JANUARY 24, 2018 | WESTBOROUGH, MA

Operational Fuel-Security Analysis

Discussion with Stakeholders

OPERATIONAL FUEL-SECURITY ANALYSIS:

Identification of fuel-security risks for multiple scenarios

- Study conducted to improve the ISO’s and the region’s understanding of operational risks and inform subsequent discussions with stakeholders
- The Operational Fuel-Security Analysis studied 23 possible resource combinations and outage scenarios during the 2024/2025 winter to illustrate a wide range of possible future power system conditions
  - Scenarios and results are not precise predictions of the future system or outcomes
  - Illustrates a range of potential operational risks that could confront a power system with fuel and energy constraints, during an entire winter

Operational Fuel-Security Analysis Differs from Previous Studies

- Unlike the ISO's previous studies on fuel challenges, this study:
  - Quantifies *operational* risk by measuring energy shortfalls and system stress
  - Focuses on the availability of energy over an entire winter period rather than capacity availability on just peak days
  - Does not directly consider fuel costs or prices
  - Does not examine impacts of expanded natural gas pipeline capacity on a winter peak day
- As with all projections, the hypothetical resource combinations described may never materialize
  - Further, power system conditions vary on a daily and hourly basis and may not behave exactly as predicted in study models

BACKDROP FOR STUDY

The Changing Grid

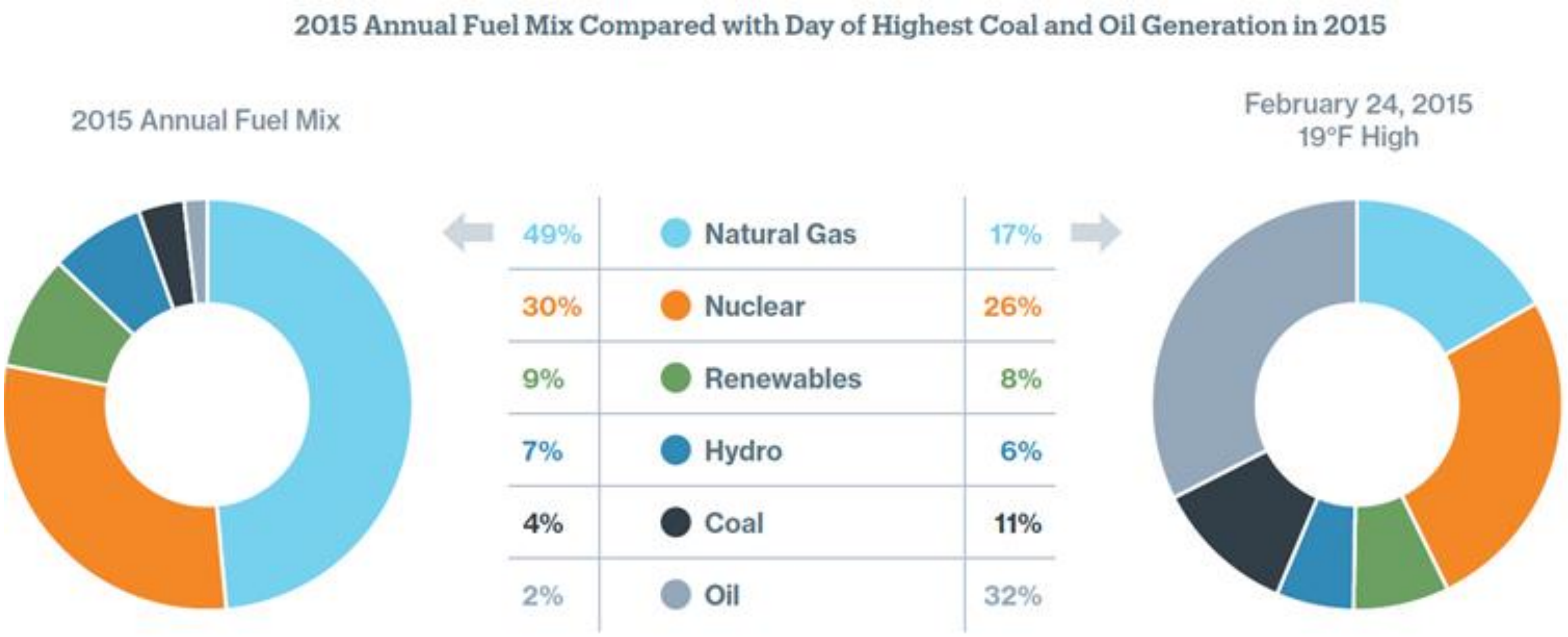
- Increased reliance on natural-gas-fired generation
  - Natural gas usage for heating, generation, and other purposes is growing
  - In 2016, 49% of the electricity generated in New England was produced by natural-gas-fired generation, with only 3% from oil- and coal-fired generation
    - However, oil- and coal-fired generation make up nearly 30% of the region’s generating capacity
- Retirements of coal, oil, and nuclear power plants
  - Despite low annual output, the coal- and oil-fired generators are needed during cold days when gas-fired generation has difficulty getting enough natural gas delivered
  - Nuclear plants represent about 13% of the generating fleet but produced 31% of the region’s electricity in 2016
    - Pilgrim will retire by 2019, removing about 680 MW of baseload power

The Changing Grid (Cont.)

- Growth of renewable resources and Energy Efficiency
  - Wind and solar resources are growing
  - Onshore wind has grown from 375 MW in 2011 to more than 1,200 MW today
  - Behind-the-meter photovoltaic (PV) has grown from 250 MW in 2012 to 1,900 MW in 2016 and is forecast to be 4,400 MW by 2024
  - By winter 2024/2025, Energy Efficiency is forecast to reduce winter peak demand, from what it would be otherwise, by about 3,900 MW



Generation Mix Changes on Cold Days



2015 Annual Fuel Mix Compared with Day of Highest Coal and Oil Generation in 2015

49%	● Natural Gas	17%
30%	● Nuclear	26%
9%	● Renewables	8%
7%	● Hydro	6%
4%	● Coal	11%
2%	● Oil	32%

Source: ISO New England, 2000-2015 Net Energy and Peak Load by Source and Daily Generation by Fuel Type 2015

Outline of Presentation

- Today's presentation is divided into four parts:

  1. Overview of the *Operational Fuel-Security Analysis*
  2. Key assumptions
  3. Summaries of the inputs and results of selected cases
  4. Key findings

- Additional information can be found in:
  - The *Operational Fuel-Security Analysis* posted for today's meeting
  - Modeled case results found in Appendix A to this presentation

- Report contains no solutions
  - Regional discussions of possible solutions to occur later in 2018

OVERVIEW OF THE OPERATIONAL FUEL-SECURITY ANALYSIS

Demand and System Stress Measurements

- Winter 2024/2025 demand was based upon Winter 2014/2015 as representative of load during sustained cold weather conditions
  - Winter 2014/2015 hourly demand levels were adjusted to account for Energy Efficiency and behind-the-meter PV in the 2024/2025 load forecast
- System stress was measured by several operational metrics including:
  - OP-4 actions
  - Depletion of ten-minute reserves
  - Load shedding

Key Fuel Variables

The study modeled a wide range of resource combinations that might be possible by winter 2024/2025 considering five key fuel variables:

1. Retirements of coal- and oil-fired generators
   - The study assumes that New England will have no coal-fired plants in winter 2024/2025
2. Imports of electricity over transmission lines from New York and Canada
3. Oil tank inventories (i.e., how often on-site oil tanks at dual-fuel power plants are filled throughout the winter)
4. Level of liquefied natural gas (LNG) injections into the region’s natural gas delivery and storage infrastructure
5. Level of renewable resources on the system

Description of the 23 Scenarios in the Study

- One reference case incorporates likely levels of each variable if the power system continues to evolve on its current path
- Eight scenarios increase or decrease the level of just one of the five key variables to assess its relative impact
- Two boundary cases illustrate what would happen if either *all favorable* or *all unfavorable* levels of variables were realized simultaneously
  - These highly unlikely scenarios are included to provide outer bounds on the scenarios studied and are summarized only in Appendix A of this presentation
- Four combination scenarios combine the five key variables at varying levels to represent potential future resource portfolios
- Eight outage scenarios illustrate the results of winter-long outages of four major energy or fuel sources

Six Major Conclusions

The study results suggest six major conclusions:

1. Outages: The region is vulnerable to the season-long outage of any of several major energy facilities
2. Key dependencies: Reliability is heavily dependent on LNG and electricity imports; more dual-fuel capability is also a key reliability factor
3. Logistics: Timely availability of fuel is critical, highlighting the importance of fuel-delivery logistics
4. Risk: All but four of 23 scenarios result in load shedding, indicating a trend towards increased fuel-security risk
5. Renewables: More renewables can help lessen fuel-security risk, but are likely to drive oil-and coal-fired generator retirements which, in turn, require more LNG
6. Positive Outcomes: Higher levels of LNG, imports, and renewables can minimize system stress and maintain reliability; delivery assurances and transmission expansion would be needed

KEY FUEL SECURITY ASSUMPTIONS

Key Fuel Security Assumptions

This section will summarize the assumptions used in the report for Winter 2024/2025:

- Fuel-security risk modeling
- Electricity demand
- Natural gas supply
- Natural gas demand
- Renewables
- Imports

Key Fuel Security Assumptions (cont.)

- Study assumed **no coal-fired generation** on the system, and **no additional natural gas pipeline capacity*** would be added, in the study timeframe
- Study focused on interplay of **five key variables**:
  1. Retirements of all coal-fired and some oil-fired generators
  2. LNG availability
  3. Oil tank inventories – i.e., how often on-site fuel tanks were filled at dual-fuel generators
  4. Electricity imports
  5. Addition of renewable resources

*Beyond incremental expansions already underway

Key Fuel Security Assumptions – Risk Modeling

Each scenario's future fuel-security risk is modeled by:

- Calculating the amount of electricity required to meet demand each hour of a 90-day winter (12/1/2024 through 2/28/2025)
- Calculating how much electric energy could be generated by each fuel type
- Calculating how much natural gas would be available, after all heating demand is met, as well as the levels of oil stored on site at oil-fired and dual-fuel power plants
- Comparing the amount of fuel required with the level of fuel the region's fuel-delivery system could supply in each scenario
- Assessing the magnitude and duration of emergency actions required if the fuels available were not sufficient to meet demand

Key Fuel Security Assumptions – Risk Modeling: Dispatch Order

- The model was based on winter conditions when oil and gas supplies are expected to be tight
- Demand is met by dispatching non-oil-fired and non-natural-gas-fired resources first
    - Resources in this category include:
        - On-shore and off-shore wind
        - PV
        - Other renewables (biomass, refuse, landfill gas)
        - Nuclear
        - Hydro, including pumped storage
        - Imports
- Next in the dispatch order were natural-gas-fired generators
- If more demand needed to be served, dual-fueled generators with stored oil and then oil-only generators were dispatched

Key Fuel Security Assumptions – Electricity Demand: Winters 2014/2015 and 2024/2025

- Consumer demand in Winter 2014/2015 serves as a baseline because:
  - Winter 2014/2015 had sustained cold, as measured by heating-degree days, (four winters in the past 38 years were colder) but did not have the coldest days recorded in the last 10 years
  - This level of sustained cold has a probability of occurring about once every eight years
  - It provides a wider perspective on cumulative use of oil and LNG inventories over an entire winter

- While actual power grid conditions could change earlier or later, the study used Winter 2024/2025 for several reasons:
  - By winter 2024-2025, the outlook for power system reliability is uncertain
  - More retirements of the remaining oil, coal, and nuclear power plants are expected
  - Gives the region time to identify and address challenges by 2024, but no buffer to defer decisions about the region’s fuel-security risks

Key Fuel Security Assumptions – Natural Gas Supplies: Pipeline

- Based on ICF's study, ***Forecast of Near-Term Natural Gas Infrastructure Projects***, the ISO's analysis assumes the region's gas supply infrastructure will expand only incrementally by 2024
  - Includes only a recently completed pipeline expansion and three smaller expansions that are underway
- The ICF study found that these four expansions:
  - Will together add 0.65 Bcf
  - Would increase New England's **internal** pipeline capacity from 4.04 Bcf/d to **4.69 Bcf/d**

Key Fuel Security Assumptions – Natural Gas Supplies: Pipeline (cont.)

- The incremental pipeline expansions are expected to be used by natural gas utilities to serve their growing base of heating customers
- This study assumes that the **external** pipeline infrastructure capable of delivering natural gas into New England and the Maritimes in 2024/2025 would total **3.86** Bcf/d over four pipelines:
  - 1.91 Bcf/d from the west through Algonquin
  - 1.39 Bcf/d from the west through Tennessee
  - 0.26 Bcf/d from the west through Iroquois
  - 0.30 Bcf/d from Quebec through Portland Natural Gas Transmission

Key Fuel Security Assumptions – Natural Gas Supplies: Pipeline (cont.)

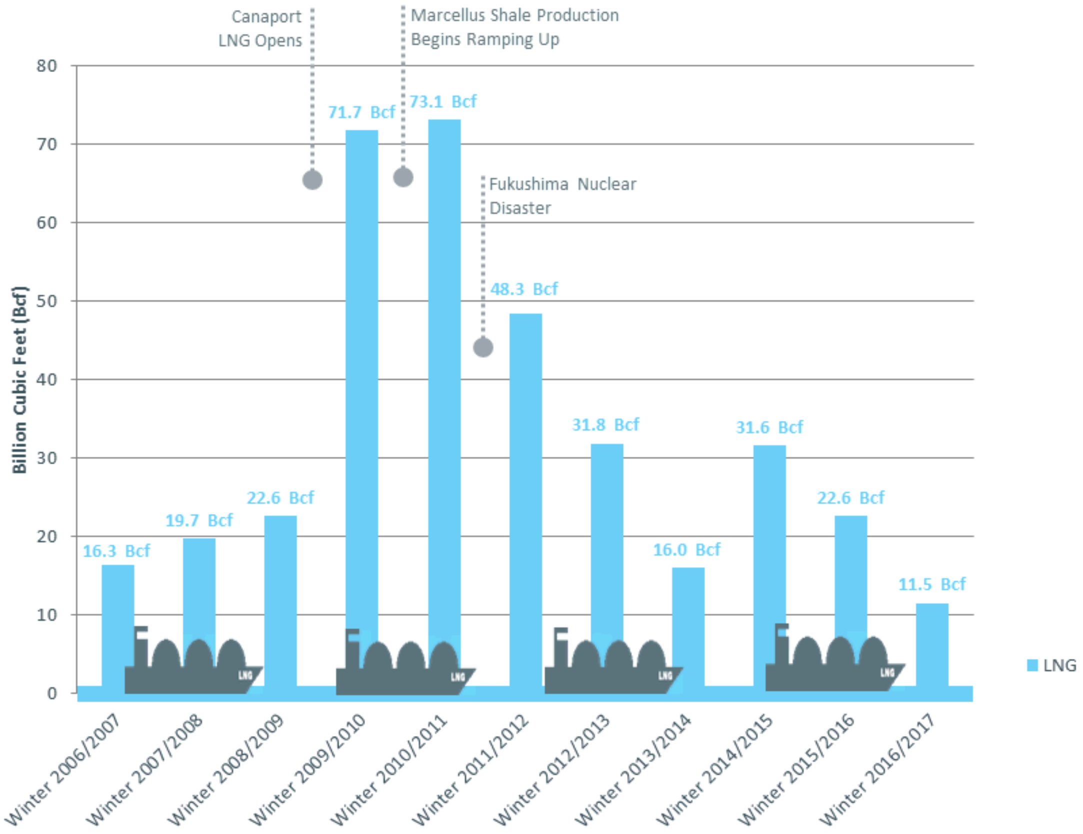
- The primary sources of natural gas to serve the Maritimes' heating demand will be Canaport LNG and the M&N pipeline transporting natural gas through New England
- By 2024/2025, the Sable Island and Deep Panuke natural gas fields are expected to be depleted
- The Maritimes and Northeast Pipeline (M&N) is not included in the 3.86 Bcf/d on the previous slide
  - M&N was considered an internal regional pipeline (part of the 4.69 Bcf/d shown on Slide 20)
  - Not a source of external natural gas

Key Fuel Security Assumptions – Natural Gas Supplies: LNG

- Gas from LNG was modeled from three sources: Canaport, Distrigas, and the Northeast Gateway Deepwater offshore buoy
- Maximum LNG delivery (i.e., injection) to New England and the Maritimes was modeled at 2.04 Bcf/d:
  - 1.2 Bcf/d from the Canaport facility (limited by current levels of Canadian demand on the Maritimes and Northeast Pipeline)
  - 0.43 Bcf/d from Distrigas
  - 0.40 Bcf/d from the off-shore buoy
- However, the maximum observed coincident delivery of LNG was 1.25 Bcf/d on one day in December 2016
- Therefore, scenarios in this study used daily LNG injection caps ranging from 0.65 Bcf/d to 1.5 Bcf/d for winter 2024/2025 deliveries

Key Fuel Security Assumptions – Natural Gas Supplies: LNG (cont.)

