2016 Economic Studies

Draft Results – Executive Summary

Planning Advisory Committee Meeting

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BACKGROUND PROCESS SUMMARY

Scope Summary

- The 2016 Economic Study request will be addressed in two phases
  - Stakeholder input will be sought throughout the study process
- Phase I will consist of traditional economic study analyses
  - Production cost analyses and related metrics will be summarized
- Phase II will supplement the Phase I analysis by discussing several market and operational issues
  - Examine representative Forward Capacity Auction (FCA) clearing prices for several scenarios
  - Analyze intra-hour ramping, regulation, and reserve requirements
  - Assess natural gas system deliverability issues
  - Can be achieved with the help of consultants

NEPOOL 2016 Economic Study Request

- Discussions concerning the 2016 NEPOOL Economic Study request have been ongoing
  - Monthly PAC presentations April through July
  - The ISO has met with representatives of NEPOOL
- Input received from the PAC is reflected in the GridView simulation program draft results
  - Simulation data inputs reflect the base assumptions and variations specified for the five scenarios
- Today the ISO is seeking PAC input on the draft results and scope of sensitivity analysis cases
  - Some previous material is shown for review and framing the discussion
- We will also discuss the status of the study and next steps

Stakeholder Process for Conducting 2016 Economic Study

The ISO will continue seeking input from the PAC

- Status of Phase I
  - High-level scope of work Complete
  - General and detailed study assumptions Complete [See http://www.iso-ne.com/static-assets/documents/2016/07/a6_2016_economic_study_update.pdf]
  - Overall study results and conclusions Discussion of five scenario draft results today
  - Additional draft results for the five base scenarios and sensitivity analysis September PAC meeting
  - Review of draft report 4th Quarter
  - Status reports and updates to be provided at every PAC meeting
- A special economic study working group can be formed to provide the ISO input on very detailed technical modeling and simulation methods not of interest to the more general PAC audience
  - This has been done to support past economic studies
  - Past study groups required a very limited number of conference calls
- Alternatively or in addition to the economic study working group
  - PAC presentations will be structured to discuss the general PAC economic study issues upfront
  - More technical discussions with PAC members as a last meeting agenda item

Observations - Process

- This presentation discusses several high level observations
- Stakeholders are invited to examine detailed results (posted separately)
- Please provide the ISO with additional observations, requests for information, and desire for sensitivity cases by 9/1
- Kindly submit comments to PACmatters@iso-ne.com

References: NEPOOL memo and the discussion of assumptions

- NEPOOL 2016 Economic Study Request
  - http://www.iso-ne.com/static-assets/documents/2016/04/a7_nepool_economic_study_request_scenario_analysis_presentation.PPTX

- 2016 Economic Study Presentations To Date
  - http://www.iso-ne.com/static-assets/documents/2016/07/a6_2016_economic_study_update.pdf
  - http://www.iso-ne.com/static-assets/documents/2016/06/a9_2016_economic_study_assumptions.pdf
  - http://www.iso-ne.com/static-assets/documents/2016/05/a3_2016_economic_study_scope_of_work_assumptions.pdf

- RPS Worksheet
  - http://www.iso-ne.com/static-assets/documents/2016/05/a3_2016_economic_study_scope_of_work_rps_spreadsheet.xlsx

THE SCENARIOS

KEY DRIVERS OF RESULTS:
RESOURCE TYPE, DISPATCH COSTS, AND LOCATIONS

Five Scenarios

See the NEPOOL memo and the discussion of assumptions

1. Generation fleet meeting existing Renewable Portfolio Standards (RPS) and retired units replaced with natural gas combined cycle (NGCC) units
   - Use the base assumptions, including the retirement assumption
   - Assume that targeted energy requirement for the New England states' RPS goals as of April 1, 2016 will be met by physical renewable/clean energy resources
     - Guidance on the RPS has been posted on the ISO website that provides a method of prioritizing resource types and locations
   - Replace all retired units with NGCC
   - Meet any net ICR shortfalls with additional NGCC units
2. Generation fleet meeting existing RPS and all future needs, including retirements, met with new renewable/clean energy resources
   - Same as Scenario 1, except assume all needed capacity will be met by renewable/clean energy resources
   - Assume the mix of renewable/clean energy resources provided by the RPS guidance posted on the ISO's website

Five Scenarios, cont.

See the NEPOOL memo and the discussion of assumptions

3. The “RPS-plus scenario” - Generation fleet meeting existing RPS plus additional renewable/clean energy resources and some modified base assumptions that are the same as Scenario 2 except include additional MW by 2025 and 2030 of new renewable/clean energy resources above the existing RPS requirements
   - The mix of resources and demand are very different than the historical experience
   - Specifics of Scenario 3 were discussed with the PAC and cases reflect input received

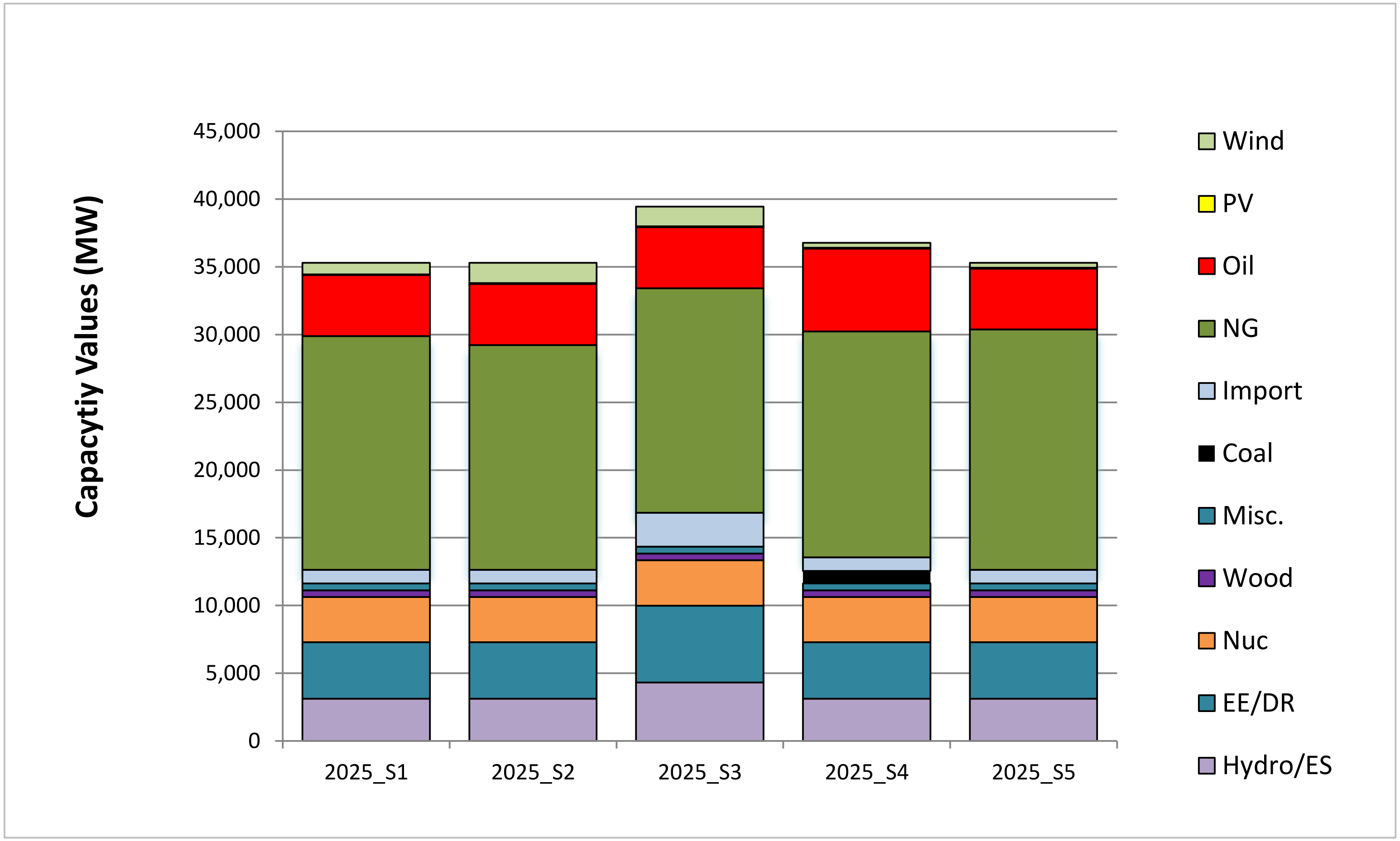
Five Scenarios, cont.

