MARCH 18, 2020 | WEBEX

ANBARIC 2019 Economic Study - Offshore Wind Results

Planning Advisory Committee Meeting

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Highlights

- Today's presentation discusses the ANBARIC 2019 Economic Study for scenarios with 8,000 to 12,000 MW of offshore wind (OSW) additions in southern New England.
- The addition of 8,000 to 12,000 MW of OSW *plus* assumed resource retirements (nearly 4,500 MW) result in SEMA/RI export interface congestion.
- Interconnecting more OSW close to load centers outside of the SEMA and RI areas, e.g. Mystic and Millstone substations, would reduce the congestion hours of the SEMA/RI export interface.
- Demand from heat pumps and electric vehicles, depending on their alignment with OSW production, may cause more SEMA/RI export interface congestion.

Highlights, Cont.

- Location of battery storage matters and installing more storage in areas with large amount of OSW development, e.g. SEMA, RI, and Boston, would reduce congestion of the SEMA/RI export interface as compared with installing storage resources elsewhere.

- Retirement of large base load must run (nuclear) generation would lower spillage associated with over generation.

- An additional sensitivity was performed using a higher threshold price for NECEC. Results show total spillage remains the same regardless of the NECEC threshold price assumed.

BACKGROUND & ASSUMPTIONS

Three 2019 Economic Study Requests

- Requests were submitted by the New England States Committee on Electricity (NESCOE), Anbaric Development Partners (Anbaric) and RENEW Northeast (Renew).
  - Presented to the PAC on April 25, 2019.

Requester	Purpose of request
NESCOE	Impacts on transmission system and wholesale market of increasing penetration of offshore wind resources https://www.iso-ne.com/static-assets/documents/2019/04/a2_nescoe_2019_economic_study_request_presentation.pptx
Anbaric	Impacts on energy market prices air emissions of large penetration of offshore wind resources https://www.iso-ne.com/static-assets/documents/2019/04/anbaric_2019_economic_study_request.pdf
Renew	Economic impact of conceptual increases in hourly operating limits on the Orrington-South interface from conceptual transmission upgrades https://www.iso-ne.com/static-assets/documents/2019/04/a2_renew_2019_economic_study_request_presentation.pdf

- Draft scope of work and high-level assumptions for each of these requests were discussed with the PAC on May 21, 2019. More detailed assumptions were discussed on August 8, 2019, and a status update was given on November 20, 2019.
- Preliminary NESCOE results for cases up to 6,000 MW were presented on December 19, 2019, with a Q&A on January 23, 2020. Detailed results for the 8,000 MW cases were presented on February 20, 2020.

Preliminary Anbaric Results

- Key results are covered in the presentation with additional supporting results attached in the Appendix
  - Energy production by fuel type
  - Systemwide Production Costs
  - Annual average locational marginal prices (LMPs)
  - Load-serving energy expense and uplift
  - Congestion by Interface
  - Native New England resource CO_2 Emissions
  - Renewable Spillage

Disclaimer:

- All results use the 2015 solar and wind profiles. The results are specific to the 2015 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.
- Curtailment of specific resources is driven by the threshold prices. Therefore, different prices and/or order may result in different outcomes.
- Production cost simulations were performed under two conditions: Unconstrained and Constrained. Unconstrained transmission is modeled as a one-bus system while constrained transmission is modeled using the “Pipe and RSP Bubble” configuration. Refer to Slide 54 for details.

Summary: Anbaric 2030 Scenarios Model Varying Degrees of Resource Expansions

<table>
<tr><th>Scenario</th><th>Gross Demand</th><th>EE</th><th>Behind-the-Meter PV (Nameplate)</th><th>Utility Scale PV (Nameplate)</th><th>Supply (incl. Demand Resources)</th><th>Retirements</th><th>RFP Committed Generation</th><th>Off-Shore Wind Additions (Nameplate)</th><th>Demand from Heat Pumps</th><th>Demand from Electric Vehicles</th><th>Battery Storage Additions</th></tr>
<tr><td>Anbaric_0
(Reference)</td><td colspan="4" rowspan="5">Based on 2019 CELT Forecast</td><td rowspan="5">2019 CELT generators and FCA 13 cleared resources</td><td rowspan="5">FCA 13, Mystic 8 & 9, 2,000 MW of nuclear[1] generation, 2,494 MW of oil units in CT and ME[2]</td><td>NECEC (1,090 MW of firm import) [3]</td><td>0 MW</td><td rowspan="4">None</td><td rowspan="4">None</td><td rowspan="4">2,000 MW</td></tr>
<tr><td>Anbaric_8000</td><td rowspan="4">NECEC (1,090 MW of firm import) [3] 2,300 MW of off-shore wind (nameplate) [4]</td><td>5,700 MW</td></tr>
<tr><td>Anbaric_10000</td><td>7,700 MW</td></tr>
<tr><td>Anbaric_12000</td><td>9,700 MW</td></tr>
<tr><td>Anbaric_10000_Sen (Electrification)</td><td>7,700 MW</td><td>2,050 MW</td><td>550,000 vehicles[5]</td><td>4,000 MW</td></tr>
</table>

[1] Generation at Seabrook and Millstone reduced by a total of 2,000 MW, proportionally to their Seasonal Claimed Capacity.

[2] No more coal units in Connecticut and Maine. All remaining coal units are located in New Hampshire.

[3] The transfer limit of the Surowiec South interface is kept at 1,500 MW in the Anbaric study (See Slide 54).

[4] Includes 1,600 MW from Massachusetts RFPs, 300 MW from Connecticut RFPs and 400 MW from Rhode Island RFPs.

[5] See Slide 62 for electric vehicle assumption.

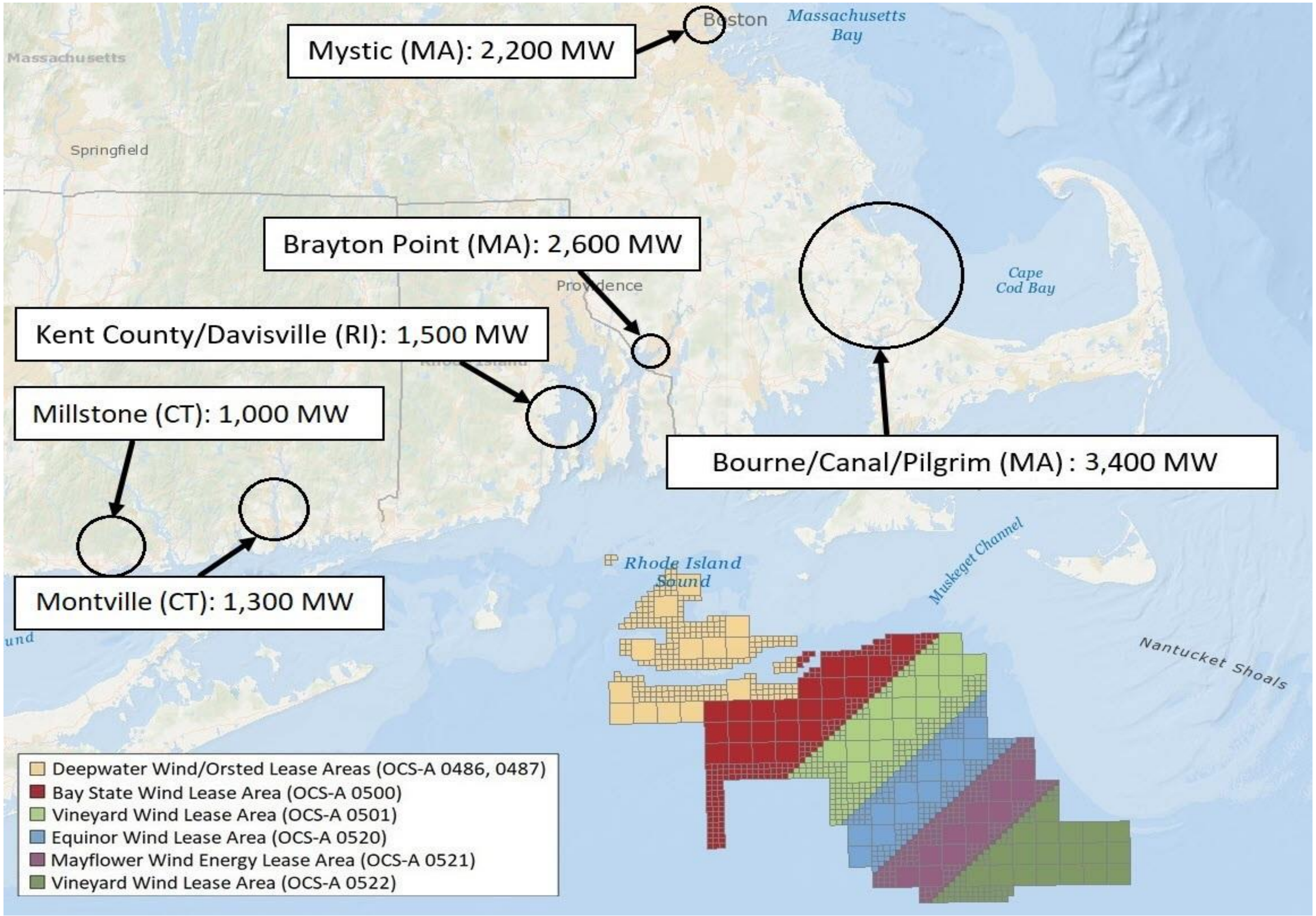
Threshold Prices are Used to Decrease Production of $0/MWh Resources During Oversupply

*Use of different threshold prices than indicated will produce different outcomes, **particularly spillage of resources***

Price-Taking Resource	Threshold Price ($/MWh)
Behind-the-Meter PV	1
NECEC (1,090 MW)	2 11 (sensitivity)*
Utility Scale PV	3
Onshore/Offshore Wind	4
New England Hydro	4.5
Imports from Hydro Quebec (HQ) including Highgate & Phase II	5
Imports from New Brunswick (NB)	10

*Under base assumptions, NB imports, HQ imports, New England hydro, and Utility PV would be curtailed before curtailing NECEC . A set of NECEC sensitivity scenarios were performed assuming a higher threshold price of $11/MWh for NECEC that would result in curtailing NECEC energy first before curtailing other resources.

Locations of OSW Sites and Interconnection Points used for the 12,000 MW OSW Scenario



Approximate locations shown

Scenarios Studied

- The Anbaric 2019 economic study covered the following scenarios under transmission constrained and unconstrained cases:
  - Unconstrained transmission is modeled as a one-bus system, while constrained transmission is modeled using the RSP pipe and bubble configuration

Anbaric Scenarios	NECEC Threshold Price	OSW Addition SEMA & RI[4] (MW)	OSW Addition BOSTON (MW)	OSW Addition CONNECTICUT (MW)
0 (Reference)	$2/MWh[1]	0	0	0
8,000		6,000	1,200	800
10,000		7,500	1,200	1,300
10,000_Sen				
12,000		7,500	2,200	2,300
0_Thresh[3]	$11/MWh[2]	0	0	0
8,000_Thresh		6,000	1,200	800
10,000_Thresh		7,500	1,200	1,300
10,000_Sen_Thresh				
12,000_Thresh		7,500	2,200	2,300

[1] Base Assumption scenarios refer to Anbaric scenarios with NECEC threshold price of $2/MWh.
[2] NECEC Threshold Price Sensitivity scenarios refer to Anbaric scenarios with NECEC curtailment price of $11/MWh.
[3] "_Thresh" is the naming convention for the NECEC threshold price sensitivity scenarios.
[4] See Slide 51 for detailed OSW MW at each interconnection points.