- Tracking LNG scheduled deliveries to the region over a winter season:
  - **Lowest** LNG deliveries winter 2016/2017 (11.5 Bcf)
  - **Highest** LNG deliveries winter 2010/2011 (73.1 Bcf)
  - **Average** winter LNG deliveries (34.9 Bcf)



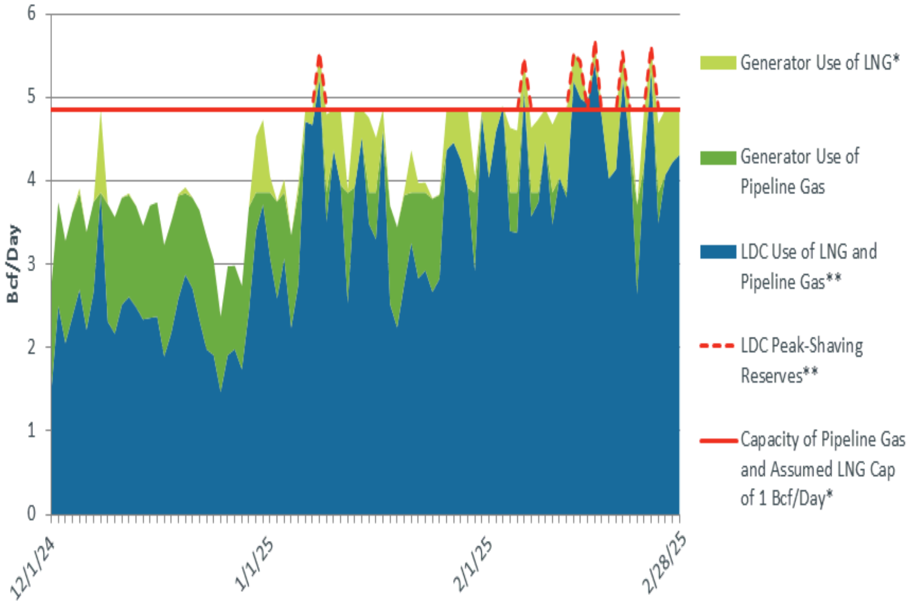
Note: Graph does not include the Mystic 8 and 9 gas-fired generators' fuel supply from the LNG facility

Source: Data from NatGas Analyst Tool by Genscape, a part of DMG Information (DMGI), www.genscape.com, based on scheduled deliveries posted to gas-industry bulletin boards

Key Fuel Security Assumptions – Natural Gas Demand

- 2025 LDC gas demand assumptions are based on an ICF analysis, which found winter natural gas demand for heating:
  - Totaled 4.4 Bcf/d on the winter peak day (calendar year 2014)
  - Forecasted peak demand from LDCs alone could reach 5.45 Bcf/d by 2025
- This leaves little, if any, gas for electric generators during near peak gas demand days

Winter 2024/2025 Supply of Pipeline Gas and LNG Compared to Use (Reference Case)

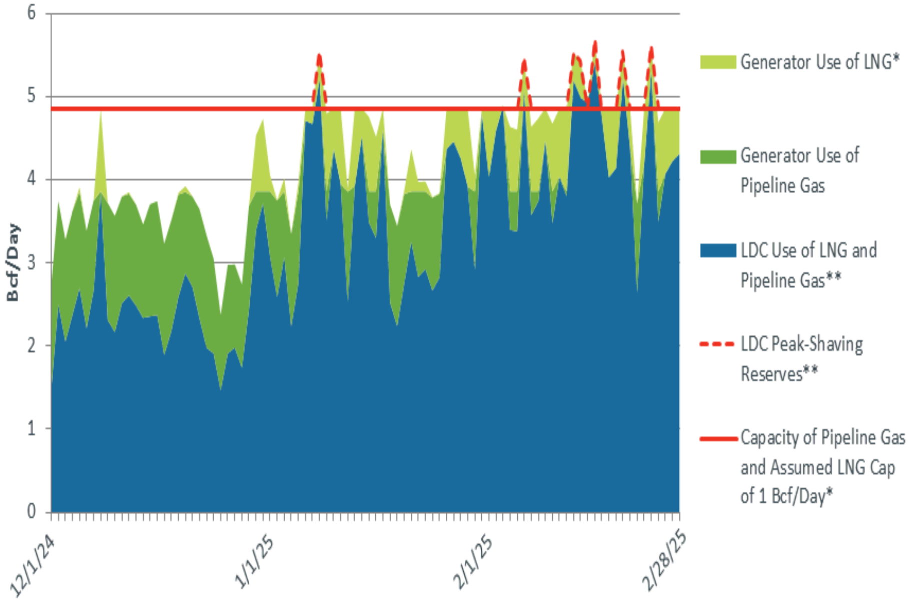


Note: LDC use includes the Maritimes' gas utility demand
*Graph does not include the Mystic 8 and 9 gas-fired generators' fuel use or supply from the LNG facility
**Per data from ICF International, *New England LDC Gas Demand Forecast Through 2030* (December 14, 2016, presentation to Planning Advisory Committee) and *The Future of Natural Gas Supply for Nova Scotia* (March 28, 2013, for Nova Scotia Department of Energy)

Key Fuel Security Assumptions – Natural Gas Demand (cont.)

- Total **annual** demand for gas utilities was 515 Bcf in 2014
  - ICF concluded that annual demand would increase just under 2% per year to 591 Bcf in 2025 and 620 Bcf in 2030
- Assumed LDC purchase requirements meet their peak gas design-day needs
- ICF's assessment of the Maritimes' gas demand estimated that Maritimes' design-day gas demand was 0.240 Bcf/d in 2012 (5.6% of New England's LDC gas demand)

Winter 2024/2025 Supply of Pipeline Gas and LNG Compared to Use (Reference Case)



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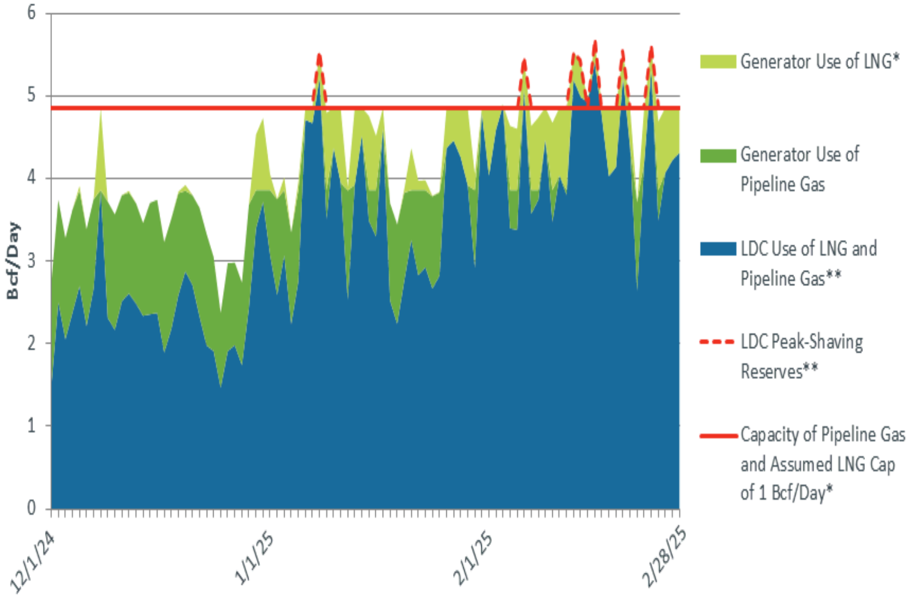
**Per data from ICF International, *New England LDC Gas Demand Forecast Through 2030* (December 14, 2016, presentation to Planning Advisory Committee) and *The Future of Natural Gas Supply for Nova Scotia* (March 28, 2013, for Nova Scotia Department of Energy)

Key Fuel Security Assumptions – Natural Gas Demand (cont.)

- On the coldest days in New England and the Canadian Maritimes, the availability of natural gas, from both pipelines and LNG facilities, for New England's power plants may be limited
  - LDC gas demand is highly correlated to the heating needs of a particular day and the heating needs over the entire winter
  - Low average daily temperatures, which translate to high degree days, drive up natural gas demand by gas LDCs and reduce the availability of gas for electric power generation

Winter 2024/2025 Supply of Pipeline Gas and LNG Compared to Use (Reference Case)



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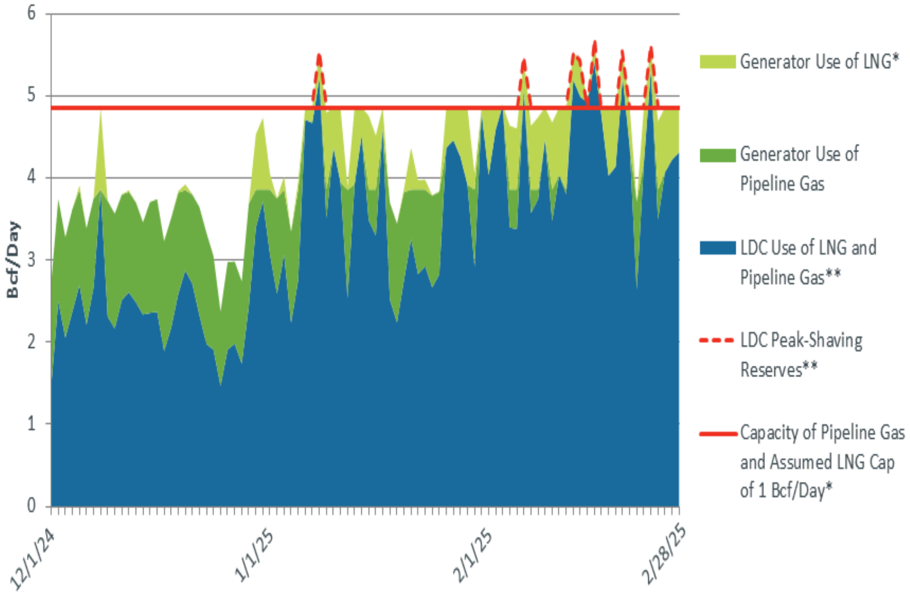
Key Fuel Security Assumptions – Natural Gas Demand (cont.)

- Growing use of natural gas to meet heating needs in New England and Canadian Maritimes can limit availability of pipeline gas and LNG
- On some 2024/2025 winter days, generators' needs are projected to exceed the capacity of **pipeline** gas and the assumed **LNG** injection cap of 1 Bcf/d in the reference case (shown as solid red line on the graph)

Winter 2024/2025 Supply of Pipeline Gas and LNG Compared to Use (Reference Case)



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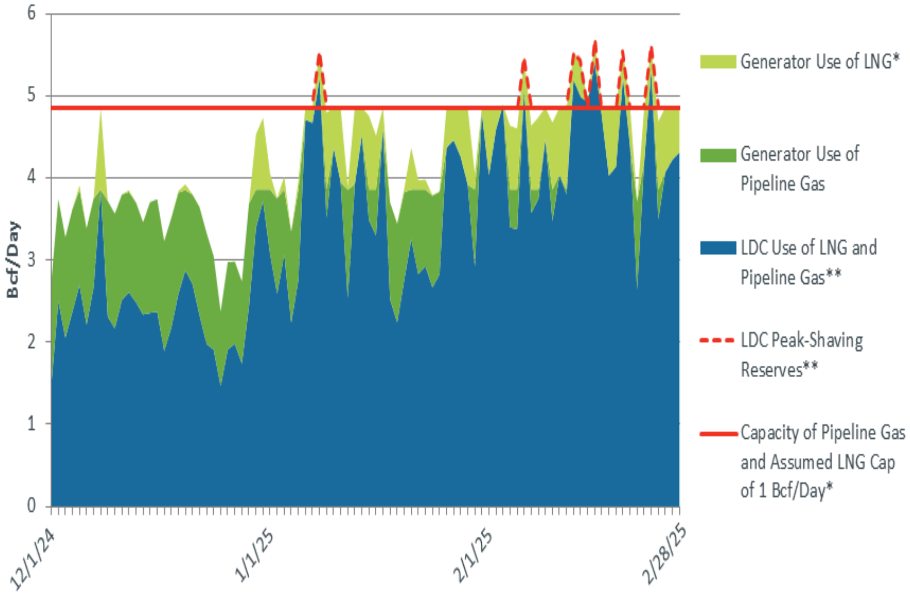
Key Fuel Security Assumptions – Natural Gas Demand (cont.)

- When the need for fuel for LDC load and generation is projected to exceed the region's total pipeline capacity, gas utilities can tap into their LNG reserves stored at "peak-shaving" facilities (shown as a broken red line on the graph)
  - The regulated LDCs have purchased the LNG stored in these tanks, which cannot be sold to power plants or other parties, but may sometimes make more natural gas available during the Operating Day
  - On days when the temperatures dropped to 12 degrees F or lower (*i.e.*, HDD of 53 degrees or higher), the peak-shaving facilities were assumed to operate

Winter 2024/2025 Supply of Pipeline Gas and LNG Compared to Use (Reference Case)



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**Per data from ICF International, *New England LDC Gas Demand Forecast Through 2030* (December 14, 2016, presentation to Planning Advisory Committee) and *The Future of Natural Gas Supply for Nova Scotia* (March 28, 2013, for Nova Scotia Department of Energy)

Key Fuel Security Assumptions - Renewables

- For each scenario, the study assumed at least 6,600 MW (nameplate capacity) of renewable resources in winter 2024/2025
  - This includes behind-the-meter PV forecasted to be installed by 2024 (4,400 MW)
- In all scenarios, the model incorporates the ISO's forecasts for growth of Energy Efficiency (EE)
  - Passive EE measures estimated to reduce peak demand by 3,907 MW in winter 2024/2025 to 20,761 MW*
- Some scenarios assumed higher levels of offshore wind and behind-the-meter solar

*based on the 90/10 winter peak forecast

Key Fuel Security Assumptions – Renewables (cont.)

- Several scenarios raised the level of renewables from 6,600 MW to 8,000 MW by adding nearly 1,400 MW of offshore wind by 2024
  - These scenarios also raised imports by 1,000 MW, assuming an additional hypothetical transmission line to import clean energy
- One combination scenario (“Max Renewables”) raised renewables to 9,500 MW by assuming:
  - 1,200 MW of onshore wind
  - 2,000 MW of offshore wind
  - 5,330 MW of behind-the meter PV
  - 960 MW of other renewables
- These assumptions are illustrated in the next slide
- In addition, the above scenario assumes 1,000 MW of clean imports, which effectively equates to a total of 10,500 MW of renewables

Key Fuel Security Assumptions – Renewables (cont.)

Case Scenario	Renewables Total MW (rounded)	Breakdown MW			
		Onshore Wind	Offshore Wind	PV	Other Renewables
2017	4,600	1,200	30	2,400	960
Reference Case	6,600	1,200	30	4,430	960
More Renewables	8,000	1,200	1,400	4,430	960
Max Renewables	9,500	1,200	2,000	5,330	960

Key Fuel Security Assumptions – Imports

- New England imports power over 13 high-voltage lines connected to New York, Quebec, and New Brunswick
  - 2,500 MW of imports in the Reference Case
  - 2,000 MW of imports in scenarios where imports are reduced
  - 3,000 MW and 3,500 MW of imports were assumed in scenarios incorporating the New England states' goals for more clean energy
    - Increases are assumed to be clean energy delivered over a hypothetical new transmission line from New York or Canada
- 500 MW of emergency imports when OP-4 actions are implemented were assumed in all scenarios
- New England and its neighbors experience winter weather at the same time and demand in Quebec and New Brunswick peaks in winter, possibly limiting exports to New England below the level of imports assumed in some of the scenarios studied

SUMMARIES OF INPUTS AND RESULTS OF SELECTED SCENARIOS

Summary of Inputs and Results of Selected Scenarios

This section presents the inputs and results of:

- Reference case
- Single-variable scenarios
- Four combination scenarios
- The winter-long outage scenarios for the four facilities listed below were each modeled against the reference case (Ref) and the combination scenario for maximum renewables and maximum retirements (Max):
  - Millstone nuclear station
  - Canaport LNG facility
  - Distrigas LNG Facility
  - A natural-gas pipeline compressor station
- More results are available in the Summary of Study Results at the end of Appendix A