See the NEPOOL memo and the discussion of assumptions

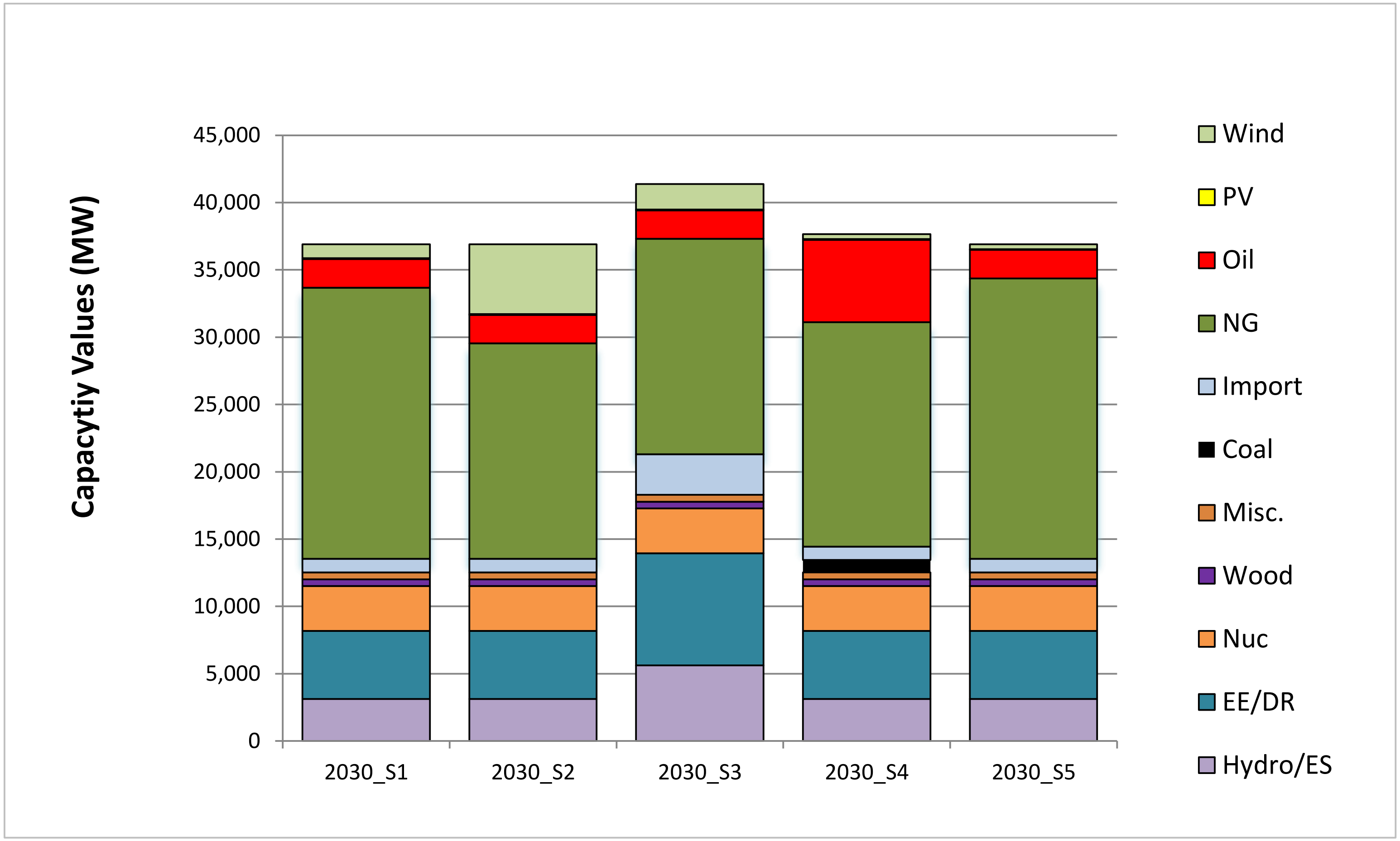
4. Generation fleet meeting existing RPS in part through Alternative Compliance Payments with NGCC additions, and with no retirements (the "no retirement scenario")
   – Use Scenario 1, except assume: (a) RPS requirements are met first physically with renewable/clean energy resources that are interconnected to the system, under construction or have an approved I.3.9 as of April 1, 2016, and then through Alternative Compliance Payments for any RPS requirements not physically met; (b) any new generation resources added to meet NICR will be NGCC units; and (c) no retirements

5. Existing fleet meeting existing RPS in part through Alternative Compliance Payments and retirement replacement with NGCC additions
   – Same as Scenario 4, except use retirement assumption and replace retired units as needed to meet NICR with NGCC generation