BASE ASSUMPTION SCENARIOS RESULTS

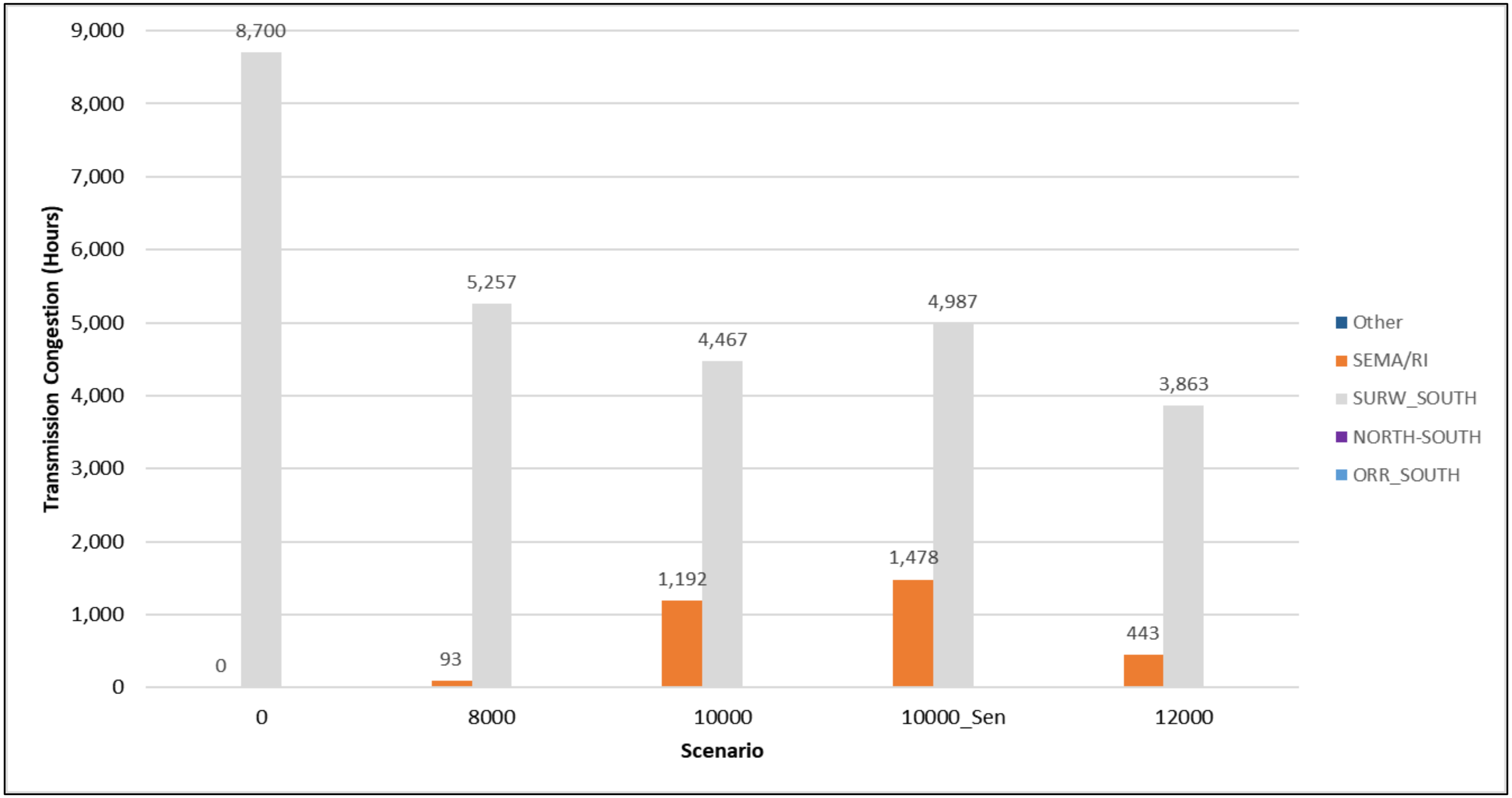
NECEC Threshold Price at $2/MWh

Includes Anbaric 0, 8000, 10000, 10000_Sen, and 12000 Scenarios

Key Observations

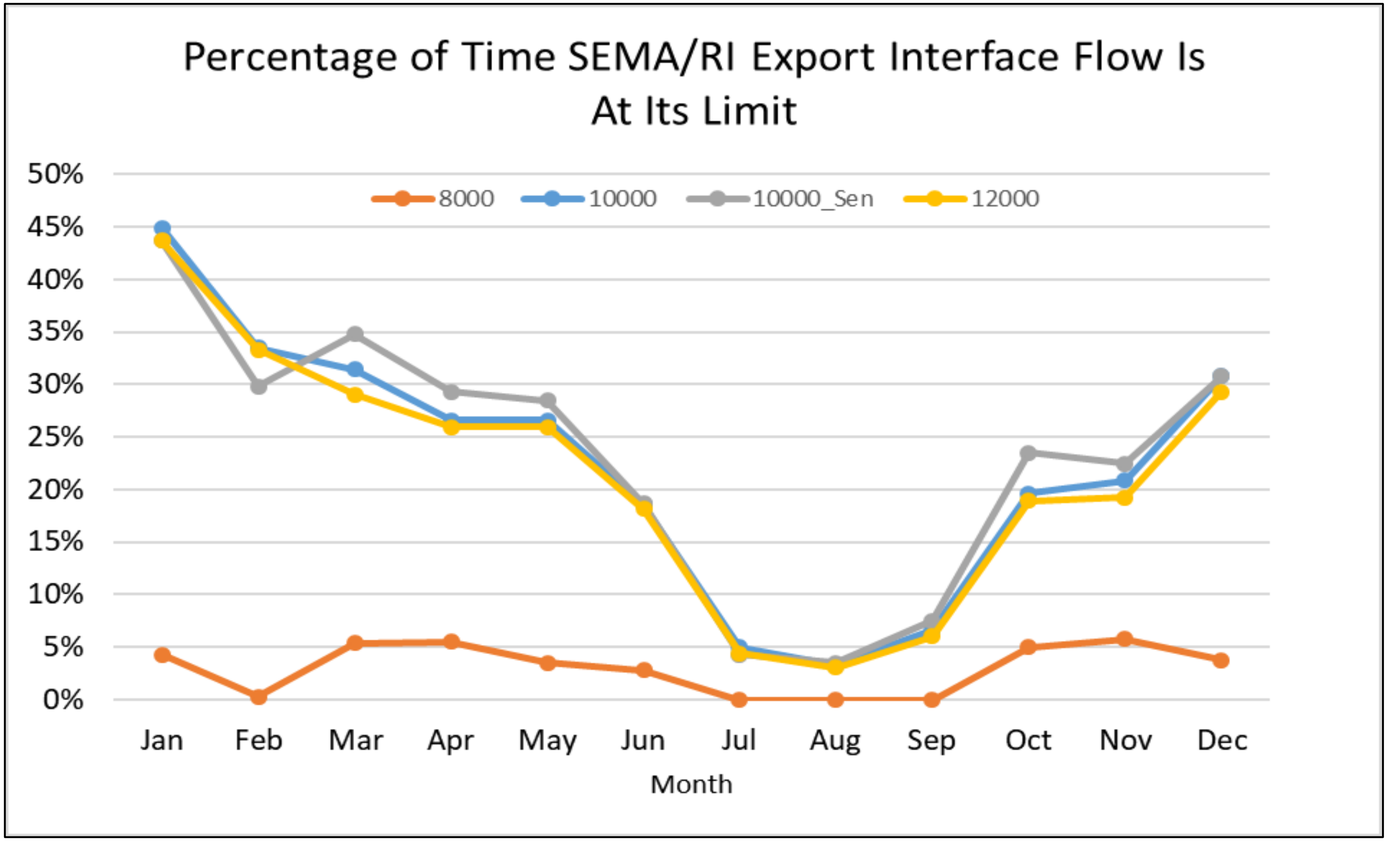
- Addition of 8,000 to 12,000 MW of OSW *plus* assumed resource retirements result in SEMA/RI export interface congestion
  - SEMA/RI export interface congestion hours are in the range of 93 to 1,478 hours per year.
  - Interconnecting more OSW close to other load centers, e.g. Mystic and Millstone substations, would provide supply to local demand; therefore, reducing SEMA/RI export interface congestion as seen in the 12000 MW scenario.
- Electrification adds a total of approximately 5 TWh of demand annually in the Anbaric 10000_Sen scenario
  - Demand from heat pumps and electric vehicles, depending on their alignment with OSW production, may cause more frequent SEMA/RI export interface congestion.
- There is spillage, due to overproduction, in all Anbaric scenarios
  - Electrification would help to lower the OSW spillage by 1.15 TWh, which is 23% of the total OSW spillage.

Congestion by Interface (Hours)



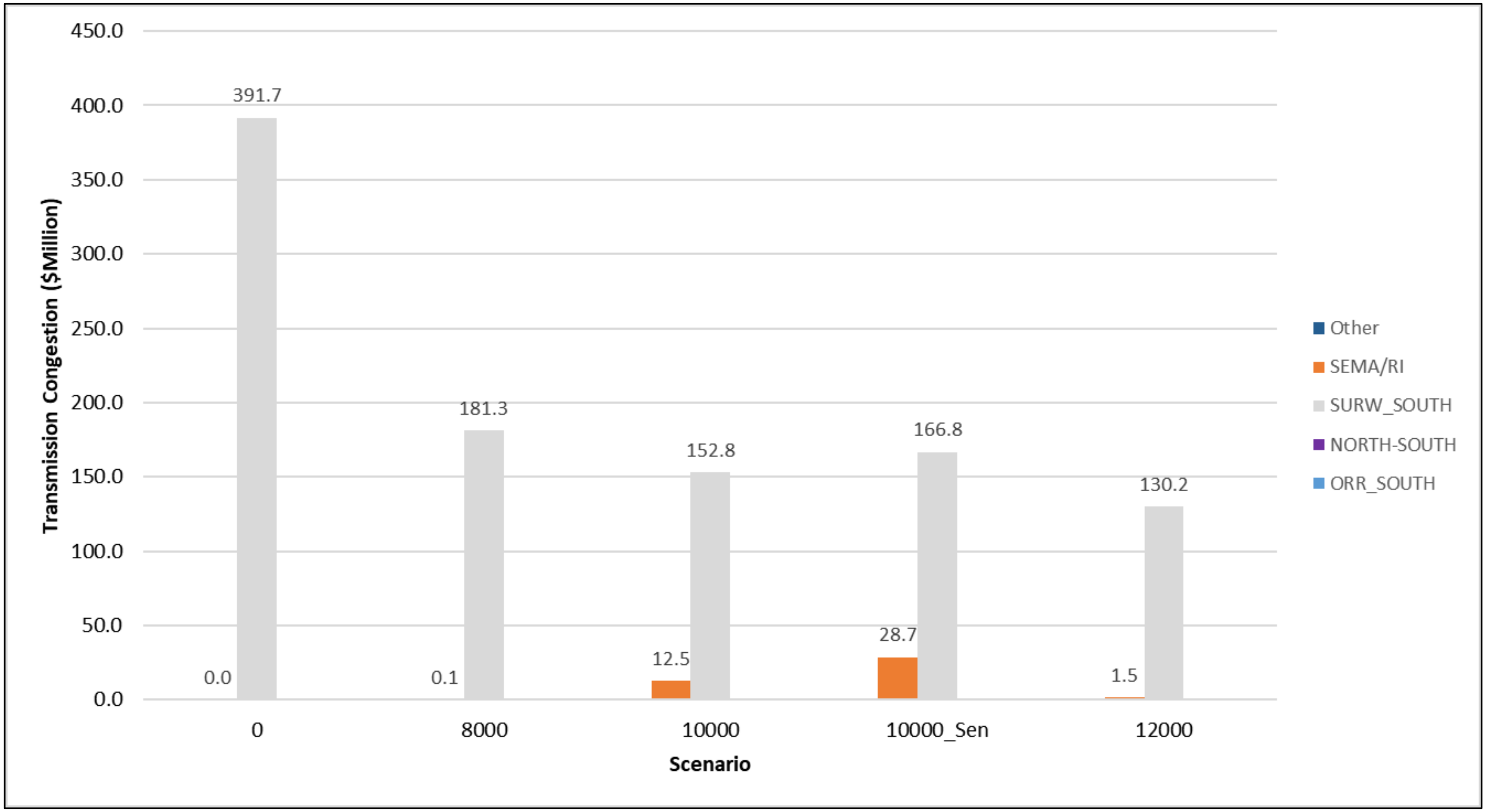
SEMA/RI export interface is congested in the 8,000 to 12,000 MW scenarios because more OSW generation is required to serve load outside of the SEMA and RI areas with the assumed nuclear retirements and majority of the OSW development concentrates in the SEMA and RI areas. Surowiec South interface is heavily constrained assuming a transfer limit of 1,500 MW. Results barely show other transmission constraints.

SEMA/RI Export Interface Congestion by Month



SEMA/RI export interface is congested more frequently with the addition of 10,000 MW or more OSW. SEMA/RI export interface congestion occurs most often in the winter months, followed by the shoulder months. The SEMA/RI interface is least congested in the summer months.

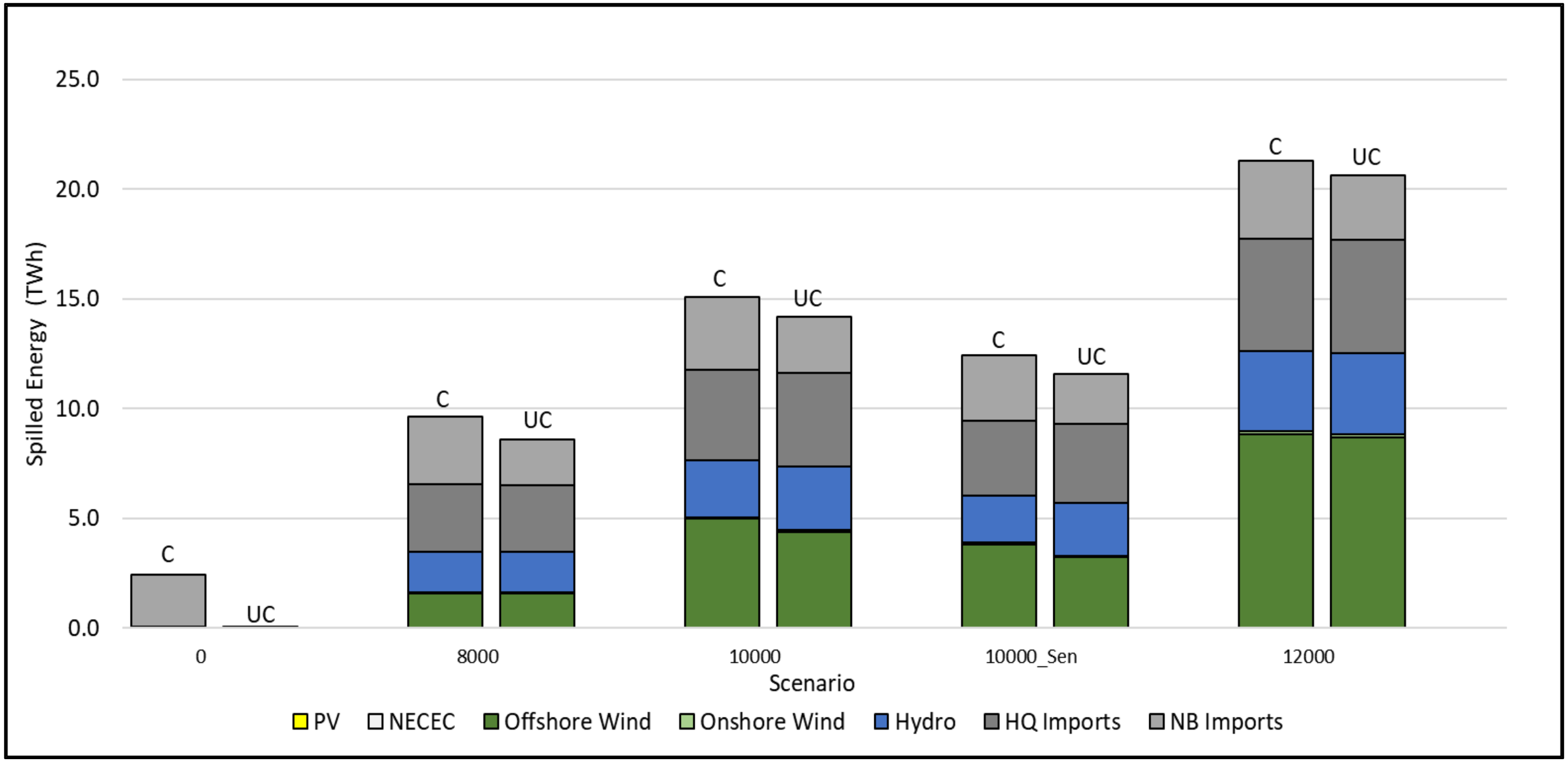
Congestion by Interface ($ Million)



SEMA/RI export interface congestion costs are the highest in the 10,000 MW OSW scenarios. Congestion costs in the 12,000 MW scenario is low because of lower shadow prices caused by the additional 2,000 MW of OSW (modeled in Boston and Connecticut) depressing LMPs outside of the SEMA and RI areas. There is barely any other congestion except for the SEMA/RI export interface and the Surowiec South interface.

Total Amount of Spilled Resource Energy (TWh)

*For Constrained ("C") and Unconstrained ("UC") Transmission**

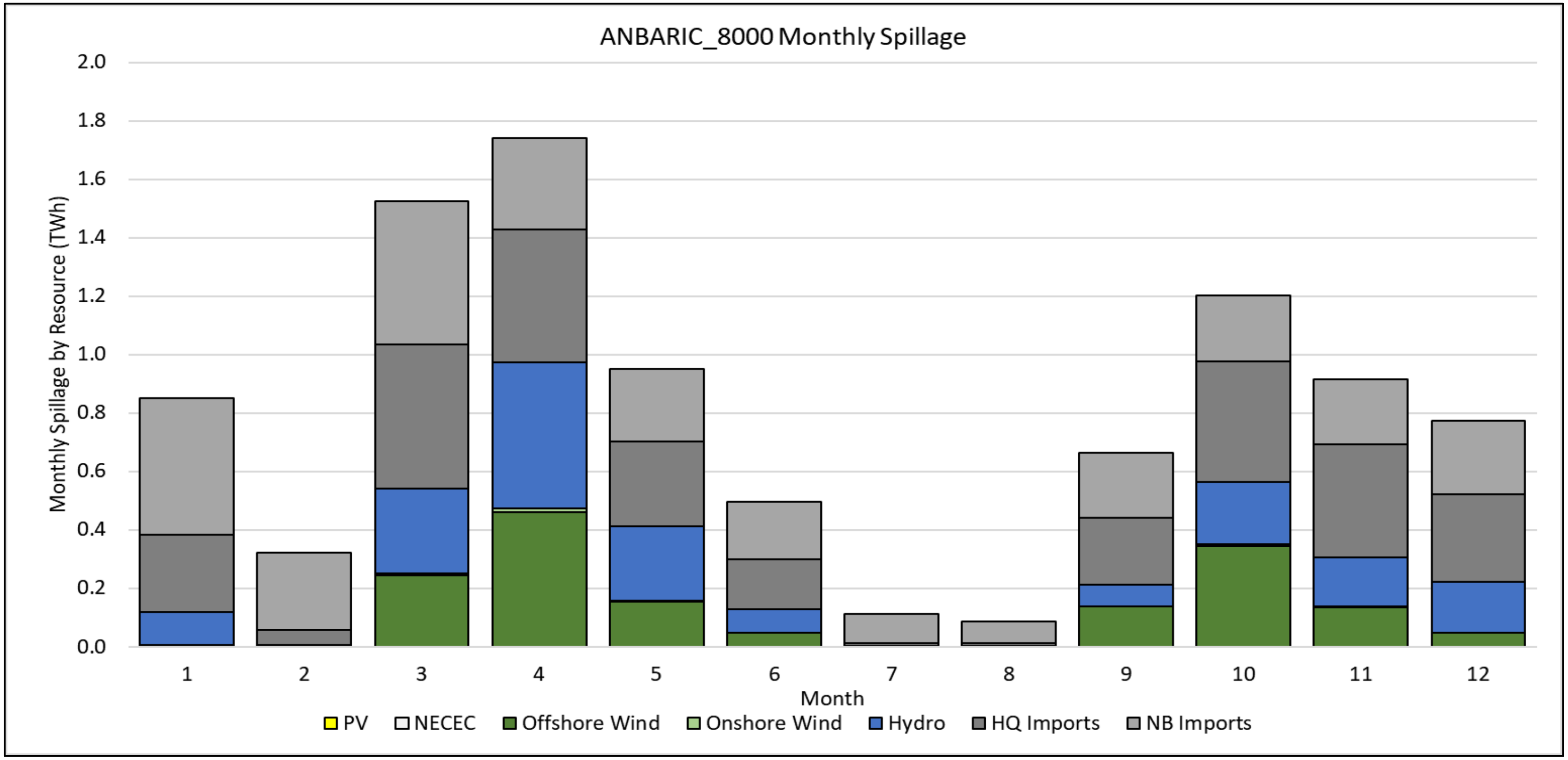


Spillage of OSW increases with higher wind penetration. Additional demand from electrification decreases spillage of renewables (primarily OSW and hydro) and total spilled energy. There is barely any spillage of onshore wind or PV across all scenarios.

* Wholesale Market Impact analyses was performed under two conditions: Unconstrained and Constrained. Unconstrained transmission is modeled as a one-bus system while constrained transmission is modeled using the "Pipe and RSP Bubble" configuration. See slide 56 for details.

Resource Energy Spilled Each Month

Anbaric 8,000 MW OSW Scenario



Spillage varies by month, ranging from 0.09 TWh in August to 1.74 TWh in April. Total spillage of OSW and hydro is 3.44 TWh in the Anbaric 8,000 MW scenario. OSW is being spilled the most in April due to high wind production and low demand. There is virtually no spillage of OSW in several summer and winter months.

