2016 Economic Studies Forward Capacity Auction Scope of Work

Planning Advisory Committee

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VICE PRESIDENT, MARKET OPERATIONS

OVERVIEW AND BACKGROUND

Overview

- The scope of work and draft results of Scenario Analysis reflect input from the Planning Advisory Committee
  - The ISO annually conducts Economic Studies in response to stakeholder requests
  - Scenario Analysis is being conducted in response to a NEPOOL request
  - The scope of work, assumptions, and draft results were discussed with the Planning Advisory Committee (PAC) and the Integrating Markets and Public Policy (IMAPP) group
- Phase I consists of production cost simulation results for five scenarios, which were examined for 2025 and 2030 with the transmission system constrained and unconstrained, and with sufficient resources to meet the Net Installed Capacity Requirement
- Today we will discuss the Phase II Scenario Analysis Scope of Work for Forward Capacity Auction Prices
  - A limited number of scenarios can be considered because the ISO requires assistance from a consultant

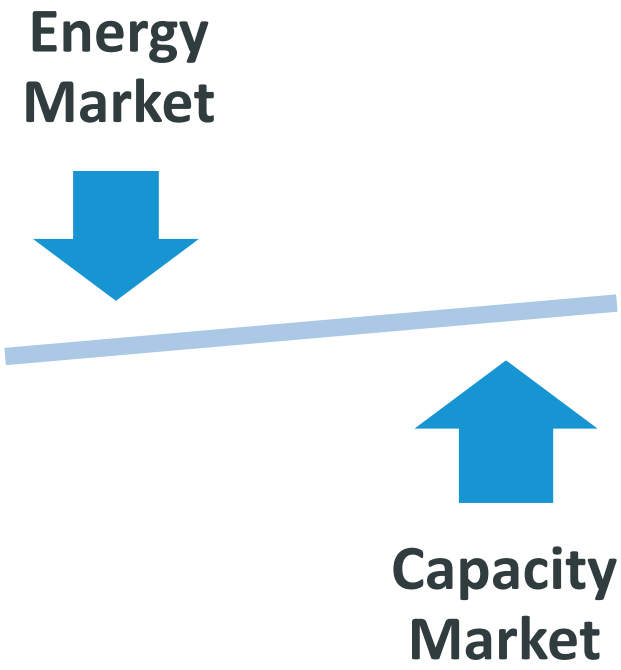
5 Scenarios Included in 2016 Economic Study

Approximately 25 metrics presented for each scenario

1. Generation fleet meeting existing Renewable Portfolio Standards (RPS) and retired units replaced with natural gas combined cycle (NGCC) units
2. Generation fleet meeting existing RPS and all future needs, including retirements, met with new renewable/clean energy resources
3. The “RPS-plus scenario” - Generation fleet meeting existing RPS plus additional renewable/clean energy resources, EE, PV, plug-in electric vehicles, and distributed storage
4. Generation fleet meeting existing RPS by resources currently under development and use of Alternative Compliance Payments with NGCC additions, and with no retirements (the “no retirement scenario”)
5. Existing fleet meeting existing RPS by resources currently under development and use of Alternative Compliance Payments and retirement replacement with NGCC additions

The Energy and Capacity Markets Are Linked; Changes in One Market Will Affect the Other

- Because renewable resources typically have **no fuel costs**, they will be dispatched ahead of conventional generation (gas, coal, and oil), putting *downward* pressure on energy-market prices and *upward* pressure on capacity prices
- The **shift in revenues** from the energy to the capacity market **will affect the resource mix**, putting additional financial pressure on energy-market dependent resources like nuclear and coal-fired units
- Competition among natural gas units decreases their revenue from the energy market



With increasing levels of renewables, the capacity market will play a key role in ensuring resource adequacy

The Analysis Group Will Model Capacity Market Outcomes for Each Scenario

- AG effort will quantify observation that lower energy prices are generally expected to increase capacity market prices
- Analyze the Five Base Scenarios for 2025 and 2030
  - Use one bus model
  - Discuss draft results with the PAC
- Build off prior capacity market modeling efforts
  - AG capacity market model previously analyzed Pay for Performance ("PFP") market rules
  - Update the model for current resource and market conditions
  - Incorporate recent FCM rule changes
  - Energy market outcomes modelled by ISO-NE will feed into FCM outcomes modelled by Analysis Group.

The Analysis Group Model

- Model estimates FCM market equilibrium based on resource supply curve and demand curve
- Supply curve is based on resource-specific capacity market offers reflecting resource-specific estimates of going forward costs ("GFC")
  - GFC reflects fixed costs less net energy and ancillary service revenues
  - Reflects performance in PFP market environment
  - Includes all existing resources in each scenario
- Demand curves reflect assumed needed capacity levels
- Single year snapshots of prices, not a price trajectory across years

Scenarios

- Initial runs will cover each of the 5 scenarios for 2025 and 2030
- Some limited additional sensitivities may be performed
  - These could include, for example, different assumptions around the application of the Minimum Offer Price Rule (MOPR)
  - Other scenarios of interest likely to arise as the modeling effort progresses

NEXT STEPS

Schedule

- May 2017
  - Discuss draft results with PAC
- June 2017
  - Post final results

Questions

APPENDIX: BACKGROUND ON THE SCENARIOS

Scenario Summary

Key differences shown in red

Scenario	Retire Oldest Oil/Coal	Gross Load	PV	EE	Wind	New NG Units	HQ and NB External Ties
1	½ in 2025 ½ in 2030	Based on 2016 Forecast	Based on 2016 Forecast	Based on 2016 Forecast	As needed to meet RPS and counted towards NICR	NGCC to meet NICR	Based on Historical Profiles
2	½ in 2025 ½ in 2030	Based on 2016 Forecast	Queue additions scaled up by same factor as wind	Based on 2016 Forecast	Queue additions scaled up to satisfy NICR	None	Based on Historical Profiles
3	½ in 2025 ½ in 2030	Based on 2016 Forecast	Provided by Stakeholders	Provided by Stakeholders	Provided by Stakeholders	None	Based on Historical Profiles plus additional Imports
4	None	Based on 2016 Forecast	Based on 2016 Forecast	Based on 2016 Forecast	Existing plus I.3.9	None	Based on Historical Profiles
5	½ in 2025 ½ in 2030	Based on 2016 Forecast	Based on 2016 Forecast	Based on 2016 Forecast	Existing plus I.3.9	NGCC to replace retirements and meet NICR	Based on Historical Profiles

