2019 Economic Study – Preliminary NESCOE Results

Planning Advisory Committee

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Highlights

- Today's presentation discusses the NESCOE 2019 Economic Study for scenarios with as much as 6,000 MW of offshore wind (OSW) additions
  - OSW additions of 8,000 MW will be discussed at a subsequent PAC meeting
- Requested OSW additions are in the southern portion of the New England system
- Noteworthy Observations of the preliminary analyses:
  - Carbon emissions decrease on an average of 1.4 to 1.5 million short tons[1] per 1,000 MW of OSW capacity added across the scenarios with the impact decreasing as MWs are added
  - Production costs decrease an average 128 million to 138 million dollars[1] per 1,000 MW of OSW capacity added across the scenarios with the impact decreasing as MWs are added
  - Annual average locational margin prices (LMP) decrease as OSW increases
  - As OSW MWs increase off of southern New England, congestion at Surowiec-South decreases by an average 16.5 million dollars per 1,000 MW of OSW capacity added across the scenarios with the impact increasing as MWs are added
  - Renewable spillage (FCM + energy only PV, onshore wind, and OSW) is driven by production oversupply, not interface constraints, as evidenced by increasing amount of spillage in unconstrained case for some scenarios
  - Renewable spillage across all scenarios is minimal (less than 2.16% of renewable energy in the 6,000 MW of OSW scenario); the rate of spillage increases as OSW deployment increases

[1] Depending on transmission constraints

BACKGROUND

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 and regional fuel security 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
  - Reference these presentations for a detailed discussion of study assumptions

ASSUMPTIONS

Summary: NESCOE 2030 Scenarios Model Varying Degrees of Resource Expansions

<table>
<tr><th>Scenario</th><th>Gross Demand</th><th>Energy Efficiency</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>Offshore Wind Additions (Nameplate)</th><th>Demand from Heat Pumps</th><th>Demand from Electric Vehicles</th><th>Battery Storage Additions</th></tr>
<tr><td>0 MW (Reference)</td><td colspan="5" rowspan="7">Based on 2019 CELT Forecast</td><td rowspan="7">2019 CELT generators and cleared FCA 13 resources[2]</td><td rowspan="7">FCA 13 and Mystic 8&9</td><td>NECEC (1,090 MW of firm import)</td><td>0 MW</td><td rowspan="7">2,050 MW[3]</td><td rowspan="7">550,000 vehicles</td><td rowspan="7">2,000 MW</td></tr>
<tr><td>1,000 MW</td><td rowspan="6">NECEC (1,090 MW of firm import) 1,000 MW of offshore wind (nameplate)</td><td>0 MW</td></tr>
<tr><td>2,000 MW</td><td>1,000 MW</td></tr>
<tr><td>3,000 MW</td><td>2,000 MW</td></tr>
<tr><td>5,000 MW</td><td>4,000 MW</td></tr>
<tr><td>6,000 MW</td><td>5,000 MW</td></tr>
</table>

[2] Existing OSW (Block Island Wind) is part of the 2019 CELT
[3] NESCOE requested Demand for Heat Pumps only be in the 6,000 MW scenario, but in theses results they are in all scenarios

- Today's results use 2006 wind/load/PV profiles similar to those used in the 2016 Economic Study

Today's Presentation

- To review the preliminary results of the 2019 NESCOE economic study covering the following scenarios under transmission constrained and unconstrained cases:
  - Reference (0 MW OSW) – New England system reflecting assumed 2030 load
  - Unconstrained transmission is modeled as a one-bus system, while constrained transmission is modeled using the RSP pipe and bubble configuration
  - Scenario refers to varying amounts of additional offshore wind, while case refers to transmission constrained or unconstrained conditions

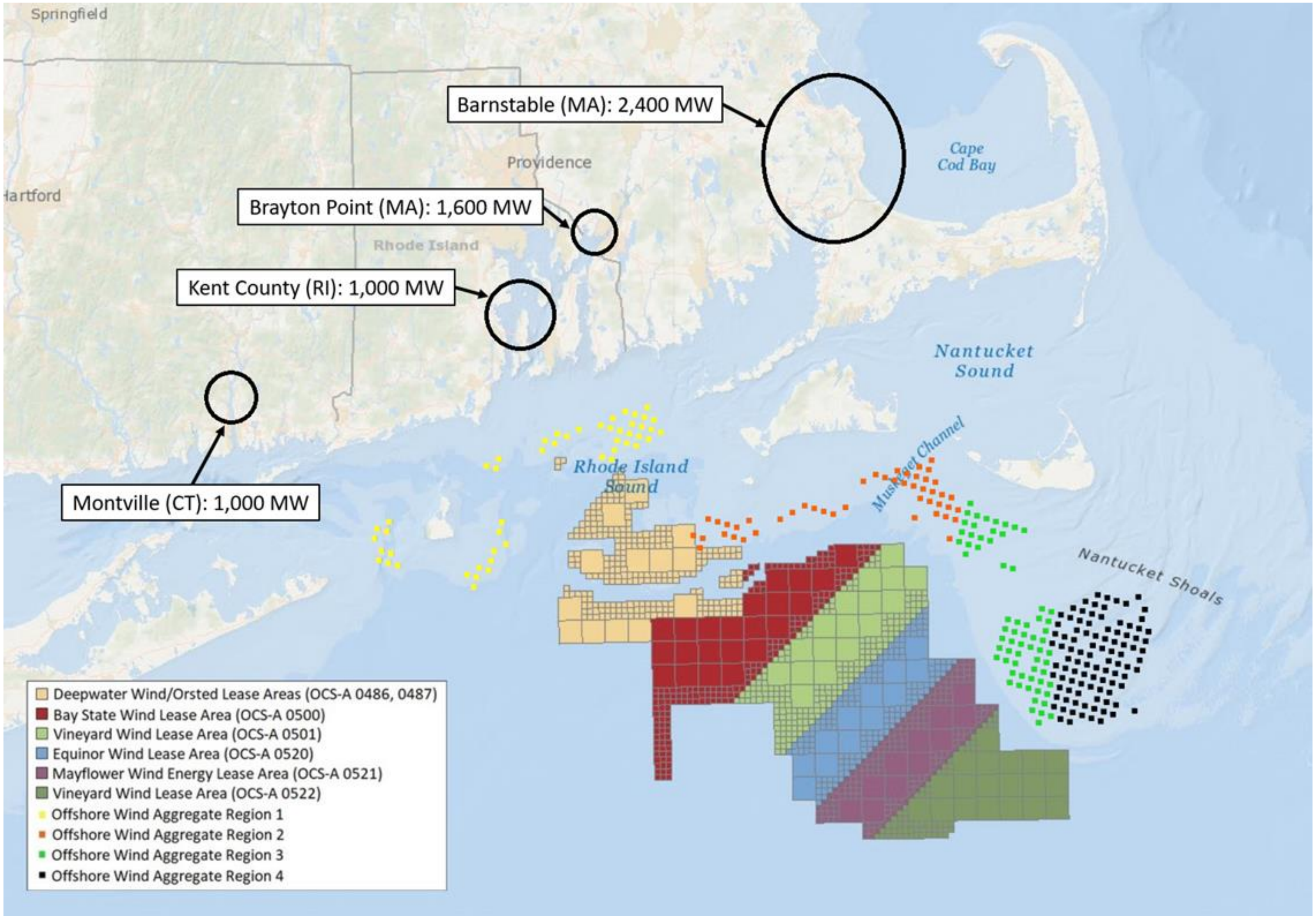
Scenario	Interconnection Points					
	Block Island (RI)	Montville (CT)	Kent County (RI)	Brayton Point (SEMA)	Barnstable (SEMA)	Total
0 MW	29	0	0	0	0	29
1000 MW	29	0	0	500	500	1029
2000 MW	29	0	700	500	800	2029
3000 MW	29	0	700	800	1500	3029
5000 MW	29	800	1000	800	2400	5029
6000 MW	29	1000	1000	1600	2400	6029

Value shown are in nameplate MW

Today's Presentation, cont.