NECEC THRESHOLD PRICE SENSITIVITY RESULTS

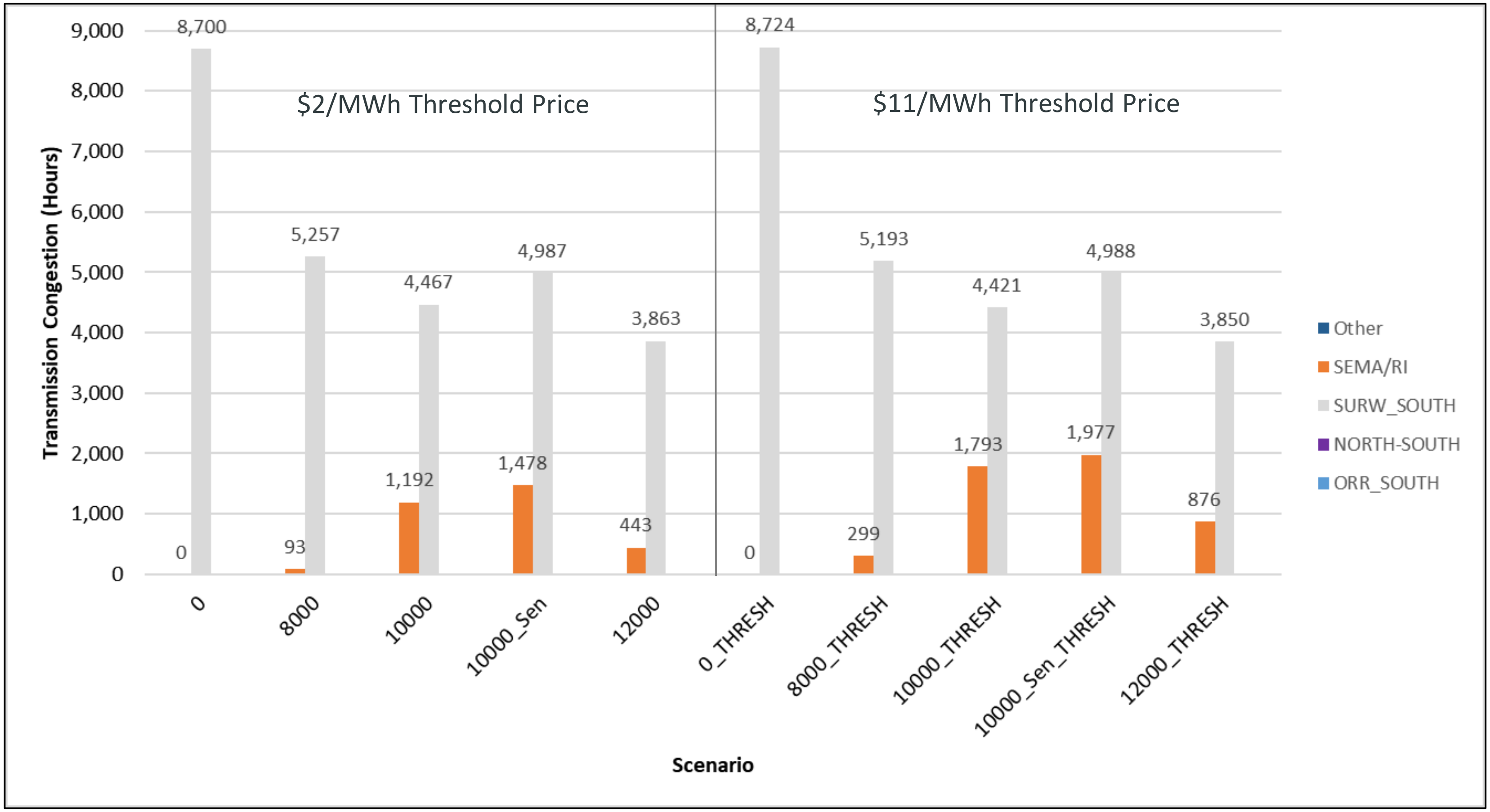
NECEC Threshold Price at $11/MWh

Includes Anbaric 0_Thresh, 8000_Thresh, 10000_Thresh, 10000_Sen_Thresh, and 12000_Thresh Scenarios

Key Observations

- When a higher threshold price of $11/MWh is modeled, NECEC is curtailed before all other price-taking resources, including native hydro, wind, PV, and existing imports from NB and HQ .
  - Production costs and carbon emissions remain the same
  - LSEEE is slightly higher and uplift is slightly lower due to higher LMPs
- SEMA/RI export interface congestion is more frequent in the NECEC threshold price sensitivity scenarios, ranging from 299 to 1,977 hours per year.
- Total spillage remains the same regardless of the NECEC threshold price sensitivity.
  - Spillage of NECEC significantly increases, while spillage of NB imports, HQ imports, hydro and offshore wind is greatly reduced.

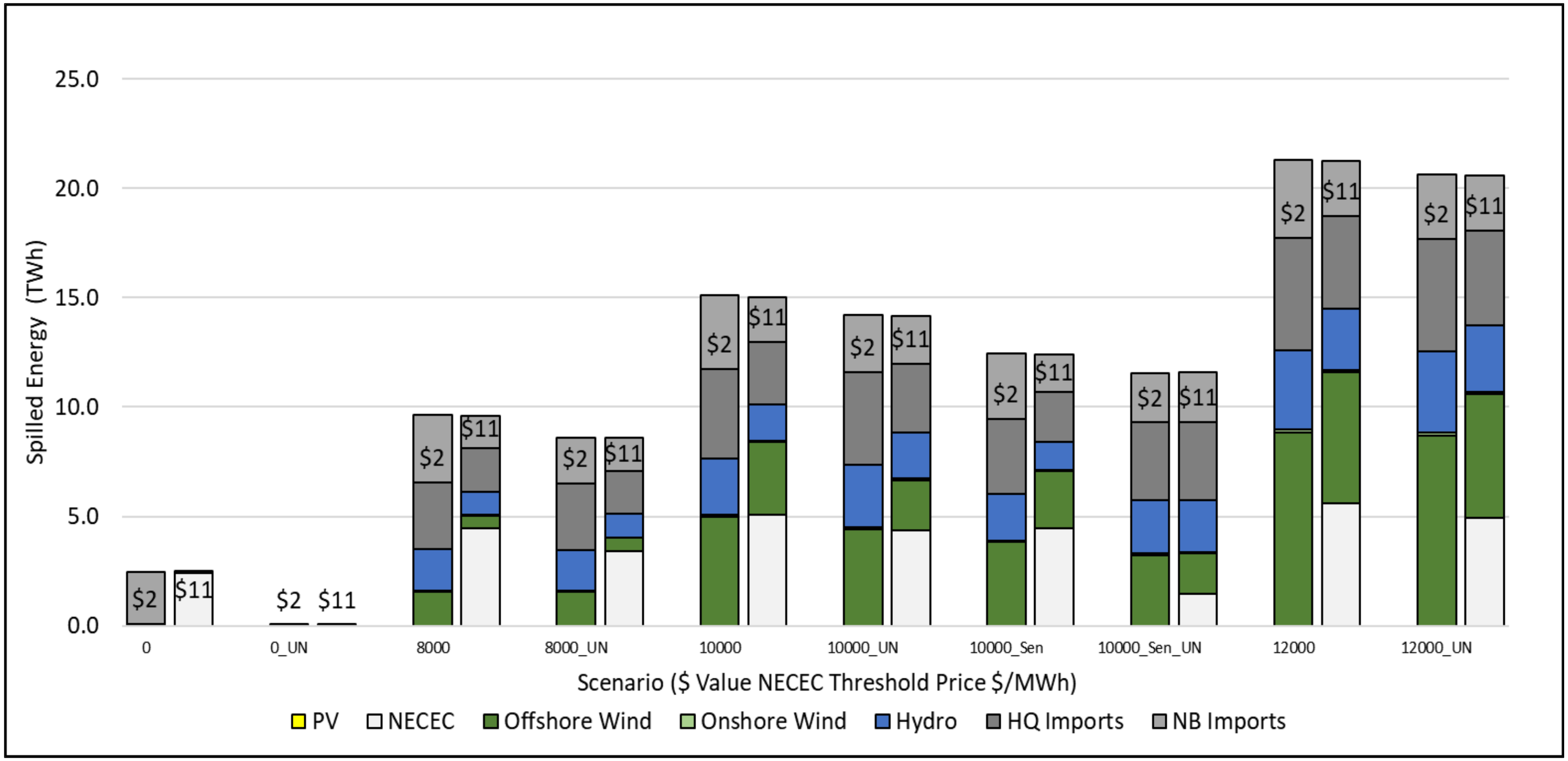
Congestion by Interface (Hours)



SEMA/RI export interface is congested more frequently in the NECEC threshold price sensitivity scenarios while Surowiec South interface is congested less frequently. This is because NECEC would be spilled (1,090 MW) when LMPs are below $11/MWh, therefore more energy from OSW would be required to meet the demand. There is barely other congestion except for the SEMA/RI export interface and the Surowiec South interface.

Total Amount of Spilled Resource Energy (TWh)

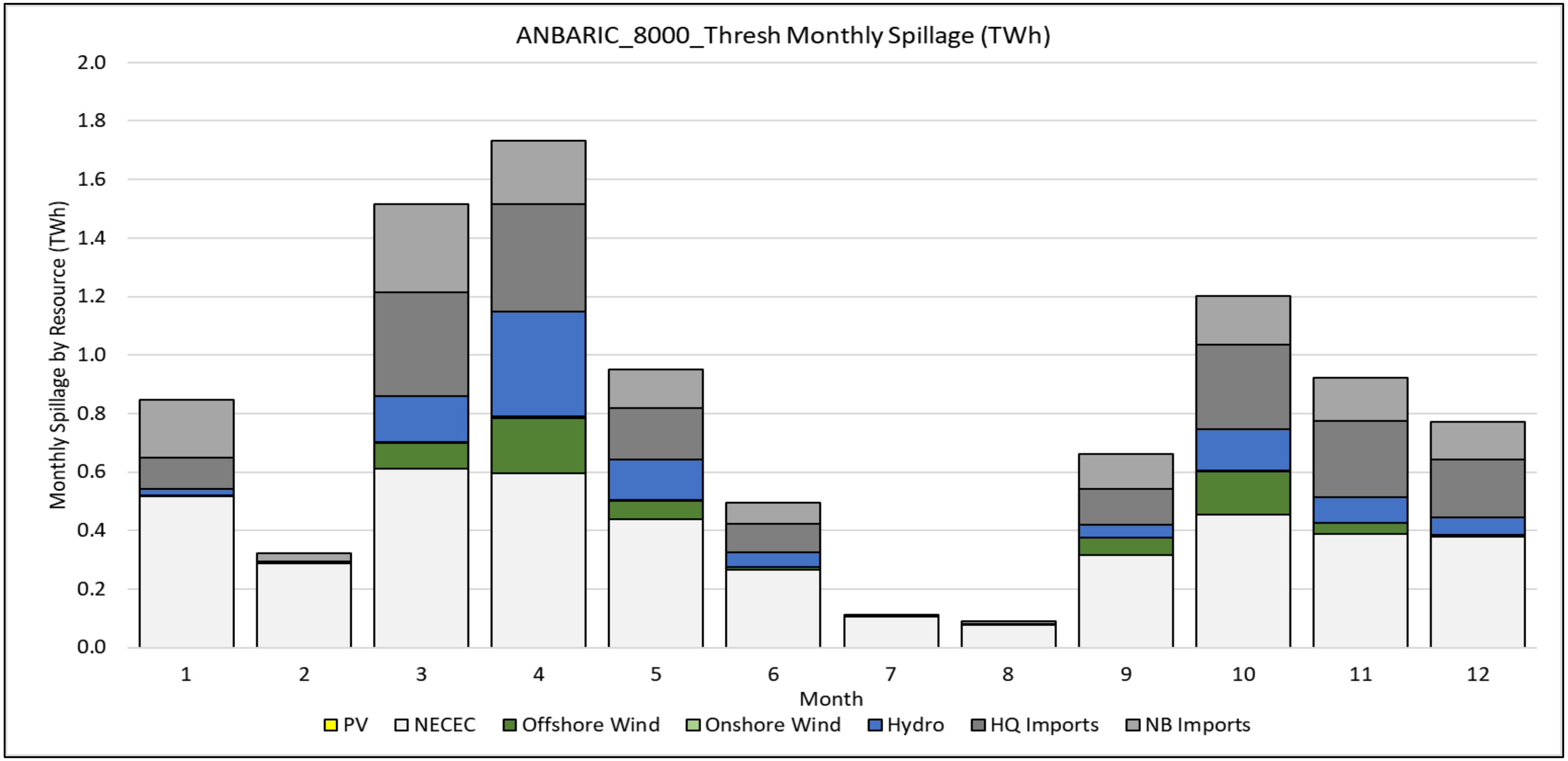
NECEC Threshold Price of $11 vs. $2 /MWh



Increasing the NECEC threshold price to $11/MWh results in significant spillage of NECEC while spillage of hydro, wind, and existing imports decrease. Total spillage remains the same regardless of NECEC threshold price sensitivity.

Resource Energy Spilled Each Month

Anbaric 8000_Thresh Scenario



Total spillage of OSW and hydro decreases more than a half between the Anbaric 8,000 MW OSW (1.67 TWh) and its NECEC threshold price sensitivity (3.44 TWh) scenarios. Energy spilled each month is nearly identical (See Slide 17) between the two scenarios because the increased NECEC spillage comes with equal amount of decreased OSW and hydro spillage.

Additional Observations

- Changing NECEC curtailment order with a higher threshold price results in less annual energy from imports, which is primarily replaced by the increased production of OSW and hydro. Energy production by other fuel types has miniscule to no change.

- No detailed discussions are provided due to the miniscule changes in energy production by natural gas fired units and other non price-taking resources.
  - Production costs remain the same between the two NECEC curtailment scenarios ($2/MWh vs. $11/MWh)
  - LSEEE is slightly higher and uplift is lower due to higher LMPs
  - Carbon emissions remain the same

COMPARISON OF NESCOE AND ANBARIC RESULTS

Anbaric_8000 vs. NESCOE_8000_2

Key Observations

- Anbaric_8000 and NESCOE 8000_2 scenarios model the same amount of OSW addition at the same point of interconnections.
- However, the Anbaric_8000 scenario assumes nearly 4,500 MW more resource retirements and no additional demand from heat pumps and electric vehicles. Comparison reveals:
  - Retirement of 2,000 MW of nuclear capacity has a significant impact on various metrics because a large amount of energy needs to be replaced by other resources, primarily natural gas fired units, offshore wind, imports and hydro.
    - Production costs, LSEEE and uplift, and carbon emission are higher in the Anbaric_8000 scenario due to more NG energy production.
  - The Anbaric_8000 scenario observes approximately 3.5 times more congestion hours over the SEMA/RI export interface.
  - Total spillage of the Anbaric_8000 scenario is 9.6 TWh, which is much less than 15 TWh of the NESCOE_8000_2 scenario.