Retire oldest oil and coal units in 2025 and remaining units in 2030
NGCC – Natural Gas Combined Cycle
RPS – Renewable Portfolio Standard

2025 Common Assumptions to All Scenarios

- Solar - values used from the 2016 PV forecast developed by the Distributed Generation Forecast Working Group
- Energy Efficiency – values used from the 2016 EE forecast developed by the Energy-Efficiency Forecast Working Group
- On-shore Wind – nameplate of existing wind plus wind in the queue, including I.3.9, that was used in all scenarios
- Off-shore Wind – nameplate of I.3.9 wind
- HQ and NB external ties – transfer limits used in all scenarios.
- RSP transmission expansion plan

Scenario Analysis Assumptions Different from the Common Assumptions

- Individual scenarios may add or retire resources in 2025
- The resource mix is different in 2030 than the common assumptions for 2025
  - EE and PV growth
  - Other changes in retirements and additions of fossil units and renewable resources
- Preliminary high-level order of magnitude transmission costs for Integrator Systems and Congestion Relief Systems

2025 Scenario Common Assumptions Summary

Scenarios	PV (MW)	EE (MW)	On-Shore Wind (MW)	Off-Shore Wind (MW)	New NG Units (MW)	HQ and NB External Ties (MW)	Battery (MW)
1 - 5	3,427.2	3,844	1,427.4	483	0	2,625	0

2025 and 2030 Scenario Resource Additions Summary

Scenario	PV (MW)	EE (MW)	On-Shore Wind (MW)	Off-Shore Wind (MW)	New NG Units (MW)	HQ and NB External Ties (MW)	Battery (MW)
1	0 (2025) 666.8 (2030)	0 (2025) 895 (2030)	1,879.1 (2025) 2,652.1 (2030)	0 (2025) 0 (2030)	656 (2025) 4,416 (2030)	0 (2025) 0 (2030)	0 (2025) 0 (2030)
2	505 (2025) 2,803.8 (2030)	0 (2025) 895 (2030)	3,305.5 (2025) 12,972.5 (2030)	0 (2025) 1,219 (2030)	0 (2025) 0 (2030)	0 (2025) 0 (2030)	0 (2025) 0 (2030)
3	4,727.2 (2025) 8,727.2 (2030)	1,000 (2025) 3,165 (2030)	2,827.1 (2025) 3,401.9 (2030)	1,000 (2025) 2,000 (2030)	0 (2025) 0 (2030)	1,500 (2025) 2,000 (2030)	1,200 (2025) 2,500 (2030)
4	0 (2025) 666.8 (2030)	0 (2025) 895 (2030)	0 (2025) 0 (2030)	0 (2025) 0 (2030)	0 (2025) 0 (2030)	0 (2025) 0 (2030)	0 (2025) 0 (2030)
5	0 (2025) 666.8 (2030)	0 (2025) 895 (2030)	0 (2025) 0 (2030)	0 (2025) 0 (2030)	1,144 (2025) 4,833 (2030)	0 (2025) 0 (2030)	0 (2025) 0 (2030)

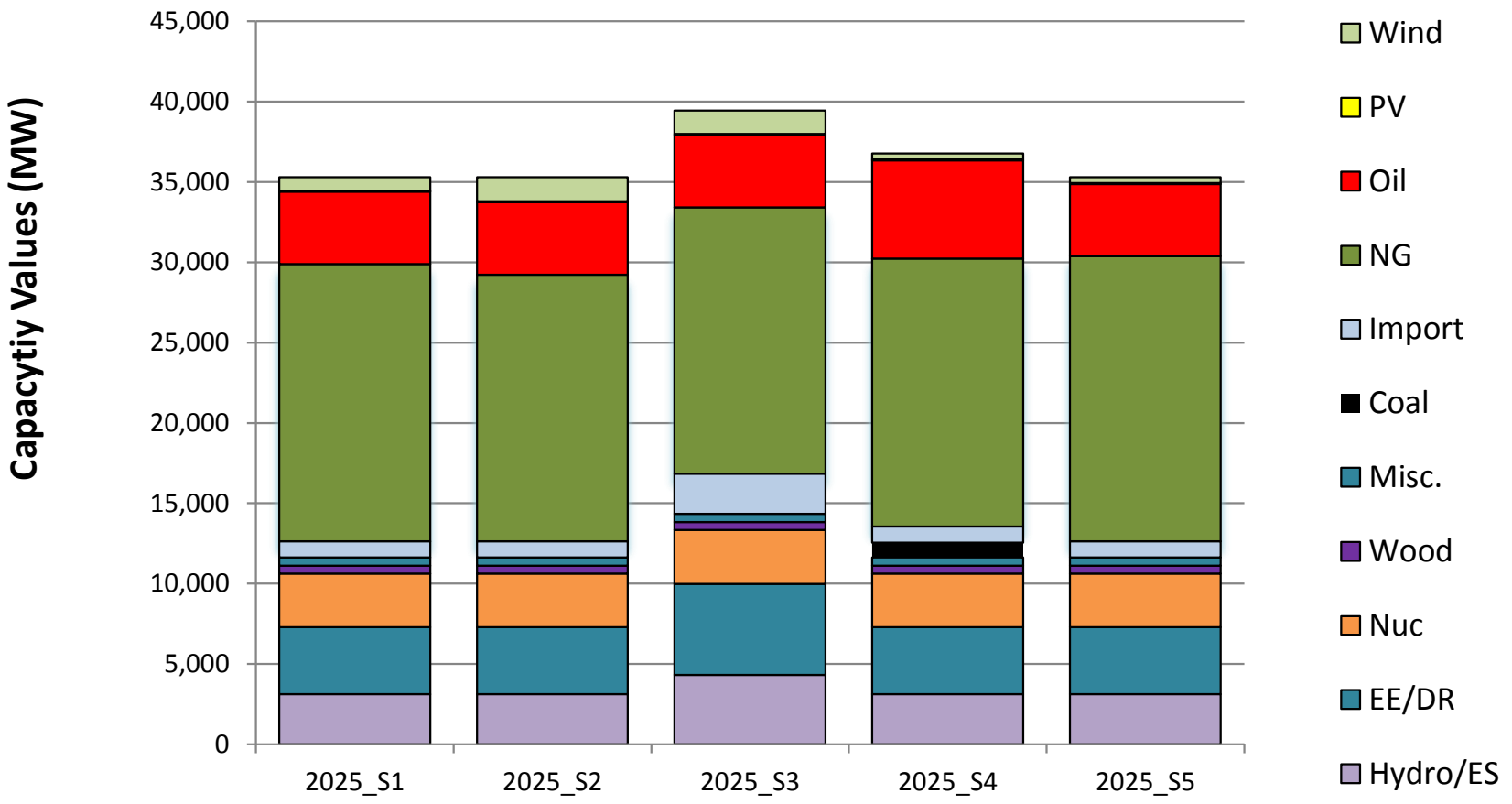
Capacity in Study Scenarios

Meets or Exceeds NICR (MW)

