575	560
Coal Steam	383	385
Gas/Oil Combined Cycle	54	57
Oil Combustion (Gas) Turbine	30	41
Bio/Refuse	11	16
Hydro (Daily Cycle - Run Of River)	4	10
Oil Internal Combustion	8	8
Hydro (Weekly Cycle)	2	2
Total	**3,158**	**3,464**

Note:
[1]Assumed retirements include Mystic 8 and 9, as well as resources that have announced retirements through FCA 14 Retirement notifications.

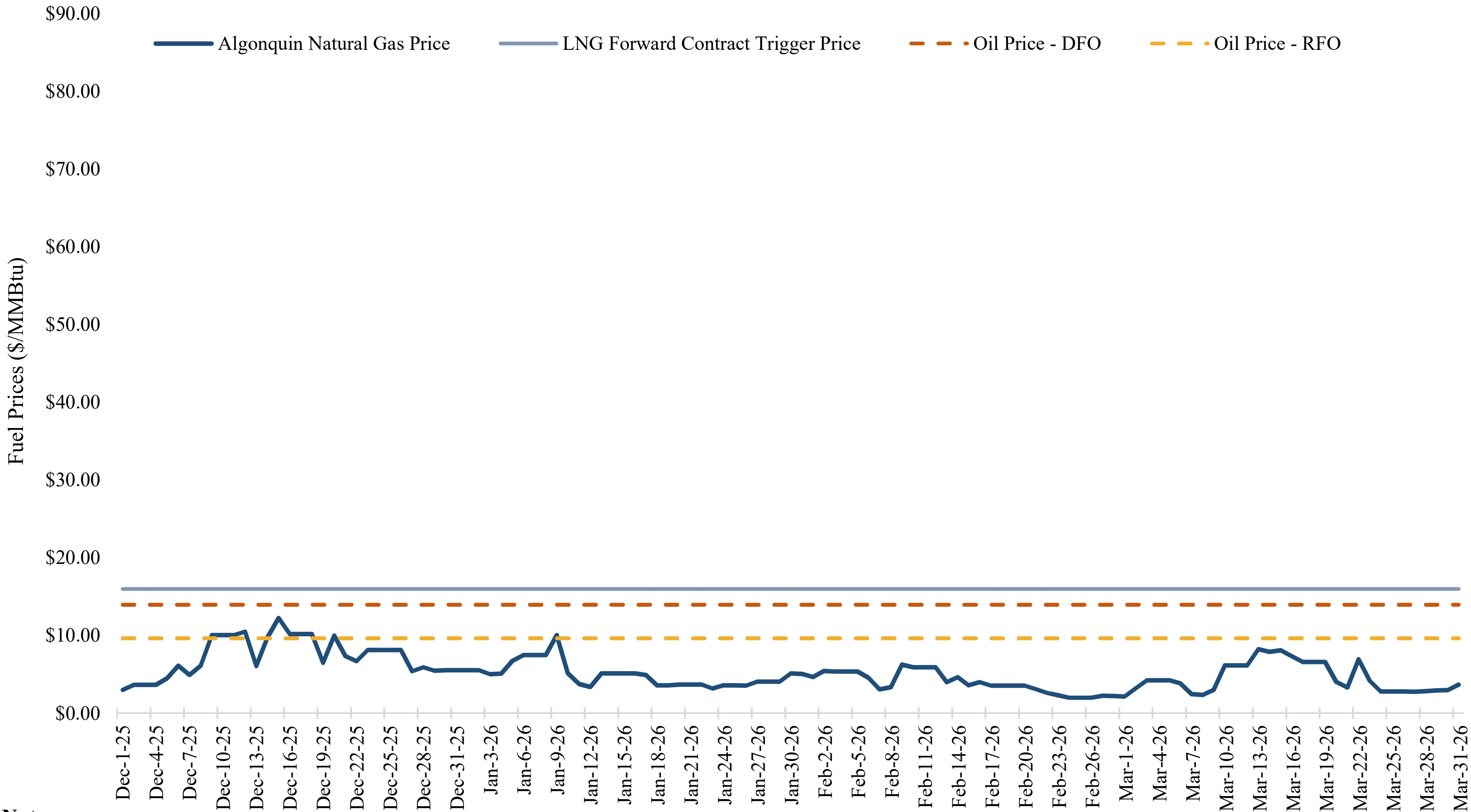
Source:
[1] ISO New England, Status of Non-Price Retirement Requests, Retirement De-List Bids and Substation Auctions, March 14, 2019.