Comparison of Energy Production by Fuel Type (TWh)

For Constrained (Cstr.) and Unconstrained (Uncstr.) Transmission

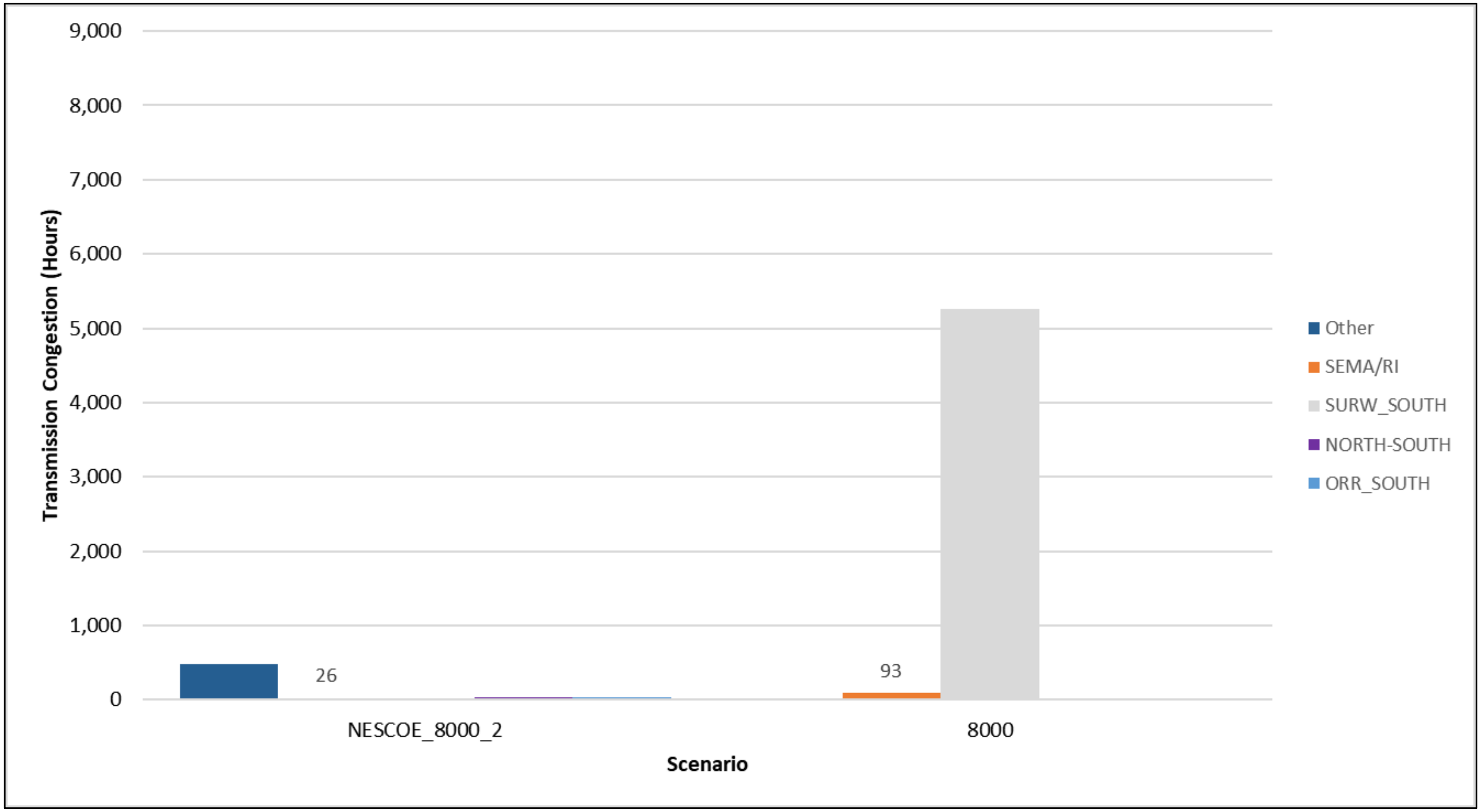
Red represents production reduction, Green represents production increase

Scenario	Total Systemwide Energy Production by Fuel Type					
	NESCOE_8000_2		8000*		Delta	
Fuel Type	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.
Offshore Wind	27.55	27.56	30.41	30.42	2.86	2.86
Onshore Wind	3.77	3.77	3.53	3.52	-0.24	-0.25
NG	16.67	16.67	23.30	22.43	6.63	5.76
Oil	0.00	0.00	0.00	0.00	0.00	0.00
Imports	19.41	19.41	20.86	21.87	1.45	2.46
Coal	0.05	0.04	0.16	0.09	0.11	0.05
LFG/MSW	2.69	2.69	3.16	3.09	0.47	0.4
PV	9.47	9.47	9.47	9.47	0.00	0.00
Wood	4.70	4.70	4.70	4.70	0.00	0.00
Nuc	29.85	29.85	12.33	12.33	-17.52	-17.52
EE/DR	36.09	36.09	36.09	36.09	0.00	0.00
Hydro	6.27	6.28	7.40	7.42	1.13	1.14
Total	156.52	156.53	151.41	151.43	-5.11	-5.10

Approximately 16 percent of the annual decrease in nuclear energy production due to assumed 2,000 MW of nuclear retirement was replaced by increase in OSW generation.

* 8000 represents the Anbaric_8000 scenario.

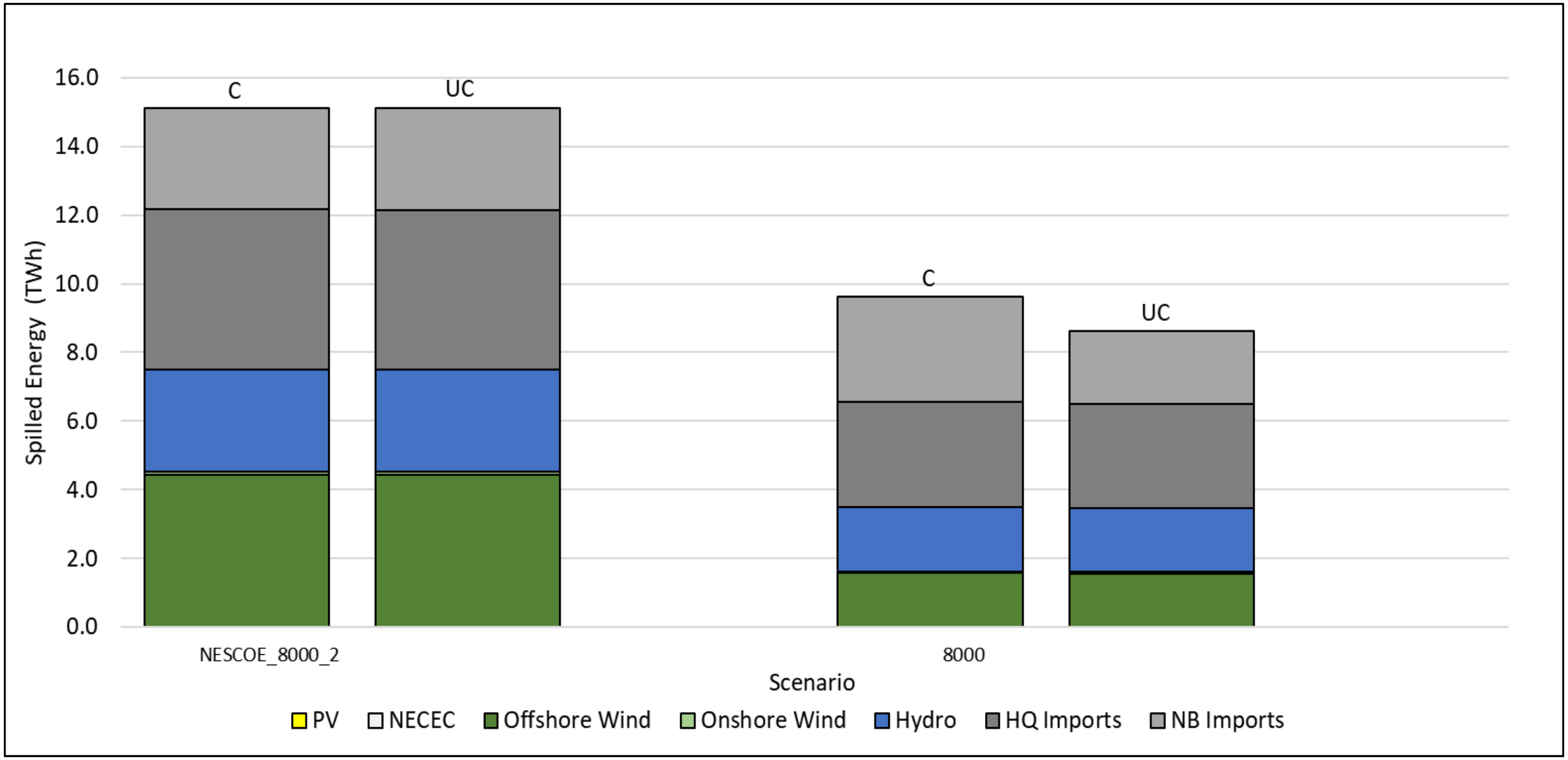
Congestion by Interface (Hours)



SEMA/RI export interface observes 93 hours of congestion in the Anbaric_8000 scenario, approximately 3.5 time more than the 26 congestion hours as seen in the NESCOE scenario. The increased constraints are due to more OSW generation (located in SEMA and RI subareas) is required to serve New England loads after nuclear retirements.

Total Amount of Spilled Resource Energy (TWh)

*For Constrained ("C") and Unconstrained ("UC") Transmission**

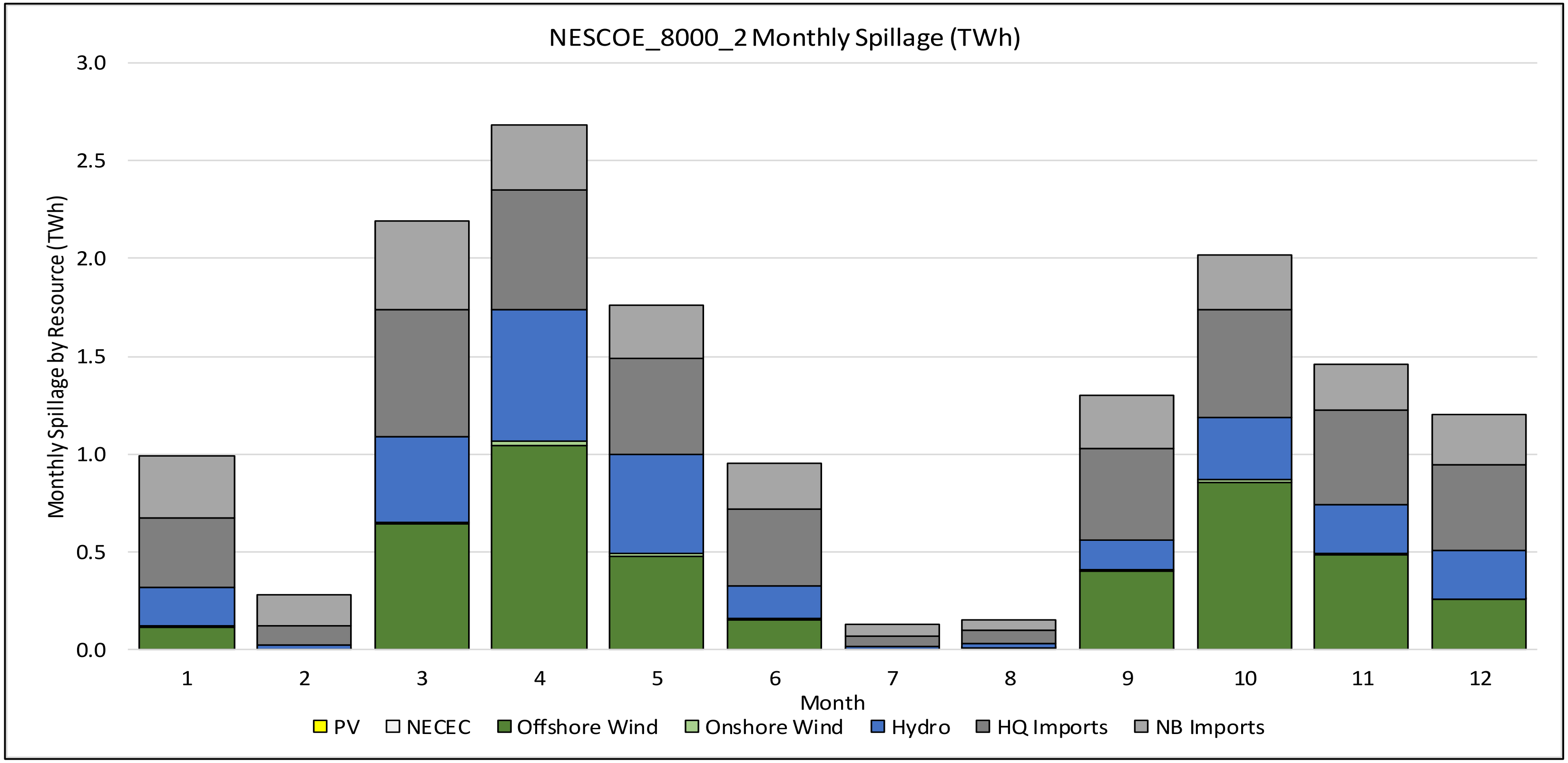


Total renewable spillage in the Anbaric_8000 scenario, primarily OSW and hydro, decreases approximately 50% compared to the NESCOE scenario. This is because the assumed nuclear retirements decrease the energy oversupply in the Anbaric scenario.

* Wholesale Market Impact analyses was performed under two conditions: Unconstrained and Constrained. Unconstrained transmission is modeled as a one-bus system while constrained transmission is modeled using the "Pipe and RSP Bubble" configuration. See slide 56 for details.

Resource Energy Spilled Each Month

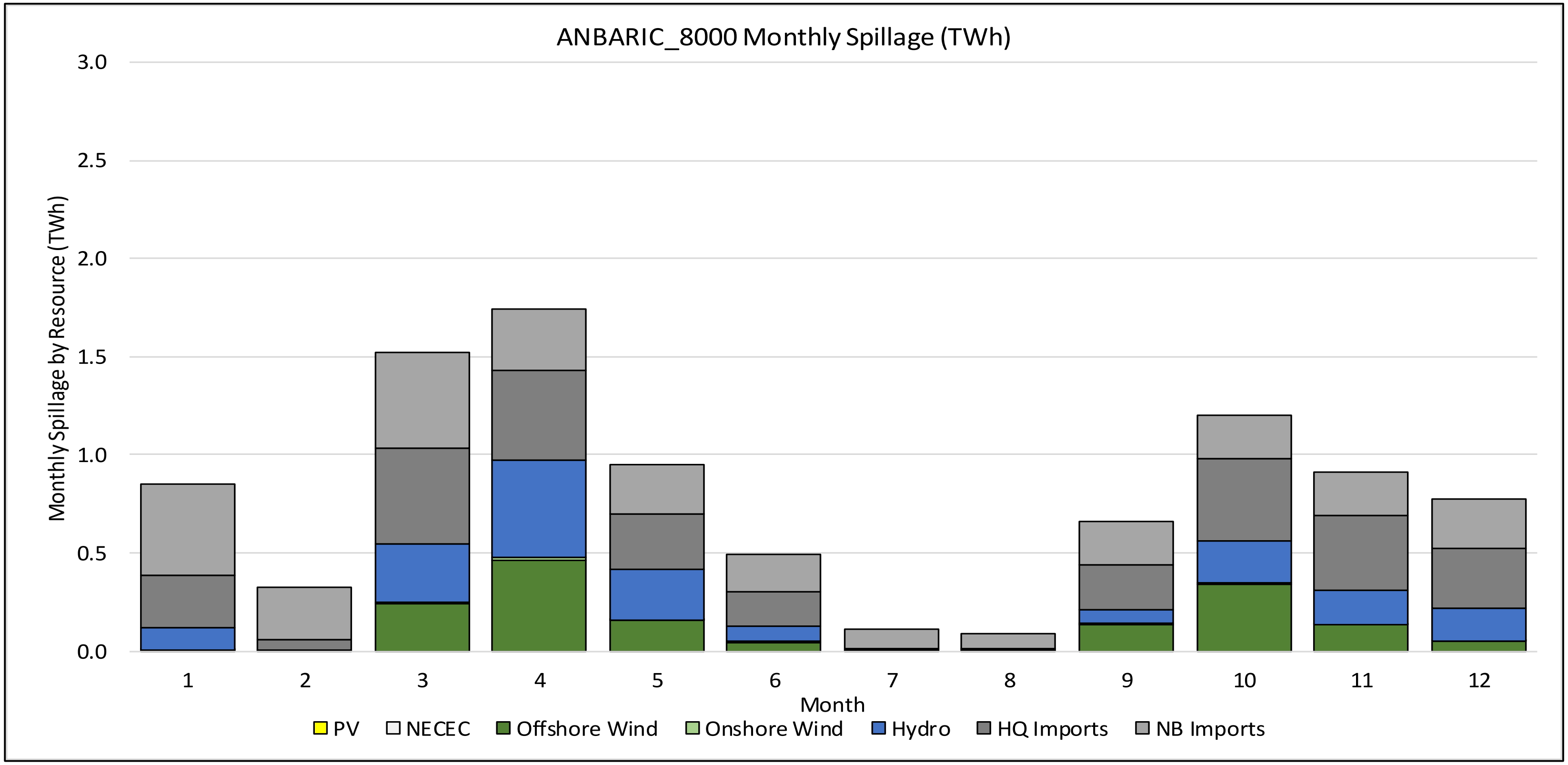
NESCOE 8000_2 Scenario



There is more monthly renewable spillage (OSW and hydro) in the NESCOE 8000_2 scenario due to higher energy oversupply.

Resource Energy Spilled Each Month

Anbaric_8000 Scenario



Total energy spilled each month shares very similar profiles between the Anbaric_8000 and NESCOE_8000_2 scenarios.

Timeline to Complete Studies

- **NESCOE** – Present additional spillage and marginal emissions results in April, if time permits. Complete ancillary service analysis by May. Publish final report by June 1.
- **Anbaric** – Present additional GridView results with 2015 load/PV/wind profiles in April, if time permits. Publish final report in June/July.
- **Transmission** – present NESCOE and Anbaric transmission cost estimates in March and April.
- **RENEW** – Present GridView results with 2015 load/PV/wind profiles in April. Publish final report in July.