	Scenario	S1		S2		S3		S4[e]		S5	
	Year	2025	2030	2025	2030	2025	2030	2025	2030	2025	2030
1	FCA 10 Cleared Renewables (Bio, LFG, etc.)	976	976	976	976	976	976	976	976	976	976
2	FCA 10 Cleared Solar	62	62	62	62	62	62	62	62	62	62
3	Forecast EE & ADR w/o RTEG	4163	5058	4163	5058	5663	8328	4163	5058	4163	5058
4	FCA 10 Cleared Nuclear	3347	3347	3347	3347	3347	3347	3347	3347	3347	3347
5	FCA 10 Cleared Hydro & Pumped Storage	3116	3116	3116	3116	3116	3116	3116	3116	3116	3116
6	Resource Serving Citizen Block Load	30	30	30	30	30	30	30	30	30	30
7	Imports [a]	1006	1006	1006	1006	2506	3006	1006	1006	1006	1006
8	Wind Capacity Value	366	366	366	366	1457	1900	366	366	366	366
9	Gas after Retirement	16582	16011	16582	16011	16582	16011	16676	16676	16582	16011
10	Oil after Retirement	4509	2114	4509	2114	4509	2114	6109	6109	4509	2114
11	Coal after Retirement	0	0	0	0	0	0	917	917	0	0
12	Total Existing Resource after Retirement	34157	32086	34157	32086	38248	38890	36768	37663	34157	32086
13	Utility Scale Battery Storage	N/A	N/A	N/A	N/A	1200	2500	N/A	N/A	N/A	N/A
14	Renewable to Meet RPS (Capacity Value)[b]	488	687	488d	687d	0	0	N/A	N/A	N/A	N/A
15	Total Existing Resource plus Storage and RPS Renewables	34646	32773	34157	32086	39448	41390	36768	37663	34157	32086
16	NICR	35302	36919	35302	36919	34804	36273	35302	36919	35302	36919
17	NGCC Capacity Added to Replace Retirement and to Meet NICR	656c	4146c	0	0	0	0	N/A	N/A	1144c	4833c
18	Renewable Capacity Added to Replace Retirement and to Meet NICR	0	0	656d	4146d	0	0	N/A	N/A	0	0
19	Additional NGCC Capacity to Meet NICR	0	0	0	0	0	0	0	0	0	0
20	Additional Renewable Capacity to Meet NICR	0	0	0	0	0	0	0	0	0	0

Resource Mix Assumptions

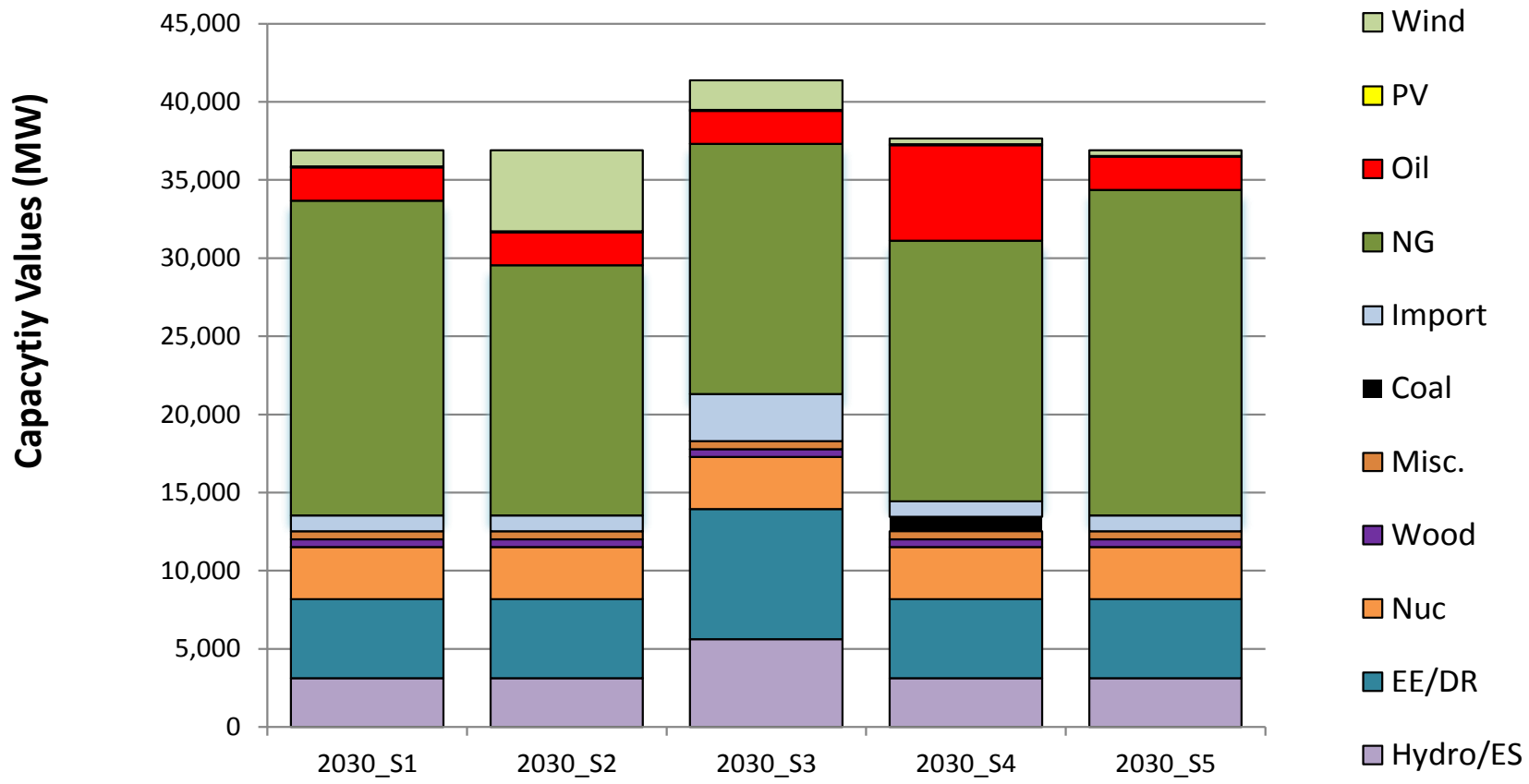
2025 Capacity Values (MW)