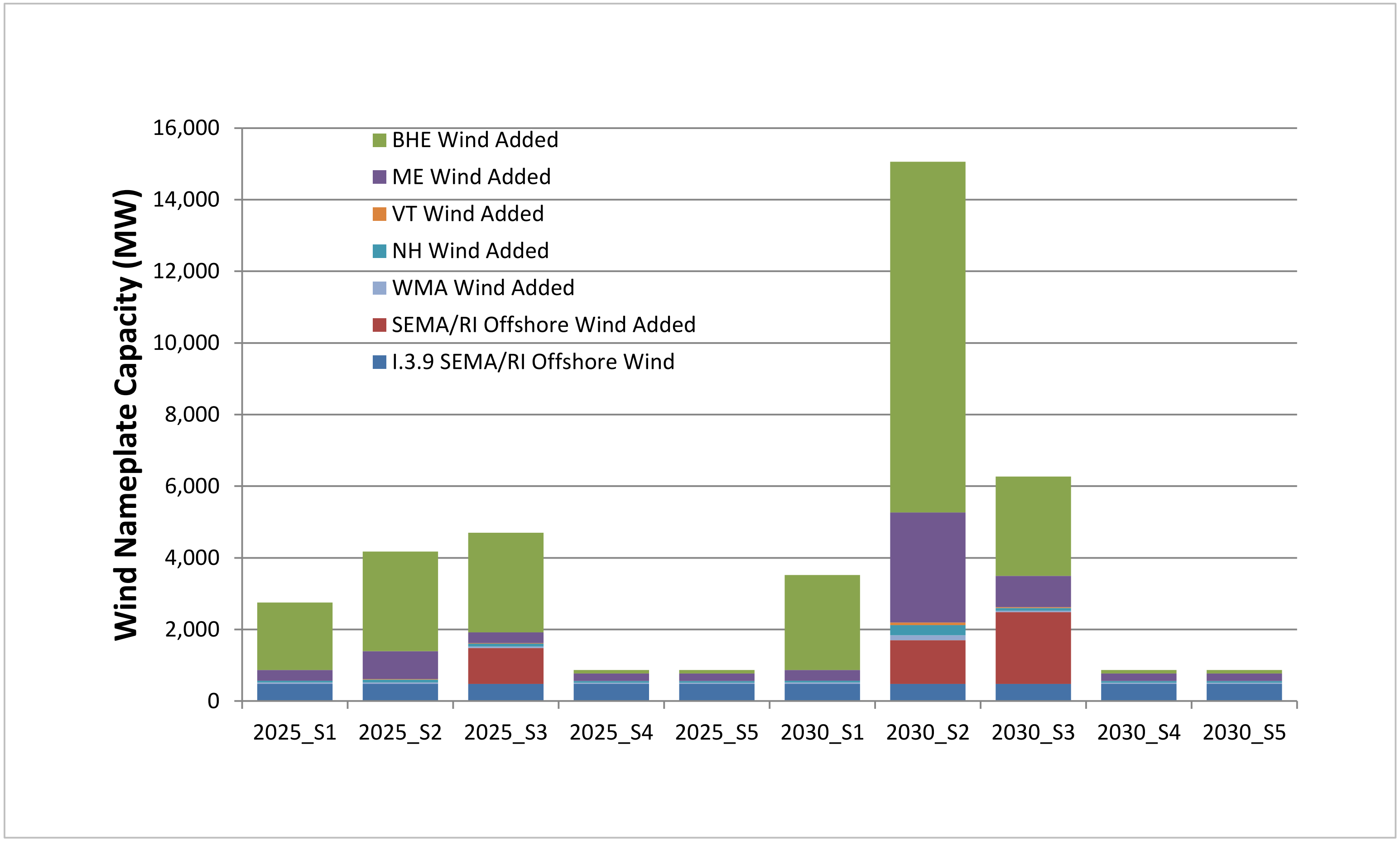
Resource Mix Assumptions
2025 Capacity Values (MW)



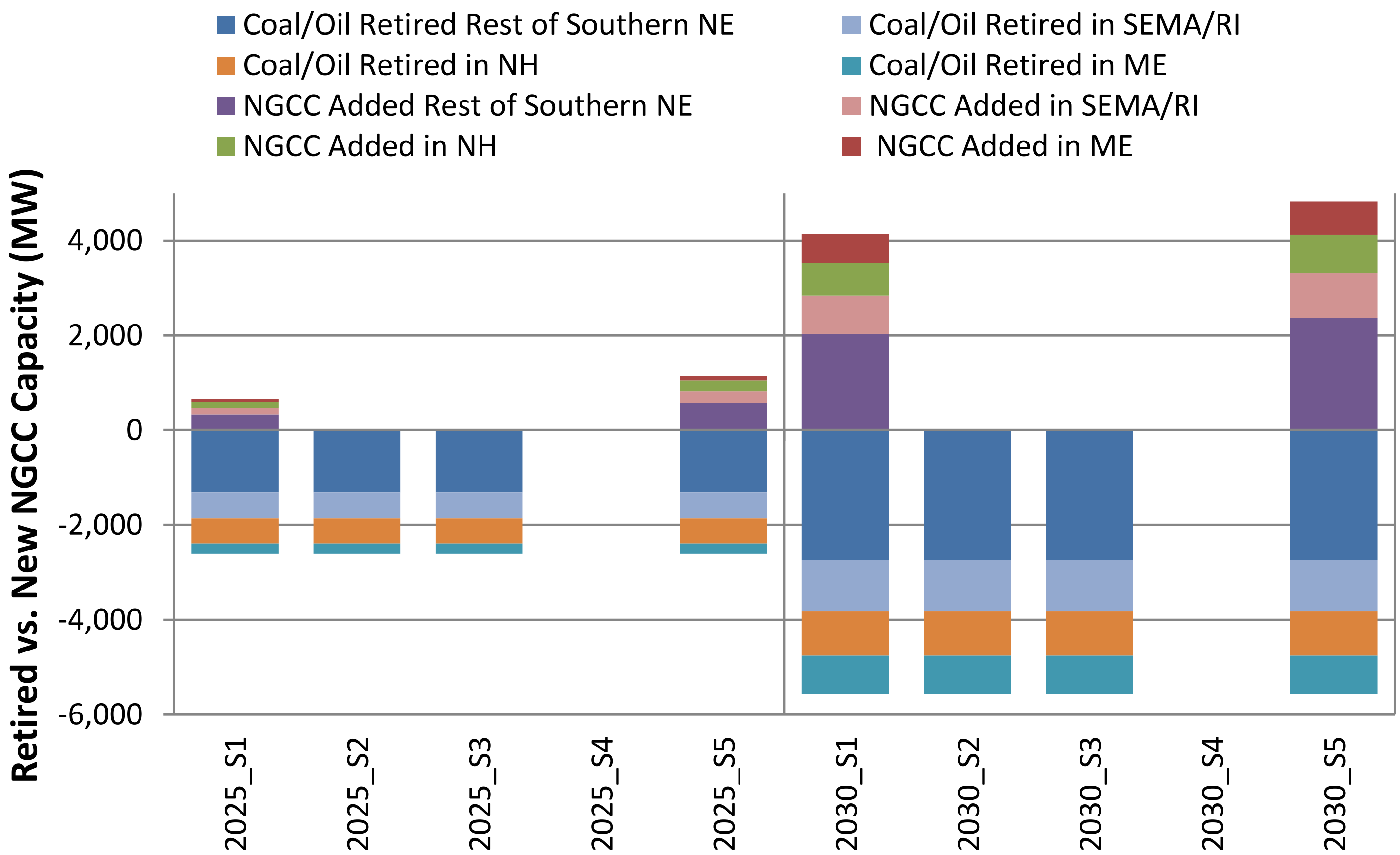
Resource Mix Assumptions
2030 Capacity Values (MW)



Assumptions for Wind Resource Additions Nameplate (MW)



Assumptions for Resource Additions and Retirements Capacity (MW)



Summary of Metrics for Comparing Scenarios

Graphical and Tabular Format [√ being discussed today]