Questions

APPENDIX I

Base Assumption Scenarios Results

Total Systemwide Energy Production by Fuel Type (TWh)

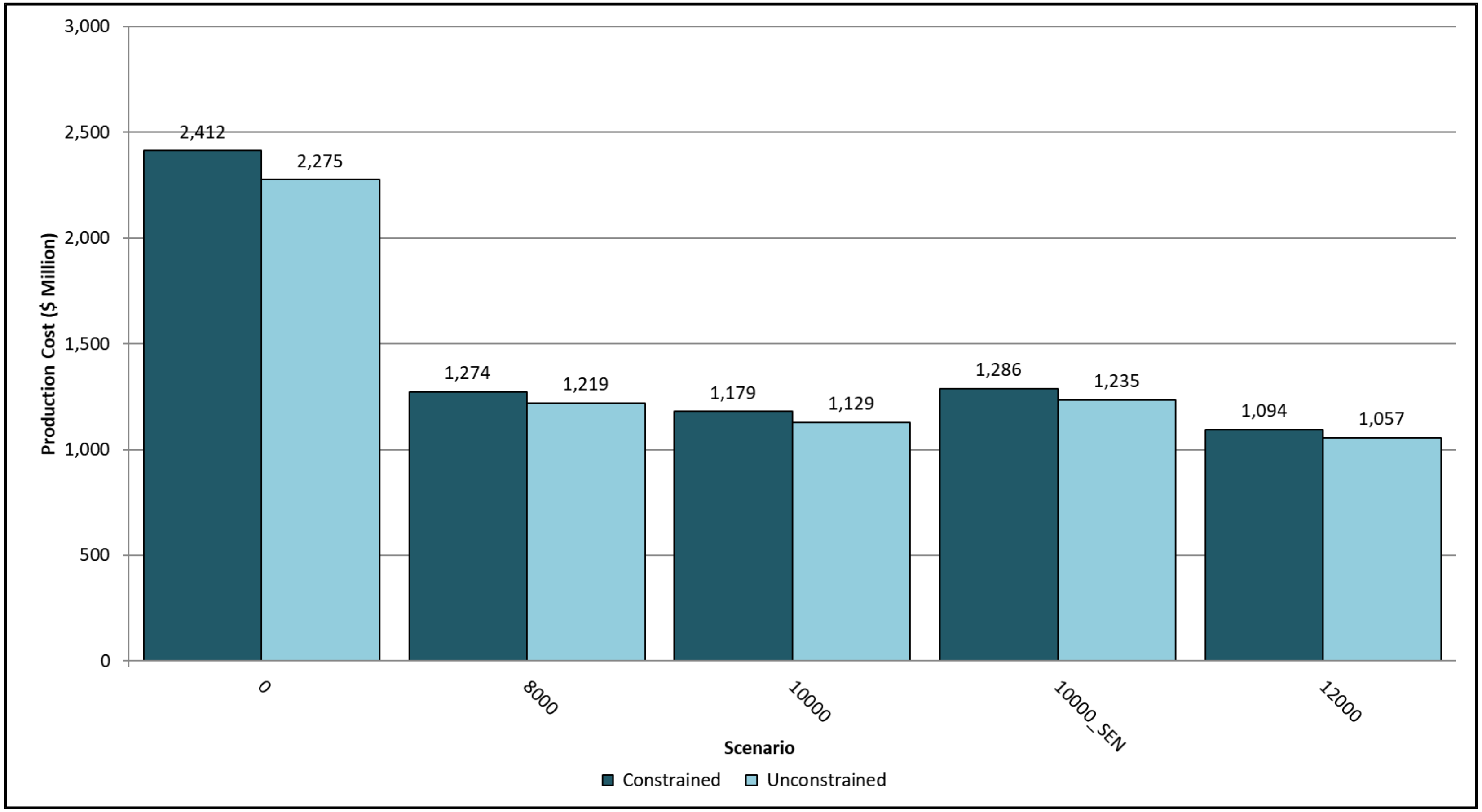
*For Constrained (Cstr.) and Unconstrained (Uncstr.) Transmission ***

Scenario	0		8000		10000		10000_Sen*		12000	
Fuel Type	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.
Offshore Wind	0.12	0.12	30.41	30.42	34.71	35.29	35.86	36.45	39.02	39.18
Onshore Wind	3.54	3.54	3.53	3.52	3.52	3.51	3.52	3.51	3.52	3.50
NG	46.25	44.05	23.30	22.43	21.31	20.54	23.41	22.65	19.52	18.95
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Imports	24.64	27.00	20.86	21.87	19.55	20.17	20.61	21.16	18.31	18.92
Coal	0.64	0.52	0.16	0.09	0.14	0.06	0.20	0.14	0.12	0.07
LFG/MSW	4.17	4.08	3.16	3.09	2.94	2.89	3.06	3.03	2.76	2.72
PV	9.47	9.47	9.47	9.47	9.47	9.47	9.47	9.47	9.47	9.47
Wood	4.72	4.71	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70
Nuc	12.33	12.33	12.33	12.33	12.33	12.33	12.33	12.33	12.33	12.33
EE/DR	36.09	36.09	36.09	36.09	36.09	36.09	36.09	36.09	36.09	36.09
Hydro	9.20	9.25	7.40	7.42	6.69	6.41	7.14	6.86	5.62	5.55

* Electrification demand (heat pumps and electric vehicles) is primarily supplied by NG, OSW, imports, and Hydro. See Slides 60-61 for fuel price assumptions.

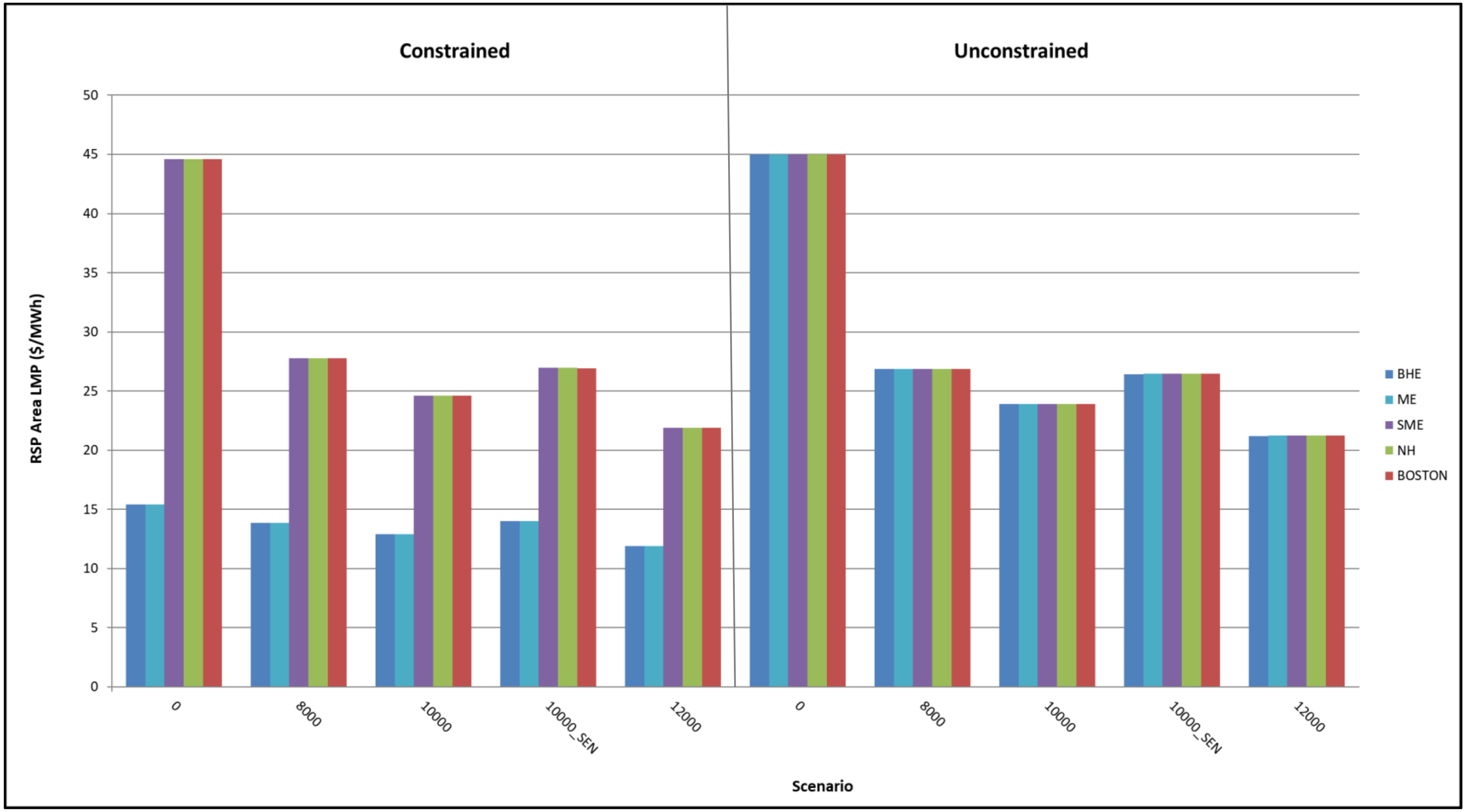
** Wholesale Market Impact analyses was performed under two conditions: Unconstrained and Constrained. Unconstrained transmission is modeled as a one-bus system while constrained transmission is modeled using the "Pipe and RSP Bubble" configuration. See slide 56 for details.

Systemwide Production Costs ($ Million)



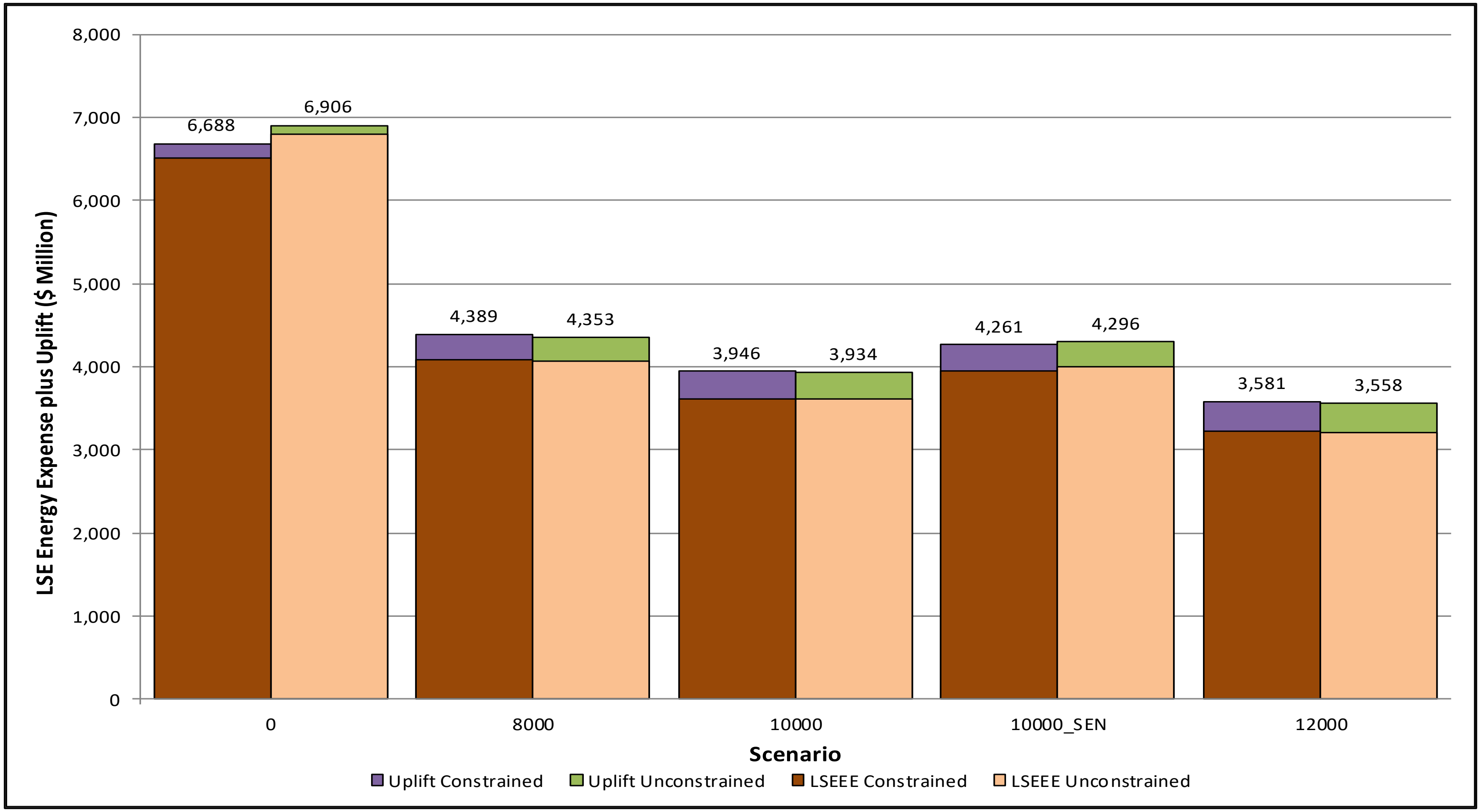
The addition of 8,000 MW OSW decreases the systemwide production costs to approximately half of the reference (0 MW OSW) scenario. However, the incremental production costs savings are less than $100 Million per each 2,000 MW of additional OSW as seen in the 10000 MW and 12000 MW OSW scenarios.

Annual Average LMPs by RSP Subarea ($/MWh)



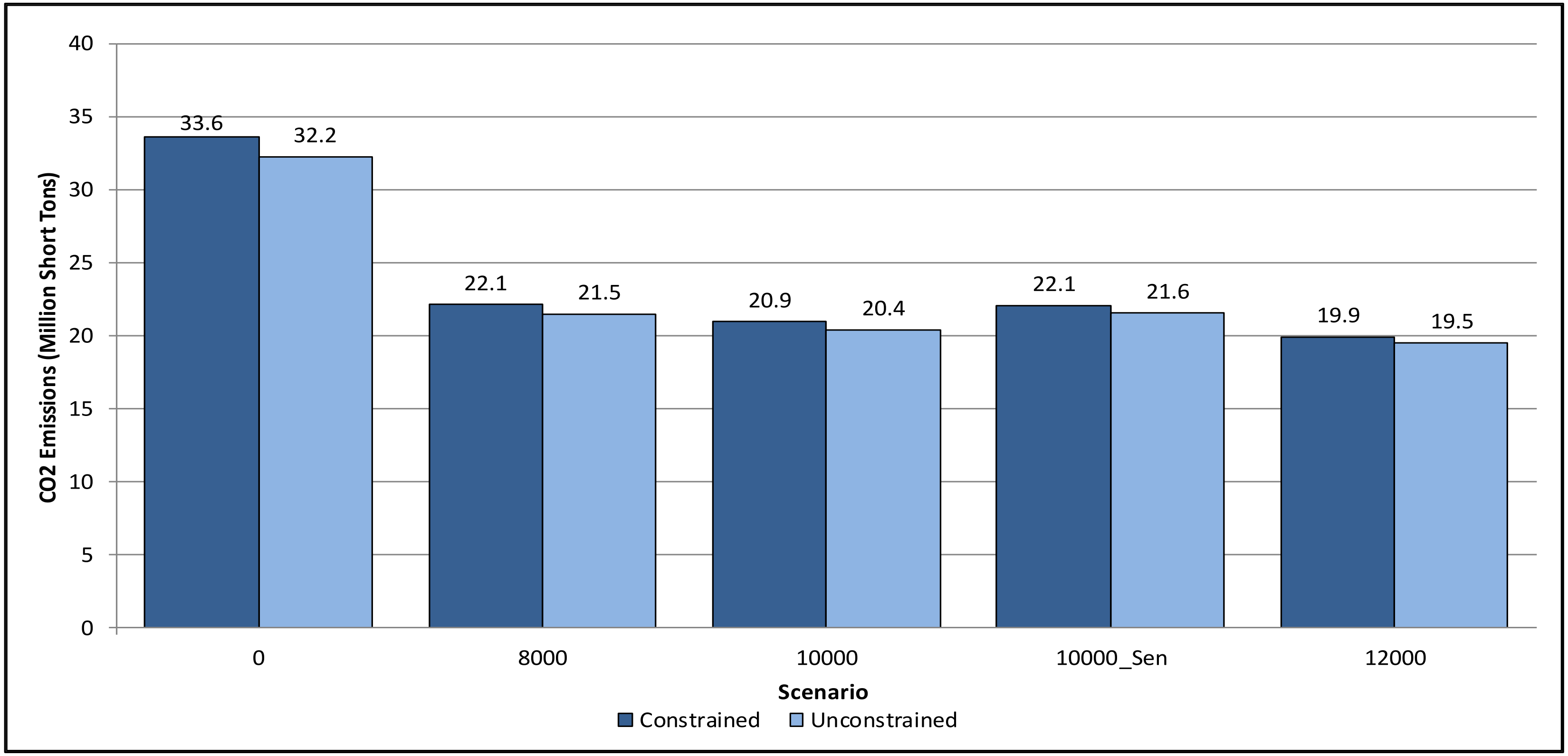
Price separation is caused by Surowiec South interface constraints. The added demand associated with electrification increases LMPs. Unconstrained cases have more energy production from price-taking resources therefore results in slightly lower LMPs for SME, NH, and Boston subareas.