Resource Mix Assumptions

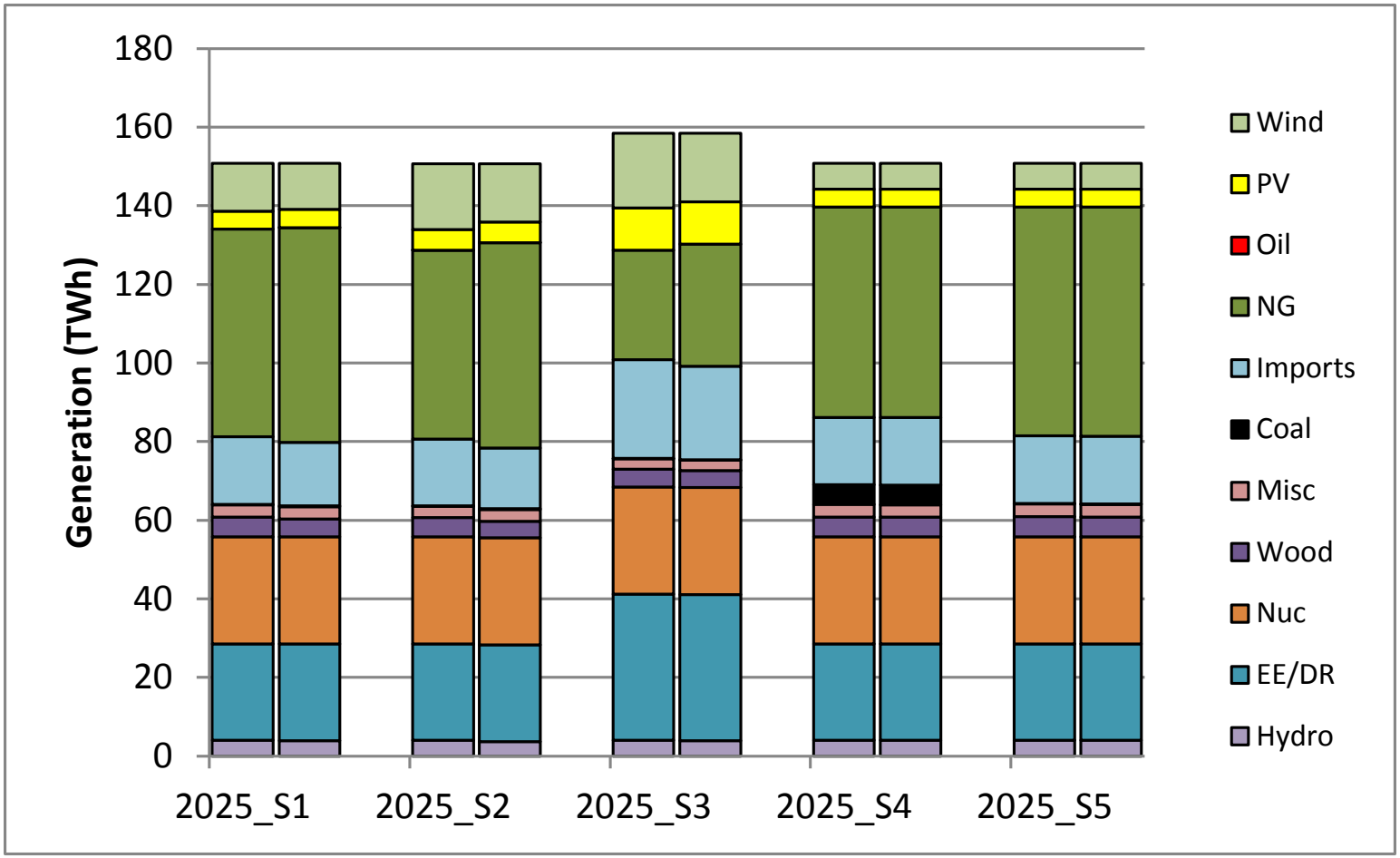
2030 Capacity Values (MW)

Natural gas resources remain the largest capacity resource across scenarios



Energy By Source 2025 (TWh)