Total and Peak Load by Winter Severity

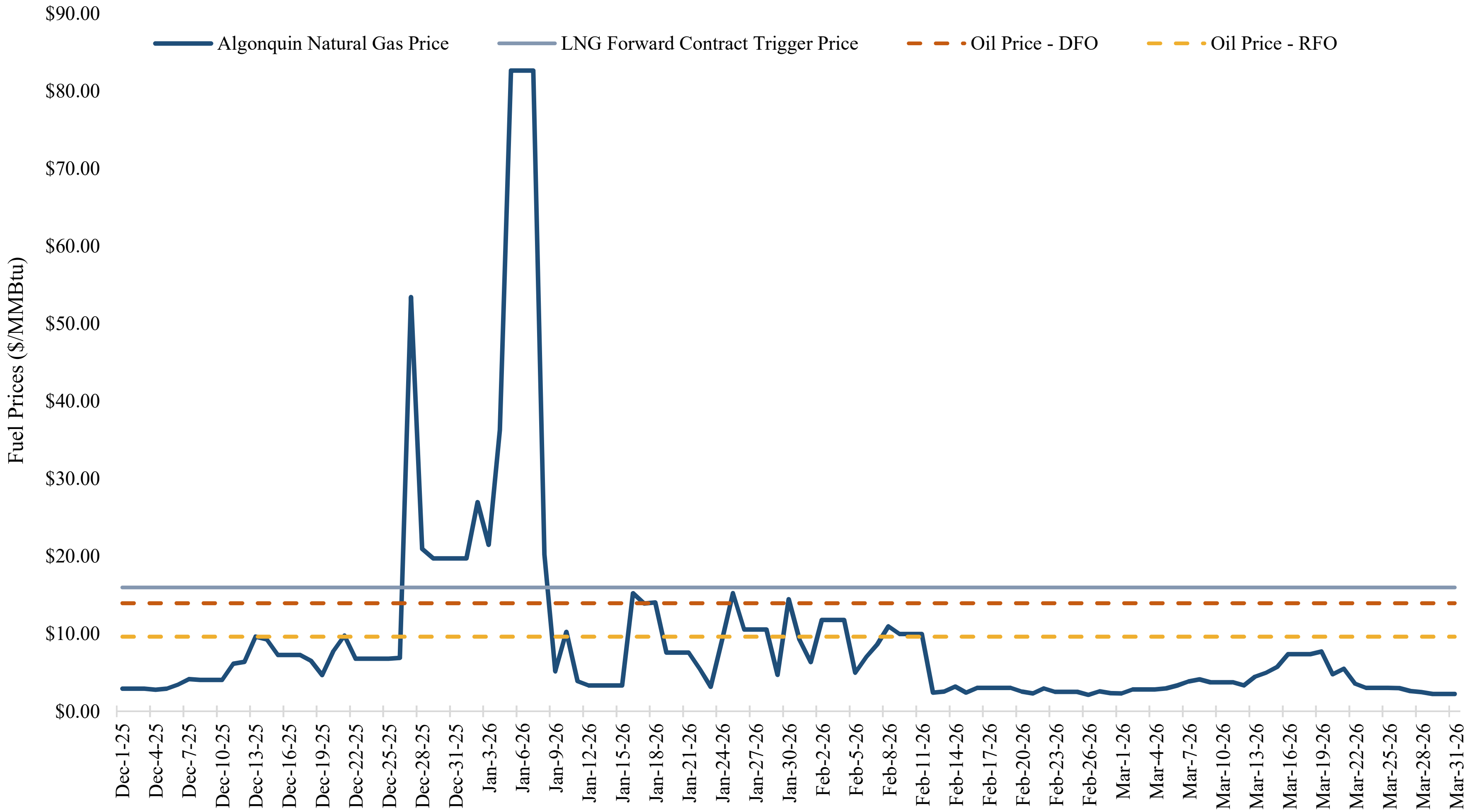
Winter Severity	Total Energy Load (MWh)	Peak Load (MW)
Infrequent Stressed Conditions	30,977,946	19,250
Extended Stressed Conditions	31,784,873	19,436
Frequent Stressed Conditions	31,843,510	19,837