Load-Serving Entity Energy Expense (LSEEE) and Uplift *($ Million)*



LSEEE and uplift decrease by approximately one third with the addition of 8,000 MW OSW from the reference scenario. Incremental LSEEE savings drop sharply when more than 8,000 MW of OSW is interconnected. Uplift increases slightly as wind penetration reduces LMPs.

Native New England Resource CO_2 Emissions
(millions of short tons)



The addition of 8,000 MW OSW reduces more than one third of the region's carbon emissions compared to the reference scenario. Carbon emissions of the 10000_Sen scenario increase to levels comparable to the 8,000 MW OSW scenario because more energy production from natural gas fired units is required to meet the additional demand associated with electrification.

Anbaric_10000_Sen Battery Storage Location Test

Locations of Battery Storage by the ISO Interconnection Queue

- Battery storage location test: a sensitivity case was performed based on the Anbaric_10000_Sen scenario assuming battery storage distribution in accordance with the ISO interconnection queue, and the observed SEMA/RI export interface congestion hours drop approximately 13%

- There is 2,041 MW of battery storage proposed in the ISO interconnection queue by end of April 2019
  - Anbaric did not specify locations of battery storage
  - Anbaric scenarios assume that battery storage is evenly distributed across the RSP zones

Battery Storage by the Queue	Percentage Distribution	Modeled Battery (MW)
BOSTON	15%	600
CT	10%	400
ME	20%	800
SEMA	40%	1600
RI	10%	400
NEMA*	2.5%	100
WMA*	2.5%	100
Total	100%	4000

** NEMA & WMA represents the co-located battery storage interconnecting into distribution system*

APPENDIX II

NECEC Threshold Price Sensitivity Results

Total Systemwide Energy Production by Fuel Type (TWh)

For Constrained (Cstr.) and Unconstrained (Uncstr.) Transmission*

Scenario	0_THRESH		8000_THRESH		10000_THRESH		10000_Sen_THRESH		12000_THRESH	
NECEC Threshold	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.
Offshore Wind	0.12	0.12	31.38	31.41	36.34	37.36	37.08	37.84	41.84	42.22
Onshore Wind	3.54	3.54	3.54	3.53	3.53	3.52	3.54	3.53	3.53	3.52
NG*	46.29	44.01	23.30	22.43	21.31	20.55	23.41	22.65	19.52	18.95
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Imports	24.59	27.00	19.08	20.10	17.00	17.34	18.56	19.69	14.69	15.22
Coal	0.63	0.49	0.17	0.09	0.14	0.06	0.20	0.14	0.12	0.06
LFG/MSW	4.13	4.15	3.16	3.09	2.93	2.89	3.06	3.03	2.76	2.72
PV	9.47	9.47	9.47	9.47	9.47	9.47	9.47	9.47	9.47	9.47
Wood	4.70	4.72	4.70	4.70	4.70	4.70	4.70	4.70	4.69	4.70
Nuc	12.33	12.33	12.33	12.33	12.33	12.33	12.33	12.33	12.33	12.33
EE/DR	36.09	36.09	36.09	36.09	36.09	36.09	36.09	36.09	36.09	36.09
Hydro	9.25	9.25	8.21	8.20	7.65	7.18	7.99	6.91	6.45	6.21

Results show miniscule change in energy by NG and other non price-taking resources, therefore, production costs, LSEEE and Uplift, LMPs, and carbon emissions will not be discussed in details in this presentation.

* Wholesale Market Impact analyses was performed under two conditions: Unconstrained and Constrained. Unconstrained transmission is modeled as a one-bus system while constrained transmission is modeled using the “Pipe and RSP Bubble” configuration. See slide 56 for details.

Comparison of Energy Production by Fuel Type (TWh)

NECEC Threshold Price of $11 vs. $2/MWh

Scenario	0_THRESH vs. 0		8000_THRESH vs. 8000		10000_THRESH vs. 10000		10000_Sen_THRESH vs. 10000_Sen		12000_THRESH vs. 12000	
Fuel Type	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.
Offshore Wind	0	0	0.97	0.99	1.63	2.07	1.22	1.39	2.82	3.04
Onshore Wind	0	0	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.02
NG*	0.04	-0.04	0	0	0	0.01	0	0	0	0
Oil	0	0	0	0	0	0	0	0	0	0
Imports	-0.05	0	-1.78	-1.77	-2.55	-2.83	-2.05	-1.47	-3.62	-3.7
Coal	-0.01	-0.03	0.01	0	0	0	0	0	0	-0.01
LFG/MSW	-0.04	0.07	0	0	-0.01	0	0	0	0	0
PV	0	0	0	0	0	0	0	0	0	0
Wood	-0.02	0.01	0	0	0	0	0	0	-0.01	0
Nuc	0	0	0	0	0	0	0	0	0	0
EE/DR	0	0	0	0	0	0	0	0	0	0
Hydro	0.05	0	0.81	0.78	0.96	0.77	0.85	0.05	0.83	0.66

Compared to Base Assumption scenarios, NECEC threshold price sensitivity scenarios have less annual energy from imports, while more emery production by OSW and hydro. The amount of the decreased energy via imports roughly equal to the amount of increased production by OSW and hydro.

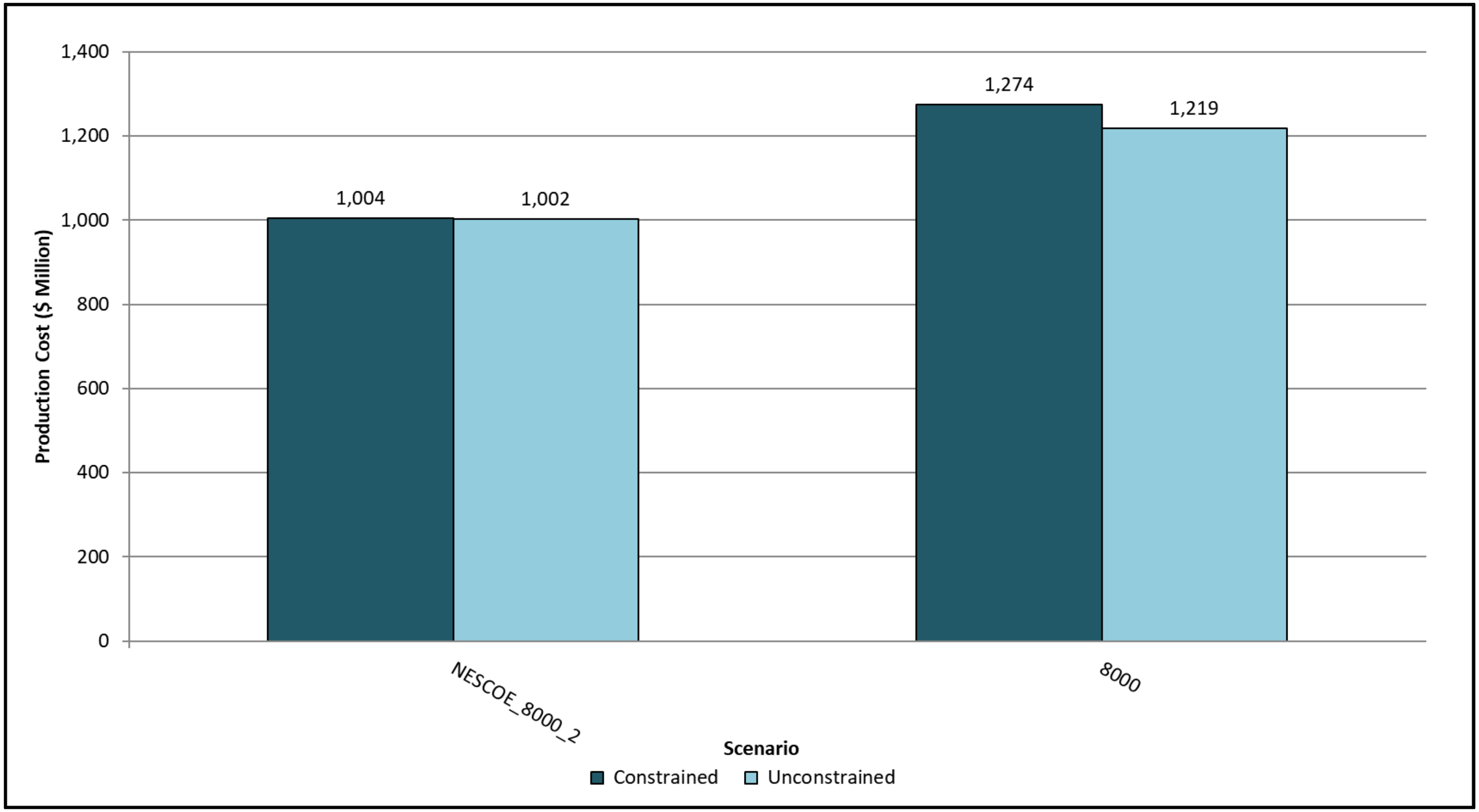
Congestion by Interface ($ Million)

SEMA/RI export interface congestion costs are higher in the NECEC threshold price sensitivity scenarios because the SEMA/RI export interface is congested more frequently (See Slide 20) .

APPENDIX III

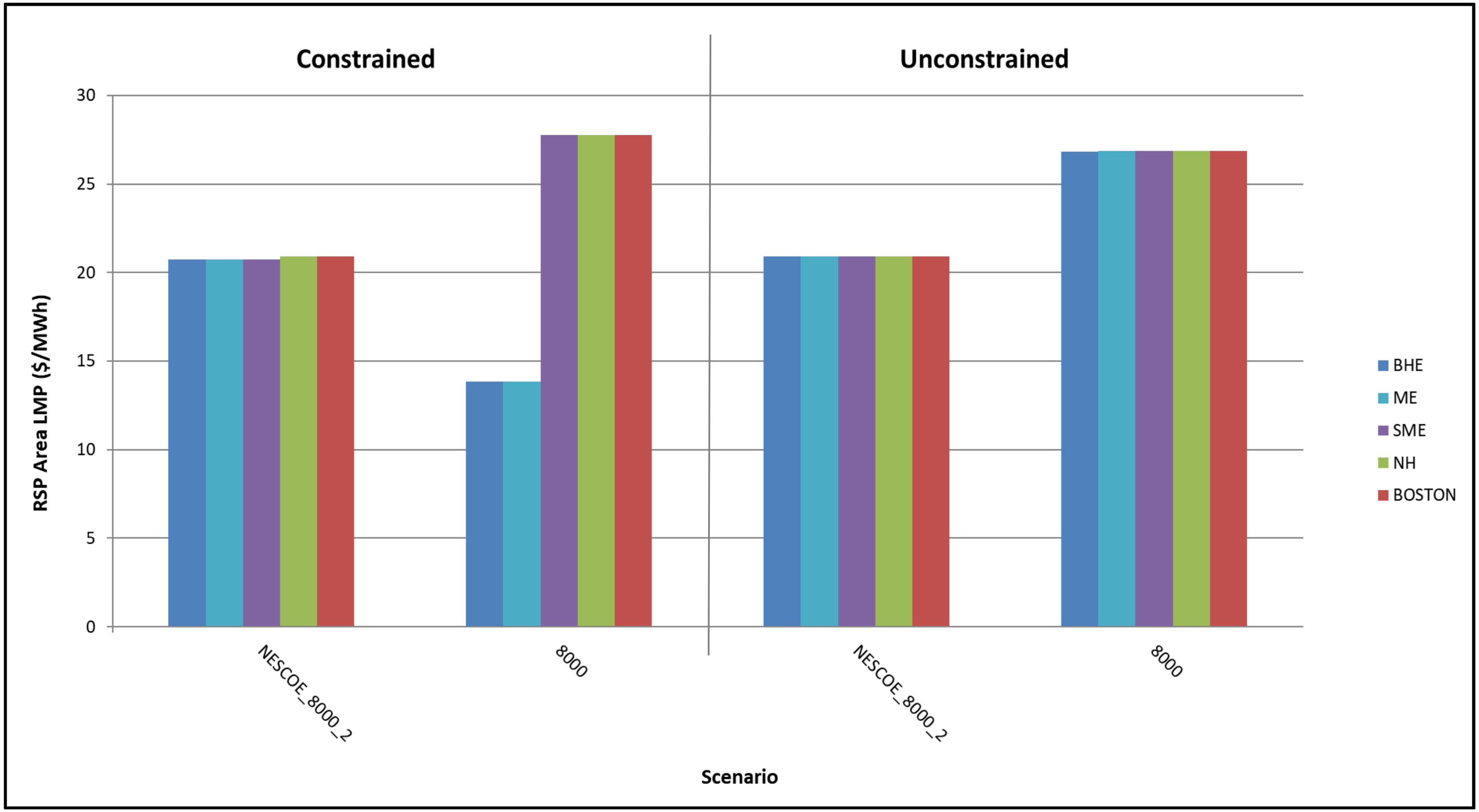
Comparison of NESCOE and Anbaric Results

Systemwide Production Costs ($ Million)



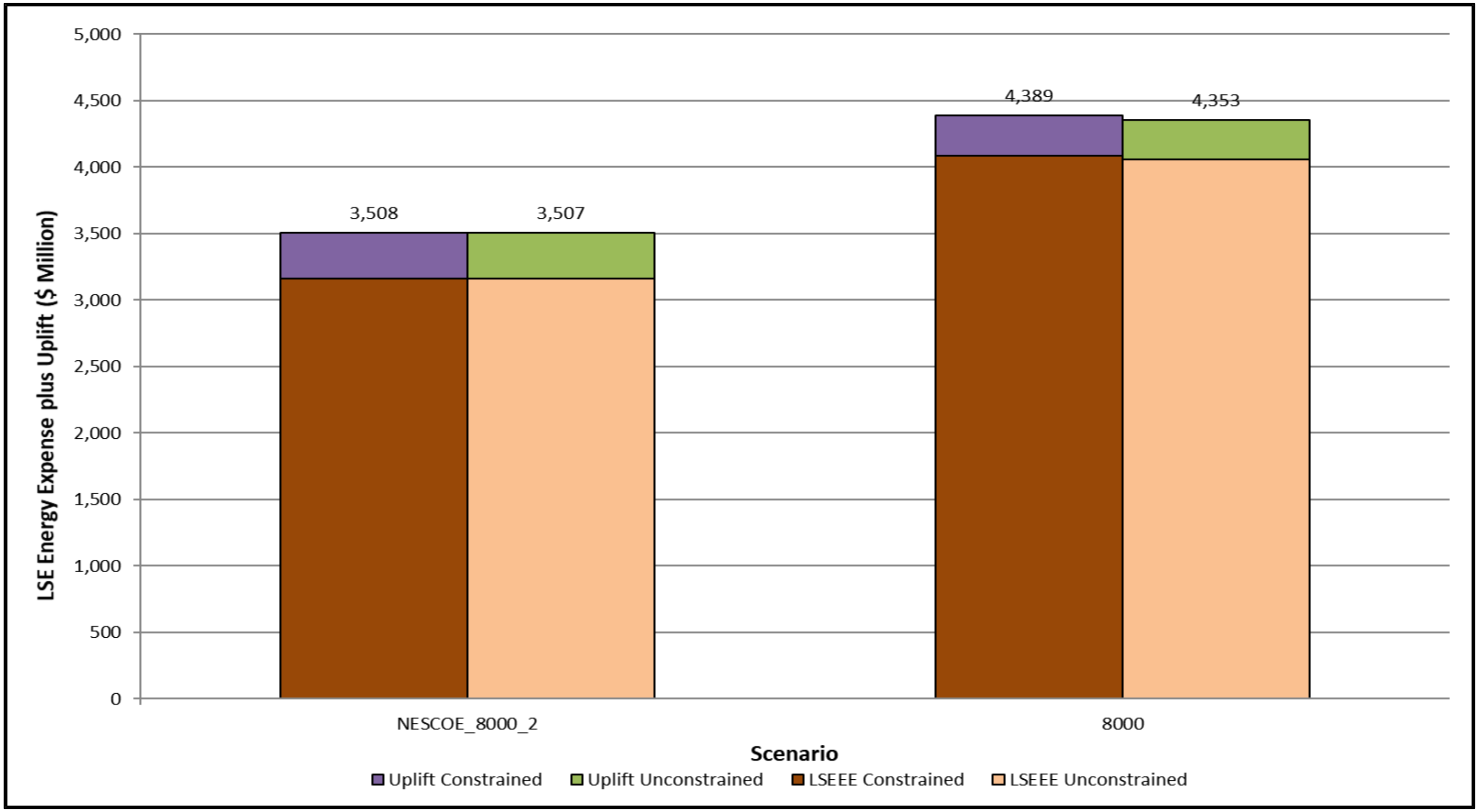
Production costs of the Anbaric_8000 scenario is 27% higher because there is more energy production by natural gas fired units due to the assumed nuclear retirements.