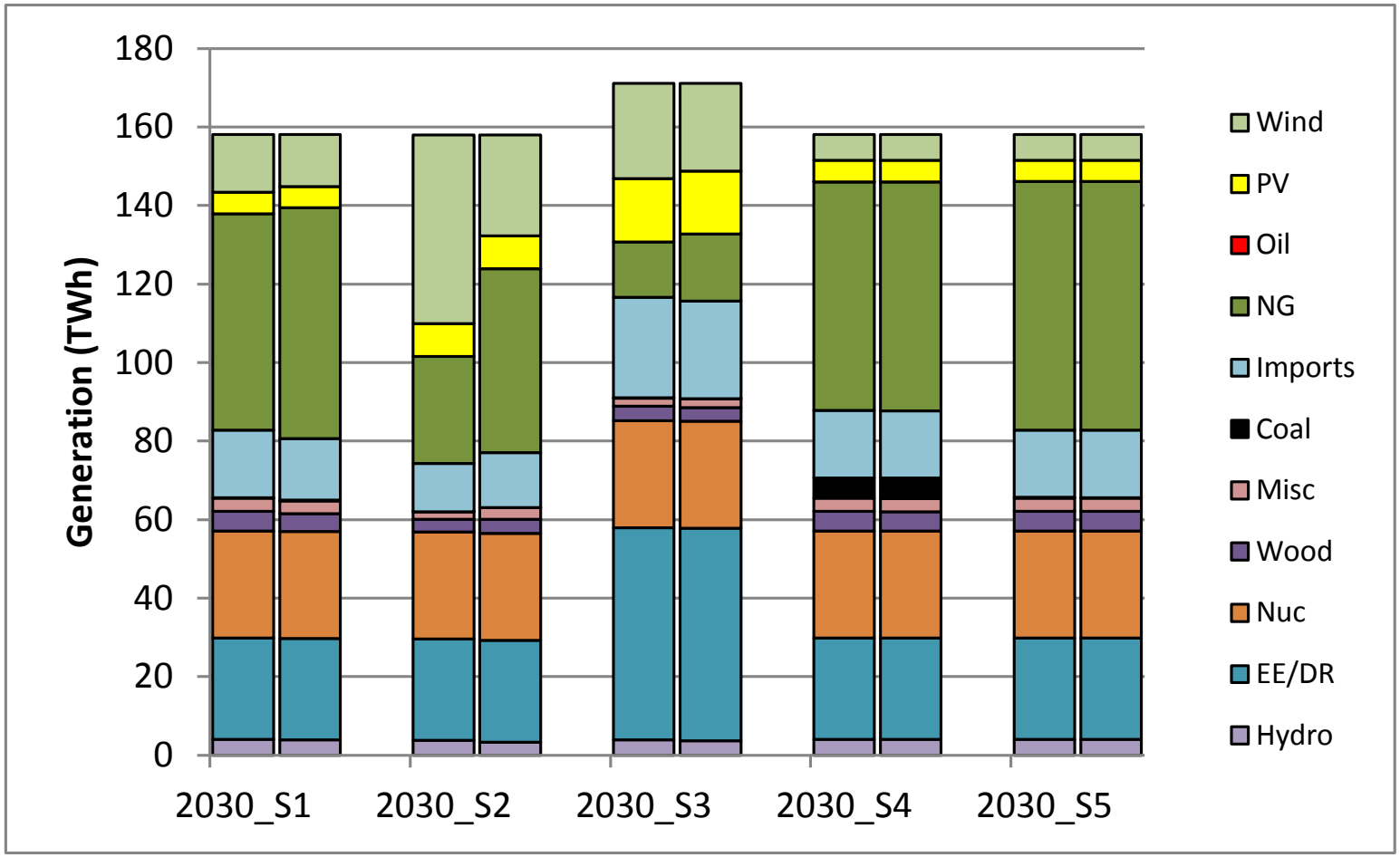
Unconstrained (Left) vs. Constrained (Right)



Energy By Source 2030 (TWh)

Unconstrained (Left) vs. Constrained (Right)

Note differences in wind generation and PV among cases. Oil units run under 0.5%, even in S4. Coal is competitive with NGCC in Scenario 4. NG capacity factors range from a high of 35% in S5 to a low of 10% in S3.



Energy By Source 2025 (TWh)

Unconstrained and Constrained

	Hydro	EE/DR	Nuc	Wood	Misc	Coal	Imports	NG	Oil	PV	Wind
2025_S1_UN	4.0	24.6	27.3	5.0	3.1	0.2	17.1	52.8	0.0	4.6	12.1
2025_S2_UN	4.0	24.6	27.3	4.8	2.9	0.2	17.0	48.0	0.0	5.3	16.8
2025_S3_UN	4.0	37.2	27.3	4.6	2.6	0.1	25.1	27.9	0.0	10.7	19.1
2025_S4_UN	4.0	24.6	27.3	5.0	3.1	5.1	17.2	53.5	0.0	4.6	6.5
2025_S5_UN	4.0	24.6	27.3	5.0	3.2	0.2	17.2	58.2	0.0	4.6	6.5
2025_S1	3.9	24.6	27.3	4.5	3.1	0.2	16.2	54.6	0.0	4.6	11.7
2025_S2	3.7	24.6	27.3	4.2	3.0	0.1	15.5	52.3	0.0	5.3	14.8
2025_S3	3.9	37.2	27.3	4.3	2.7	0.1	23.8	31.0	0.0	10.7	17.6
2025_S4	4.0	24.6	27.3	4.9	3.1	5.1	17.2	53.6	0.0	4.6	6.5
2025_S5	4.0	24.6	27.3	4.9	3.2	0.2	17.2	58.3	0.0	4.6	6.5

Energy By Source 2030 (TWh)

Unconstrained and Constrained

	Hydro	EE/DR	Nuc	Wood	Misc	Coal	Imports	NG	Oil	PV	Wind
2030_S1_UN	4.0	25.9	27.3	5.0	3.3	0.1	17.2	55.2	0.0	5.5	14.7
2030_S2_UN	3.8	25.9	27.3	3.2	1.9	0.1	12.2	27.3	0.0	8.3	48.0
2030_S3_UN	3.9	54.0	27.2	3.7	2.0	0.1	25.6	14.2	0.0	16.0	24.4
2030_S4_UN	4.0	25.9	27.3	5.0	3.3	5.2	17.2	58.2	0.0	5.5	6.5
2030_S5_UN	4.0	25.9	27.3	5.0	3.4	0.1	17.2	63.2	0.0	5.5	6.5
2030_S1	3.9	25.9	27.3	4.5	3.3	0.1	15.7	58.7	0.0	5.5	13.2
2030_S2	3.3	25.9	27.3	3.6	2.9	0.0	13.9	46.9	0.0	8.3	25.7
2030_S3	3.7	54.1	27.2	3.5	2.3	0.0	24.8	17.0	0.0	16.0	22.4
2030_S4	4.0	25.9	27.3	4.9	3.3	5.2	17.2	58.3	0.0	5.5	6.5
2030_S5	4.0	25.9	27.3	4.9	3.4	0.1	17.2	63.3	0.0	5.5	6.5

Total Overnight Generator Costs and Typical Annual Carrying Charges for New Resources