- Assessment of OSW additions for this study do not take into consideration transmission upgrades associated with interconnection to the New England power grid pursuant to Schedules 22/23 of the Tariff (Minimum Interconnection Standard) or FCM participation pursuant to Market Rule 1, Section 13 (initial interconnection analysis including overlapping impact analyses)
- 2006 NREL offshore wind profiles were used for preliminary results due to availability, new 2015 OSW profiles will be used in the final results
  - Though new wind profiles will affect the model, trends seen in this presentation are not expected to vary significantly from the use of a new wind profile
- Threshold prices are assigned to certain resource types to facilitate the analysis of load levels where the amount of $0/MWh resources exceeds the system load
  - They are not indicative of "true" cost, expected bidding behavior, or the preference for one type of resource over an other

Locations of NREL OSW Sites and Interconnection Points used for Preliminary Results



Approximate locations shown

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

- The study used similar threshold prices as prior Economic Studies (2016 and 2017), with two adjustments:
  - The behind-the-meter PV and utility scale PV (FCM & energy-only) are differentiated
  - A threshold price was added to reduce energy delivery from the NECEC tie
  - Use of different threshold prices than indicated may produce different outcomes

Price-Taking Resource	Threshold Price ($/MWh)
Behind-the-Meter PV	1
NECEC (1,090 MW)	2
Utility Scale PV	3
Onshore/Offshore Wind	4
New England Hydro	4.5
Imports from QC (Highgate & Ph. II)	5
Imports from NB	10

METRICS AND RESULTS

Summary of Metrics Analyzed in the 2019 NESCOE Scenario Analysis

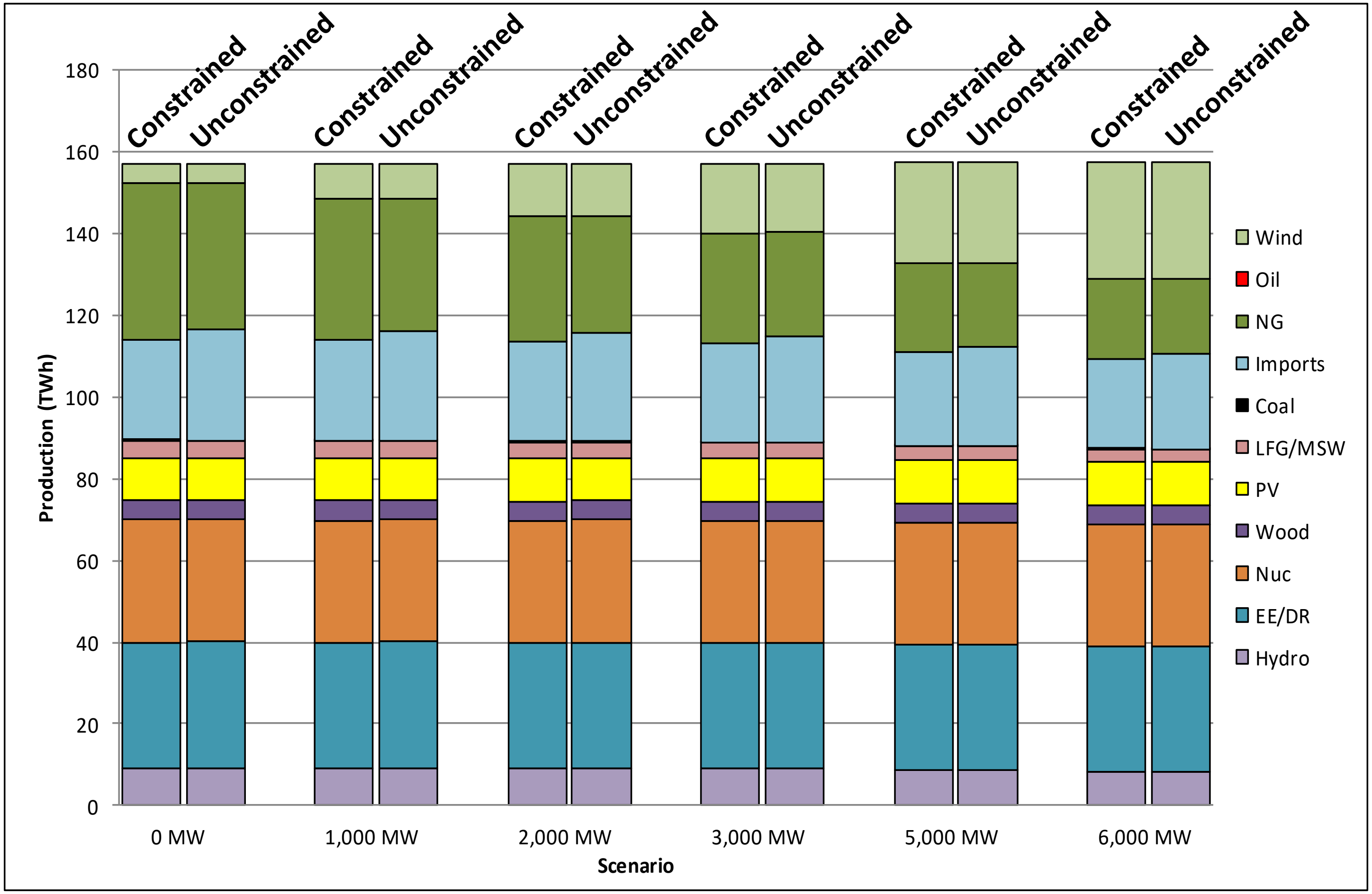
- Total systemwide energy production by fuel type
- Systemwide production costs
- Annual average locational marginal prices (LMPs)
- Load-serving entity energy expenses and uplift
- Congestion by interface
- Carbon emissions
- Renewable spillage

Key Observations

- Surowiec-South is the most constrained interface in all scenarios
- The large amount of OSW drives the results
  - Carbon emissions decrease as OSW replaces natural-gas fired generation
  - Production costs decrease as offshore wind increases
- Surowiec-South interface constraints keep LMPs lower in BHE and ME versus the rest of the system
  - Increasing OSW in southern NE reduces the price separation
- Renewable spillage is driven primarily by oversupply, not interface constraints
  - Oversupply and can be impacted by thermal ramping and system reserve needs

Total Systemwide Production by Fuel Type (TWh)

For Constrained and Unconstrained Transmission



Total Systemwide Production by Fuel Type (TWh), cont.