Metrics: How System Stress was Measured

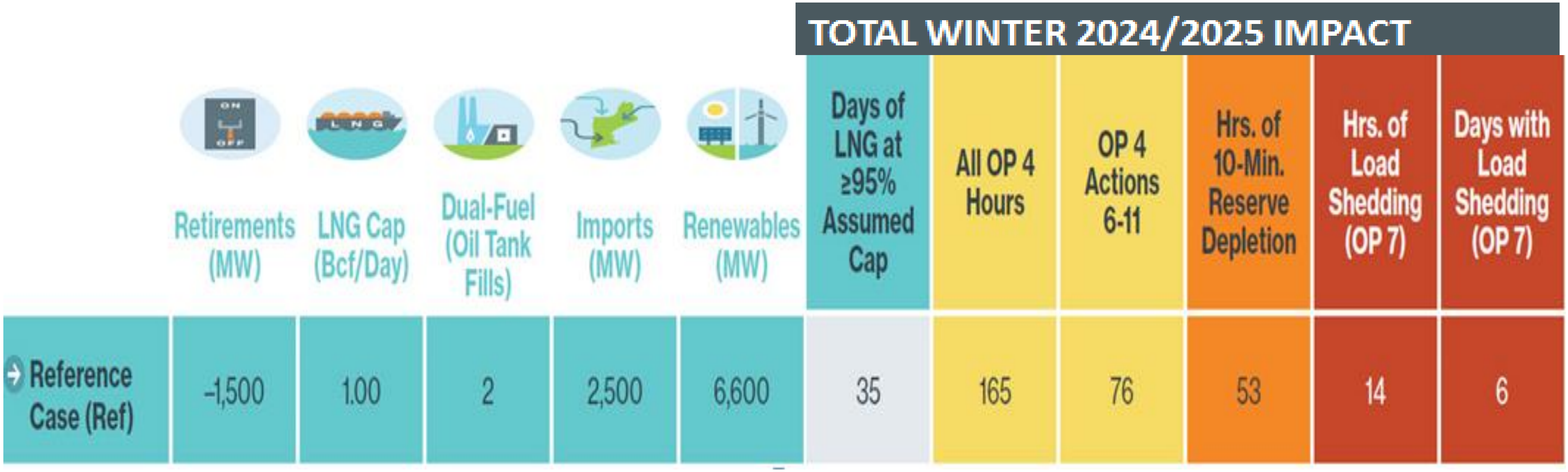
- The results of each case are quantified by the following operational metrics in hours, days, and megawatt-hours:
  - Use of Operating Procedure OP-4, Action During a Capacity Deficiency
    - Both total OP-4 Actions and OP-4 Actions 6-11 are quantified
  - Depletion of 10-minute operating reserve
  - Need for OP-7 load shedding
- These metrics illustrate the level of risk involved in each scenario and the relative benefits of the key variables
- Results are not a precise prediction of future outcomes; they provide a basis for comparing fuel-security risk across scenarios

Reference Case Inputs

The reference case incorporated each of the five key variables at levels that can reasonably be expected to materialize in New England given current trends

- 1,500 MW of additional coal- and oil-fired power plant retirements
- 2,500 MW of imports
  - On average, over the last five winters about 2,500 MW was flowing into New England just over 60% of the time
- 1 Bcf/d of maximum daily combined LNG injections from Canaport, Distrigas, and the Northeast Gateway offshore buoy
- Dual-fuel oil tanks start the season full and refill once during the winter season for combined cycle power plants, while fast-start units replenished continuously
  - For dual-fuel resources this is represented as 2 Dual-Fuel Oil Tank Fills
- 6,600 MW (nameplate) of assumed renewables

Reference Case Inputs and Results



						TOTAL WINTER 2024/2025 IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
➔ Reference Case (Ref)	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6

Reference Case Results Summary

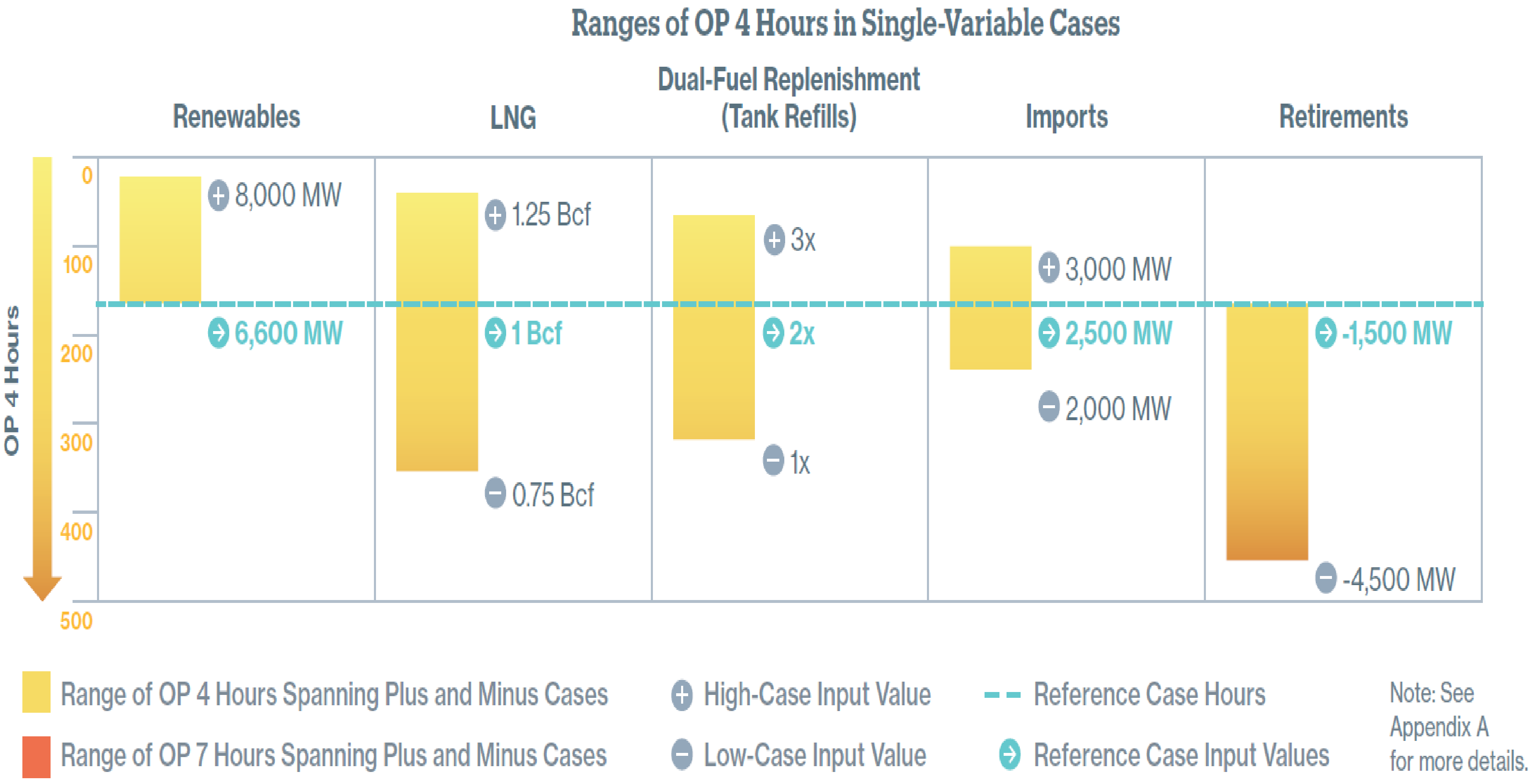
- The reference case shows exposure to 14 hours of load shedding spread over six days, the depletion of 10-minute reserves for 53 hours, and use of OP-4 Actions 6-11 for 76 hours
- In the reference case, the region would use 62.4 Bcf of LNG over the entire winter for both heating and power generation
  - That is significantly more than the 34.9 Bcf imported on average over the past 10 winters, but less than the highest level of LNG ever imported into New England (73 Bcf in winter 2010/2011)
  - There were 35 days when at least 95% of the 1 Bcf/d daily LNG injection cap was needed

Single-Variable Scenario Inputs

These scenarios adjusted just one of the five variables at a time to show the effects of differing LNG levels, retirements, electricity imports, renewables, and dual-fuel oil inventories

- These scenarios increased or decreased one key variable from the reference case:
  - LNG (increase and decrease)
  - Dual-fuel (increase and decrease)
  - Imports (increase and decrease)
  - Retirements (increase only)
  - Renewables (increase only)
- Appendix A shows the inputs and results of each of the single-variable scenarios

Single-Variable Scenarios Summary: Input Levels of Five Variables Are Key to Fuel-Security Risk



Note: See Appendix A for more details.

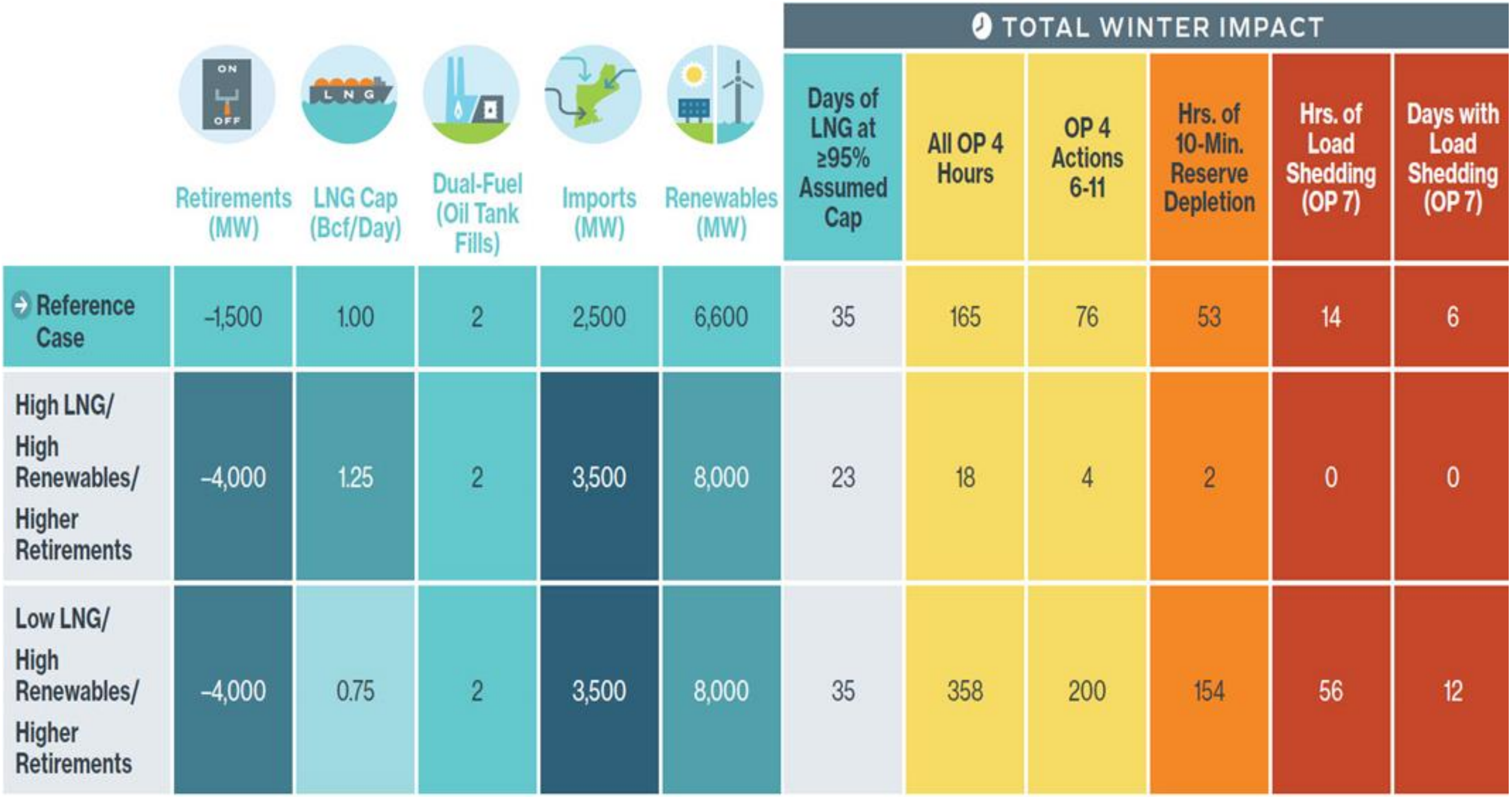
Combination Scenario Inputs: LNG

High LNG with High Renewables and Higher Retirements and *Low LNG* with High Renewables and Higher Retirements

These scenarios used the following levels of the five key variables:

- High LNG: 1.25 Bcf/d daily LNG injection cap
- Low LNG: 0.75 Bcf/d daily LNG injection cap
- High Renewables: 8,000 MW (nameplate)
- Higher Retirements: 4,000 MW of coal- and oil-fired power plants
- Higher Imports: 3,500 MWs
- Dual-fuel oil tanks start the season full and refill once during the winter season for combined cycle power plants, while fast-start units replenished continuously
  - For dual-fuel resources, this is represented as 2 Dual-Fuel Oil Tank Fills

Combination Scenarios Inputs and Results: LNG



						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Reference Case	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6
High LNG/ High Renewables/ Higher Retirements	-4,000	1.25	2	3,500	8,000	23	18	4	2	0	0
Low LNG/ High Renewables/ Higher Retirements	-4,000	0.75	2	3,500	8,000	35	358	200	154	56	12

Combination Scenario Results Summary: *High LNG* with High Renewables and Higher Retirements

Measured against the reference case, this scenario:

- Decreases exposure to load shedding from 14 hours over six days to 0 hours of OP-7 load shedding
- The depletion of 10-minute reserves declines from 53 hours to two hours
- Use of OP-4 Actions 6-11 decreases from 76 hours to four hours
- LNG use:
  - 61.6 Bcf over the winter (62.4 Bcf in the reference case)
  - 23 days when at least 95% of the 1.25 Bcf/d daily LNG injection cap was needed (35 days in the reference case with a daily LNG injection cap of 1 Bcf/d)

Combination Scenario Results Summary: *Low LNG* with High Renewables and Higher Retirements

Measured against the reference case, this scenario:

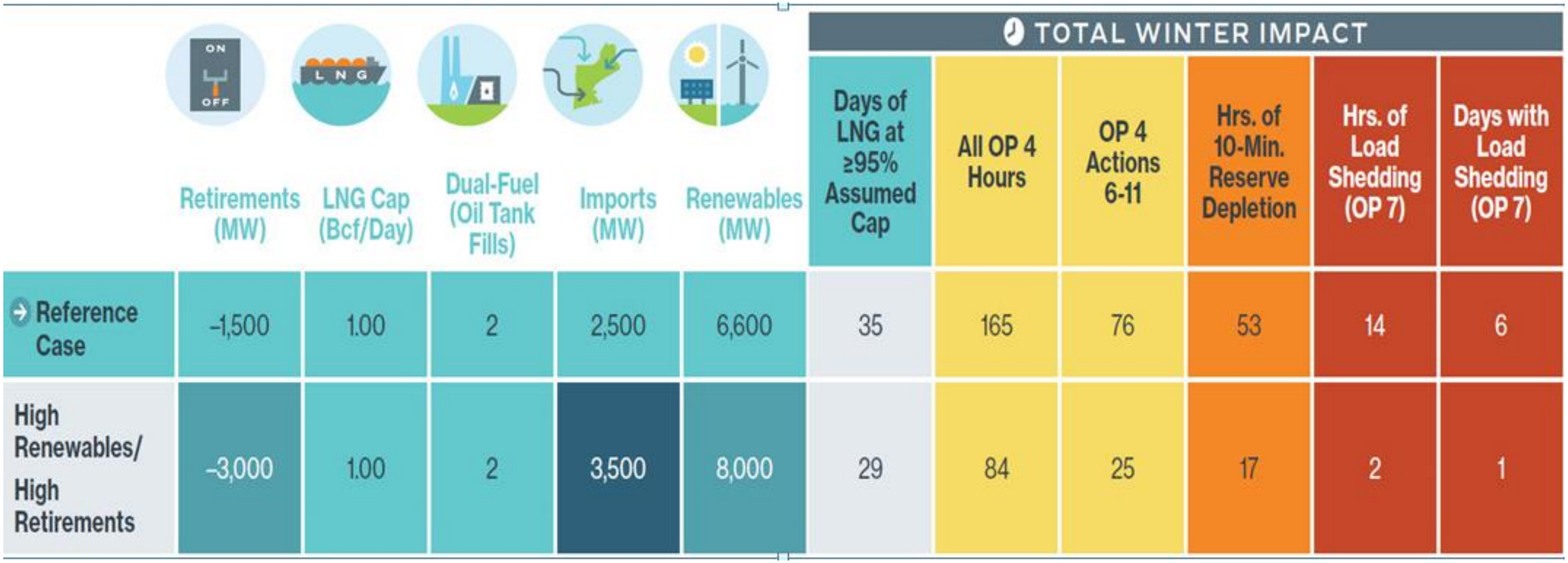
- Increases exposure to load shedding from 14 hours over 6 days to 56 hours over 12 days
- The depletion of 10-minute reserves increases from 53 hours to 154 hours
- Use of OP-4 Actions 6-11 increases from 76 hours to 200 hours
- LNG use:
  - 46.3 Bcf over the winter (62.4 Bcf in the reference case)
  - 35 days when at least 95% of the 0.75 Bcf/d daily LNG injection cap was needed (35 days in the reference case with a daily LNG injection cap of 1 Bcf/d)

Combination Scenario Inputs: High Renewables and High Retirements

This scenario used the following levels of the five key variables:

- High Renewables: 8,000 MW (nameplate)
- High Retirements: 3,000 MW of coal- and oil-fired power plants
- Higher Imports: 3,500 MW
- LNG 1.0 Bcf/d daily LNG injection cap
- Dual-fuel oil tanks start the season full and refill once during the winter season for combined cycle power plants, while fast-start units replenished continuously
  - For dual-fuel resources, this is represented as 2 Dual-Fuel Oil Tank Fills

Combination Scenario Inputs and Results: High Renewables and High Retirements



						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Reference Case	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6
High Renewables/ High Retirements	-3,000	1.00	2	3,500	8,000	29	84	25	17	2	1

Combination Scenario Results Summary: High Renewables and High Retirements

Measured against the reference case, this scenario:

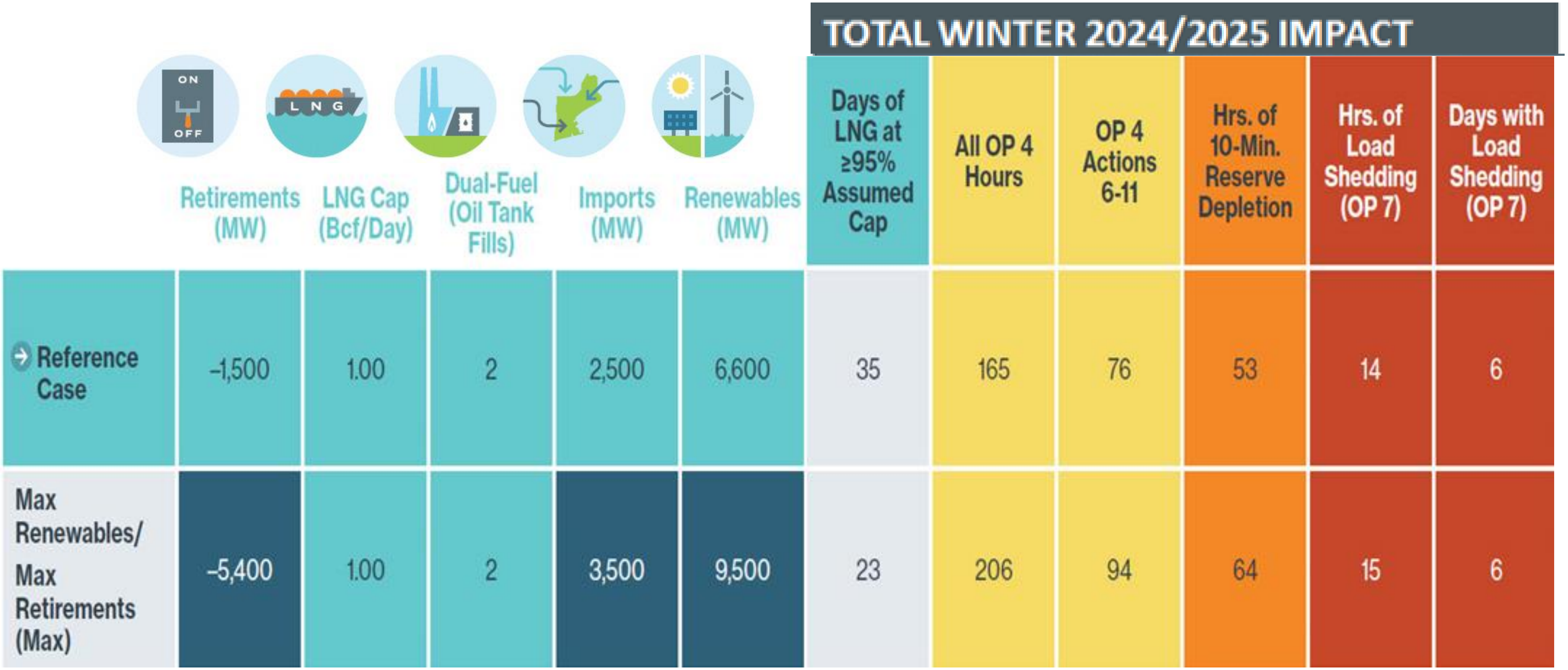
- Decreases exposure to load shedding from 14 hours over 6 days to two hours in one day
- The depletion of 10-minute reserves declines from 53 hours to 17 hours
- Use of OP-4 Actions 6-11 decreases from 76 hours to 25 hours
- LNG use:
  - 54.6 Bcf over the winter (62.4 Bcf in the reference case)
  - 29 days when at least 95% of the 1.0 Bcf/d daily LNG injection cap was needed (35 days in the reference case)

Combination Scenario Inputs: Maximum Renewables and Maximum Retirements

This scenario used the following levels of the five key variables:

- Maximum Renewables: 9,500 MW (nameplate)
- Maximum Retirements: 5,400 MW of coal- and oil-fired power plants
- Higher Imports: 3,500 MW
- LNG: 1 Bcf/d of daily LNG injection cap
- Dual-fuel oil tanks start the season full and refill once during the winter season for combined cycle power plants, while fast-start units replenished continuously
  - For dual-fuel resources, this is represented as 2 Dual-Fuel Oil Tank Fills

Combination Scenario Inputs and Results: Maximum Renewables and Maximum Retirements



						TOTAL WINTER 2024/2025 IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Reference Case	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6
Max Renewables/ Max Retirements (Max)	-5,400	1.00	2	3,500	9,500	23	206	94	64	15	6

Combination Scenario Results Summary: Maximum Renewables and Maximum Retirements

Measured against the reference case, this scenario:

- Increases exposure to load shedding from 14 hours to 15 hours over six days
- Depletion of 10-minute reserves increases from 53 hours to 64 hours
- Use of OP-4 Actions 6-11 increases from 76 hours to 94 hours
- LNG use:
  - 52.9 Bcf over the winter (62.4 Bcf in the reference case)
  - 23 days when at least 95% of the 1.0 Bcf/d daily LNG injection cap was needed (35 days in the reference case)

Outages of Key Facilities

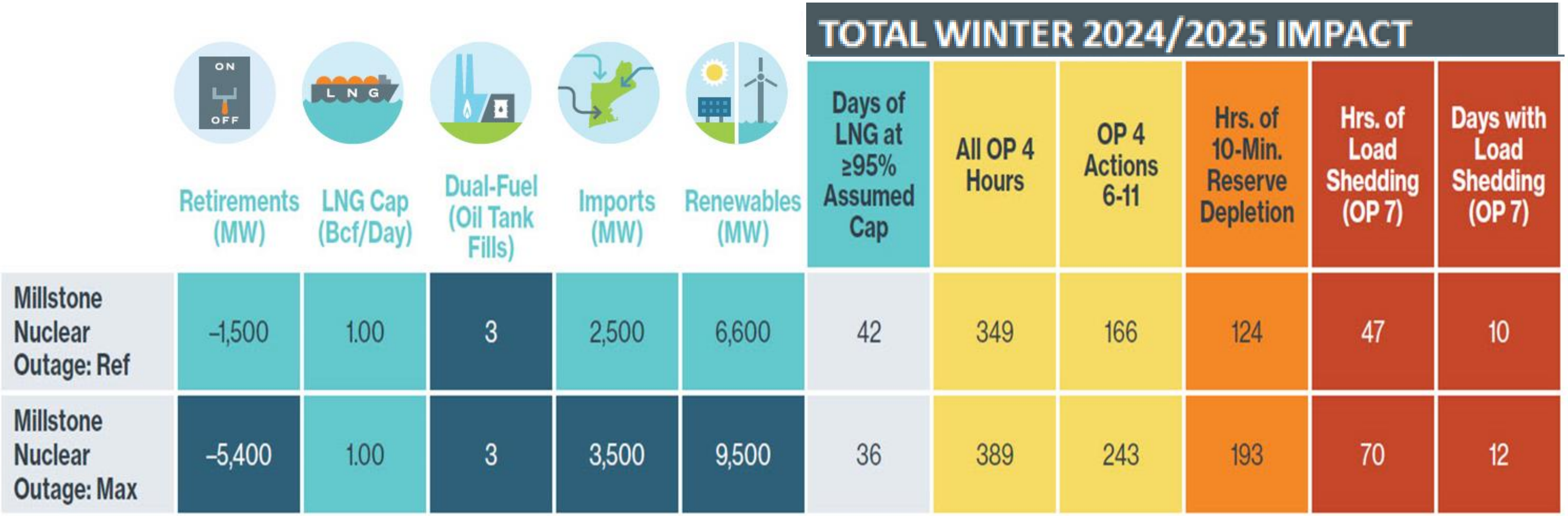
These scenarios assessed the effects of a winter-long outage of each of four major energy facilities on the reliability of the power system

- All outage scenarios increased the Dual-Fuel Oil Tank Fills from the two used in the reference case to three
  - Start the season full and refill twice during the winter season for combined cycle power plants, while fast-start units replenished continuously

- Winter-long outages were each modeled in both the reference case and the combination scenario of maximum renewables and maximum retirements for:
  - Millstone
  - Canaport
  - Distrigas
  - A compressor station on a gas pipeline

- This results in eight total outage scenarios, which are illustrated in the following slides

Outage Scenarios: Millstone



						TOTAL WINTER 2024/2025 IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Millstone Nuclear Outage: Ref	–1,500	1.00	3	2,500	6,600	42	349	166	124	47	10
Millstone Nuclear Outage: Max	–5,400	1.00	3	3,500	9,500	36	389	243	193	70	12

Outage Scenarios: Millstone

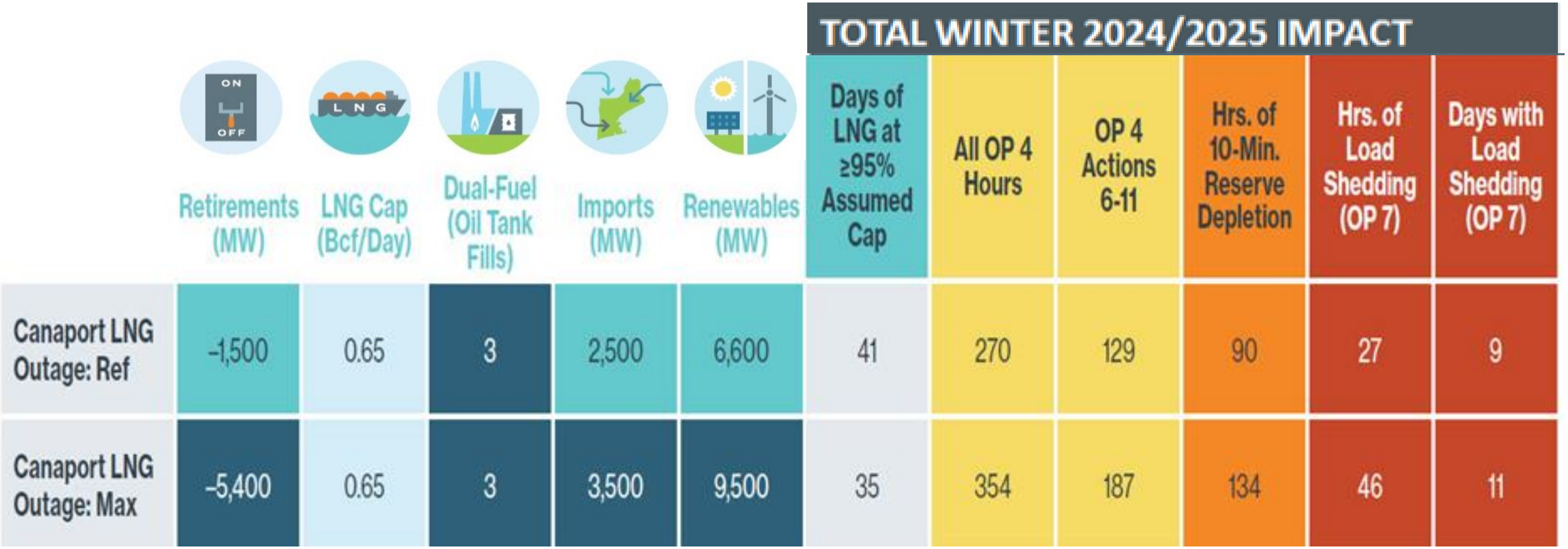
- The winter-long outage of the Millstone nuclear station (2,100 MW) was modeled for both the reference case (Ref) and the maximum retirements/maximum renewables scenario (Max)

- Millstone Nuclear Outage (Ref): 47 hours of load shedding over 10 days

- Millstone Nuclear Outage (Max retirements/renewables): 70 hours of load shedding over 12 days

- Millstone Nuclear Outage (Ref):
  - 72.9 Bcf of total LNG injection over the winter
    - About the same as the most LNG imports seen to date
  - 42 days when at least 95% of the 1.0 Bcf/d daily LNG injection cap was needed

Outage Scenarios: Canaport

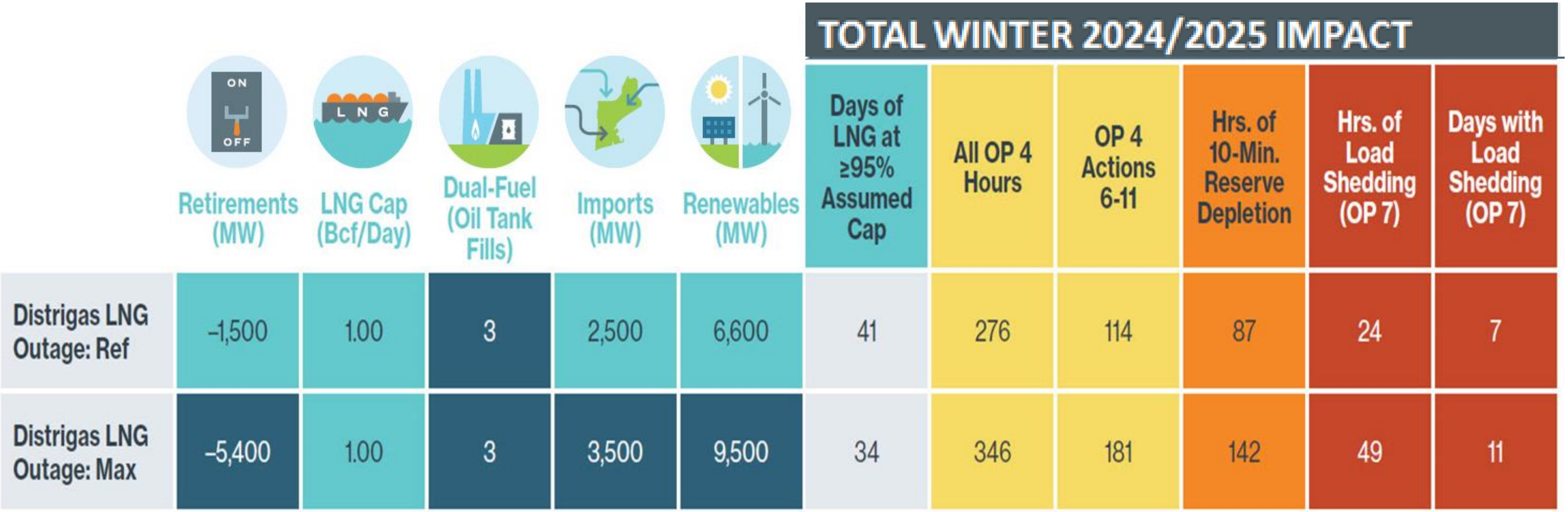


						TOTAL WINTER 2024/2025 IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Canaport LNG Outage: Ref	-1,500	0.65	3	2,500	6,600	41	270	129	90	27	9
Canaport LNG Outage: Max	-5,400	0.65	3	3,500	9,500	35	354	187	134	46	11

Outage Scenarios: Canaport

- These scenarios modeled the loss of the Canaport LNG import facility, eliminating injections into both the Maritimes and New England (via the Maritimes and Northeast pipeline)
  - The study reflects this by reducing the daily LNG injection cap to 0.65 Bcf/d
- Canaport LNG Outage (Ref): 27 hours of load shedding over nine days
- Canaport LNG Outage (Max): 46 hours of load shedding over 11 days
- Canaport LNG Outage (Ref):
  - 48.1 Bcf total LNG injection over the winter
  - 41 days when at least 95% of the 0.65 Bcf/d daily LNG injection cap was needed

Outage Scenarios: Distrigas and Mystic 8 and 9

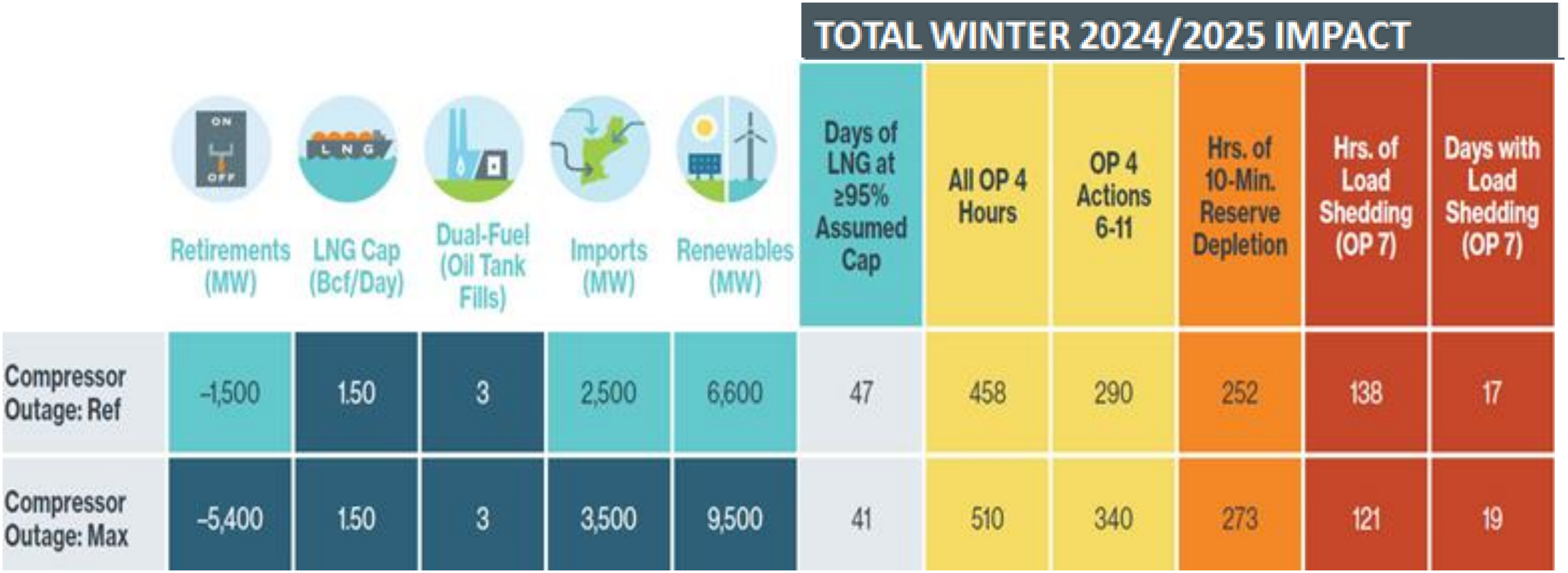


						TOTAL WINTER 2024/2025 IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Distrigas LNG Outage: Ref	–1,500	1.00	3	2,500	6,600	41	276	114	87	24	7
Distrigas LNG Outage: Max	–5,400	1.00	3	3,500	9,500	34	346	181	142	49	11