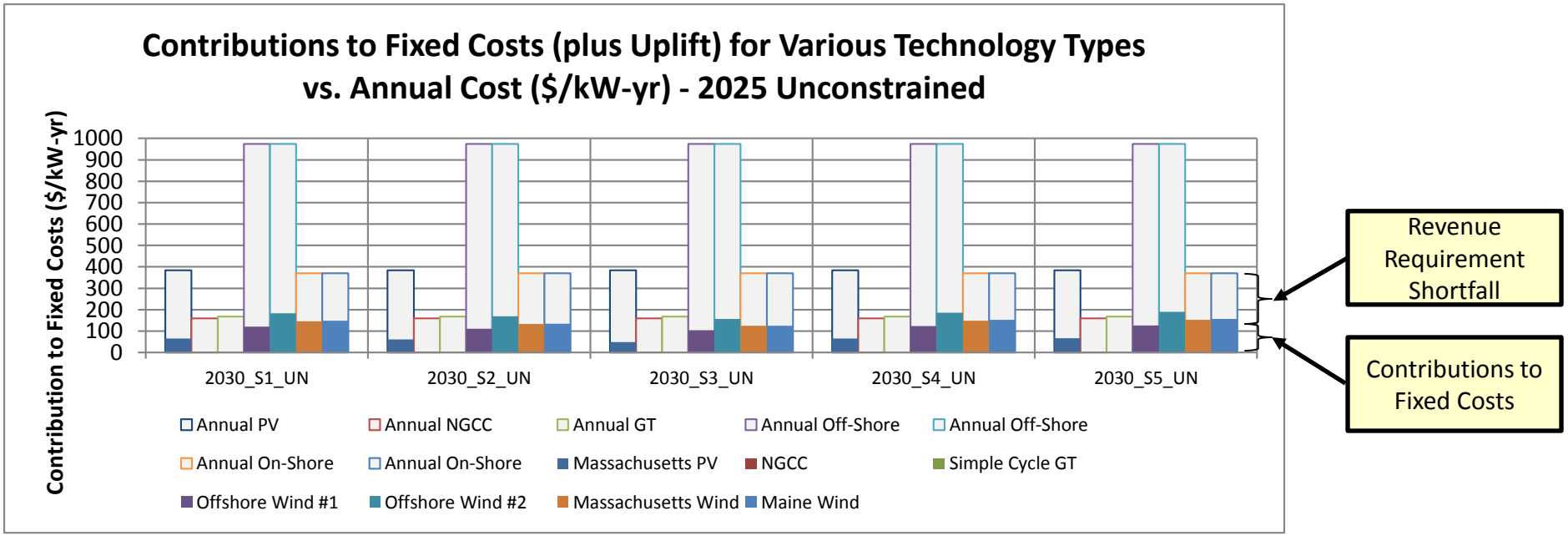
Technology Type	Typical Plant Size (MW)	Generic / New England-Specific Total Overnight Plant Cost (2015 $/kW) (Note 1)	Typical Annual Carrying Charge using 15% ($/kW-year)
Conventional CC	702	911 / 1,062	159
Conventional CT	100	1,026 / 1,119	168
Offshore Wind	400	4,605 / 6,496	974
Onshore Wind	100	1,536 / 2,465	370
Solar Photovoltaic*	150	2,362 / 2,559	384

*Net MWe AC Power

https://www.iso-ne.com/static-assets/documents/2016/08/a5_generic_and_region_specific_costs_of_new_generating_technologies.pdf

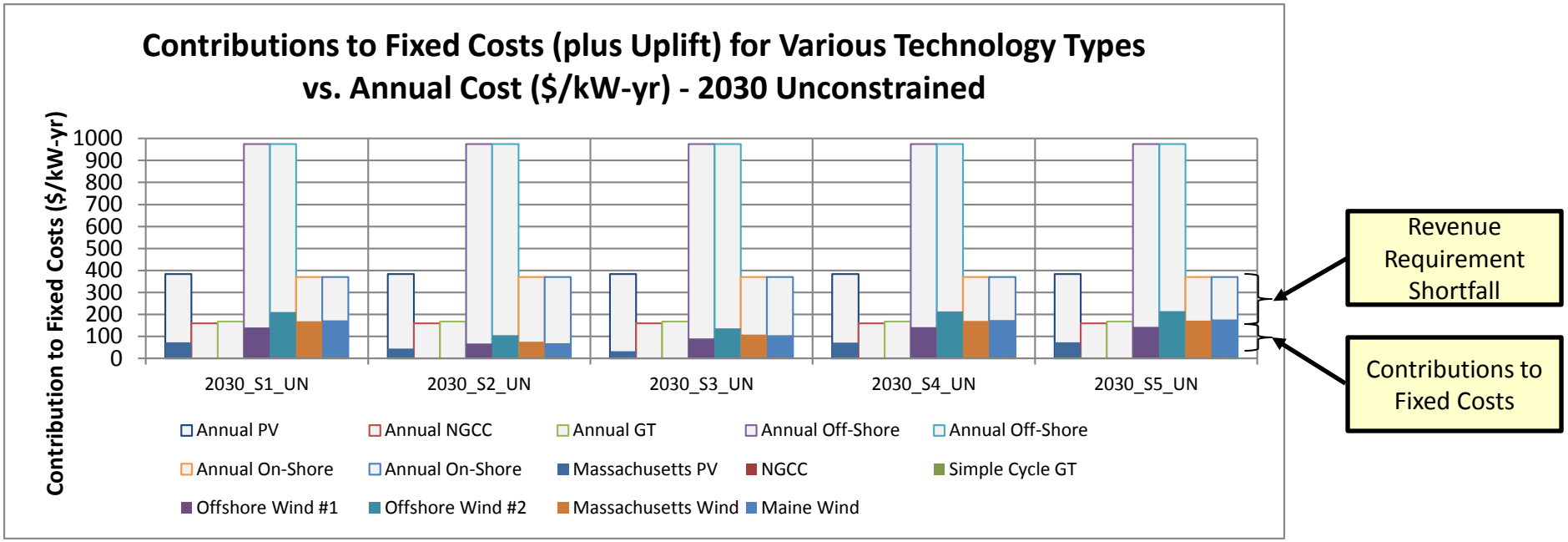
Note 1: The lower cost is the Overnight Plant Cost. The higher cost is the New England-Specific Total Overnight Cost which includes: 1) a project Contingency Factor, and 2) a Technological Optimism Factor, and 3) Locational Adjustments. A Contingency Factor allowance is defined by the American Association of Cost Engineers as the "specific provision for unforeseeable elements of costs within a defined project scope; particularly important where previous experience has shown that unforeseeable events which will increase costs are likely to occur." The Technological Optimism Factor is applied to the first four (4) units of a new, unproven design; it reflects the demonstrated tendency to underestimate actual costs for a first-of-a-kind unit. These costs represent new projects initiated in the year 2015.