Systemwide production costs ($) √	Total production in GWh and percent for each resource type, including imports √	Total air emissions of CO2 (Compare with RGGI regional goal) √
Average Locational Marginal Prices by RSP bubble ($/MWh)	Capacity factors of units that suggest the need for other types of units	Total air emissions of NOx √
Load-Serving Entity Energy Expenses (LSEEE) ($) √	Ramp rates over hourly periods	Total air emissions of SO2√
MW flow duration curves that interfaces exceed 90% of limit for the unconstrained constrained cases	Hourly operating reserve requirements	
Congestion ($) √	Hours where the spinning reserve requirements are not met	
Percent of time that interfaces exceed 100% of limit for unconstrained cases √ (See Appendix)		
Chronological curves for interface flows that are above 90% of limit		
Diurnal flows of interfaces		
Seasonal flow duration curves for interfaces		
Interface flows on representative summer and winter days		
The fuel that sets the marginal clearing price summarized annually √		
Wholesale energy market revenues and contributions to fixed cost by resource type		

OBSERVATIONS

EXECUTIVE SUMMARY

Scenario Analysis Results and Observations

Additional Results to be Posted and Discussed with PAC 9/21

- Effect of resource mix on metrics
  - Energy sources
  - Production Costs
  - Average LMPs
  - LSE Energy Expenses
  - Time Natural Gas is on the Margin and Total Natural Gas Generation
  - CO_2 Emissions
- Effect of resource types, resource locations, and transmission constraints on the metrics
  - Transmission Interface Flows
  - Congestion
  - Interface metrics

OBSERVATIONS

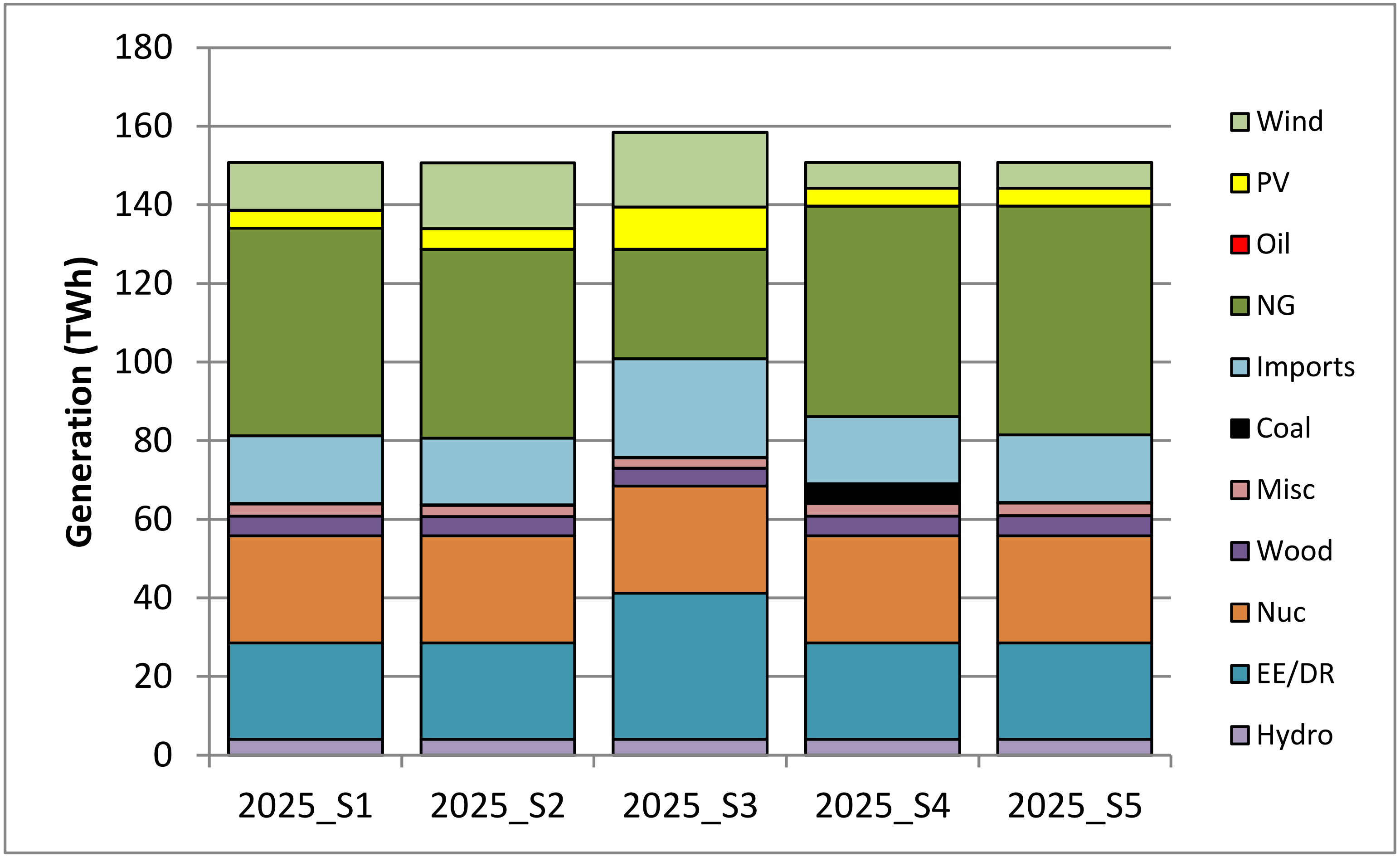
EFFECT OF RESOURCE MIX ON METRICS SHOWN BY UNCONSTRAINED CASES