Outage Scenarios: Distrigas and Mystic 8 and 9

- These scenarios modeled the loss of the Distrigas LNG facility in Boston, eliminating up to 0.435 Bcf/d injected into New England pipelines and eliminating fuel supply to Mystic 8 and 9
- Distrigas Outage (Ref): 24 hours of load shedding over seven days
- Distrigas Outage (Max): 49 hours of load shedding over 11 days
- The Distrigas LNG facility outage (Ref):
  - 50.9 Bcf of total LNG injection over the winter
  - 41 days when at least 95% of the 1.0 Bcf/d daily LNG injection cap was needed
    - The daily LNG injection cap was not reduced below 1 Bcf/d because it was assumed the region's other LNG facilities would increase their imports

Outage Scenarios: Compressor Station



	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	TOTAL WINTER 2024/2025 IMPACT					
						Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Compressor Outage: Ref	-1,500	1.50	3	2,500	6,600	47	458	290	252	138	17
Compressor Outage: Max	-5,400	1.50	3	3,500	9,500	41	510	340	273	121	19

Outage Scenarios: Compressor Station

- These scenarios modeled the winter-long loss of a natural gas pipeline compressor station eliminating 1.2 Bcf/d
  - The study assumes that the loss of a natural gas pipeline compressor station would spur higher imports of LNG and more frequent oil tank refills
    - 1.5 Bcf/d daily LNG injection cap
    - Three Dual-Fuel Oil Tank Refills (as described on Slide #52)
- Compressor Outage (Ref): 138 hours of load shedding over 17 days
- Compressor Outage (Max): 121 hours of load shedding over 19 days
- Compressor Outage (Ref):
  - 127.8 Bcf of total LNG consumption over the winter
  - Far higher than the highest level of LNG delivered to New England pipelines (73 Bcf in winter 2010/2011)

FUEL SECURITY STUDY KEY FINDINGS

Key Findings

- Overview of key findings and their impacts on:
  - Key energy facility outages
  - Combination scenarios for High and Low LNG with High Renewables and Higher Retirements
  - Combination scenarios for Maximum Renewables and Maximum Retirements and for High Renewables/High Retirements
  - Single-variable scenarios
  - Graph illustrating the magnitude of load shedding (in all but the two boundary cases)
- A summary of the results for all 23 scenarios can be found in Appendix A of this presentation
- Additional information can be found in the *Operational Fuel-Security Analysis* posted for today's meeting

Key Findings – Outages of Key Facilities

- All outage scenarios involving the winter-long loss of key energy facilities—Millstone, Distrigas LNG facility, Canaport LNG facility, or a pipeline compressor station—produced severe outcomes
- Each outage resulted in hundreds of hours of emergency operating procedures and emergency actions, and 24–100+ hours of load shedding
- A compressor station outage would have the most severe impact on reliability, with more than 120 hours of load shedding spread across 19 days

Key Findings – Combination Scenarios

High LNG/High Renewables/Higher Retirements Scenario and High Renewables/High Retirements Scenario

- These two combination scenarios showed that higher levels of retirements of oil-fired power plants could be addressed with higher levels of LNG, renewables, and imports
- This would reduce the hours of emergency actions and the need to deplete operating reserves
- The inputs in these cases fall in the range between the Reference Case and the Maximum Renewables/Maximum Retirements scenario (see the Summary of Results in Appendix A for more information)
  - The power system can be expected to remain extremely vulnerable to outages of any of the region's key energy suppliers

Key Findings – Combination Scenarios (cont.)

Low LNG/High Renewables/Higher Retirements Scenario

- This scenario has a higher level of retirements of non-gas-fired generators than the Reference Case, coupled with lower LNG injections
- This combination required frequent emergency actions and multiple hours of load shedding, despite higher levels of imports and renewables
  - Over 200 hours of emergency actions
  - 56 hours of load shedding over 12 days

Key Findings – Combination Scenarios (cont.)

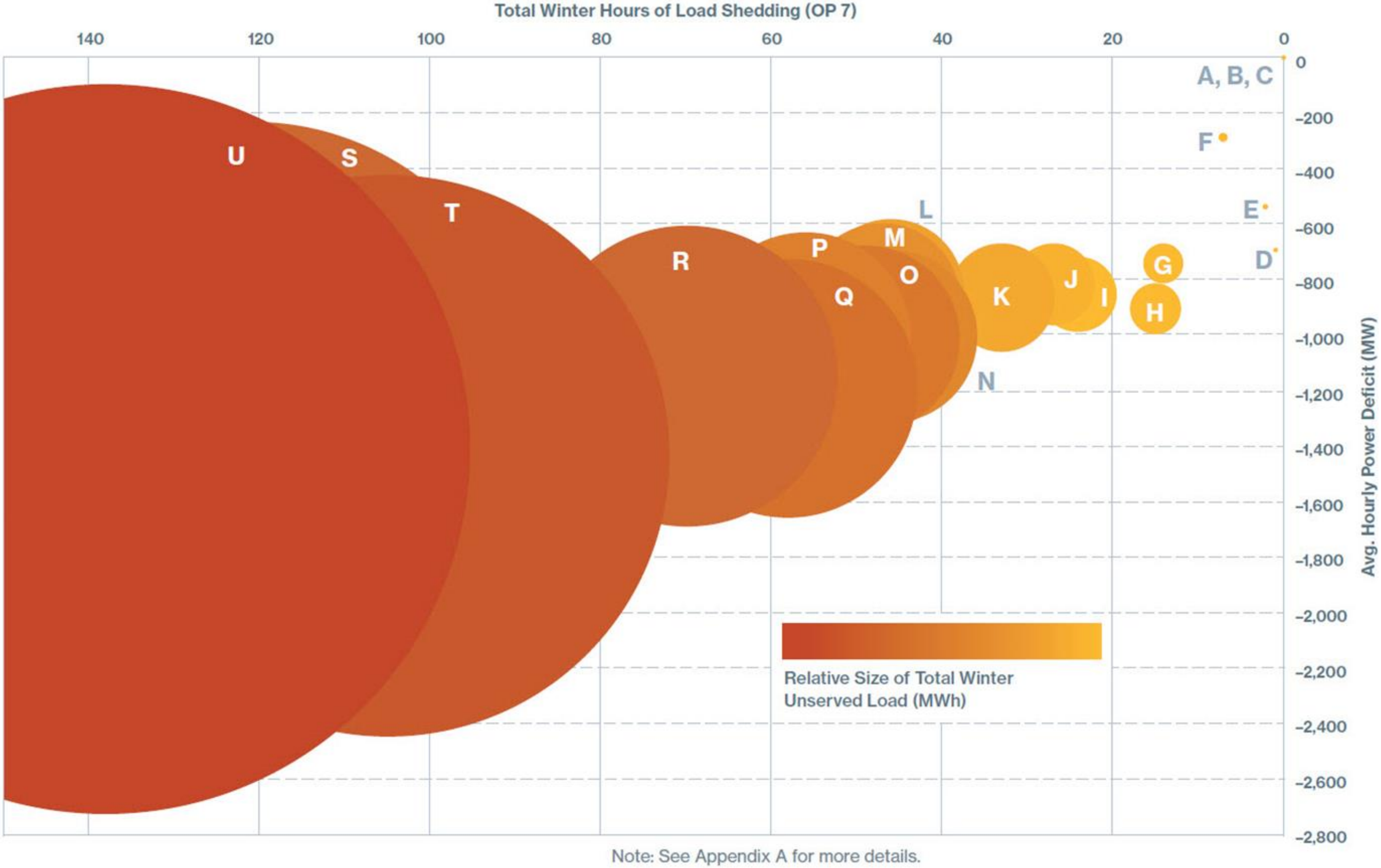
Maximum Renewables/Maximum Retirements

- This combination scenario illustrated the impacts of retiring every at-risk coal- and oil-fired generator in the region and developing the highest level of renewable resources
- With moderate levels of LNG, imports, and oil tank inventories, more than 200 hours of emergency actions and more than 12 hours of load shedding over six days were required to maintain system balance
- Modeling the outage scenarios with this combination scenario demonstrated that the loss of a key energy facility would exacerbate the use of emergency procedures

Key Findings – Single-Variable Scenarios

- Retirements of oil- and coal-fired power plants had the greatest impact on the region's fuel-security risk
- Lower LNG injections had the next greatest impact
- Large amounts of renewable resources, combined with additional imports, lowered fuel-security risk
  - No load shedding and greatly reduced need for emergency actions
- Increased oil inventories at dual-fuel generators significantly improved fuel security

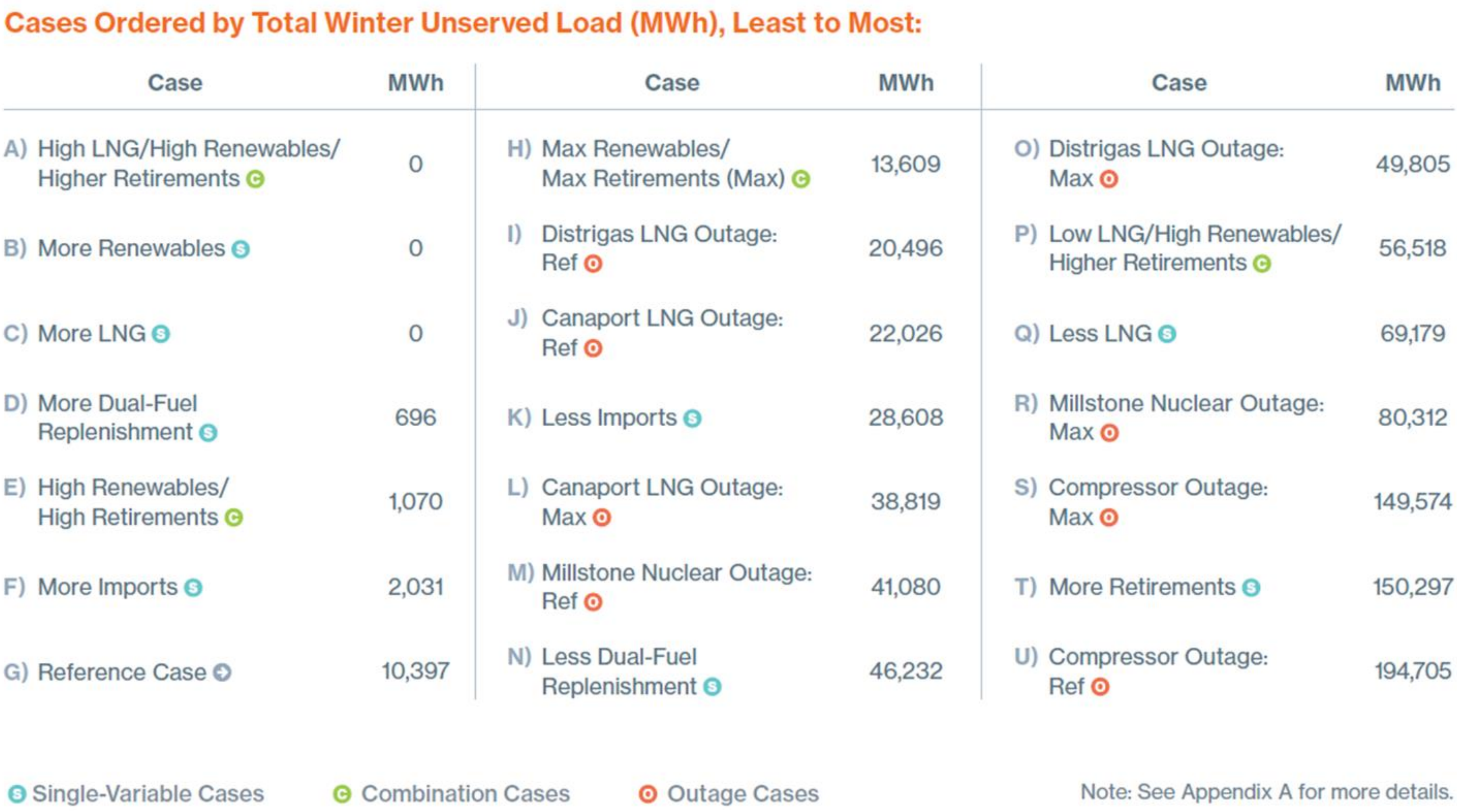
Magnitude of Load Shed: All Scenarios



Note: See Appendix A for more details.

This chart reflects the magnitude of load shedding (i.e., OP 7) in each of the scenarios. (The high and low boundary cases were omitted.) The bubble size represents the total megawatt-hours of load shedding for the winter, illustrating the region's vulnerability to outages of major energy facilities, increases in retirements, and drops in LNG or oil supplies.

Magnitude of Load Shed (cont.)



Cases Ordered by Total Winter Unserved Load (MWh), Least to Most:

Case	MWh	Case	MWh	Case	MWh
A) High LNG/High Renewables/ Higher Retirements Ⓒ	0	H) Max Renewables/ Max Retirements (Max) Ⓒ	13,609	O) Distrigas LNG Outage: Max Ⓞ	49,805
B) More Renewables Ⓢ	0	I) Distrigas LNG Outage: Ref Ⓞ	20,496	P) Low LNG/High Renewables/ Higher Retirements Ⓒ	56,518
C) More LNG Ⓢ	0	J) Canaport LNG Outage: Ref Ⓞ	22,026	Q) Less LNG Ⓢ	69,179
D) More Dual-Fuel Replenishment Ⓢ	696	K) Less Imports Ⓢ	28,608	R) Millstone Nuclear Outage: Max Ⓞ	80,312
E) High Renewables/ High Retirements Ⓒ	1,070	L) Canaport LNG Outage: Max Ⓞ	38,819	S) Compressor Outage: Max Ⓞ	149,574
F) More Imports Ⓢ	2,031	M) Millstone Nuclear Outage: Ref Ⓞ	41,080	T) More Retirements Ⓢ	150,297
G) Reference Case ➜	10,397	N) Less Dual-Fuel Replenishment Ⓢ	46,232	U) Compressor Outage: Ref Ⓞ	194,705

Ⓢ Single-Variable Cases Ⓒ Combination Cases Ⓞ Outage Cases

Note: See Appendix A for more details.

Conclusions

This study illustrates:

- The potential vulnerability of New England's power system to the prolonged loss of any one of several key energy facilities
- The region's dependence on oil, LNG, and electricity imports
- The timely deliverability of oil, LNG, or imports (e.g. due to weather conditions or contractual arrangements) affects fuel-security risk
  - There are similar questions concerning electricity imports from neighboring power systems with high winter demand
- Current trends are pushing the New England power system toward greater fuel-security risks; all but four of the 23 scenarios studied resulted in load shedding
  - High LNG/High Renewables/Higher Retirements
  - More Renewables
  - More LNG
  - High Boundary Case

Conclusions (cont.)