Net Resource Revenues from the Energy Market 2025



Net Resource Revenues from the Energy Market 2030

Resource revenues from the energy market contribute little to fixed costs across all technologies due to $0 cost resources and NGCC on NGCC competition. Capacity factors of fossil units are low.



Contributions to Fixed Costs (plus Uplift) for Various Technology Types vs. Annual Cost –Unconstrained 2025 ($/kW-yr)

Net Resource Revenues from the Energy Market

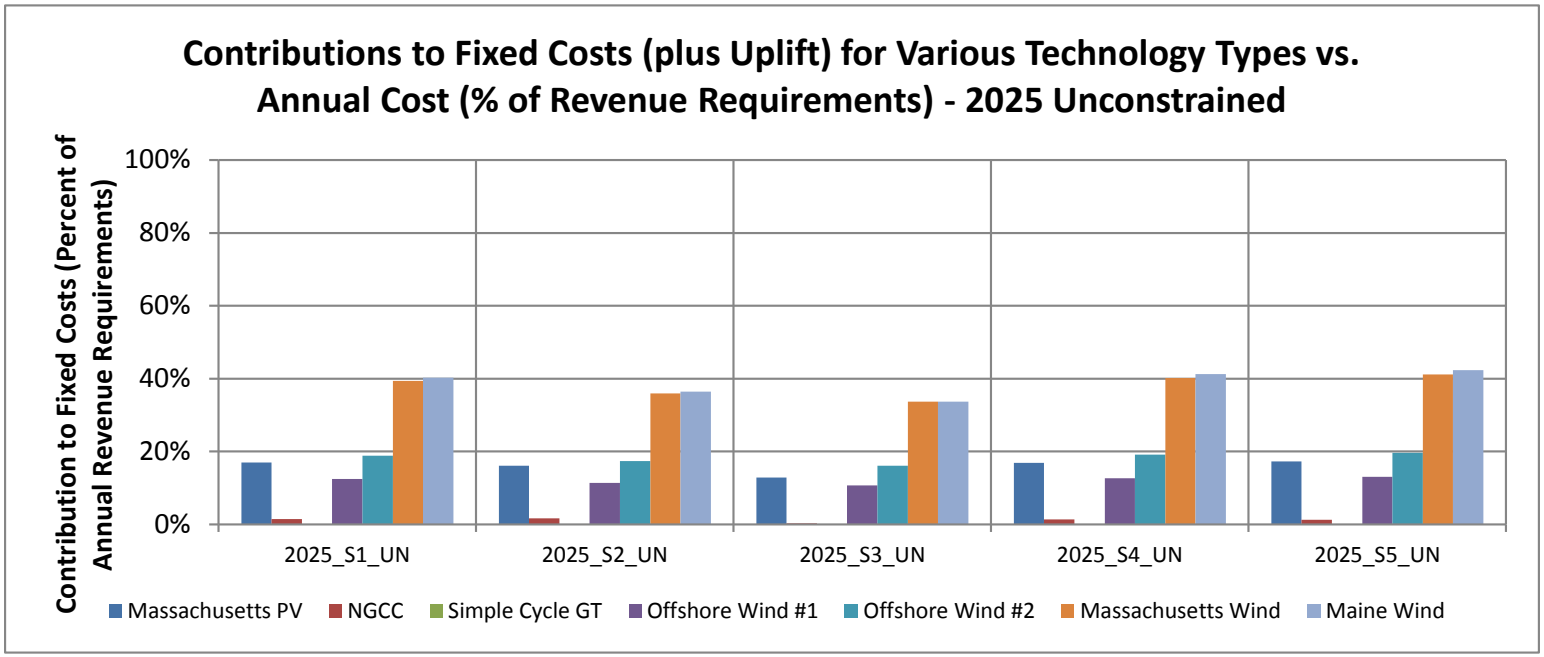
	Massachusetts PV	NGCC	Simple Cycle GT	Offshore Wind #1	Offshore Wind #2	Massachusetts Wind	Maine Wind
2025_S1_UN	65.0	2.3	0.1	121.3	183.2	145.5	148.9
2025_S2_UN	61.8	2.6	0.2	111.0	169.4	132.8	134.7
2025_S3_UN	49.3	0.3	0.0	104.3	156.8	124.5	124.6
2025_S4_UN	64.9	2.1	0.1	123.6	186.3	148.5	152.5
2025_S5_UN	66.2	1.9	0.1	126.6	190.7	152.1	156.5
2025_S1	65.7	2.7	0.3	124.2	187.3	149.2	69.3
2025_S2	63.8	3.4	0.9	120.9	182.8	145.2	43.9
2025_S3	50.7	0.2	0.0	112.6	168.4	134.9	49.3
2025_S4	65.1	2.2	0.1	124.3	187.2	149.3	149.7
2025_S5	66.1	2.0	0.1	126.6	190.6	152.0	152.5
Annual Revenue Requirement	383.9	159.3	167.9	974.4	974.4	369.8	369.8

Contributions to Fixed Costs (plus Uplift) for Various Technology Types vs. Annual Cost –Unconstrained 2030 ($/kW-yr)