Energy Sources

Transmission Interfaces Unconstrained

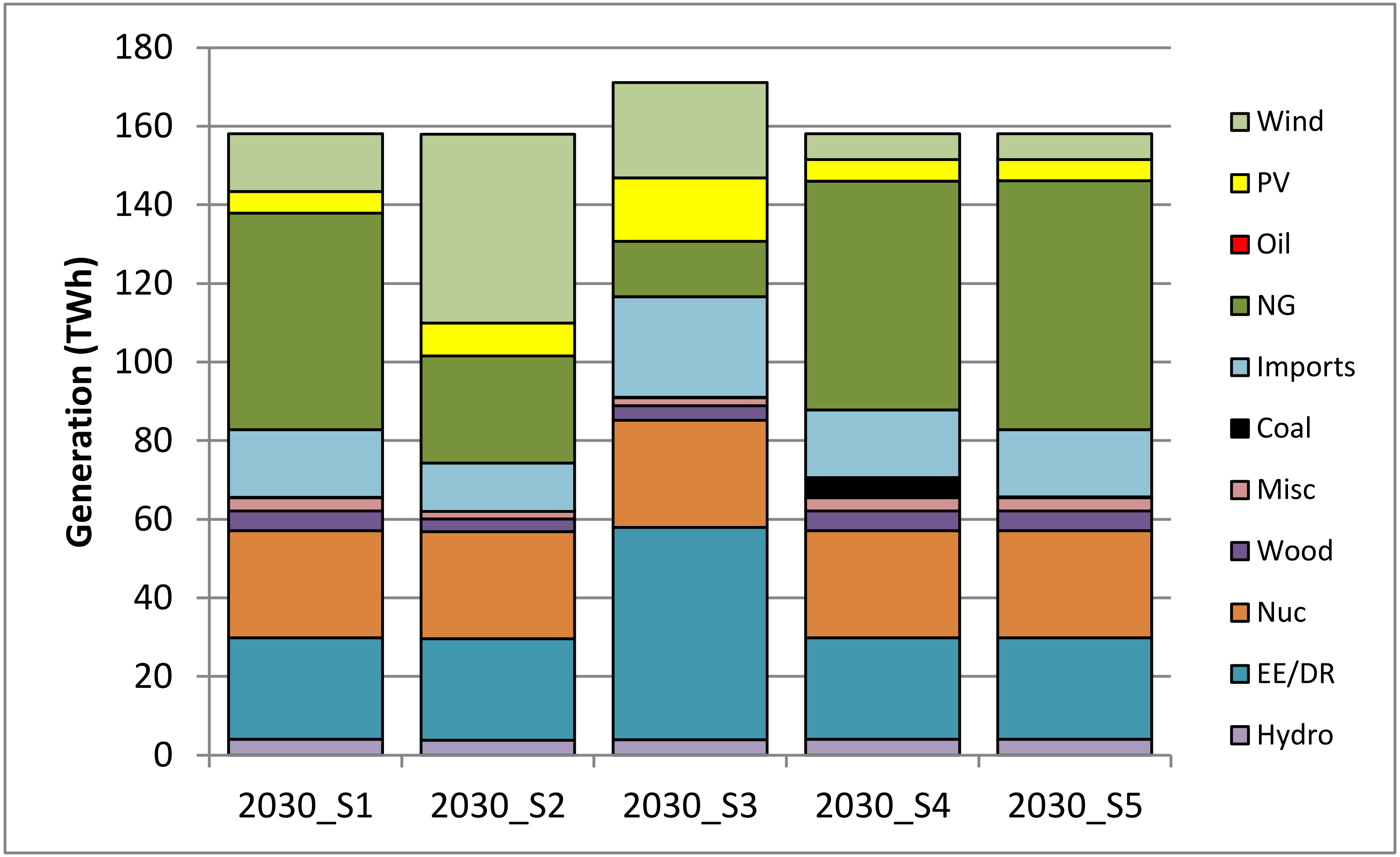
- The energy production by fuel type for the 2025 scenarios shows less differences among the cases than for the 2030 scenarios
- Generation by fuel type is similar for Scenarios 1, 4, and 5 and closer for Scenarios 2 and 3
  - Scenarios 1, 4, and 5 have fossil-steam resources burning oil, coal, and natural gas fuels at existing locations
  - Scenarios 2 and 3 have very larger amounts of resources with zero dispatch cost (wind, EE, and PV), which grow in 2030
- Little to no oil generation production is evident across all cases
- The coal generation dispatch price is competitive with NGCC in Scenario 4, which lowers use of natural gas as compared with Scenario 5
- Although Scenario 3 adds new import capability, energy imports are about the same as the other scenarios for 2030 because of the large scale addition of zero cost resources

Energy By Source 2025 (TWh)
Transmission Interfaces Unconstrained



Energy By Source 2030 (TWh)