Future Infrequent Stressed Conditions Fuel Prices ($/MMBtu)



Notes:
[1] The Algonquin Natural Gas Price series is based on 2016/17 prices.
[2] The LNG Forward Contract Trigger Price is $16/MMBtu, which indicates a resource would exercise the LNG Forward Contract whenever the price of Natural Gas rises above $16/MMBtu. The modeled LNG contract is a forward contract with 10 calls, where one call is reserved to supply DA energy options. The commodity charge under an LNG Forward Contracts is $10/MMBtu.
[3] The DFO - Oil price is $13.97/MMBtu ($81.27/BBL), based on December 2021 Futures.
[4] The RFO - Oil price is $9.64/MMBtu ($60.58/BBL), based on December 2021 Futures.

Future Extended Stressed Conditions Fuel Prices ($/MMBtu)



Notes:
[1] The Algonquin Natural Gas Price series is based on 2017/18 prices.
[2] The LNG Forward Contract Trigger Price is $16/MMBtu, which indicates a resource would exercise the LNG Forward Contract whenever the price of Natural Gas rises above $16/MMBtu. The modeled LNG contract is a forward contract with 10 calls, where one call is reserved to supply DA energy options. The commodity charge under an LNG Forward Contracts is $10/MMbtu.
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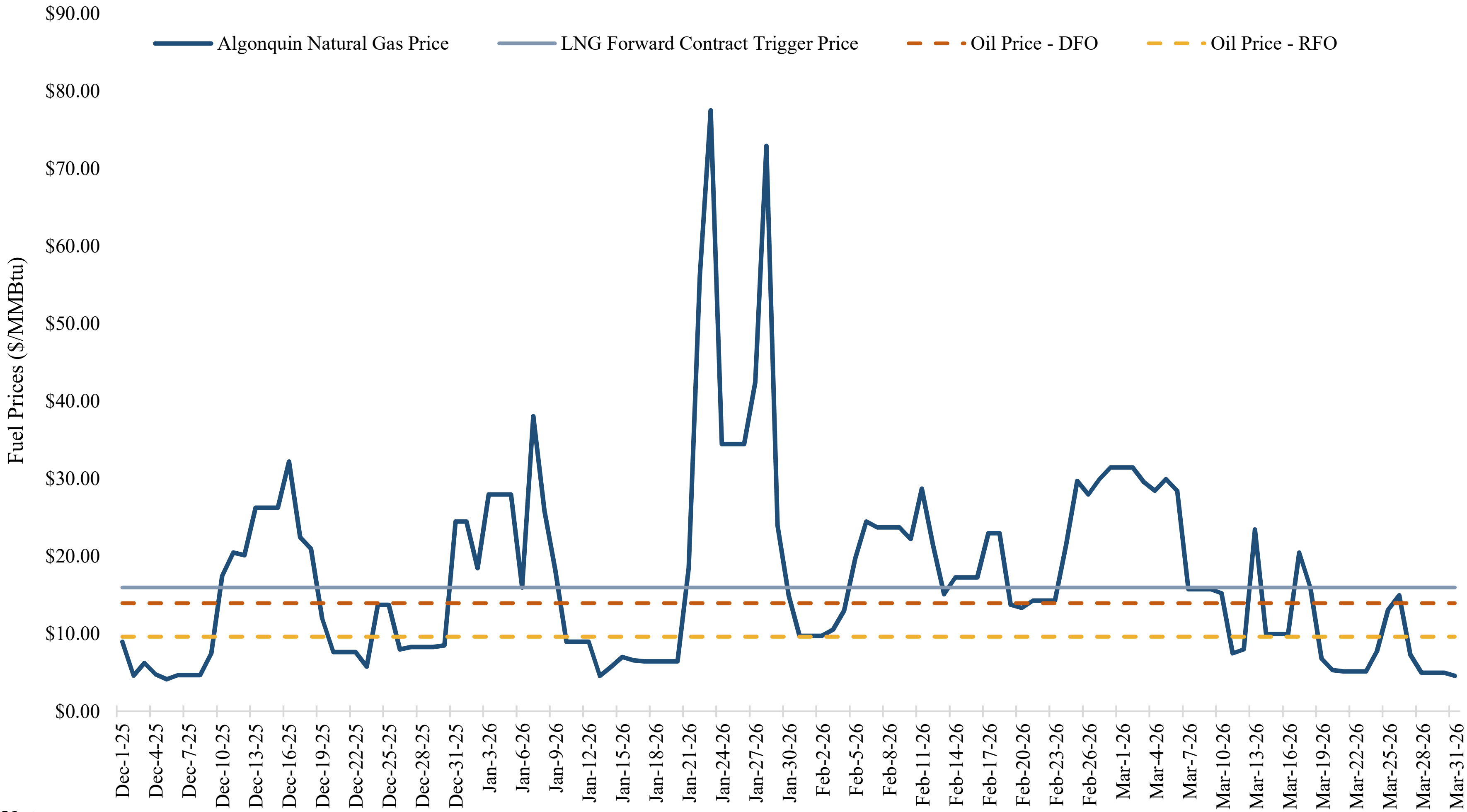
Future Frequent Stressed Conditions Fuel Prices ($/MMBtu)