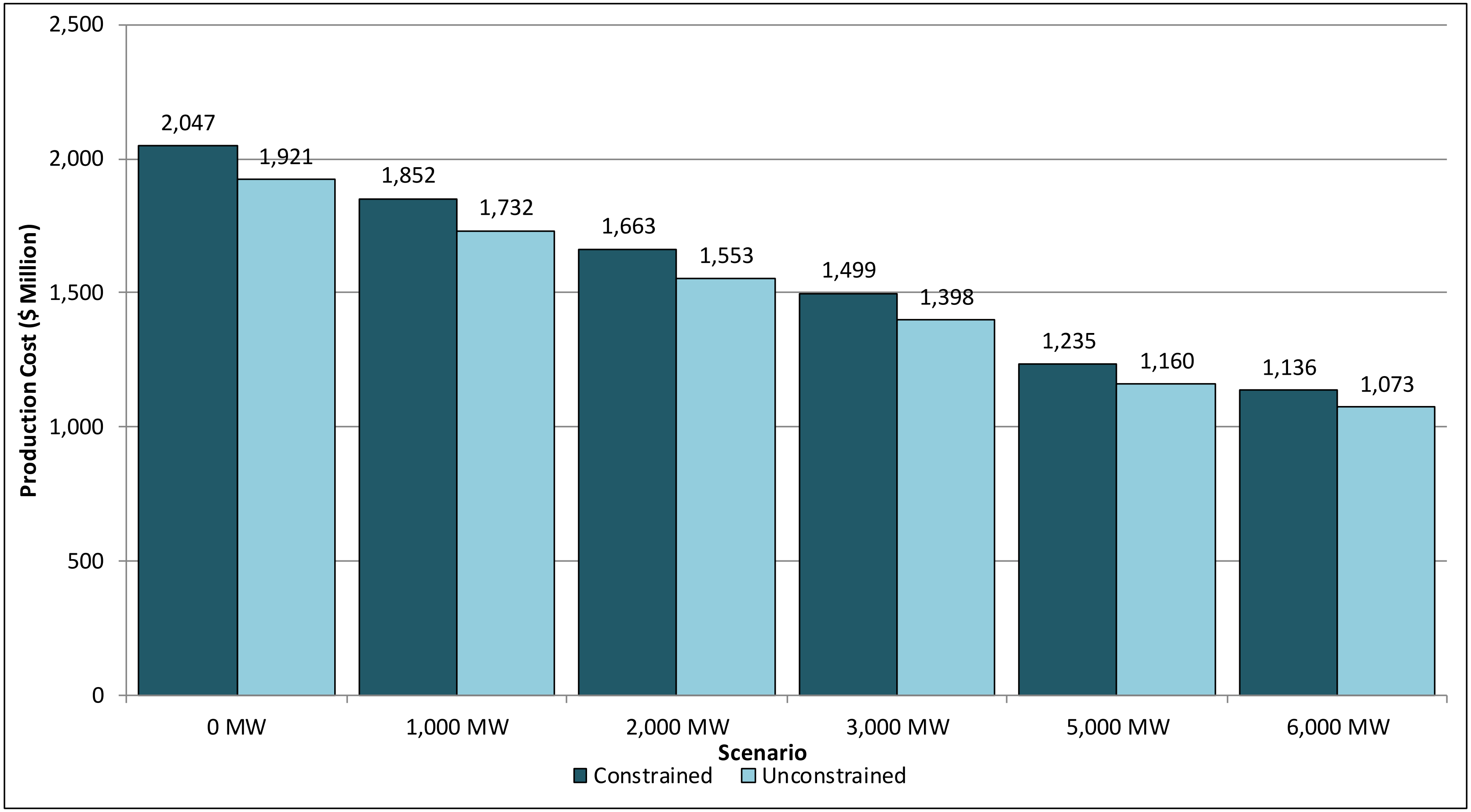
For Constrained and Unconstrained Transmission

Scenario	0 MW		1,000 MW		2,000 MW		3,000 MW		5,000 MW		6,000 MW	
Fuel Type	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.	Cstr.	Uncstr.
Wind	4.62	4.62	8.76	8.76	12.98	12.97	17.03	17.01	24.76	24.73	28.46	28.43
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NG	38.25	36.10	34.37	32.28	30.56	28.60	27.18	25.39	21.74	20.41	19.70	18.54
Imports	24.66	26.90	24.59	26.79	24.44	26.55	24.09	26.05	22.75	24.28	21.83	23.16
Coal	0.40	0.28	0.30	0.20	0.22	0.14	0.18	0.11	0.14	0.08	0.12	0.08
LFG/MSW	4.12	4.11	4.07	4.05	3.99	3.93	3.84	3.74	3.45	3.35	3.22	3.11
PV	10.43	10.43	10.43	10.43	10.43	10.43	10.43	10.43	10.43	10.43	10.43	10.43
Wood	4.72	4.72	4.72	4.72	4.71	4.71	4.71	4.71	4.70	4.70	4.70	4.70
Nuclear	29.85	29.85	29.85	29.85	29.85	29.85	29.85	29.85	29.85	29.85	29.85	29.85
EE/DR	30.81	30.81	30.81	30.81	30.81	30.81	30.81	30.81	30.81	30.81	30.81	30.81
Hydro	9.20	9.25	9.18	9.23	9.15	9.19	9.07	9.12	8.67	8.68	8.24	8.25

Total Systemwide Production by Fuel Type (TWh) - Observations

- The amount of resources assumed for each scenario is adequate to meet the systemwide *energy* requirements without significant transmission upgrades
- As OSW increases across the scenarios natural gas-fired generation decreases
- Oil-fired generation is not committed in these scenarios, however a very small amount coal-fired generation is committed in all scenarios
  - Based on EIA data, coal prices are lower than natural gas prices resulting in economic dispatch of remaining coal plants

Systemwide Production Costs ($ Million)



- Production costs are lower in unconstrained cases since they utilize more zero-cost energy north of Surowiec-South

Systemwide Production Costs ($ Million), cont.