- A resource mix with higher levels of LNG, imports, and renewables shows less system stress than the reference case
  - Achieving these levels of LNG, imports, and renewables would require:
    - Firm contracts for LNG
    - Assured delivery of imports in winter
    - Aggressive development of renewables (including expansion of the transmission system)
- More renewables help, but do not eliminate the risk
  - Renewable resources can mitigate the region's fuel-security risk
  - Low operating costs are likely to drive greater retirements of aging coal- and oil-fired power plants
  - Delivery and performance assurances would be needed
  - Transmission expansion would be needed
  - The region will have greater dependence on LNG

Next Steps

- The ISO released this fuel-security report on January 17, 2018 and will continue to discuss its results with stakeholders
- A key question to be addressed will be the level of fuel-security risk that the ISO, the region, policymakers, and regulators are willing to tolerate
- As the system operator responsible for system reliability, the ISO must independently assess the level of risk to reliable operation
- Discussions with stakeholders on potential solutions to address fuel-security risks are targeted to begin later in 2018

Stakeholder Meeting Schedule

Stakeholder Meetings	Scheduled Project Milestone
January 24, 2018 Reliability Committee Meeting	Begin discussion of the study inputs and results
February 15, 2018	Written comments due with requested assumptions to the RC Secretary (Marc Lyons)
March 29, 2018 Reliability Committee Meeting	Reliability Committee to discuss results of any stakeholder assumptions
April 12, 2018	Written comments due with requested assumptions to the RC secretary (Marc Lyons)
May 22, 2018 Reliability Committee Meeting	Reliability Committee to discuss final report and next steps

Questions

Acronyms Used in this Presentation

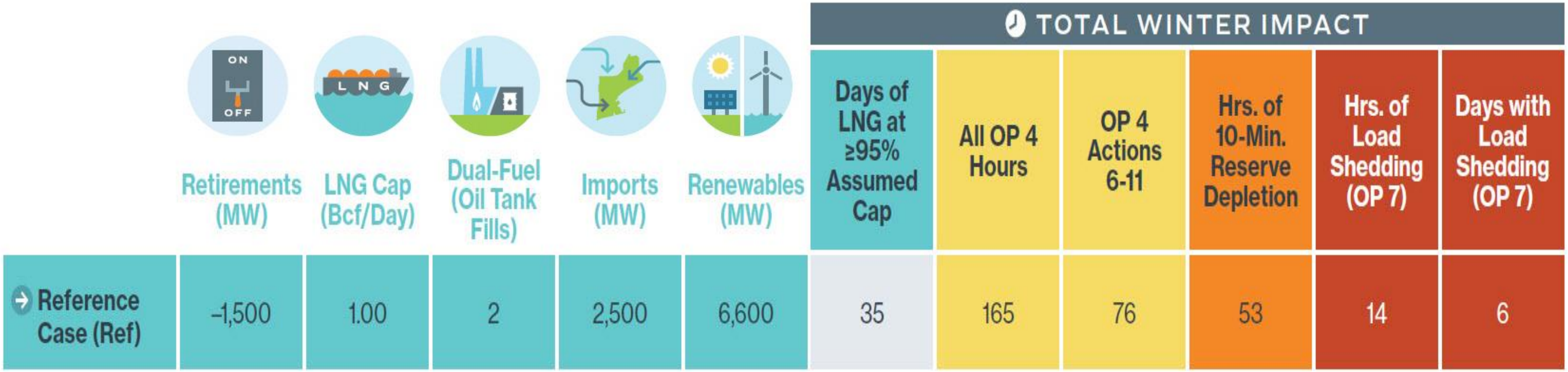
- Bcf = billion cubic feet
- Bcf/d = billion cubic feet per day
- EE = Energy Efficiency
- ICF = ICF International, Inc.
- ISO = ISO New England Inc.
- LDC = Local Distribution Company
- LNG = liquefied natural gas
- MW = megawatt or megawatts
- MWh = megawatt-hours
- PV = photovoltaics
- RC = NEPOOL Reliability Committee

APPENDIX A

Modeled Scenario Results

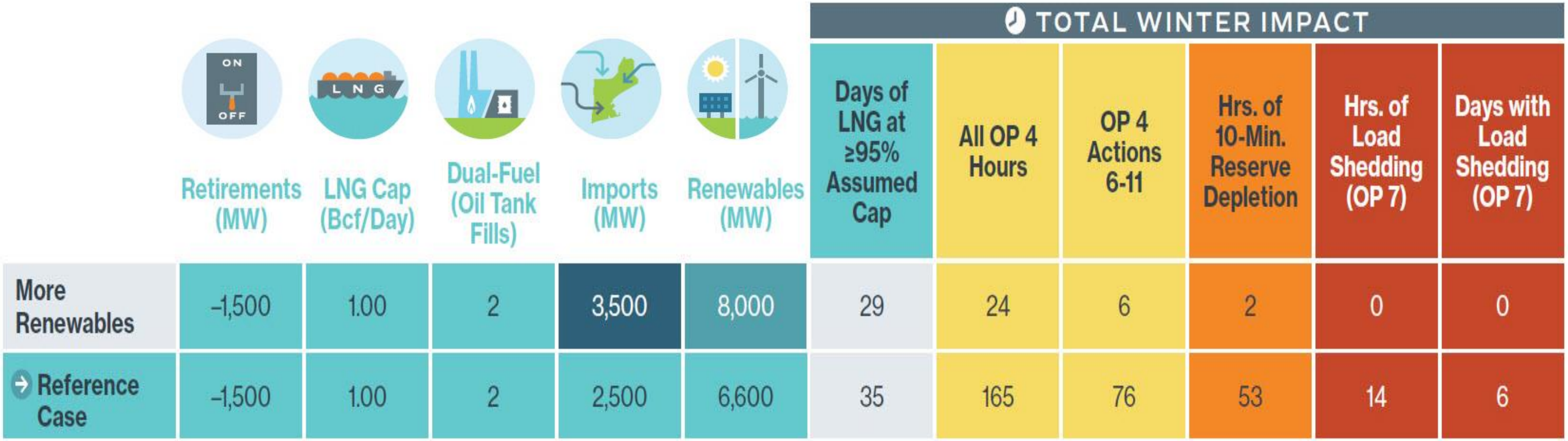
Study Results

Reference Scenario (Ref)



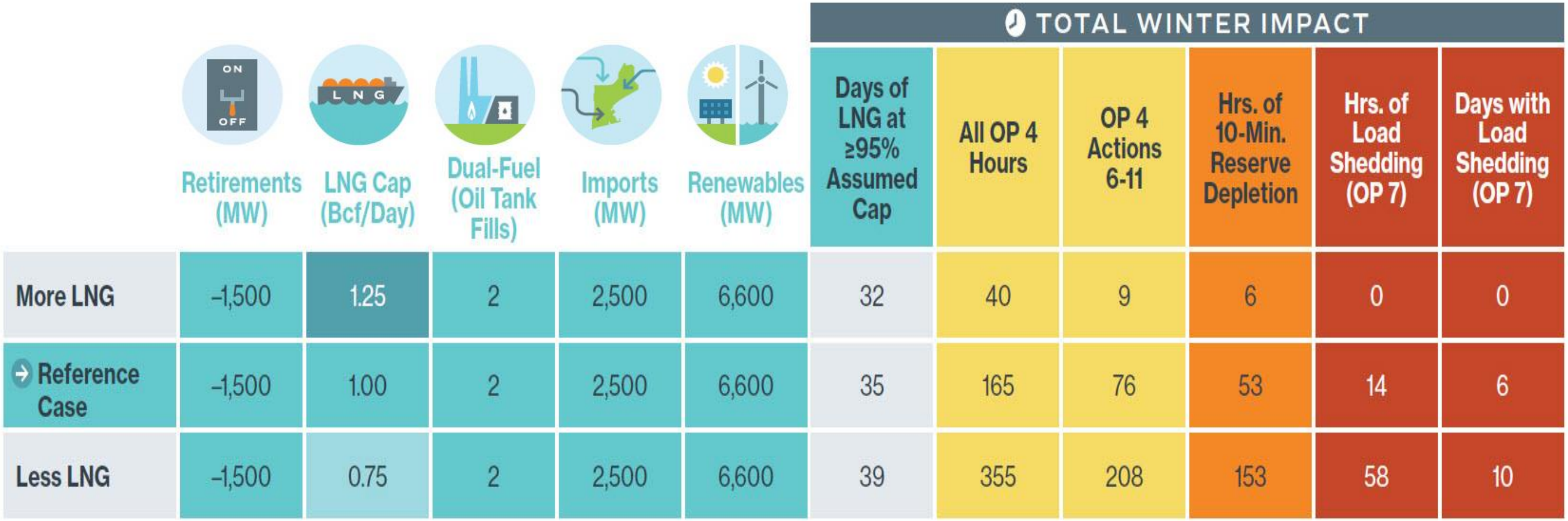
						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
→ Reference Case (Ref)	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6

Single-Variable Scenarios: Renewables



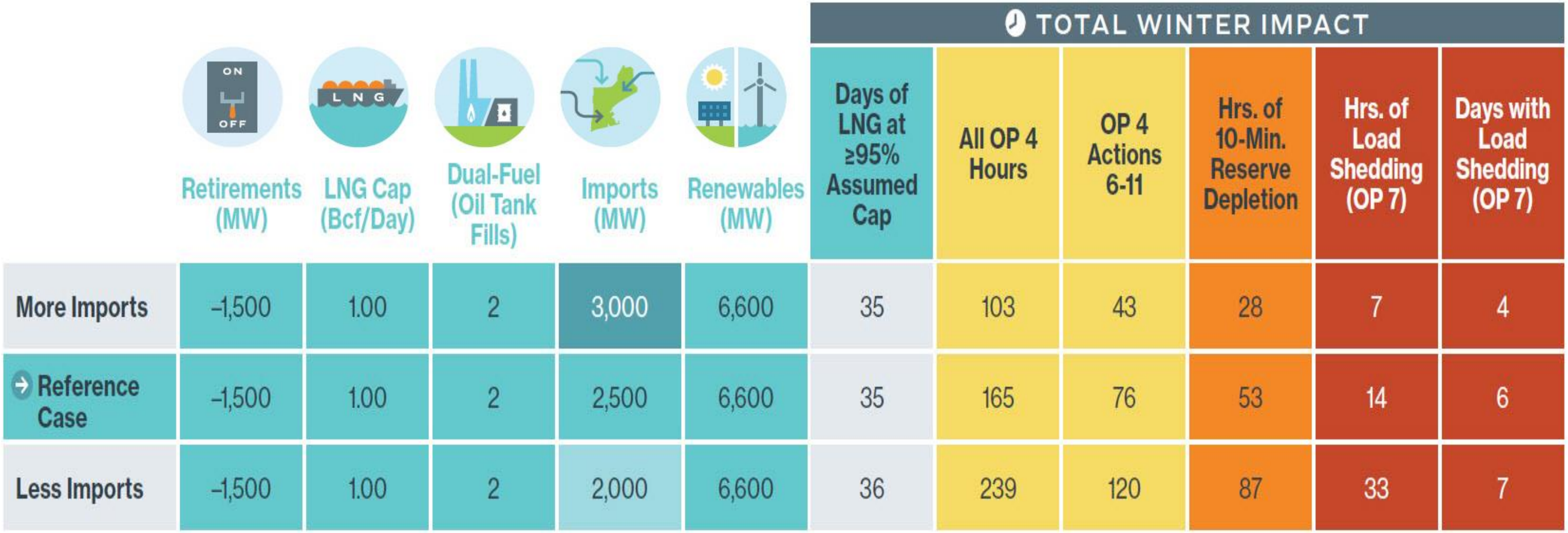
						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
More Renewables	-1,500	1.00	2	3,500	8,000	29	24	6	2	0	0
→ Reference Case	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6

Single-Variable Scenarios: LNG



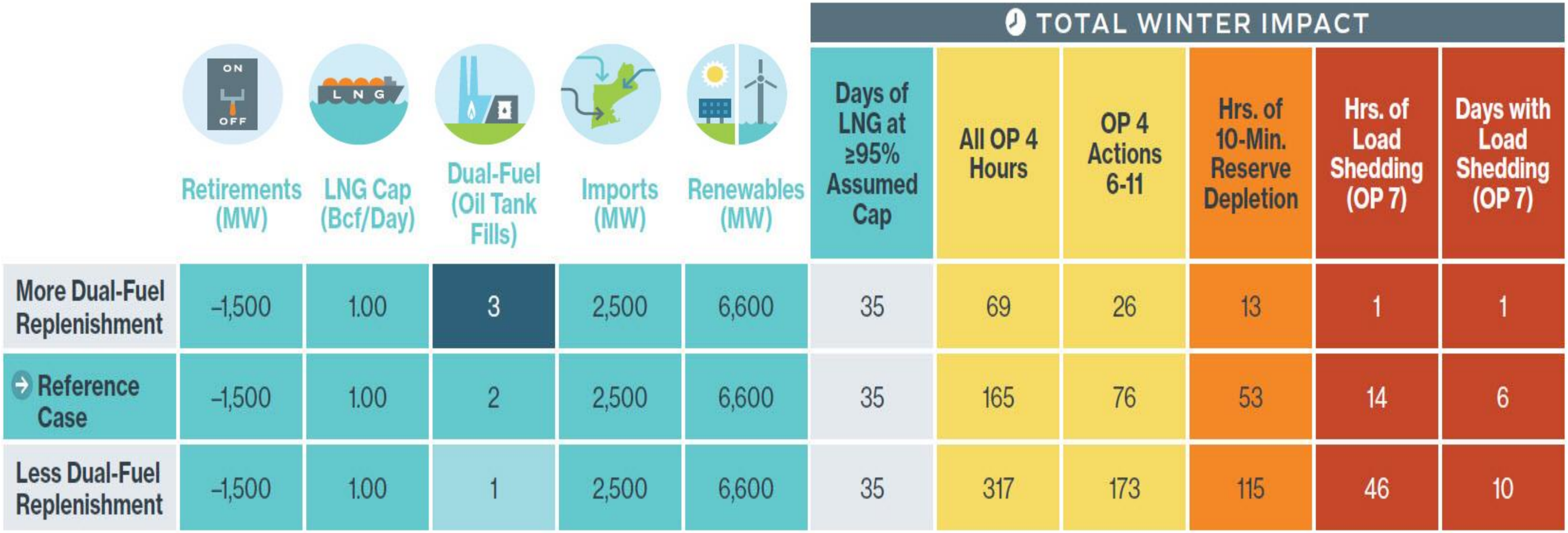
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	TOTAL WINTER IMPACT					
						Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
More LNG	-1,500	1.25	2	2,500	6,600	32	40	9	6	0	0
➔ Reference Case	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6
Less LNG	-1,500	0.75	2	2,500	6,600	39	355	208	153	58	10

Single-Variable Scenarios: Imports



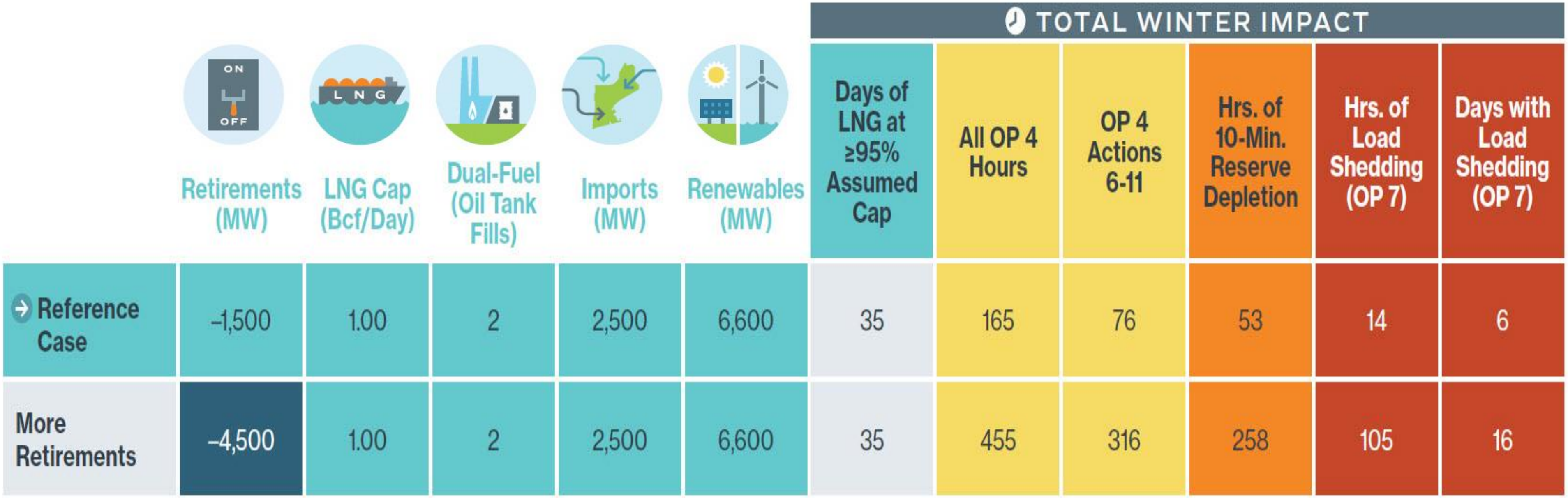
						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
More Imports	-1,500	1.00	2	3,000	6,600	35	103	43	28	7	4
→ Reference Case	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6
Less Imports	-1,500	1.00	2	2,000	6,600	36	239	120	87	33	7