Annual Average LMPs by RSP Subarea ($/MWh)



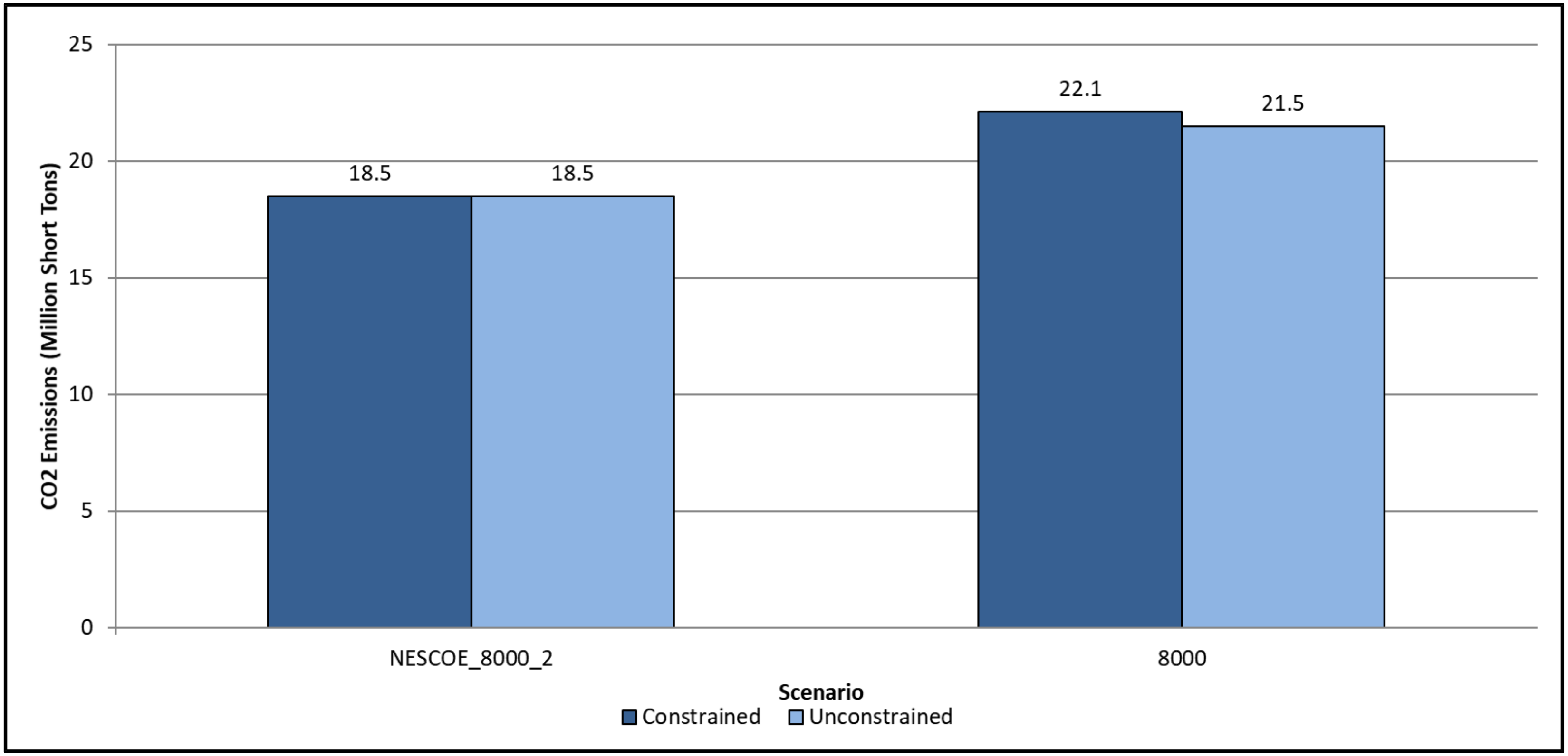
Price separation is obvious in the Anbaric_8000 scenario due to its lower Surowiec South interface transfer limit assumption (1,500 MW in Anbaric and 2,100 MW in NESCOE scenarios). Unconstrained LMPs in the Anbaric_8000 scenario are higher compared to the NESCOE scenario, due to high cost resources being dispatched to replace the low cost nuclear energy.

Load-Serving Entity Energy Expense (LSEEE) and Uplift *($ Million)*



LSEEE and uplift in the Anbaric_8000 scenario are approximately 25% higher than the NESCOE scenario, which is associated with the higher LMPs in the Anbaric scenario.

Native New England Resource CO_2 Emissions *(millions of short tons)*



Carbon emission is approximately 20% more in the Anbaric_8000 scenario. This is due to increased generation from natural gas fired units with the assumed nuclear retirements.

APPENDIX IV

Assumptions

The NESCOE and Anbaric 2019 Economic Study Offshore Wind Injection Locations (MW)

Interconnection Point	Bourne/Canal /Pilgrim	Brayton Point	Kent County /Davisville	Montville	Mystic	Millstone	Assumed Major Additional Transmission Reinforcement(s)	Total MW
RSP Area	SEMA	SEMA	RI	CT	Boston	CT		
NESCOE_2000	800	500	700				None	2000
NESCOE_3000	1,500	800	700				None	3000
NESCOE_5000	2,400	800	1,000	800			None	5000
NESCOE_6000	2,400	1,600	1,000	800	200		None	6000
NESCOE_8000_1	2,400	1,600	1,000	800	2,200		#1: Direct injection into K Street	8000
NESCOE_8000_2	3,400	1,600	1,000	800	1,200		#2: 345 kV reinforcements from the Cape to Stoughton/K. Street	8000
NESCOE_8000_3	2,400	2,600	1,000	800	1,200		#3: 345 kV reinforcements from Brayton Point to Millbury/West Medway/West Walpole	8000
NESCOE_8000_4	2,400	1,600	1,500	1,300	1,200		#4: 345 kV reinforcements between Montville and Kent County	8000
Anbaric_8000	3,400	1,600	1,000	800	1,200		#2: 345 kV reinforcements from the Cape to Stoughton/K. Street	8000
Anbaric_10000 Anbaric_Sens	3,400	2,600	1,500	1,300	1,200		#2, #3 and #4	10000
Anbaric_12000	3,400	2,600	1,500	1,300	2,200	1,000	#1, #2, #3 and #4	12000

Offshore wind injections distributed to mimic 1) awarded RFPs 2) locations of queue position requests and 3) location of assumed transmission reinforcements

Red: Signals anticipated maximum level of MW injection at the interconnection point before major additional 345 kV reinforcements are needed

Yellow: Signals MW injection at the interconnection point requiring major additional 345 kV reinforcement(s)

The NESCOE and Anbaric 2019 Economic Study Offshore Wind Injection Locations (MW), Cont.

Anbaric Scenario	Interconnection Points (MW)						
	Montville (CT)	Millstone (CT)	Kent County (RI)	Brayton Point (SEMA)	Barnstable (SEMA)	Mystic (Boston)	Total
Anbaric_0	–	–	–	–	–	–	0
Anbaric_8000	800	–	1,000	1,600	3,400	1,200	8,000
Anbaric_10000	1,300	–	1,500	2,600	3,400	1,200	10,000
Anbaric_12000	1,300	1,000	1,500	2,600	3,400	2,200	12,000
Anbaric_10000_Sen (Electrification)	1,300	–	1,500	2,600	3,400	1,200	10,000

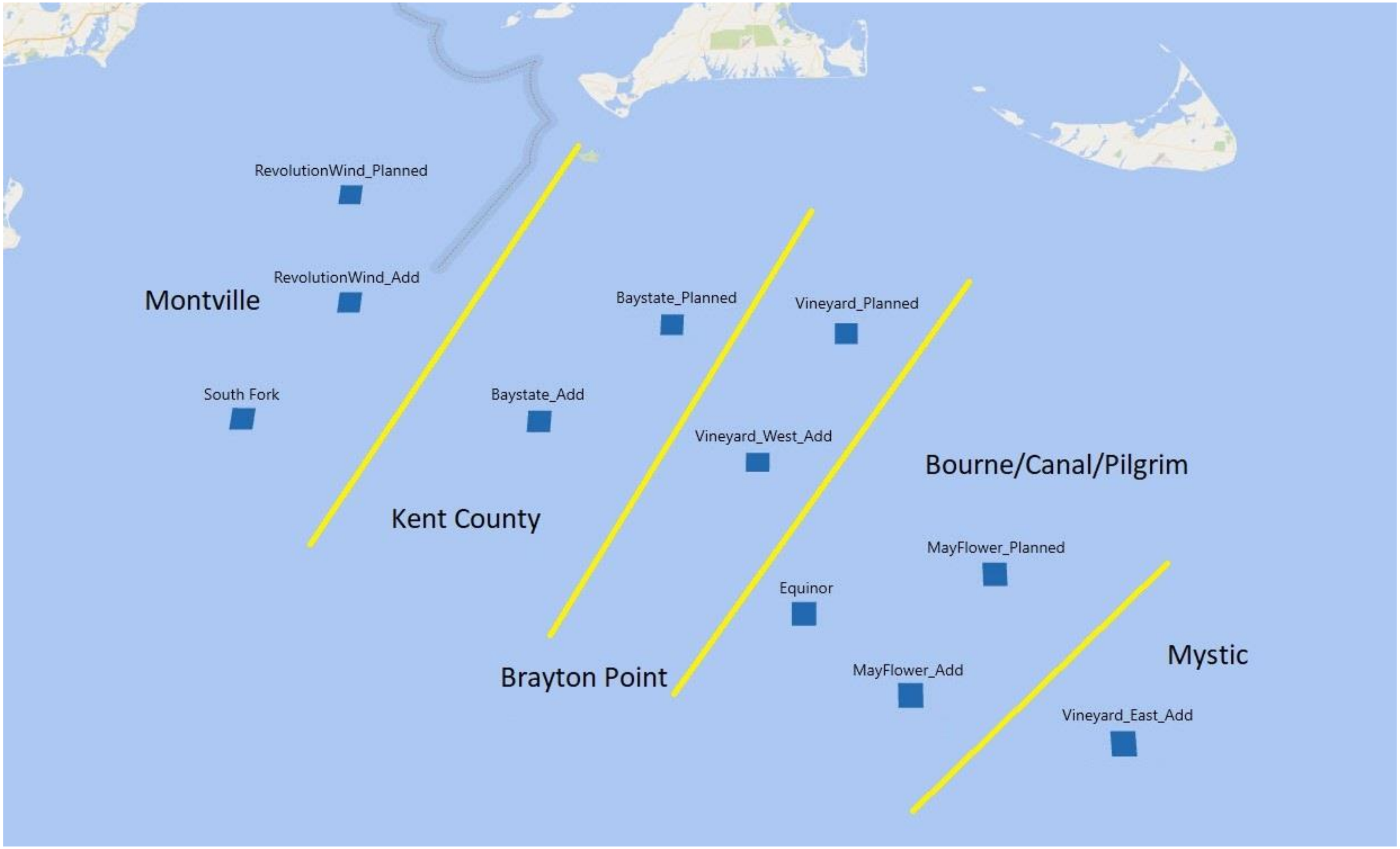
NESCOE Scenario	Interconnection Points (MW)						
	Montville (CT)	Millstone (CT)	Kent County (RI)	Brayton Point (SEMA)	Barnstable (SEMA)	Mystic (Boston)	Total
NESCOE _8000_1	800	_	1,000	1,600	2,400	2,200	8,000
NESCOE_8000_2	800	–	1,000	1,600	3,400	1,200	8,000
NESCOE_8000_3	800	–	1,000	2,600	2,400	1,200	8,000
NESCOE_8000_4	1,300		1,500	1,600	2,400	1,200	8,000

Resource Assumptions in Anbaric Scenarios

- Retirements modeled in the Anbaric scenarios
  - 2,000 MW of nuclear generation
    - Generation at Seabrook and Millstone reduced by a total of 2,000 MW, proportionally to their Seasonal Claimed Capability
  - Oil units in Connecticut and Maine with a total of 2,494 MW
    - All remaining coal units are located in New Hampshire

Name	RSP Subarea	Fuel Type	2019 CELT Seasonal Claimed Capacity (MW)	Fuel
Montville 5	CT	RFO	82	Oil
Yarmouth 1	SME	RFO	49	Oil
Middletown 2 & 3	CT	RFO	353	Oil
Yarmouth 2	SME	RFO	51	Oil
Yarmouth 3	SME	RFO	113	Oil
Montville 6	CT	RFO	400	Oil
Middletown 4	CT	RFO	403	Oil
New Haven Harbor 1	CT	RFO	440	Oil
Yarmouth 4	SME	RFO	603	Oil

2015 DNV Offshore Wind Sites and Aggregate Zones by Point of Interconnection



Internal Transmission Interface Limits (MW)

Single-Value, Summer Peak,[a] Non-Firm, Transmission Interface Limits for Use in Subarea Transportation Models										
Interface	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Orrington South Export	1325	1325	1325	1325	1325	1325	1325	1325	1325	1325
Surowiec South	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Maine-New Hampshire	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Northern New England-Scobie + 394	3450	3450	3450	3450	3450	3450	3450	3450	3450	3450
North-South	2725	2725	2725	2725	2725	2725	2725	2725	2725	2725
East-West	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
West-East	2200	2200	2200	2200	3000[f]	3000	3000	3000	3000	3000
Boston Import (N-1)	5400[b]	5400	5700[c]	5700	5700	5700	5700	5700	5700	5700
Boston Import (N-1-1)	4500[b]	4500	4600[c]	4600	4600	4600	4600	4600	4600	4600
SEMA/RI Export	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400
SEMA/RI Import (N-1)	1280	1280	1280	1280	1800[f]	1800	1800	1800	1800	1800
SEMA/RI Import (N-1-1)	720	720	720	720	800[f]	800	800	800	800	800
Southeast New England Import (N-1)	5400[b]	5400	5700[c]	5700	5700	5700	5700	5700	5700	5700
Southeast New England Import (N-1-1)	4500[b]	4500	4600[c]	4600	4600	4600	4600	4600	4600	4600
Connecticut Import (N-1)	2950	3400[d]	3400	3400	3400	3400	3400	3400	3400	3400
Connecticut Import (N-1-1)	1750	2200[d]	2200	2200	2200	2200	2200	2200	2200	2200
SW Connecticut Import (N-1)	2500	2500	2800[e]	2800	2800	2800	2800	2800	2800	2800
SW Connecticut Import (N-1-1)	1750	1750	1900[e]	1900	1900	1900	1900	1900	1900	1900

- *The internal transmission interface limits for 2025 will also be used for 2030*
- *N-1 limits will be used in the 2019 Economic Studies*
- *https://www.iso-ne.com/static-assets/documents/2019/03/a8_fca14_transmission_transfer_capabilities_and_capacity_zone_development.pdf*

Internal Interface Transfer Capability (Notes)

a) Limits are for the summer period, except where noted to be winter
   - The limits may not include possible simultaneous impacts, and should not be considered as “firm”
   - For the years within the FCM horizon (CCP 2023-2024 and sooner), only accepted certified transmission projects are included when identifying transfer limits
   - For the years beyond the FCM horizon (CCP 2024-2025 and later), proposed plan approved transmission upgrades are included according to their expected in-service dates