Transmission Case	Scenario					
	0 MW	1,000 MW	2,000 MW	3,000 MW	5,000 MW	6,000 MW
Constrained	2,047	1,852	1,663	1,499	1,235	1,136
Unconstrained	1,921	1,732	1,553	1,398	1,160	1,073

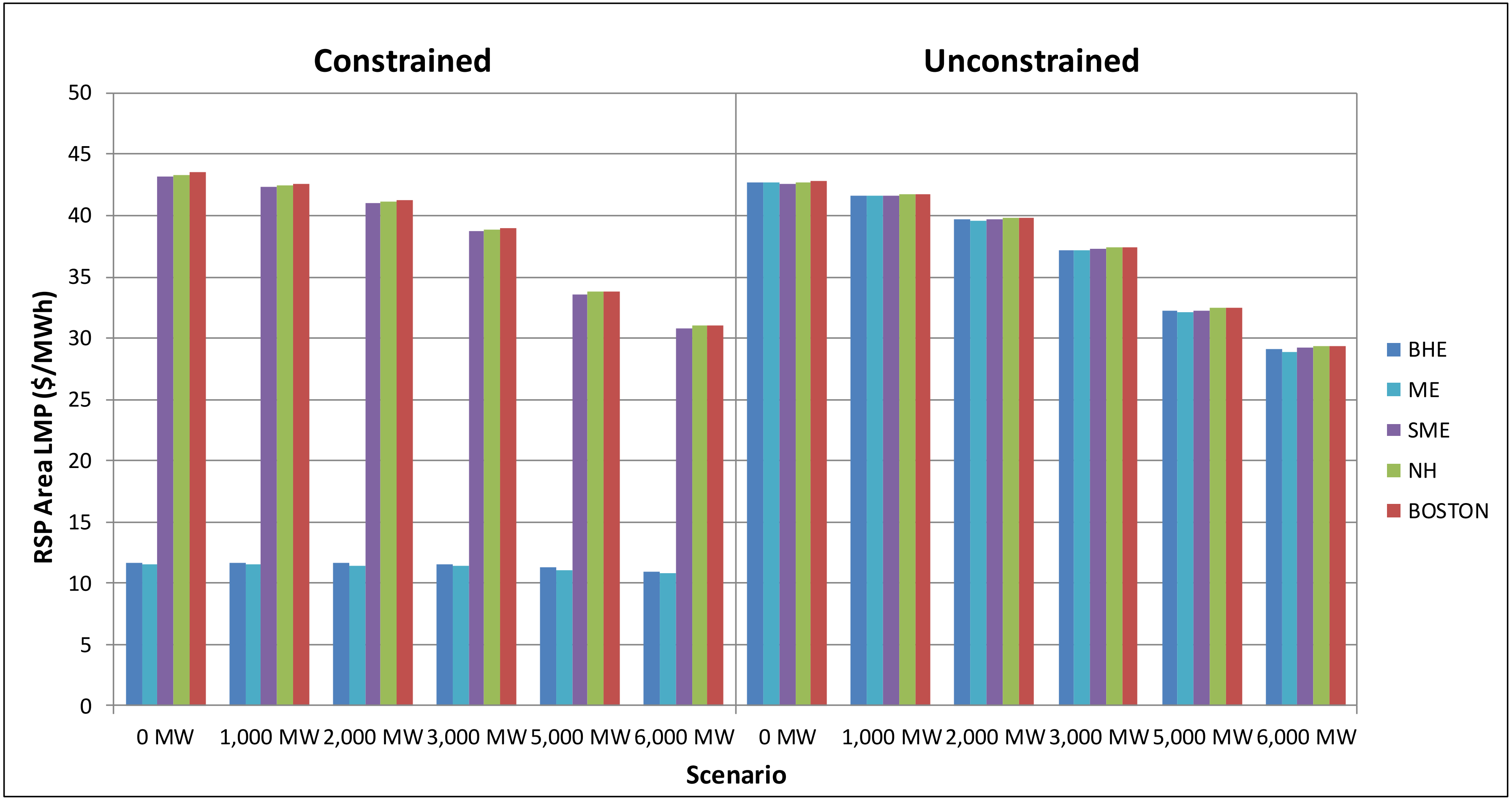
Savings from the reference scenario:

Transmission Case	Scenario					
	0 MW	1,000 MW	2,000 MW	3,000 MW	5,000 MW	6,000 MW
Constrained	-	195	385	549	813	911
Unconstrained	-	189	368	523	761	848

Systemwide Production Costs - Observations

- Production costs decrease by an average of 128-138 million dollars per 1,000 MW of OSW capacity in the scenarios
- The incremental production savings per MW decrease as OSW increases
  - At 6,000 MW OSW the savings are below 100 million per 1,000 MW of OSW
  - The production cost impact of additional OSW MW at 6,000 MW is ~70% of the initial OSW MW
- The 6,000 MW OSW scenario has the lowest systemwide production costs while the reference scenario of 0 MW OSW has the highest
- Production costs are mainly driven by variations in natural gas utilization and to a lesser extent, other fuels
  - Increased OSW results in a decrease in utilization of fossil-fueled production which reduces production costs
  - Transmission constraints reduce the ability to utilize (mostly) onshore wind and increases reliance on natural gas generation

Annual Average LMPs by RSP Subarea ($/MWh)



- Price separation is caused by Surowiec-South interface constraints

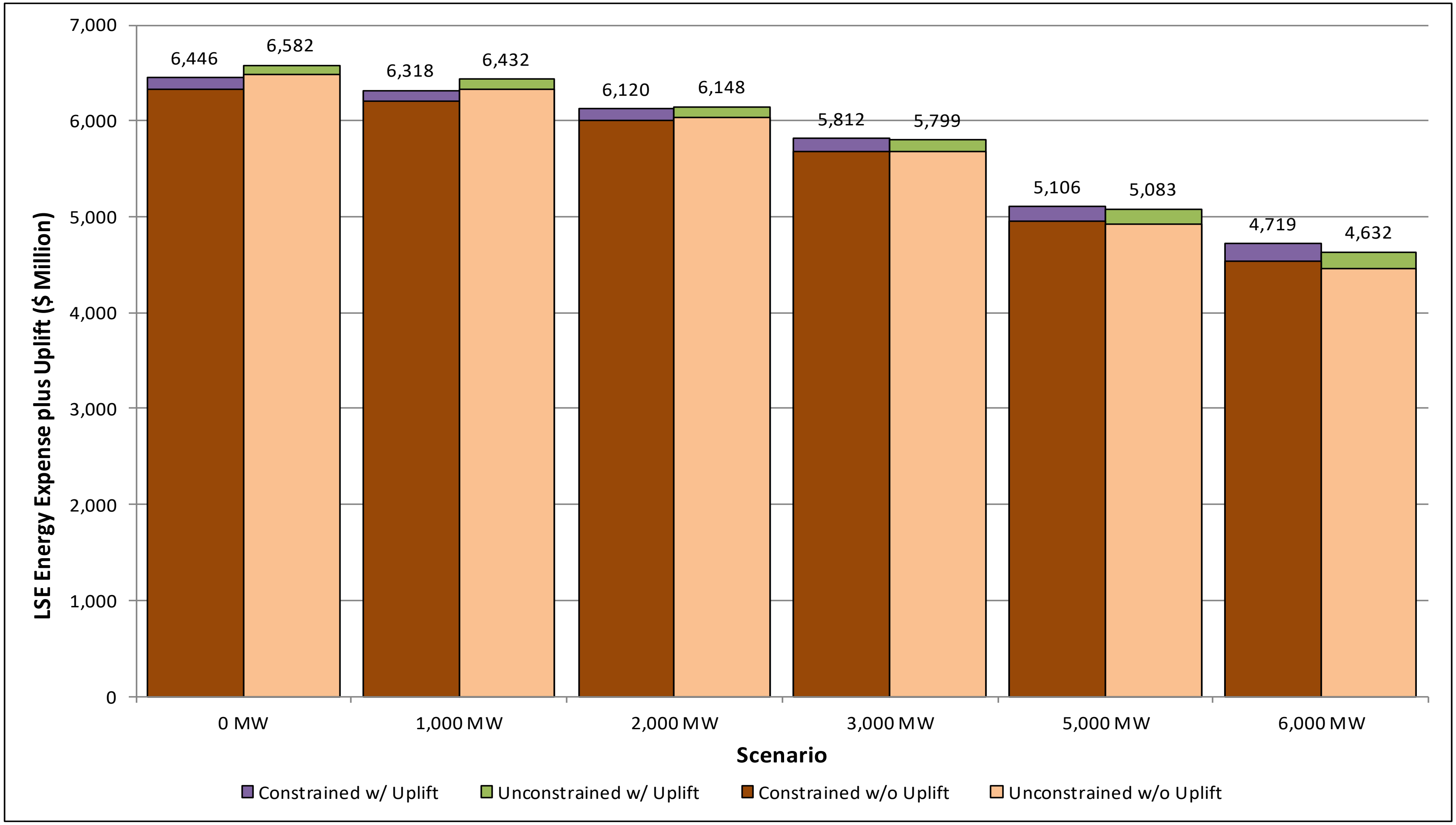
Annual Average LMPs by RSP Subarea ($/MWh)