Single-Variable Scenarios: Dual-Fuel Replenishment



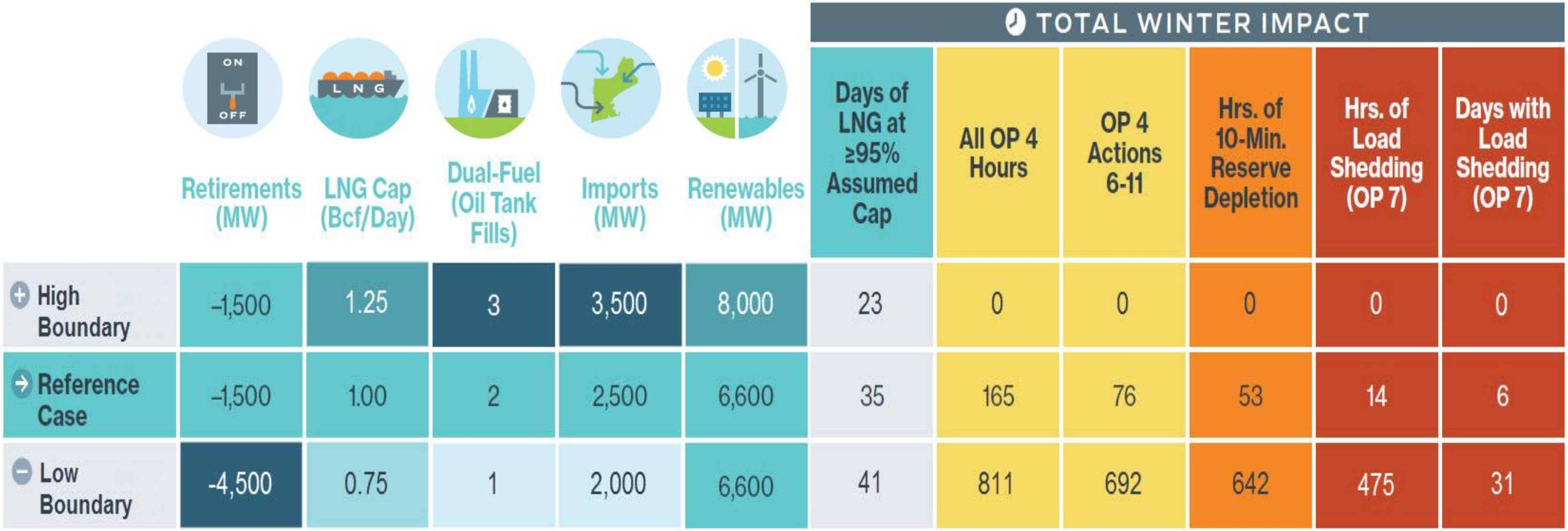
						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
More Dual-Fuel Replenishment	-1,500	1.00	3	2,500	6,600	35	69	26	13	1	1
→ Reference Case	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6
Less Dual-Fuel Replenishment	-1,500	1.00	1	2,500	6,600	35	317	173	115	46	10

Single-Variable Scenarios: Retirements



						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Reference Case	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6
More Retirements	-4,500	1.00	2	2,500	6,600	35	455	316	258	105	16

Boundary Cases

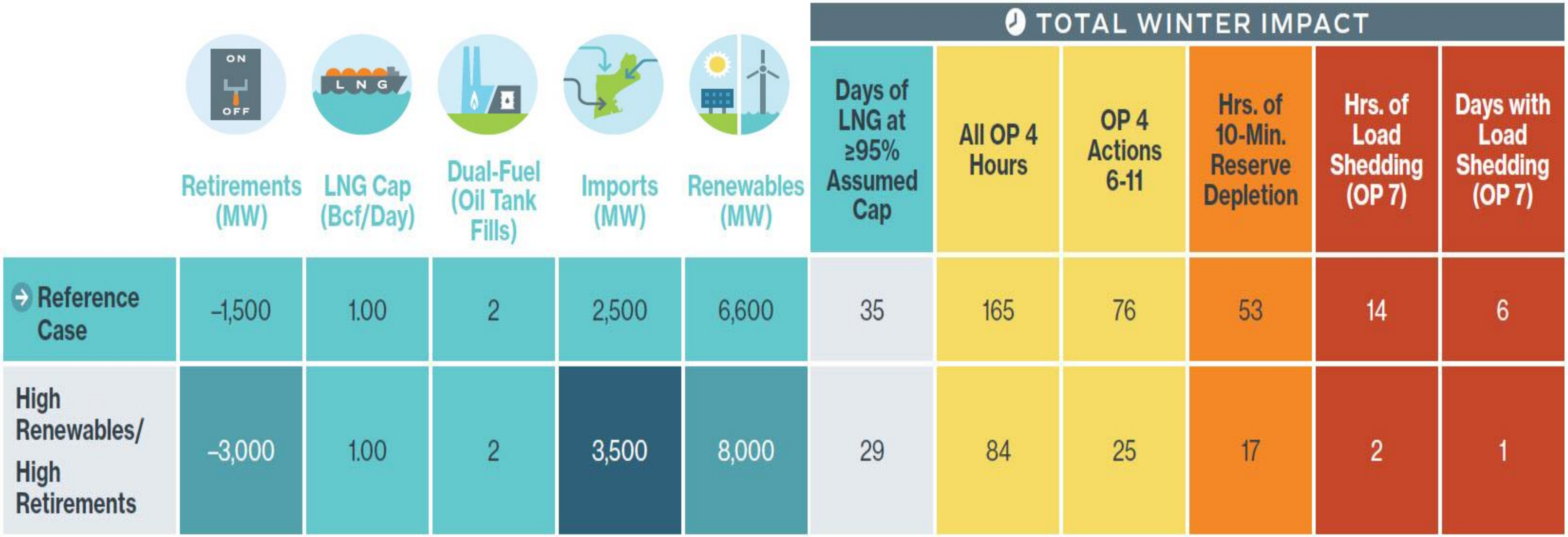


						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
+ High Boundary	-1,500	1.25	3	3,500	8,000	23	0	0	0	0	0
→ Reference Case	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6
− Low Boundary	-4,500	0.75	1	2,000	6,600	41	811	692	642	475	31

Combination Scenarios: LNG

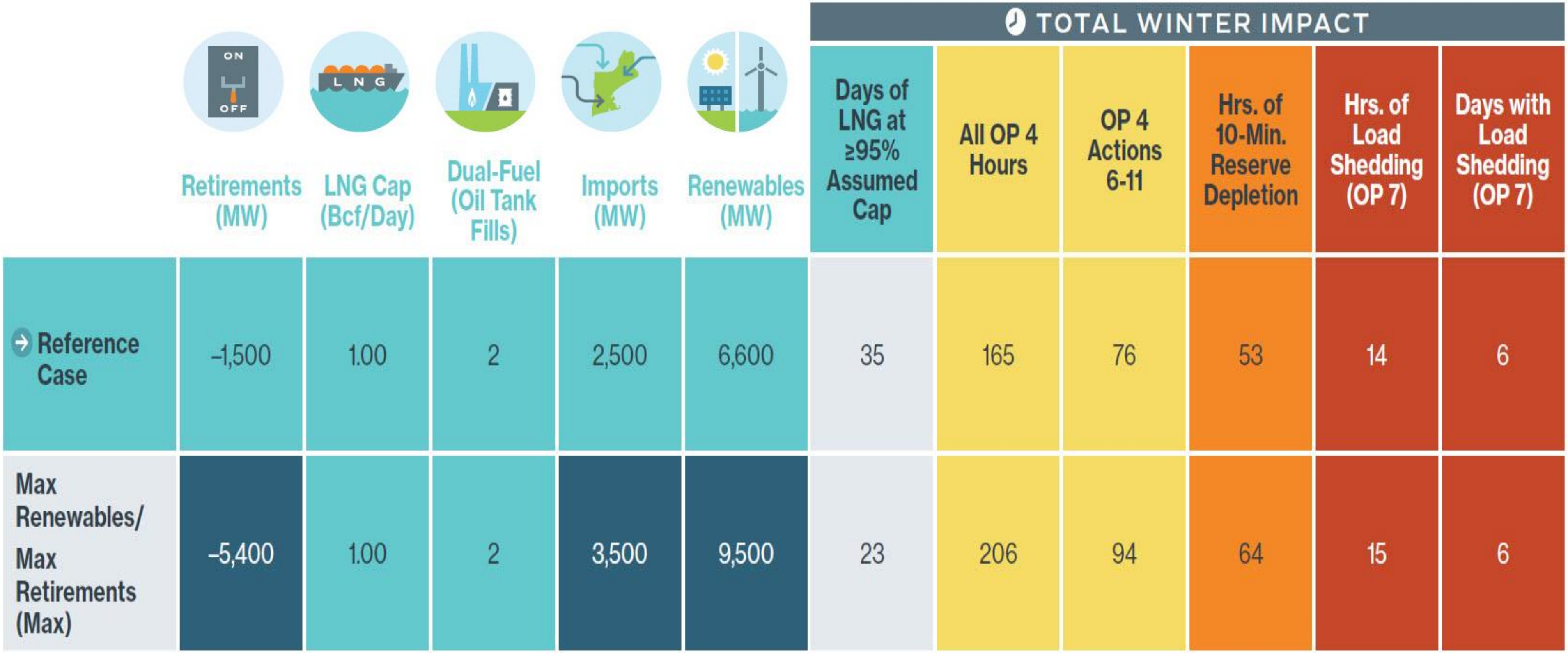
						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
→ **Reference Case**	-1,500	1.00	2	2,500	6,600	35	165	76	53	14	6
High LNG/ High Renewables/ Higher Retirements	-4,000	1.25	2	3,500	8,000	23	18	4	2	0	0
Low LNG/ High Renewables/ Higher Retirements	-4,000	0.75	2	3,500	8,000	35	358	200	154	56	12

Combination Scenarios: High Retirements & High Renewables



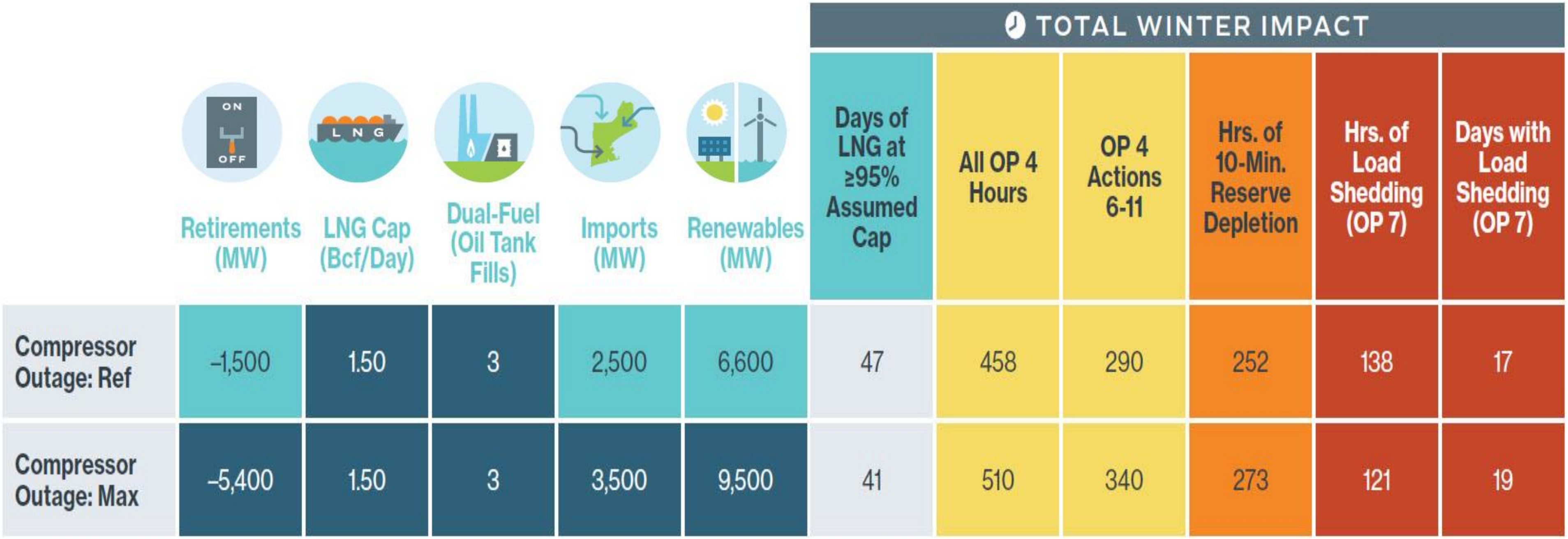
						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Reference Case	–1,500	1.00	2	2,500	6,600	35	165	76	53	14	6
High Renewables/ High Retirements	–3,000	1.00	2	3,500	8,000	29	84	25	17	2	1

Combination Scenarios: Maximum Renewables/ Maximum Retirements (Max)



						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
→ Reference Case	–1,500	1.00	2	2,500	6,600	35	165	76	53	14	6
Max Renewables/ Max Retirements (Max)	–5,400	1.00	2	3,500	9,500	23	206	94	64	15	6

Outage Scenarios: Compressor

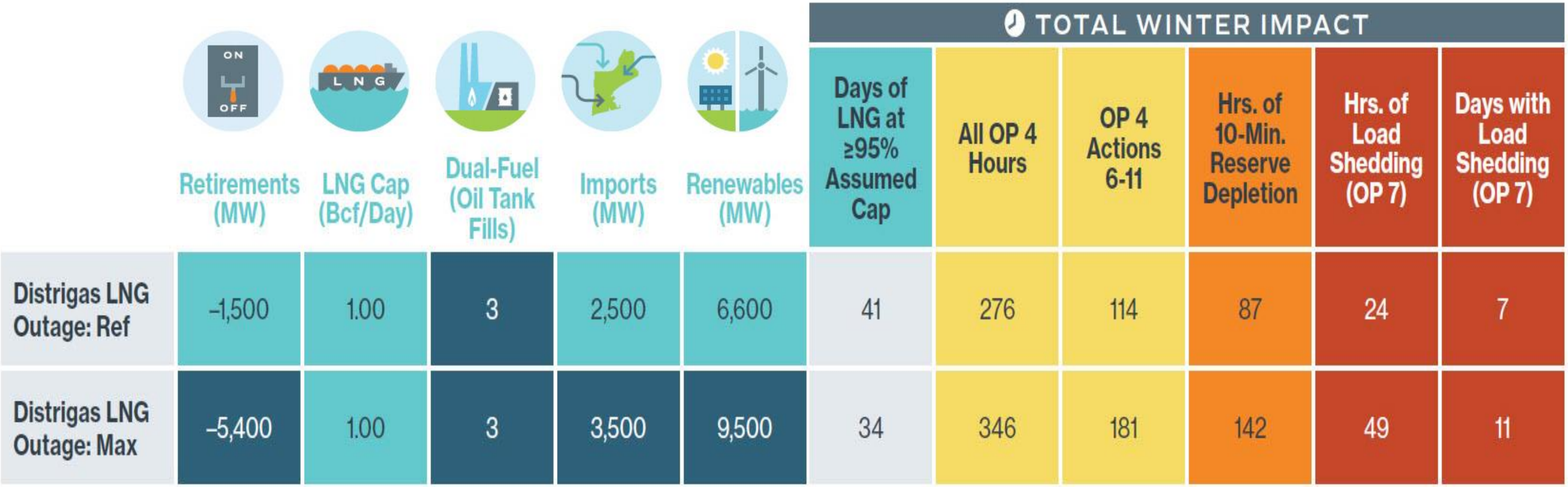


	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	TOTAL WINTER IMPACT					
						Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Compressor Outage: Ref	–1,500	1.50	3	2,500	6,600	47	458	290	252	138	17
Compressor Outage: Max	–5,400	1.50	3	3,500	9,500	41	510	340	273	121	19

Outage Scenarios: Millstone Nuclear Plant

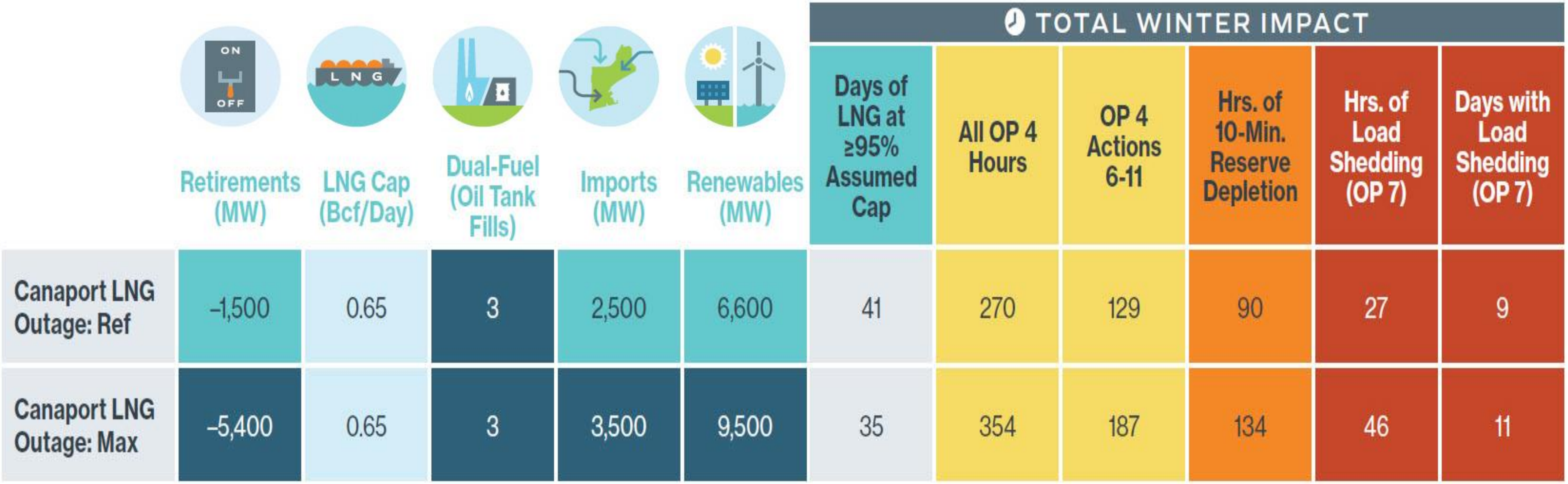
						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Millstone Nuclear Outage: Ref	–1,500	1.00	3	2,500	6,600	42	349	166	124	47	10
Millstone Nuclear Outage: Max	–5,400	1.00	3	3,500	9,500	36	389	243	193	70	12