Notes:
[1] The Algonquin Natural Gas Price series is based on 2013/14 prices.
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Quantity Available for LNG Forward Contracting

Step 1: Calculation of Unmet LDC Design Day Demand

			Source
LDC Design Day Temperature (EDD)	[A]	75	Assumption
Pipeline Import Capacity (Bcf/day)	[B]	3.59	FCA 14 presentation
LDC Demand on Design Day (Bcf/day, ISO Model)	[C]	5.76	ISO NE model
Satellite LNG Injection Quantity on Design Day (Bcf/day, ISO Model)	[D]	1.46	ISO NE model, capped at 1.456 Bcf/day
LDC Design Day Demand to be met by LNG (Bcf/day)	[E]=[C]-[B]-[D]	**0.71**	

Step 2: Calculation of Available LNG Terminal Deliverable Capacity

			Source
Canaport LNG Terminal Capacity (Bcf/day)	[F]	1.20	OFSA
M&N Pipeline Capacity (Bcf/day)	[G]	0.833	OFSA
Canaport Deliverable Capacity (Bcf/day)	[H]= Min([F],[G])	0.833	OFSA
Total LNG Capacity without DOMAC (Bcf/day)	[I]=[H]	**0.833**	Calculation

Step 3: Calculation of LNG Terminal Deliverable Capacity Available to Electricty Sector

Total LNG Capacity Available for LNG Forward Contracting without DOMAC (Bcf/day)	[J]=[I]-[E]	**0.12**
Total LNG Capacity Available for LNG Forward Contracting without DOMAC (MMBtu/hr)	[K] = [J] converted	**5,313**

Sources:

[1] ISO-NE, LDC Gas Demand model, "2018_ICF_LDC_gas_demand.xlsx."
[2] ISO-NE, "Operation Fuel-Security Analysis," January 17, 2018.
[3] Discussion with ISO-NE, July 10, 2019.

Fuel Oil Starting Storage

	CMR	ESI
Total December Starting Storage (MWh)[1]	2,058,307	2,696,225
Stored Energy at Winter Start (Days)	**Share of Generating Units**	
(0-5]	69.8%	70.5%
(5-10]	12.4%	11.6%
(10+)	17.8%	17.8%
Total	**100%**	**100%**

Note:
[1] Starting storage for each fuel oil plant is the average of December starting storage from 2014-2017 for ESI and December 2018 for CMR using data collected from ISO New England.

Active Demand Response

Step	Capacity (MW)	Marginal Costs ($/MWh)
1	11.0	100
2	9.7	300
3	246.5	1,000

Notes:

[1] Active Demand Response (DR) is modeled in three steps. The Quantity and Marginal Costs of DR are based on ISO-NE analysis of active DR participation since the implementation of Price Responsive Demand (PRD), effective 6/1/2018.

[2] Marginal Costs are used in modeling both Energy and Day-Ahead Ancillary Services offers.

Import Assumptions

Interface	Import Quantity
Roseton	502.8 MW at LMP>$0
	Add'l 286.5 MW at LMP>$20
	Add'l 153.7 MW at LMP>$40
	Add'l 89.2 MW at LMP>$60
Northport	0 MW net non-price-responsive
Shoreham/Salisbury	453.6 MW non-price-responsive
Hydro Quebec (Highgate)	211.2 MW non-price responsive
Hydro Quebec (P1/2)	1,363.9 MW non-price-responsive

Note:
[1] Import quantity and prices are based on analysis of historical import averages in relation to hub prices over time.