Transmission Interfaces Unconstrained

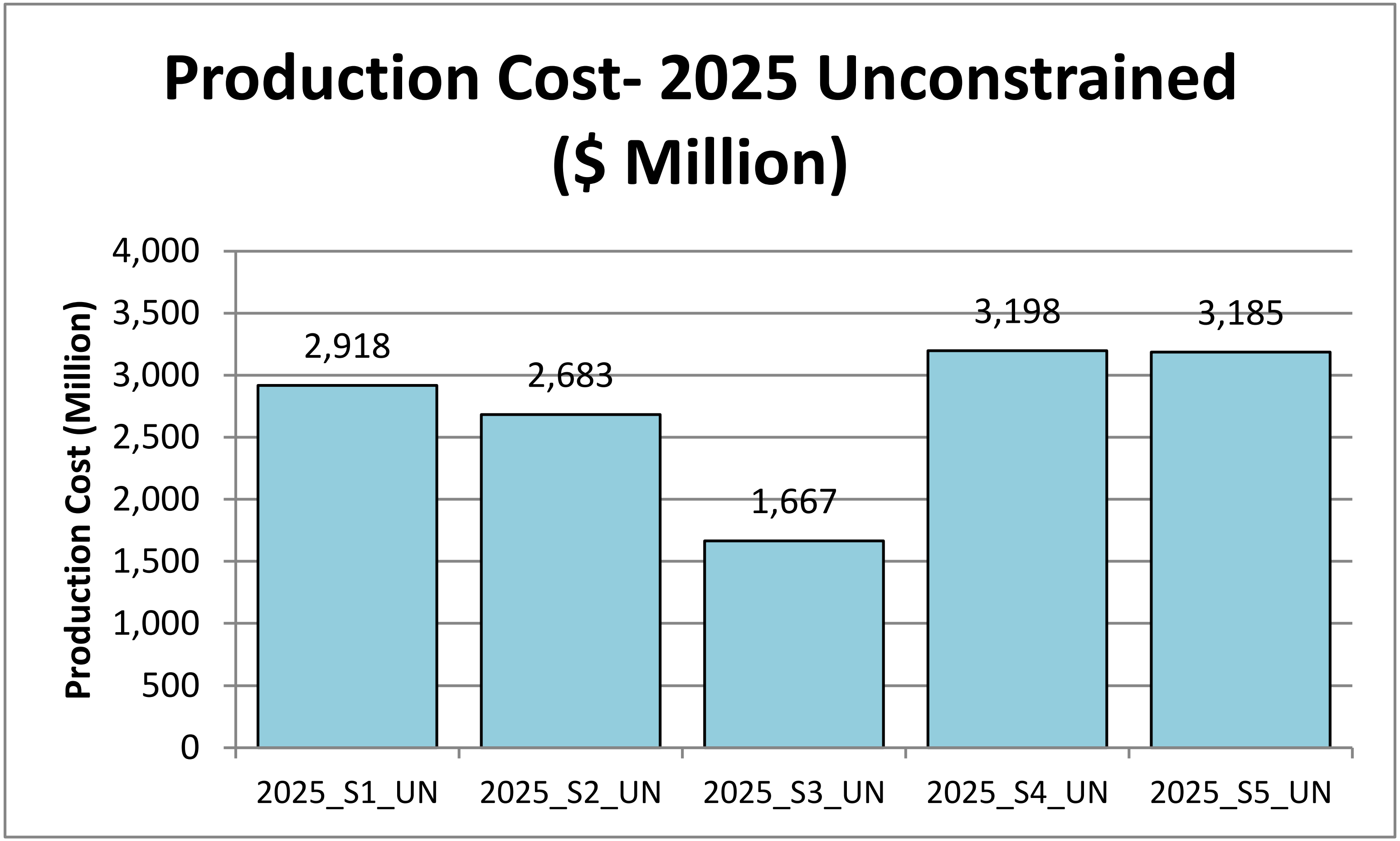


Unconstrained Systemwide Production Costs

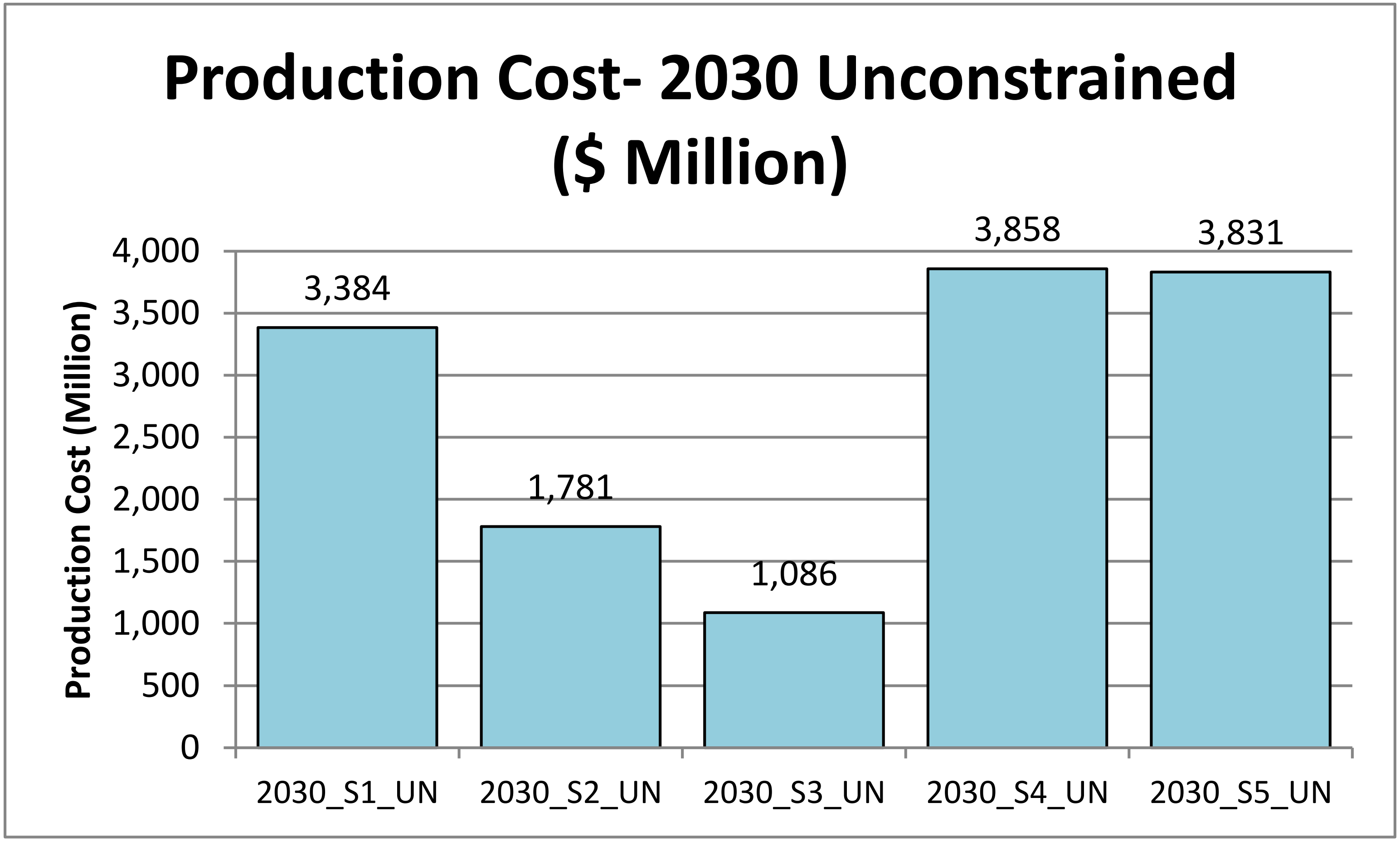
Production costs largely reflected fuel-related costs, including dispatch, unit commitment, and emission allowance costs

- Production costs for Scenarios 2 and 3 are lower in 2030 than 2025
  - These scenarios have more renewable and EE development in 2030 than 2025
- Production costs for Scenarios 1, 4 and 5 are higher in 2030 than 2025
  - Greater use of fossil fueled units in 2030 than 2025
  - Higher fossil fuel prices combined with higher energy production from fossil fueled generation in 2030 than 2025
  - Slower growth of renewables in 2030 over 2025 as compared with Scenarios 2 and 3
- As expected, larger amounts of wind, EE, and PV resources in Scenarios 2 and 3 result in lower production costs than the other scenarios
- More expensive production by fossil generating units in Scenarios 4 and 5 causes higher production cost results than for the other scenarios

Annual Systemwide Production Costs ($M/Year) – 2025 Transmission Interfaces Unconstrained



Annual Systemwide Production Costs ($M/Year) – 2030 Transmission Interfaces Unconstrained