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

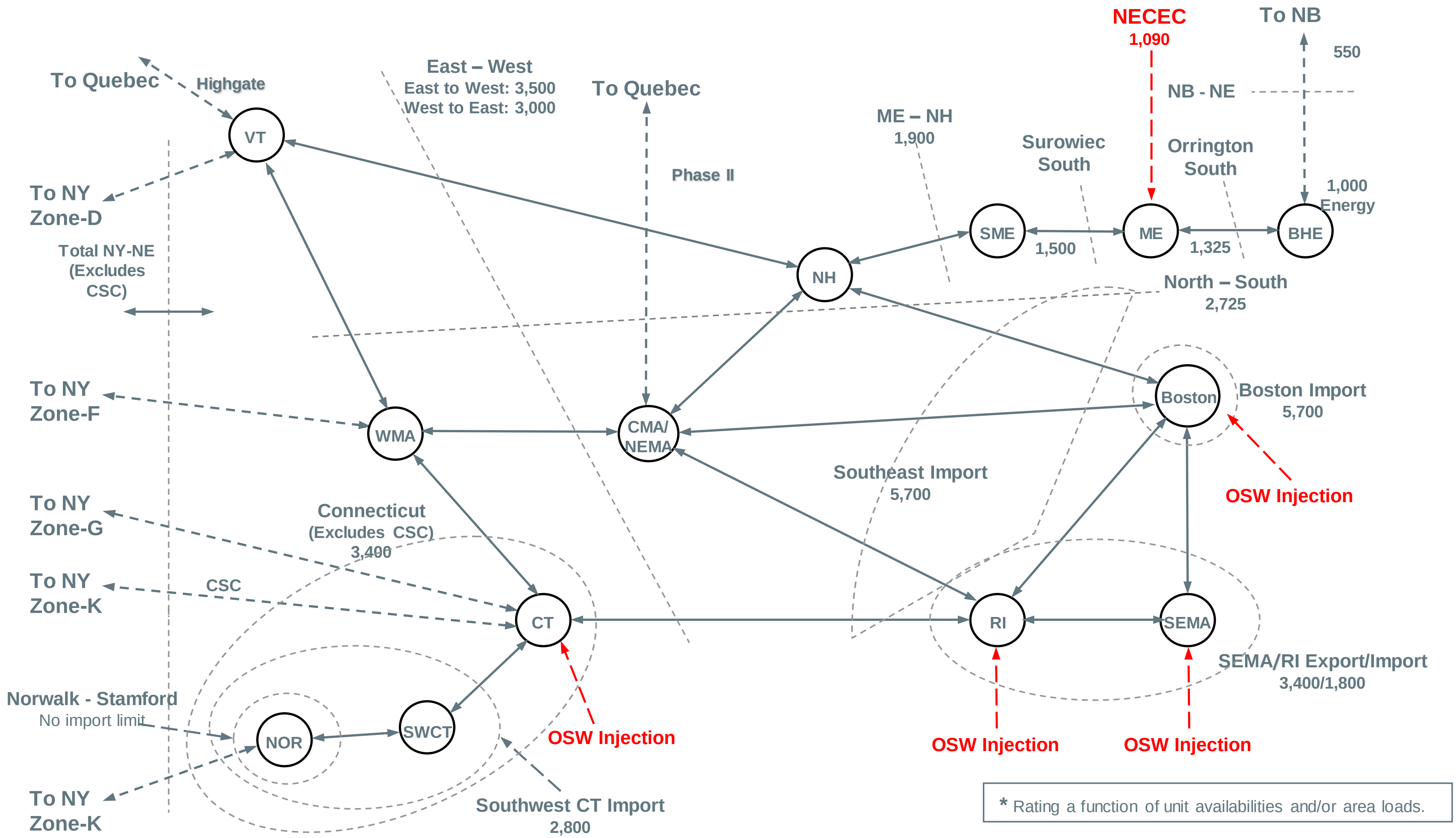
c) Increase associated with the Greater Hartford/Central Connecticut upgrades

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

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

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

Assumed New England Transmission Constrained Representation for 2030 (MW)



Profiles Used in the 2019 Study

- Net load profiles (load shape and daily peak) reflect price-taking resources, including EE, PV, wind, hydro and imports.
- Profiles for charging plug-in hybrid electric vehicles (PHEVs) model charging based on recent EnviroPro data showing peak charging in the evening.
- New England Clean Energy Connect (NECEC) modeled as importing 1,090 MW at all times (excluding threshold price curtailment).
- The storage and discharge of energy by pumped-storage generation and battery systems are dispatched by GridView to further smooth out the net load profile after PHEV, PV, wind, local hydro, interchange and new imports.

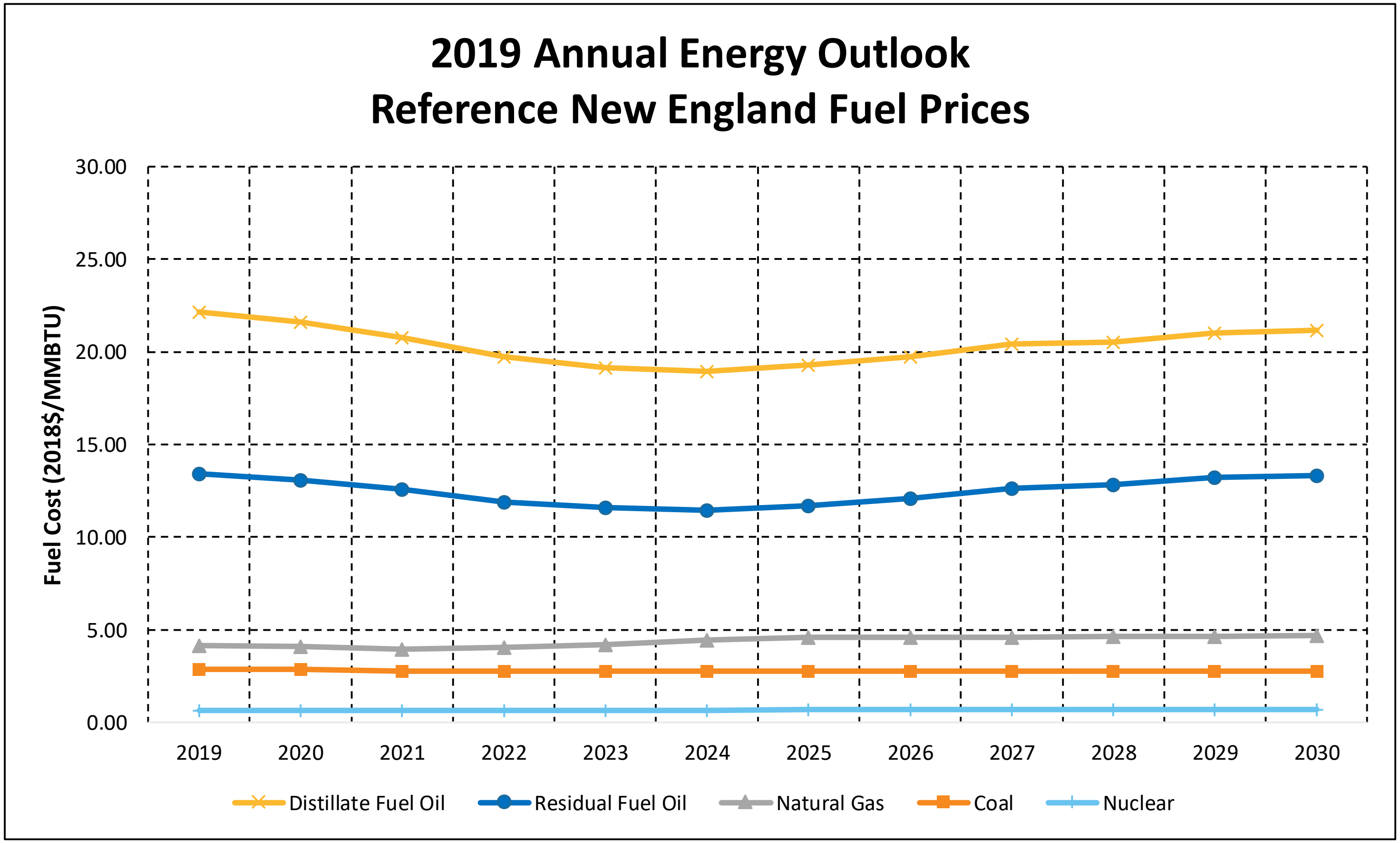
The 2019 Study Uses the Same Basic Assumptions That Were Used in Recent Economic Studies

- Gross demand, solar photovoltaic (PV), and energy-efficiency (EE) forecasts summarized in the ISO's *2019 Capacity, Energy, Load, and Transmission (CELT) Report* are used to establish net load for 2025. The quantities for 2030 assume growth continuing at the same rate for 2028 compared with 2027.
- A representative installed reserve margin of 13.7% above the net 50/50 peak load and rounding to the nearest 100 MW is assumed to meet the net Installed Capacity Requirement.
- The fleet of supply and demand resources expected as of 2019/2020 using the results of the thirteenth Forward Capacity Auction (FCA 13) are reflected in the simulations. These cleared resources include renewables (i.e., biofuel, landfill gas, and other fuels); utility scale PV (FCM and energy-only); coal-, oil-, and gas-fired generators; nuclear; hydroelectric and pumped-storage resources; and external capacity contracts, which will have Capacity Supply Obligations from June 1, 2022 to May 31, 2023. Retired resources known as of FCA 13 are also removed from the simulation databases.

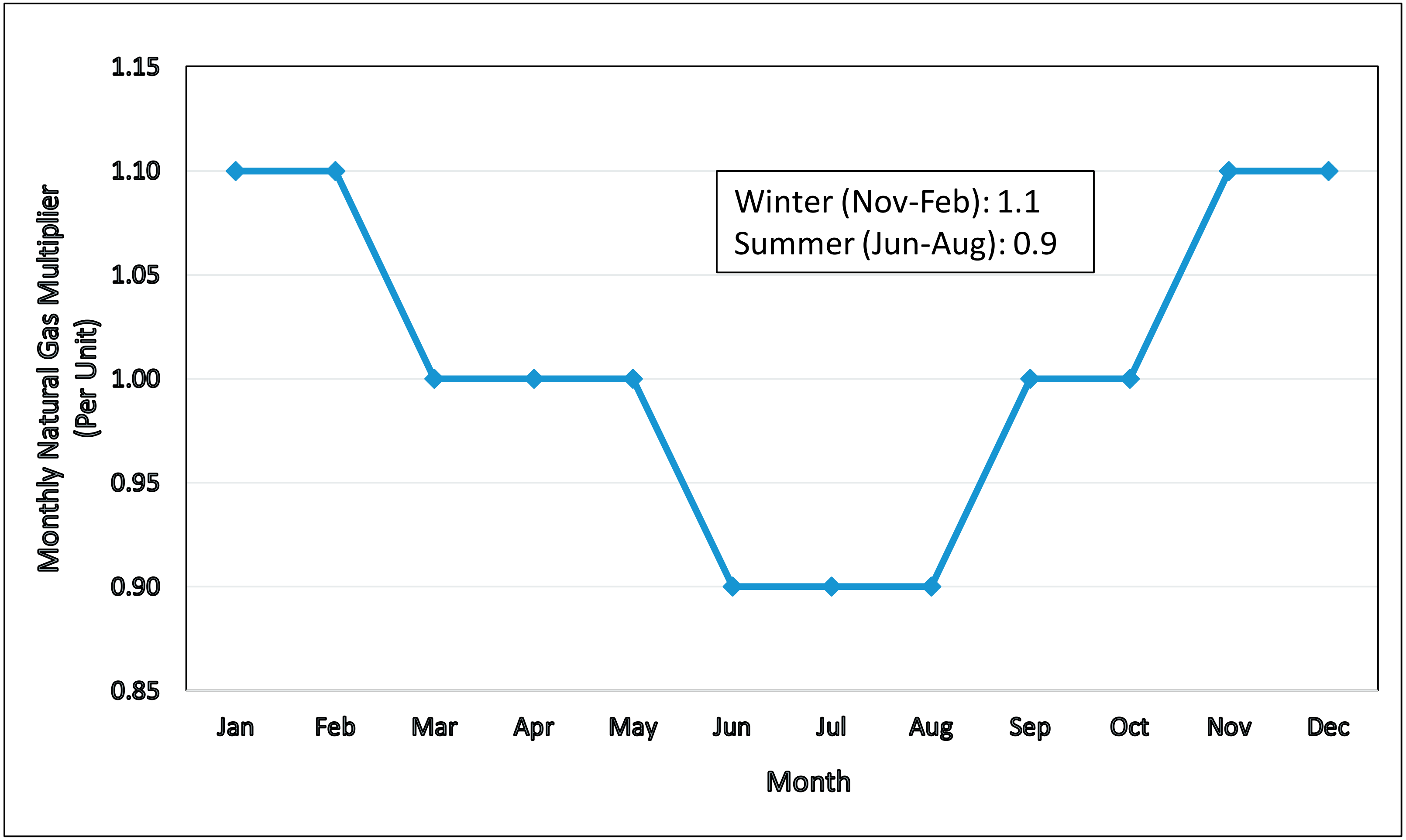
The 2019 Study Uses the Same Basic Assumptions That Were Used in Recent Economic Studies, cont.

- FCM and energy-only generators are simulated at their summer seasonal claimed capabilities (SCC) and then reduced to reflect forced outages and average daily unavailabilities of generators.
- The as-planned transmission system is used for estimating the system's transfer limits for internal and external interfaces under constrained conditions. The 2030 internal and external transmission-interface transfer capabilities are based on the values established for 2025 for regional planning studies. However, Surowiec South uses a projected limit of 2,500 MW based on the project's filing with the Maine PUC and per request from NESCOE for this study.
- U.S. Energy Information Administration (EIA) fuel-price forecasts, with reference projections to 2030, are used for estimating costs to produce electric energy. Monthly multipliers have been applied to the EIA forecasted natural gas price to reflect seasonal adjustment.
- Prices for the Regional Greenhouse Gas Initiative (RGGI) carbon (CO_2) emission allowances and allowances for other environmental emissions are specified at $24/ton for 2030 and used for estimating the costs to produce electric energy.

Fuel Price Forecast: EIA's 2019 AEO Base Forecast

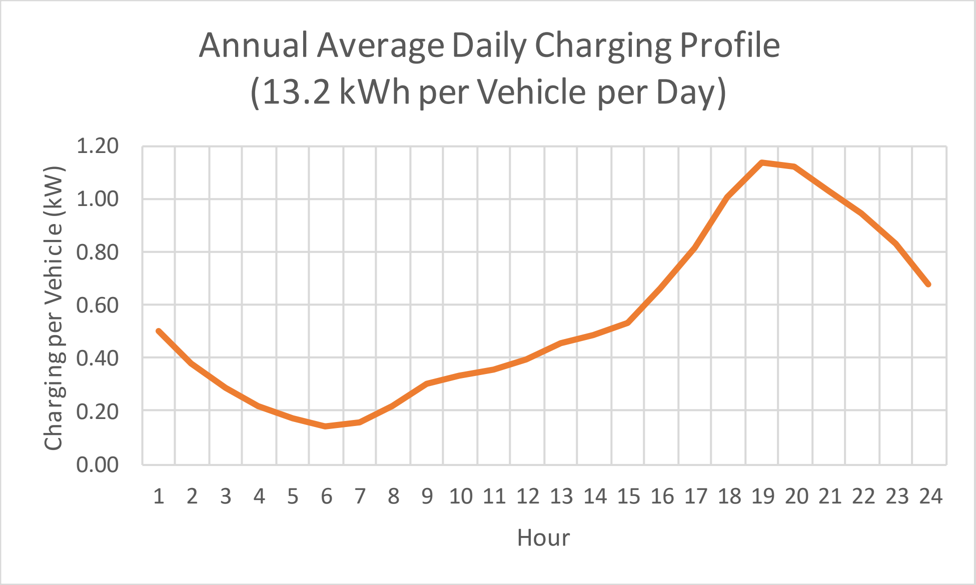


Fuel Price Forecast: Per Unit Multiplier for Monthly Natural Gas Price Assumptions



Plug-in Hybrid Electric Vehicles (PHEVs) Characteristics

- Historical data from NREL suggests that PHEV charging tends to start in the later part of the day and continue into the night
  - The ISO modified the daily PHEV charging profile it used in the 2016 Economic Study to reflect this shift in the charging period
  - Charging ramps-up between 4 pm and midnight



Penetration (Thousand PHEVs)	550
Max charging (MW) (7PM)	627
Annual Charging Energy (GWh)	2,650

Acronyms

- BOEM – Bureau of Ocean Energy Management
- CELT – Capacity, Energy, Load, and Transmission Report
- CSO – Capacity Supply Obligation
- Cstr. – Constrained
- DR – Demand-Response
- EE – Energy Efficiency
- EIA – U.S. Energy Information Administration
- FCA – Forward Capacity Auction
- FCM – Forward Capacity Market
- LMP – Locational Marginal Price
- LSE – Load-Serving Entity
- MSW – Municipal Solid Waste

Acronyms, cont.

- NECEC – New England Clean Energy Connect
- NESCOE – New England States Committee on Electricity
- NG – Natural Gas
- NICR – Net Installed Capacity Requirement
- NREL – National Renewable Energy Laboratory
- OSW – Offshore Wind
- PHEV – Plug-in Hybrid Electric Vehicle
- PV – Photovoltaic
- RFP – Request for Proposals
- RGGI – Regional Greenhouse Gas Initiative
- SCC – Seasonal Claimed Capability
- Uncstr. – Unconstrained