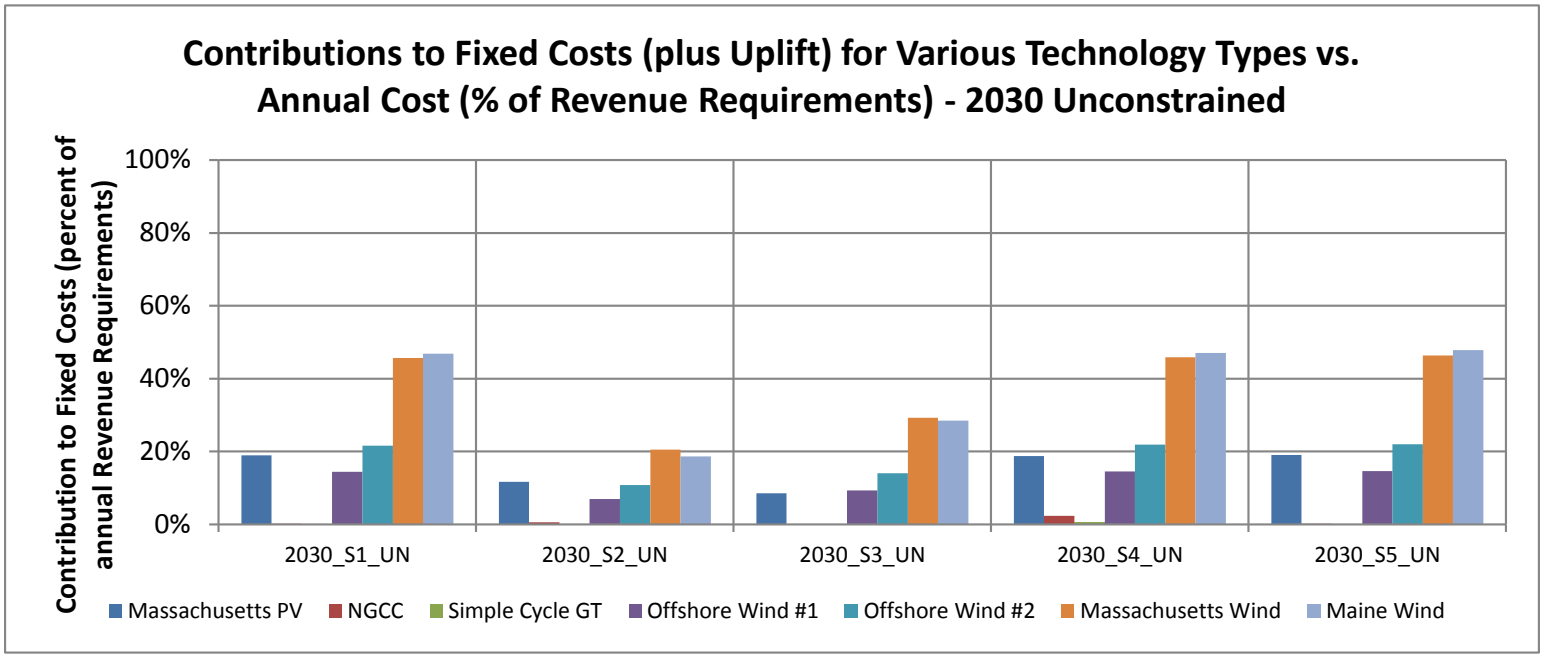
Net Resource Revenues from the Energy Market

	Massachusetts PV	NGCC	Simple Cycle GT	Offshore Wind #1	Offshore Wind #2	Massachusetts Wind	Maine Wind
2030_S1_UN	72.7	0.3	0.0	140.5	210.7	168.7	173.2
2030_S2_UN	44.8	0.9	0.0	67.6	105.0	75.9	69.1
2030_S3_UN	32.7	0.0	0.0	90.7	136.2	108.2	105.3
2030_S4_UN	72.1	3.7	1.0	141.2	212.8	169.7	173.9
2030_S5_UN	73.0	0.3	0.0	142.6	214.0	171.5	176.9
2030_S1	72.9	0.3	0.0	142.2	213.2	170.8	58.7
2030_S2	64.2	1.9	0.8	133.4	199.2	159.2	12.2
2030_S3	32.2	0.0	0.0	104.5	154.9	125.4	43.1
2030_S4	72.1	3.7	1.0	141.6	213.2	170.2	168.4
2030_S5	72.9	0.4	0.0	143.0	214.4	171.7	174.1
Annual Revenue Requirement	383.9	159.3	167.9	974.4	974.4	369.8	369.8

Net Resource Revenues from the Energy Market 2025



Net Resource Revenues from the Energy Market 2030



Net Resource Revenues from the Energy Market 2025

Net Resource Revenues from the Energy Market
as percentage of Annual Revenue Requirements

	Massachusetts PV	NGCC	Simple Cycle GT	Offshore Wind #1	Offshore Wind #2	Massachusetts Wind	Maine Wind
2025_S1_UN	16.9%	1.4%	0.0%	12.4%	18.8%	39.4%	40.3%
2025_S2_UN	16.1%	1.7%	0.1%	11.4%	17.4%	35.9%	36.4%
2025_S3_UN	12.9%	0.2%	0.0%	10.7%	16.1%	33.7%	33.7%
2025_S4_UN	16.9%	1.3%	0.1%	12.7%	19.1%	40.2%	41.2%
2025_S5_UN	17.3%	1.2%	0.1%	13.0%	19.6%	41.1%	42.3%
2025_S1	17.1%	1.7%	0.2%	12.7%	19.2%	40.3%	18.7%
2025_S2	16.6%	2.1%	0.5%	12.4%	18.8%	39.3%	11.9%
2025_S3	13.2%	0.1%	0.0%	11.6%	17.3%	36.5%	13.3%
2025_S4	16.9%	1.4%	0.1%	12.8%	19.2%	40.4%	40.5%
2025_S5	17.2%	1.2%	0.1%	13.0%	19.6%	41.1%	41.2%

Net Resource Revenues from the Energy Market 2030

Net Resource Revenues from the Energy Market
as percentage of Annual Revenue Requirements

	Massachusetts PV	NGCC	Simple Cycle GT	Offshore Wind #1	Offshore Wind #2	Massachusetts Wind	Maine Wind
2030_S1_UN	18.9%	0.2%	0.0%	14.4%	21.6%	45.6%	46.8%
2030_S2_UN	11.7%	0.6%	0.0%	6.9%	10.8%	20.5%	18.7%
2030_S3_UN	8.5%	0.0%	0.0%	9.3%	14.0%	29.3%	28.5%
2030_S4_UN	18.8%	2.3%	0.6%	14.5%	21.8%	45.9%	47.0%
2030_S5_UN	19.0%	0.2%	0.0%	14.6%	22.0%	46.4%	47.8%
2030_S1	19.0%	0.2%	0.0%	14.6%	21.9%	46.2%	15.9%
2030_S2	16.7%	1.2%	0.5%	13.7%	20.4%	43.1%	3.3%
2030_S3	8.4%	0.0%	0.0%	10.7%	15.9%	33.9%	11.6%
2030_S4	18.8%	2.3%	0.6%	14.5%	21.9%	46.0%	45.5%
2030_S5	19.0%	0.2%	0.0%	14.7%	22.0%	46.4%	47.1%