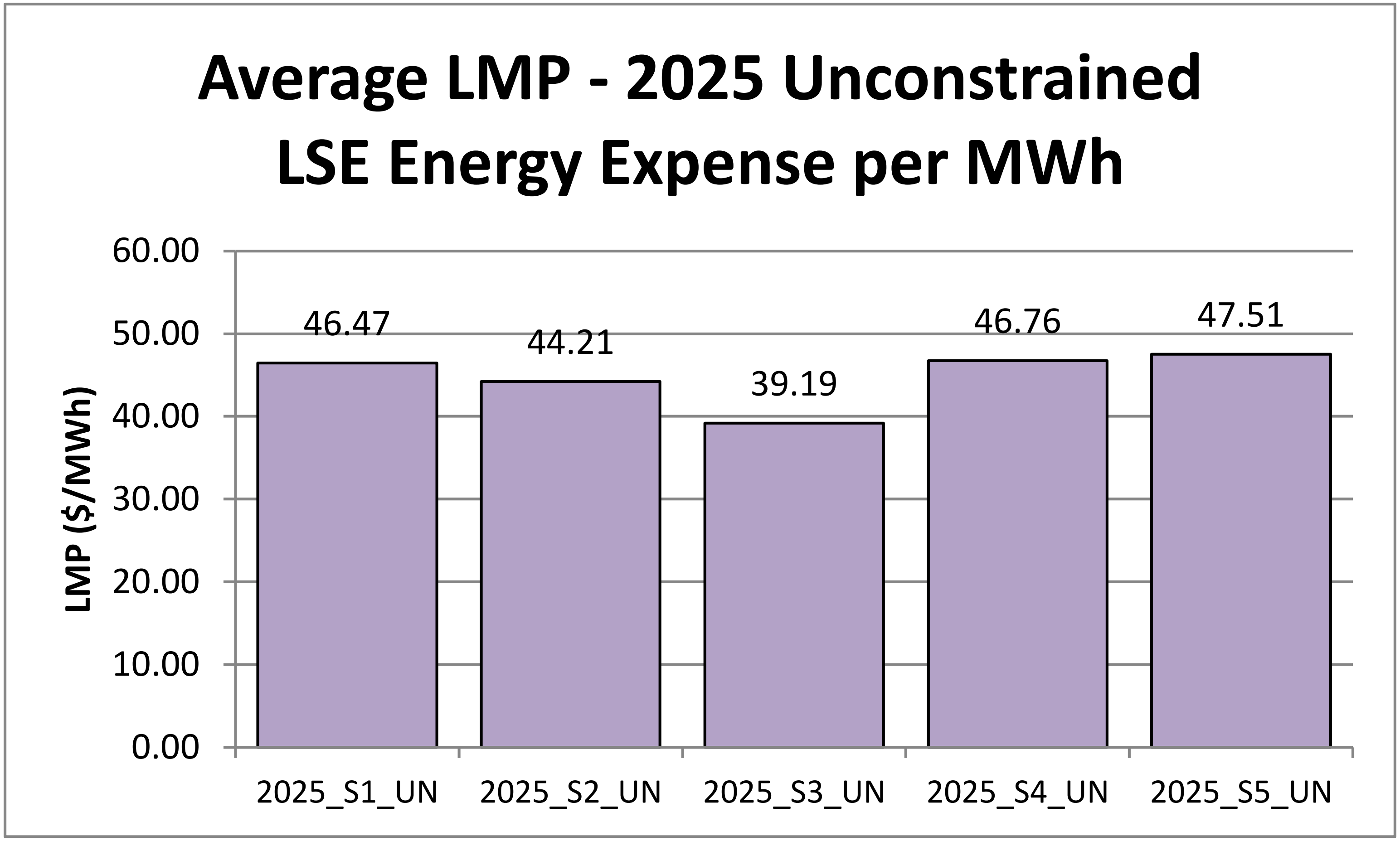
LMPs and LSE Energy Expenses

Transmission Interfaces Unconstrained

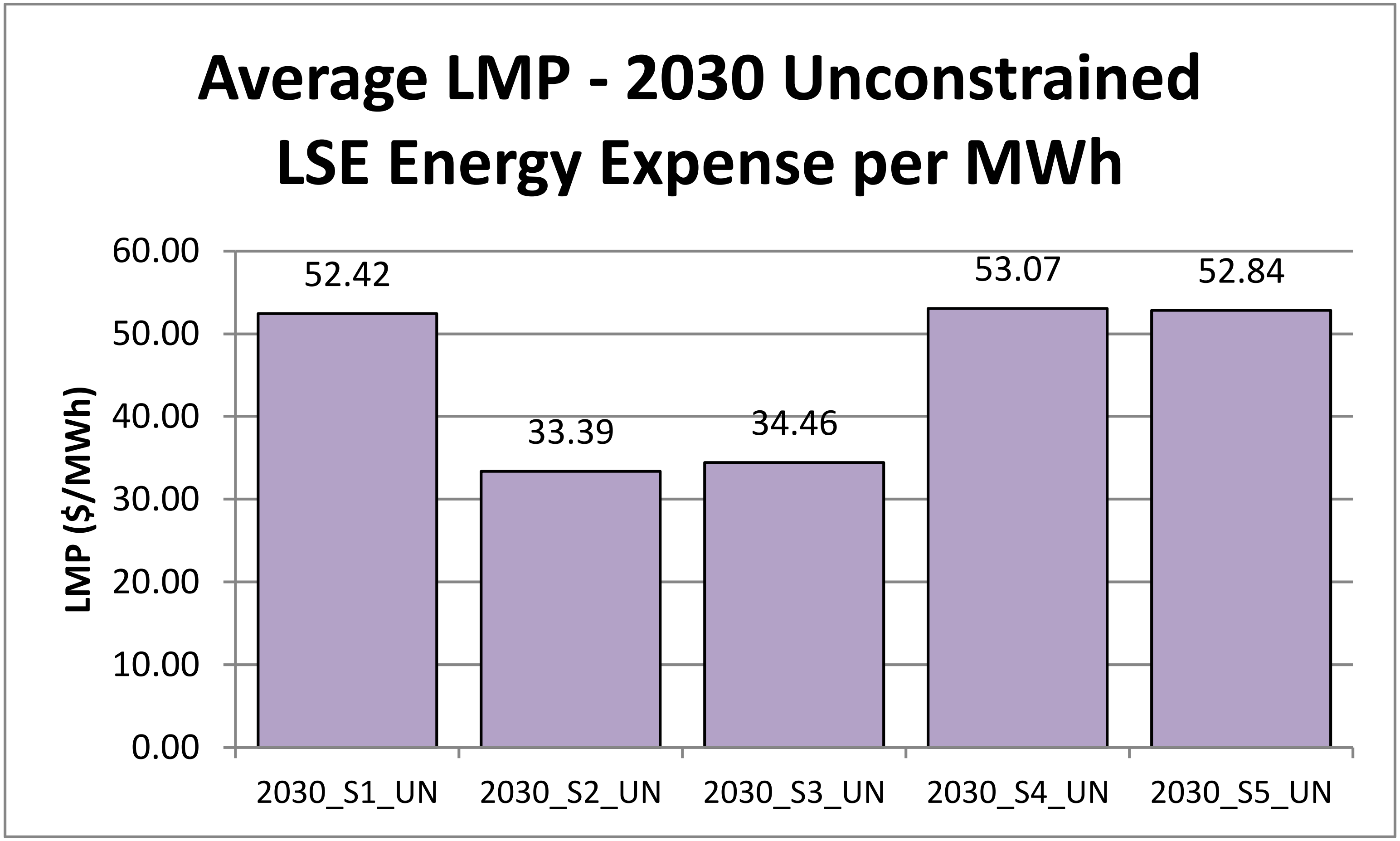
The resource mix and fuel prices drive average clearing prices and LSE Energy Expenses

- 2030 has greater variation in the resource mix across all cases as compared with 2025
- Fossil fuel prices are higher in 2030 than 2025
- Natural gas typically remains on the margin across Scenarios 1, 4, and 5
- Resource mix with more efficient units lead to lower marginal prices
- Large amounts of renewable resources reduce the amount of time that natural gas units set LMPs in Scenarios 2 and 3
- The LMP results for 2030 show greater variation among the cases than the LMP results for 2025
- LMPs are lower for Scenarios 2 and 3 over many hours
- Lower LMPs result in lower LSE Energy Expenses