Transmission Case	Scenario	BHE	ME	SME	NH	BOSTON
Constrained	0 MW	11.61	11.49	43.17	43.30	43.53
	1000 MW	11.71	11.57	42.36	42.50	42.63
	2000 MW	11.61	11.48	40.98	41.16	41.22
	3000 MW	11.52	11.38	38.71	38.91	38.97
	5000 MW	11.28	11.11	33.61	33.82	33.85
	6000 MW	11.00	10.83	30.79	31.00	31.02
Unconstrained	0 MW	42.67	42.72	42.64	42.76	42.80
	1000 MW	41.61	41.64	41.59	41.73	41.77
	2000 MW	39.64	39.63	39.64	39.81	39.86
	3000 MW	37.21	37.13	37.23	37.40	37.45
	5000 MW	32.21	32.06	32.29	32.47	32.49
	6000 MW	29.11	28.92	29.22	29.39	29.39

Annual Average LMPs by RSP Subarea - Observations

- During the unconstrained case, scenarios that have more energy production from price-taking resources are characterized by lower LMPs
  - 6,000 MW OSW scenario has the lowest LMPs
  - All scenarios have lower LMPs than the reference scenario
- When modeling the constrained case, Surowiec-South interface experiences congestion which results in lower LMPs in Maine subareas compared to those in southern New England
  - The reference scenario has the largest price separation between BHE/ME and the rest of the system, the separation decreases as OSW is added which lowers LMPs outside of Maine

Load-serving Entity (LSE) Energy Expense and Uplift ($ Million)



- Uplift increases as wind penetration reduces LMPs

Load-serving Entity Energy Expense and Uplift ($ Million)

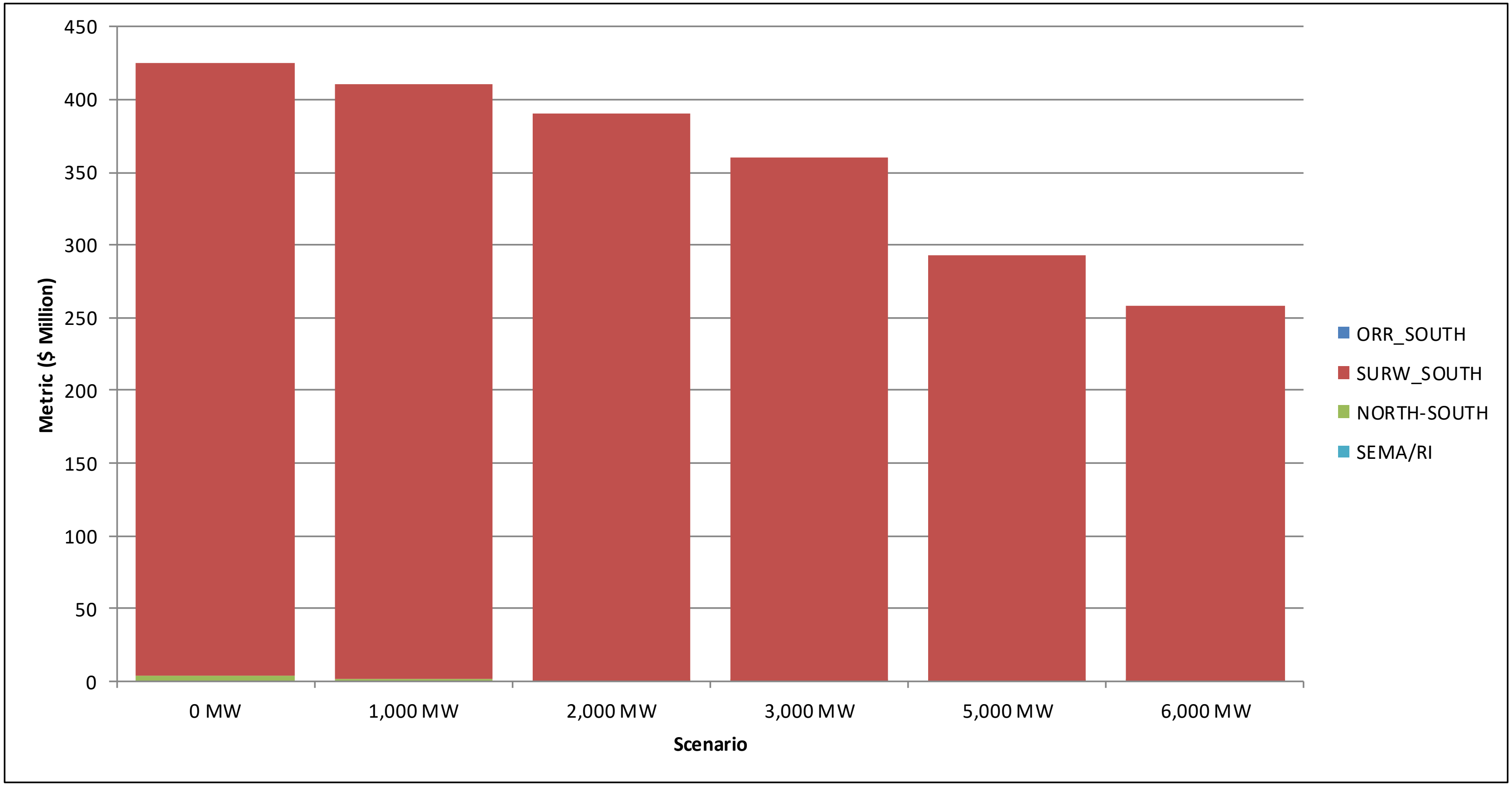
Transmission Case	Type	Scenario					
		0 MW	1,000 MW	2,000 MW	3,000 MW	5,000 MW	6,000 MW
Constrained	LSE energy expense	6,332	6,206	6,006	5,684	4,951	4,543
	Uplift	114	111	115	127	155	176
	Total	6,446	6,318	6,120	5,812	5,106	4,719
Unconstrained	LSE energy expense	6,485	6,329	6,040	5,677	4,928	4,458
	Uplift	97	103	108	122	155	174
	Total	6,582	6,432	6,148	5,799	5,083	4,632

Load-serving Entity Energy Expense Savings and Uplift ($ Million), cont.