Outage Scenarios: Distrigas LNG



						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Distrigas LNG Outage: Ref	-1,500	1.00	3	2,500	6,600	41	276	114	87	24	7
Distrigas LNG Outage: Max	-5,400	1.00	3	3,500	9,500	34	346	181	142	49	11

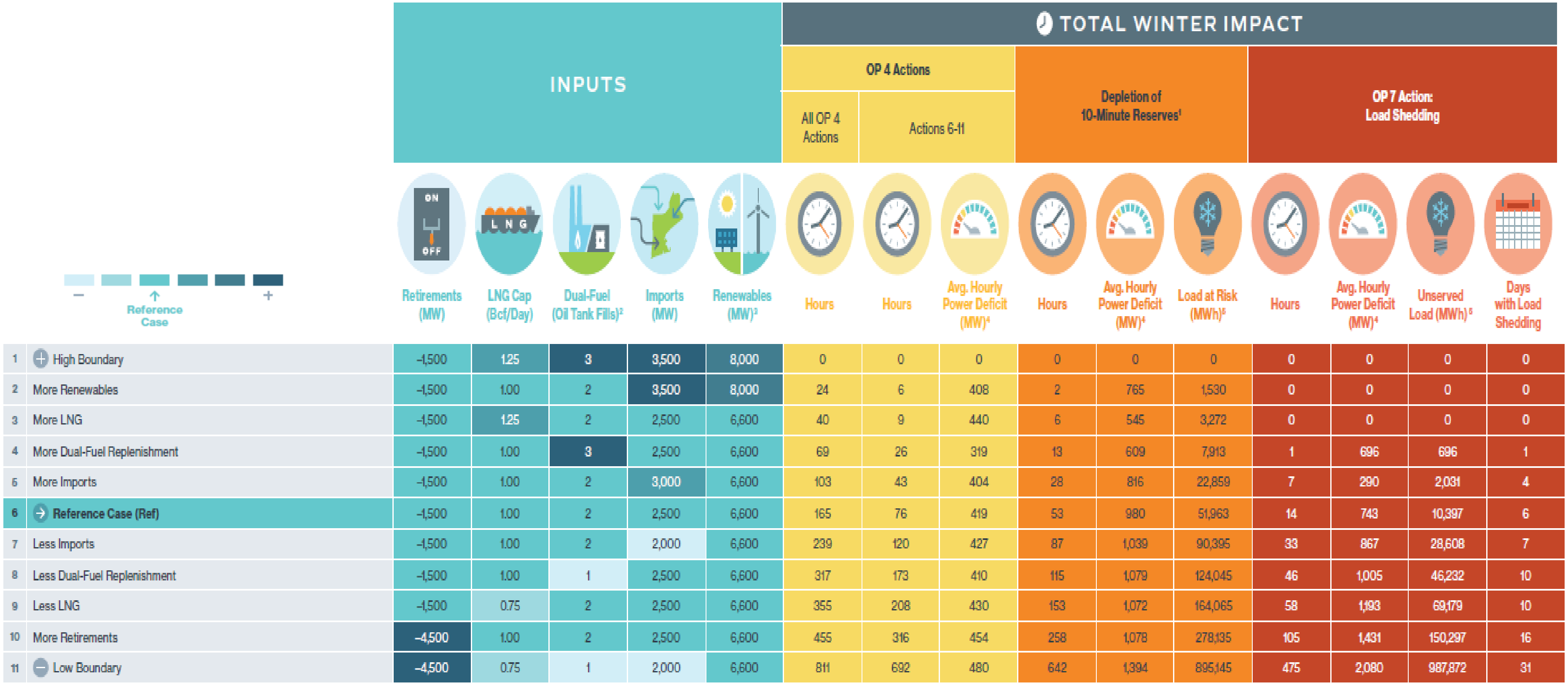
Outage Scenarios: Canaport LNG



						TOTAL WINTER IMPACT					
	Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)	Imports (MW)	Renewables (MW)	Days of LNG at ≥95% Assumed Cap	All OP 4 Hours	OP 4 Actions 6-11	Hrs. of 10-Min. Reserve Depletion	Hrs. of Load Shedding (OP 7)	Days with Load Shedding (OP 7)
Canaport LNG Outage: Ref	–1,500	0.65	3	2,500	6,600	41	270	129	90	27	9
Canaport LNG Outage: Max	–5,400	0.65	3	3,500	9,500	35	354	187	134	46	11

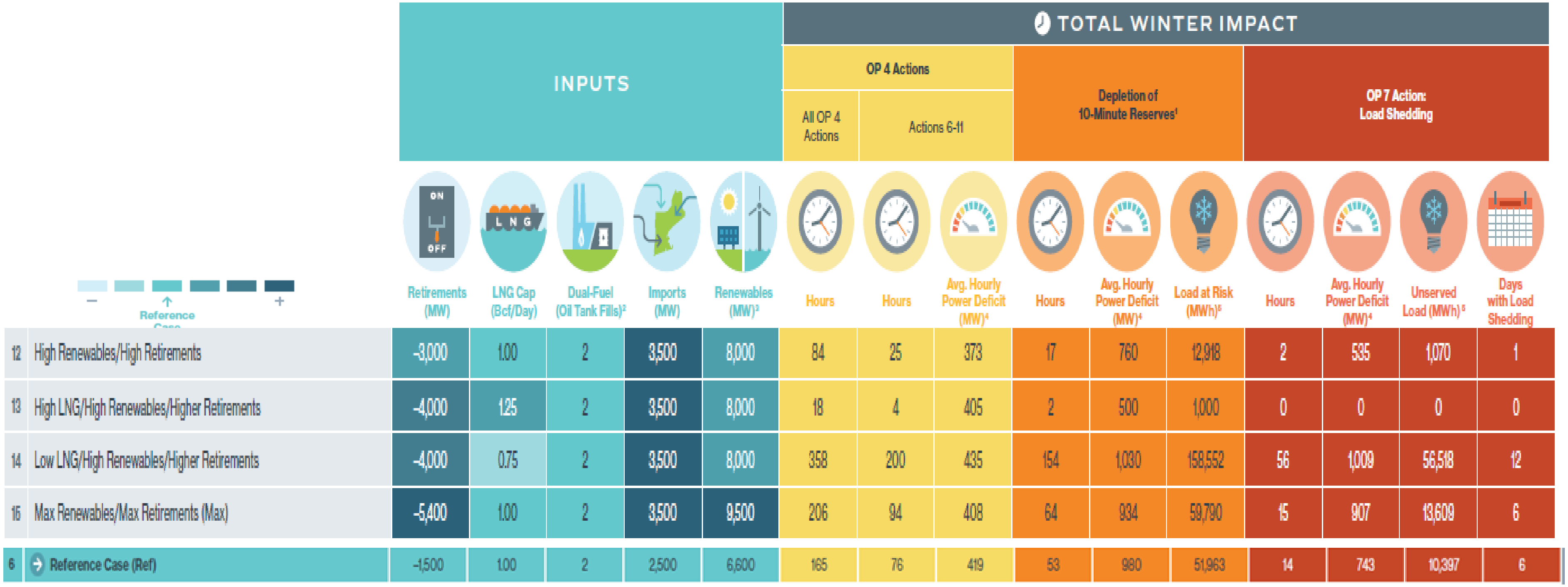
SUMMARY OF STUDY RESULTS

Reference Case (i.e., Current Trends) and Single-Variable Scenarios



		INPUTS					TOTAL WINTER IMPACT									
							OP 4 Actions			Depletion of 10-Minute Reserves[1]			OP 7 Action: Load Shedding			
							All OP 4 Actions	Actions 6-11								
		Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)[2]	Imports (MW)	Renewables (MW)[3]	Hours	Hours	Avg. Hourly Power Deficit (MW)[4]	Hours	Avg. Hourly Power Deficit (MW)[4]	Load at Risk (MWh)[5]	Hours	Avg. Hourly Power Deficit (MW)[4]	Unserved Load (MWh)[5]	Days with Load Shedding
1	+ High Boundary	-1,500	1.25	3	3,500	8,000	0	0	0	0	0	0	0	0	0	0
2	More Renewables	-1,500	1.00	2	3,500	8,000	24	6	408	2	765	1,530	0	0	0	0
3	More LNG	-1,500	1.25	2	2,500	6,600	40	9	440	6	545	3,272	0	0	0	0
4	More Dual-Fuel Replenishment	-1,500	1.00	3	2,500	6,600	69	26	319	13	609	7,913	1	696	696	1
5	More Imports	-1,500	1.00	2	3,000	6,600	103	43	404	28	816	22,859	7	290	2,031	4
6	→ **Reference Case (Ref)**	-1,500	1.00	2	2,500	6,600	165	76	419	53	980	51,963	14	743	10,397	6
7	Less Imports	-1,500	1.00	2	2,000	6,600	239	120	427	87	1,039	90,395	33	867	28,608	7
8	Less Dual-Fuel Replenishment	-1,500	1.00	1	2,500	6,600	317	173	410	115	1,079	124,045	46	1,005	46,232	10
9	Less LNG	-1,500	0.75	2	2,500	6,600	355	208	430	153	1,072	164,065	58	1,193	69,179	10
10	More Retirements	-4,500	1.00	2	2,500	6,600	455	316	454	258	1,078	278,135	105	1,431	150,297	16
11	– Low Boundary	-4,500	0.75	1	2,000	6,600	811	692	480	642	1,394	895,145	475	2,080	987,872	31

Combination Scenarios

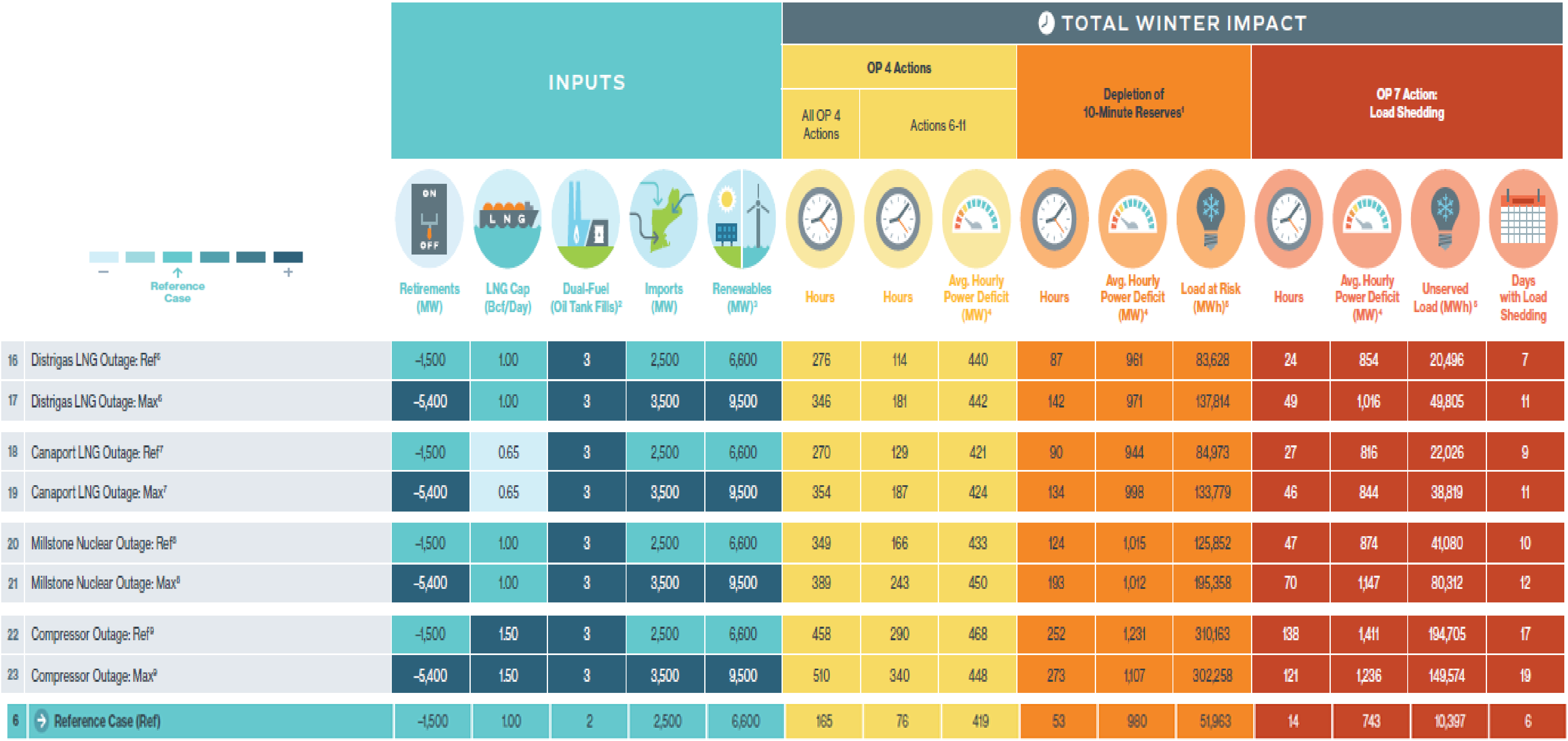


		INPUTS					TOTAL WINTER IMPACT									
							OP 4 Actions			Depletion of 10-Minute Reserves[1]			OP 7 Action: Load Shedding			
							All OP 4 Actions	Actions 6-11								
		Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)[2]	Imports (MW)	Renewables (MW)[3]	Hours	Hours	Avg. Hourly Power Deficit (MW)[4]	Hours	Avg. Hourly Power Deficit (MW)[4]	Load at Risk (MWh)[5]	Hours	Avg. Hourly Power Deficit (MW)[4]	Unserved Load (MWh)[5]	Days with Load Shedding
12	High Renewables/High Retirements	-3,000	1.00	2	3,500	8,000	84	25	373	17	760	12,918	2	535	1,070	1
13	High LNG/High Renewables/Higher Retirements	-4,000	1.25	2	3,500	8,000	18	4	405	2	500	1,000	0	0	0	0
14	Low LNG/High Renewables/Higher Retirements	-4,000	0.75	2	3,500	8,000	358	200	435	154	1,030	158,552	56	1,009	56,518	12
15	Max Renewables/Max Retirements (Max)	-5,400	1.00	2	3,500	9,500	206	94	408	64	934	59,790	15	907	13,609	6
6	Reference Case (Ref)	-1,500	1.00	2	2,500	6,600	165	76	419	53	980	51,963	14	743	10,397	6

1. Once reserves are depleted, any resource loss or transmission line trip that cuts imports would trigger load shedding.
2. Count assumed tanks were filled before winter, plus refilled during winter. For example, "2x" counted the initial full tank, plus one refill.
3. Cases with increased renewables also included increased imports to reflect expected additions of clean energy imports from Canada or New York.
4. On average, one megawatt (MW) of electricity can serve about 860 homes in New England, which has about 7.1 million retail customers, encompassing not just residential customers but also commercial and industrial.
5. A megawatt-hour (MWh) of electricity can serve about 860 homes for one hour in New England, on average.

Outage Scenarios

(Modeled on Ref and Max Cases; Assumed More Dual-Fuel Tank Fills)



		INPUTS					TOTAL WINTER IMPACT									
							OP 4 Actions			Depletion of 10-Minute Reserves[1]			OP 7 Action: Load Shedding			
							All OP 4 Actions	Actions 6-11								
		Retirements (MW)	LNG Cap (Bcf/Day)	Dual-Fuel (Oil Tank Fills)[2]	Imports (MW)	Renewables (MW)[3]	Hours	Hours	Avg. Hourly Power Deficit (MW)[4]	Hours	Avg. Hourly Power Deficit (MW)[4]	Load at Risk (MWh)[5]	Hours	Avg. Hourly Power Deficit (MW)[4]	Unserved Load (MWh)[5]	Days with Load Shedding
16	Distrigas LNG Outage: Ref[6]	-1,500	1.00	3	2,500	6,600	276	114	440	87	961	83,628	24	854	20,496	7
17	Distrigas LNG Outage: Max[6]	-5,400	1.00	3	3,500	9,500	346	181	442	142	971	137,814	49	1,016	49,805	11
18	Canaport LNG Outage: Ref[7]	-1,500	0.65	3	2,500	6,600	270	129	421	90	944	84,973	27	816	22,026	9
19	Canaport LNG Outage: Max[7]	-5,400	0.65	3	3,500	9,500	354	187	424	134	998	133,779	46	844	38,819	11
20	Millstone Nuclear Outage: Ref[8]	-1,500	1.00	3	2,500	6,600	349	166	433	124	1,015	125,852	47	874	41,080	10
21	Millstone Nuclear Outage: Max[8]	-5,400	1.00	3	3,500	9,500	389	243	450	193	1,012	195,358	70	1,147	80,312	12
22	Compressor Outage: Ref[9]	-1,500	1.50	3	2,500	6,600	458	290	468	252	1,231	310,163	138	1,411	194,705	17
23	Compressor Outage: Max[9]	-5,400	1.50	3	3,500	9,500	510	340	448	273	1,107	302,258	121	1,236	149,574	19
6	Reference Case (Ref)	-1,500	1.00	2	2,500	6,600	165	76	419	53	980	51,963	14	743	10,397	6