Savings from the reference scenario:

Transmission Case	Type	Scenario					
		0 MW	1,000 MW	2,000 MW	3,000 MW	5,000 MW	6,000 MW
Constrained	LSE energy expense savings	-	125	326	648	1,381	1,788
	Uplift	-	3	-1	-13	-41	-62
	Total	-	128	326	634	1,340	1,727
Unconstrained	LSE energy expense savings	-	156	445	808	1,557	2,028
	Uplift	-	-6	-11	-25	-58	-77
	Total	-	151	434	783	1,499	1,951

Congestion by Interface ($ Million)



- Constraints are concentrated at Surowiec-South and lessen as OSW increases

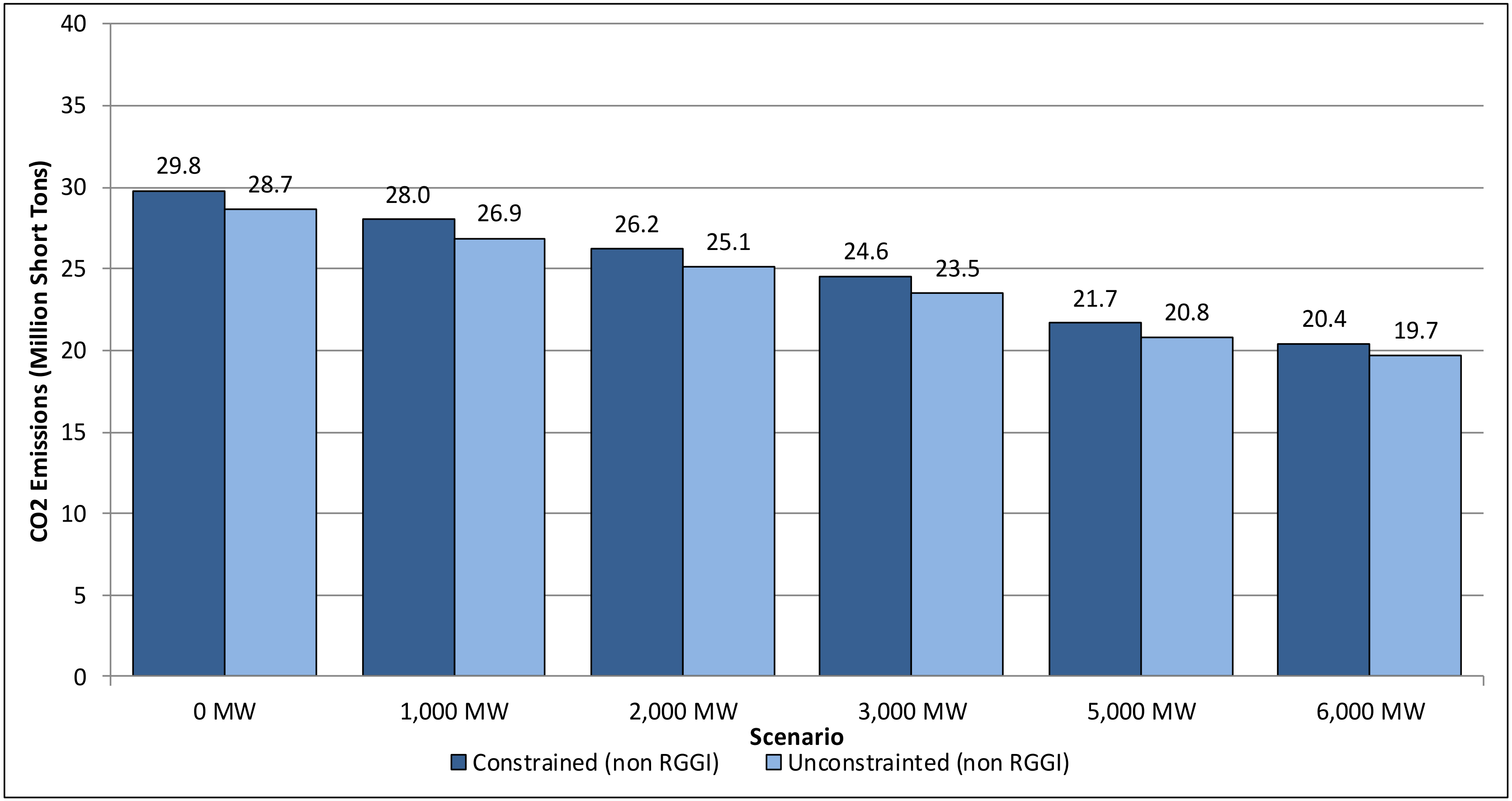
Congestion by Interface ($ Million)

Interface	Scenario					
	0 MW	1,000 MW	2,000 MW	3,000 MW	5,000 MW	6,000 MW
Orrington South	0.0	0.0	0.0	0.0	0.0	0.0
Surowiec South	421.1	408.6	390.3	359.6	292.3	257.8
North-South	3.7	1.7	0.4	0.3	0.1	0.4
SEMA/RI	0.0	0.0	0.0	0.0	0.0	0.0
Total	424.8	410.3	390.7	359.9	292.4	258.2

Load-serving Entity Energy Expense Savings, Uplift and Congestions - Observations

- Congestion is concentrated at Surowiec-South, as OSW is increased in SEMA congestion at Surowiec-South decreases
  - The SEMA/RI and Orrington-South interfaces have no congestion in any of the scenarios
- As OSW MWs increase off of southern New England, congestion at Surowiec-South decreases across the scenarios by an average 16.5 million dollars per 1,000 MW of OSW capacity added
  - The more MWs of OSW that is added, the greater the rate at which congestion is decreased
- The LSE energy expense and uplift follows the same pattern as the LMPs across all scenarios
- Uplift is relatively small compared with the LSE energy expense savings for all scenarios

2030 CO_2 Emissions (millions of short tons)



- Emissions are lower in the unconstrained case since more emission-free energy is available from north of Surowiec-South

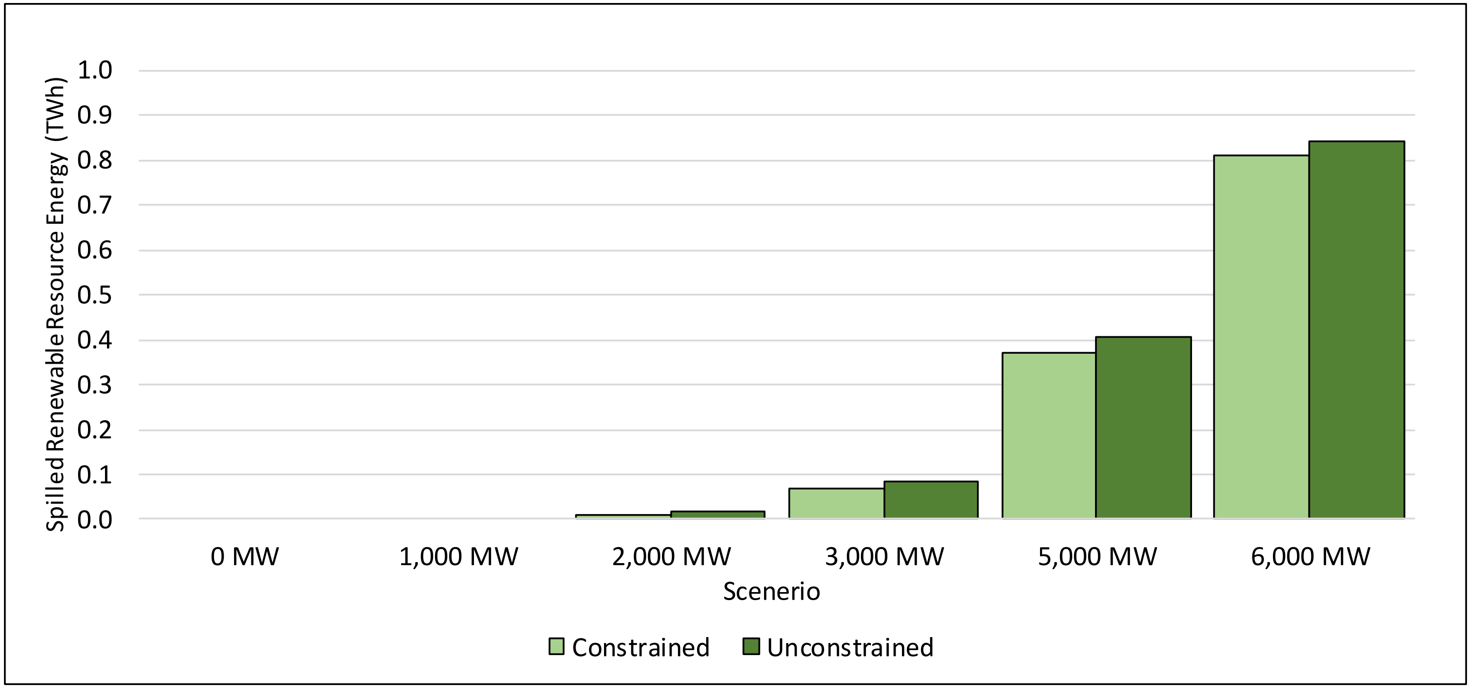
2030 CO_2 Emissions (millions of short tons)

Scenario	Transmission Case	
	Constrained	Unconstrained
0 MW	29.80	28.65
1,000 MW	28.01	26.89
2,000 MW	26.22	25.13
3,000 MW	24.56	23.51
5,000 MW	21.66	20.83
6,000 MW	20.43	19.71

CO2 Emissions - Observations

- In the case with transmission constraints carbon emissions decrease 1.50 short tons on average for every 1,000 MW of OSW nameplate capacity added
- In the case without transmission constraints carbon emissions decrease 1.41 short tons on average for every 1,000 MW of OSW nameplate capacity added

Total Amount of Spilled Renewable Resource Energy (TWh)



Renewables include PV (FCM and energy-only), Onshore Wind, and OSW

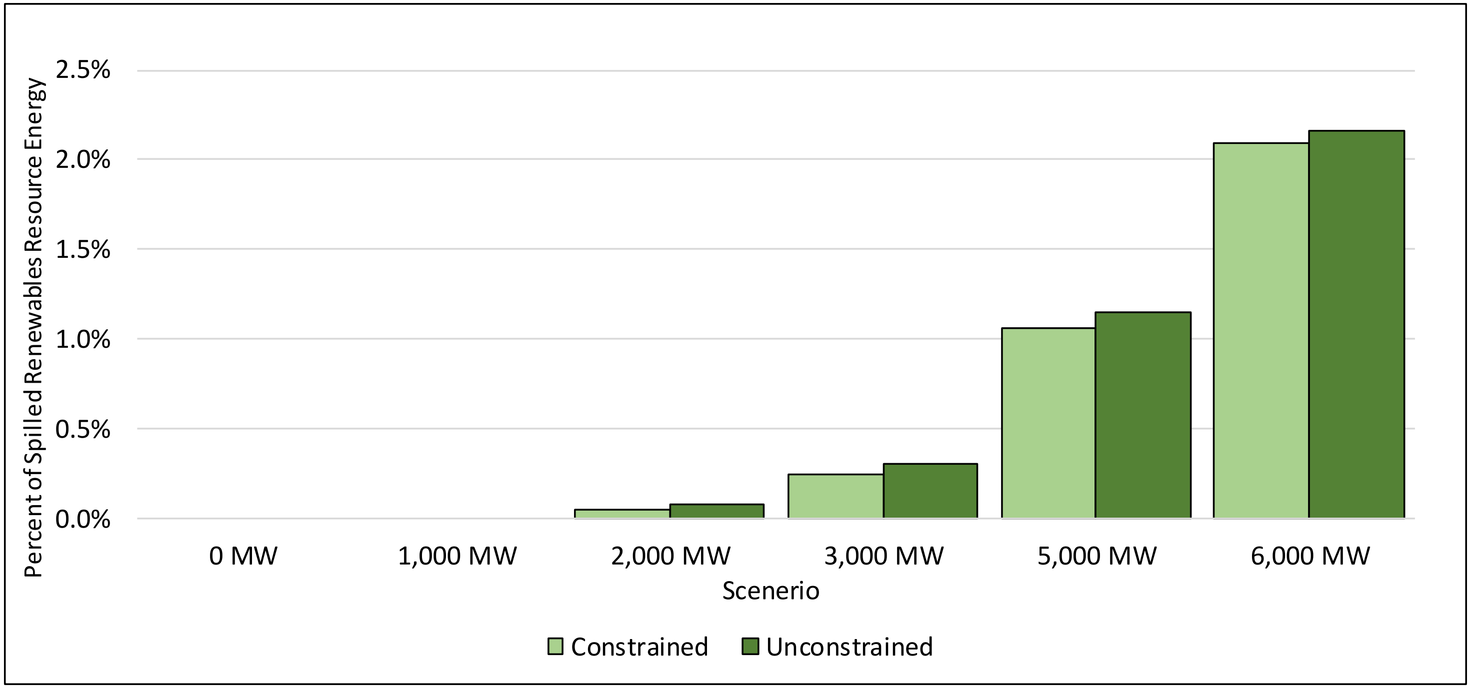
- Curtailment of specific resources is driven by the threshold prices and order, which can vary from the assumptions used in this model

Total Amount of Spilled Renewable Resource Energy (TWh), cont.

Scenario	Transmission Case	
	Constrained	Unconstrained
0 MW	0.000	0.000
1,000 MW	0.000	0.000
2,000 MW	0.011	0.019
3,000 MW	0.068	0.085
5,000 MW	0.372	0.405
6,000 MW	0.812	0.841

Renewables include PV (FCM and energy-only), Onshore Wind, and OSW

Percentage of Spilled Energy vs Total Generation for Renewable Resource



Renewables include PV (FCM and energy-only), Onshore Wind, and OSW

- Renewable spillage is minimal even in the unconstrained 6,000 MW OSW scenario where **2.16%** of production is spilled

Percentage of Spilled Energy vs Total Generation for Renewable Resource, cont.

Scenario	Transmission Case	
	Constrained	Unconstrained
0 MW	0.00%	0.00%
1,000 MW	0.00%	0.00%
2,000 MW	0.05%	0.08%
3,000 MW	0.25%	0.31%
5,000 MW	1.06%	1.15%
6,000 MW	2.09%	2.16%

Renewables include PV (FCM and energy-only), Onshore Wind, and OSW

Total Amount of Spilled Renewable Resources - Observations

- Renewable spillage is being driven by oversupply of generation versus load, not interface constraints, particularly in the 5,000 and 6,000 MW OSW scenarios where there is more spillage in the case without constraints
  - Renewable spillage is minimal even in the 6,000 MW OSW scenario
- The additional renewable spillage in constrained scenarios is driven by the Surowiec-South interface
- Renewable spillage increases ~0.25 TWh on average for every 1,000 MW of OSW nameplate capacity added regardless of transmission constraints
- The incremental increase in renewable spillage increases for each MW of OSW added, but the curve is not linear

NEXT STEPS

Next Steps of the NESCOE 2019 Economic Study

- Update results with revised 2015 load/PV/wind profiles and complete production for all NESCOE scenarios by February 2020
- Target to perform and complete additional analyses by March 2020
- Final report expected Q2 2020

Next Steps of the Anbaric 2019 Economic Study

- Produce preliminary results by Q1 2020
  - Using the same 2006 load/PV/wind profiles that have been used in the 2016 and 2017 Economic Studies
- Update preliminary results with revised 2015 load/PV/wind profiles and complete production for all scenarios by Q2 2020
- Target to perform and complete additional analyses by Q2 2020
- Final report expected Q2 2020

Next Steps of the Renew 2019 Economic Study

- Produce preliminary results by Q1 2020
  - Using the same 2006 load/PV/wind profiles that have been used in the 2016 and 2017 Economic Studies
- Update preliminary results with revised 2015 load/PV/wind profiles and complete production for all scenarios by Q2 2020
- Final report expected Q2 2020

Questions

APPENDIX

The 2019 Study Reflects 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 of 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 data bases.

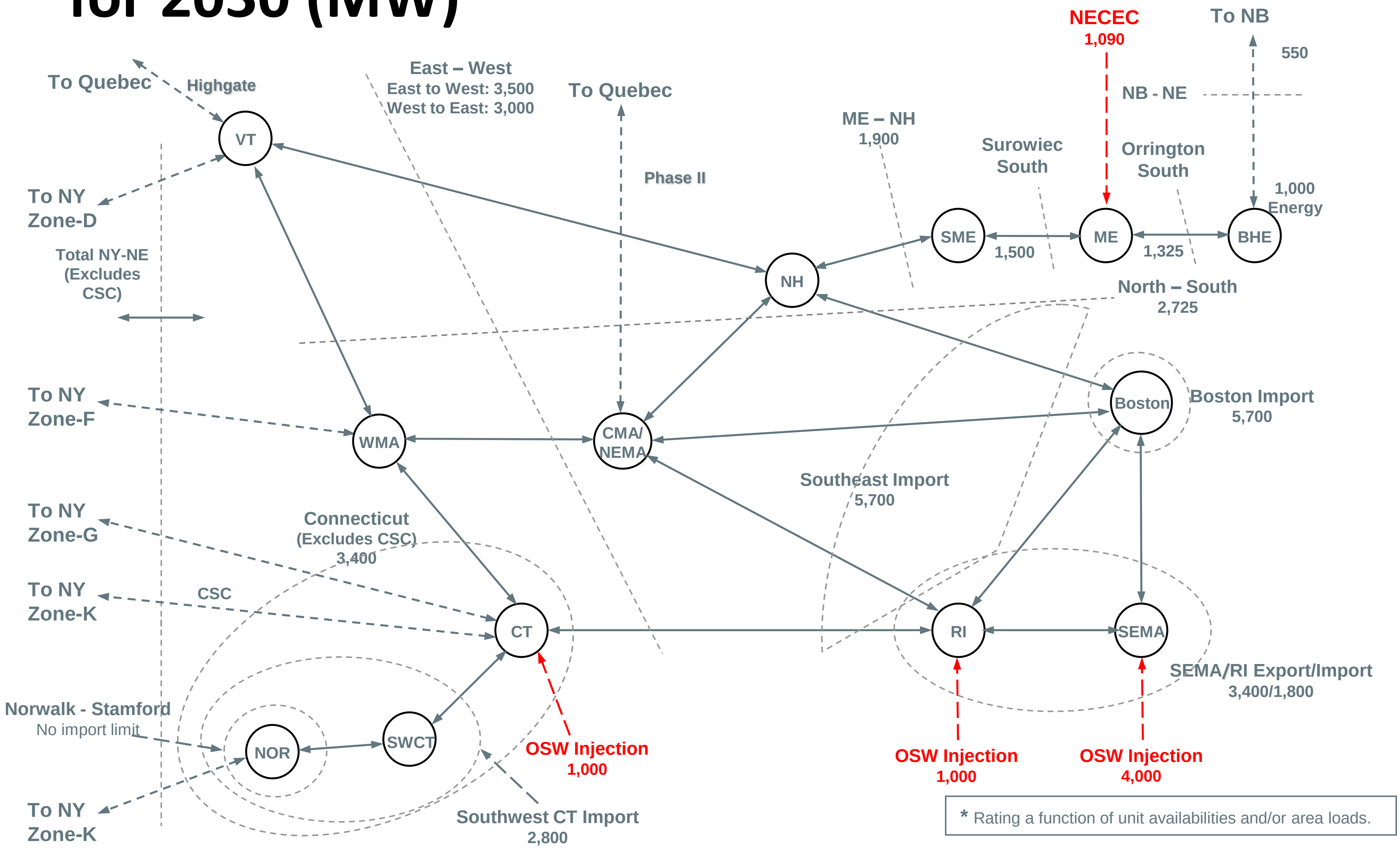
The 2019 Study Reflects the Same Basic Assumptions That Were Used in Recent Economic Studies, cont.

- 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.
- 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.

Profiles Used in the 2019 Study

- Load profiles (load shape and daily peak) reflect price-taking resources, including EE, PV, wind, hydro and imports.
- These preliminary results use Wind and PV profiles hourly profiles developed by the National Renewable Energy Lab (NREL) compatible with the hourly system loads used in the GridView simulations.
- Profiles for charging plug-in hybrid electric vehicles (PHEVs) model charging based on recent NREL 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.

Assumed New England System Representation for 2030 (MW)



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
- NECEC – New England Clean Energy Connect

Acronyms, cont.

- 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