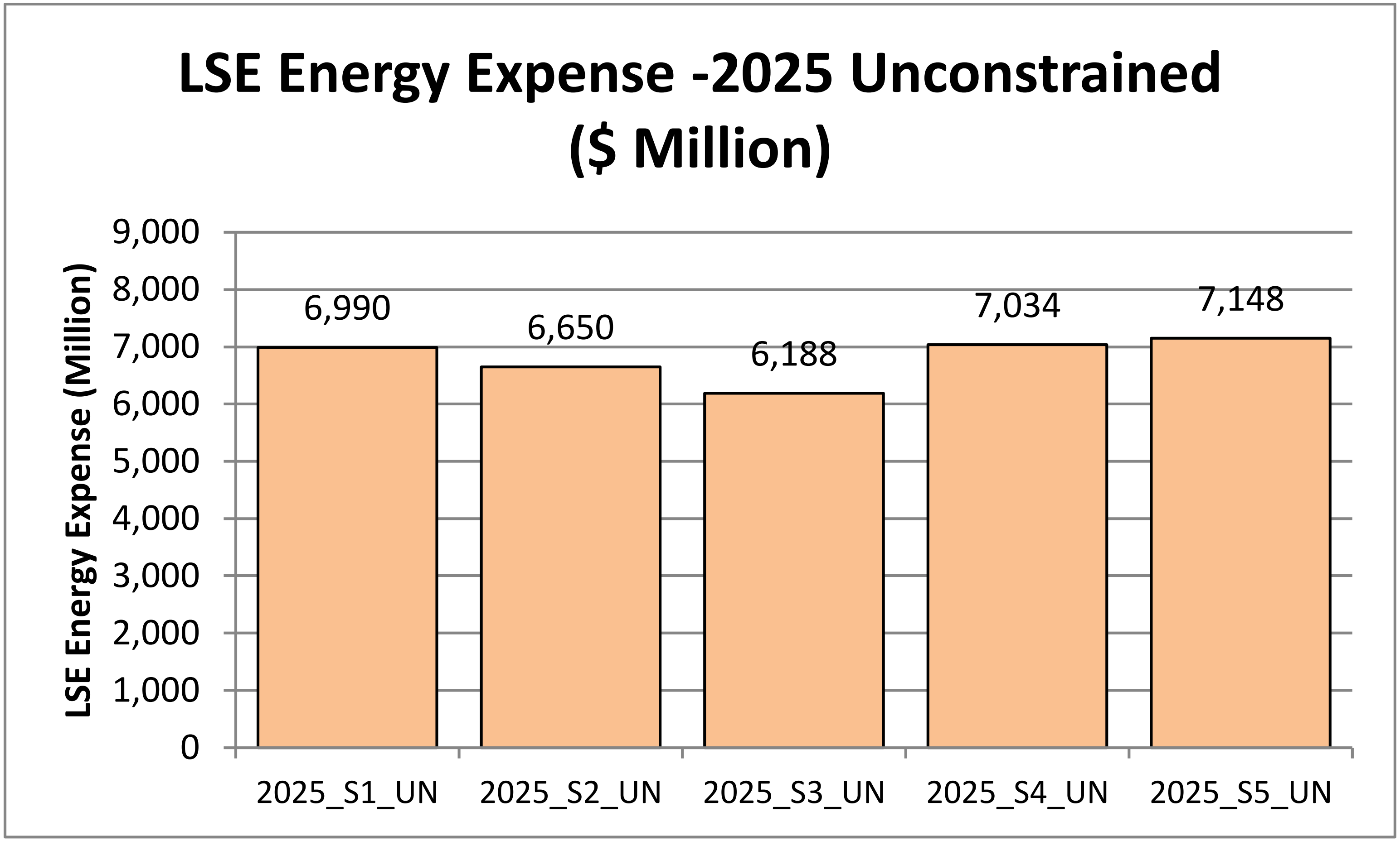
Annual Average System LMP ($/MWh) – 2025 Transmission Interfaces Unconstrained



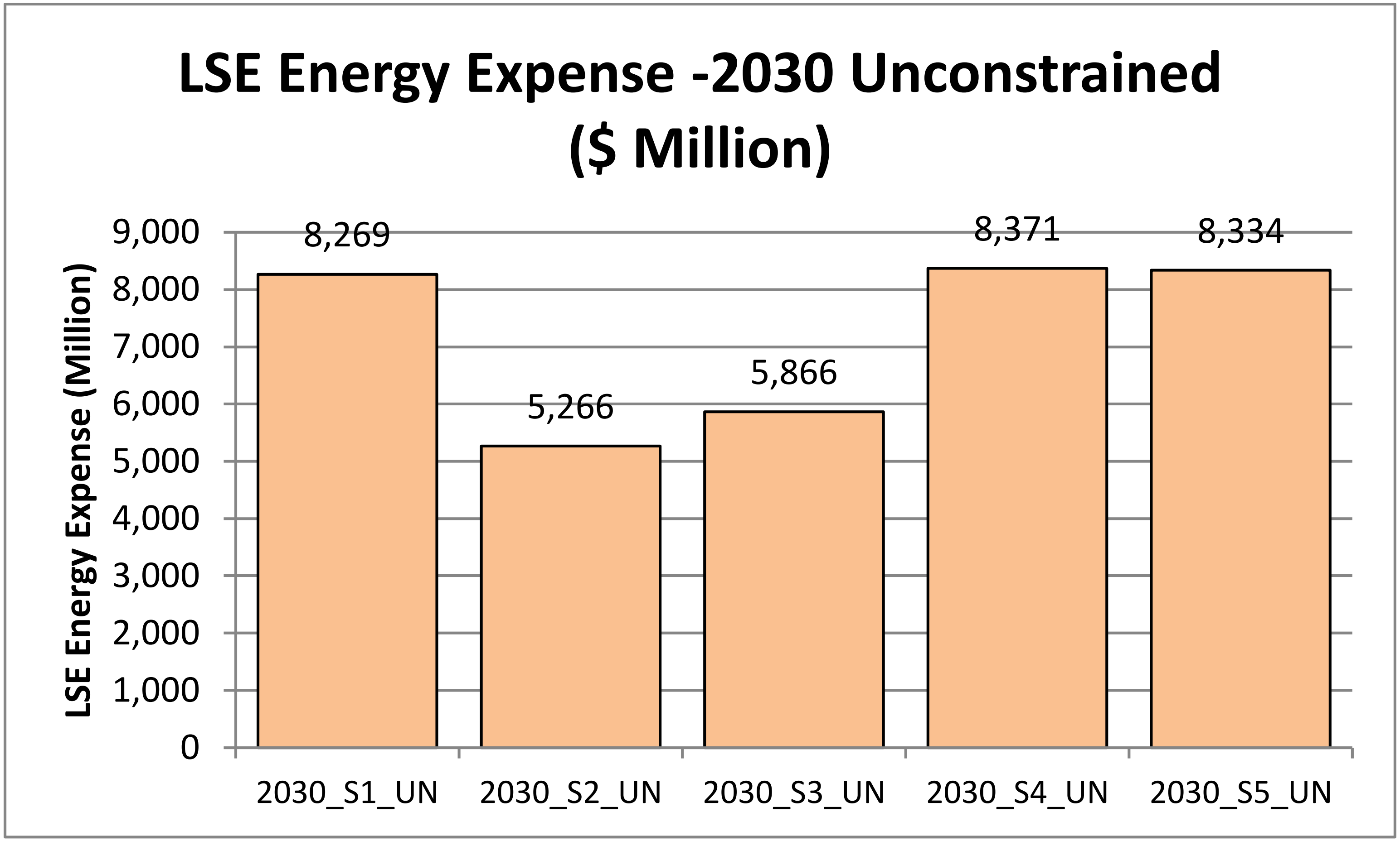
Annual Average System LMP ($/MWh) – 2030 Transmission Interfaces Unconstrained



Annual Systemwide LSE Energy Expenses ($M/Year) - 2025 Transmission Interfaces Unconstrained

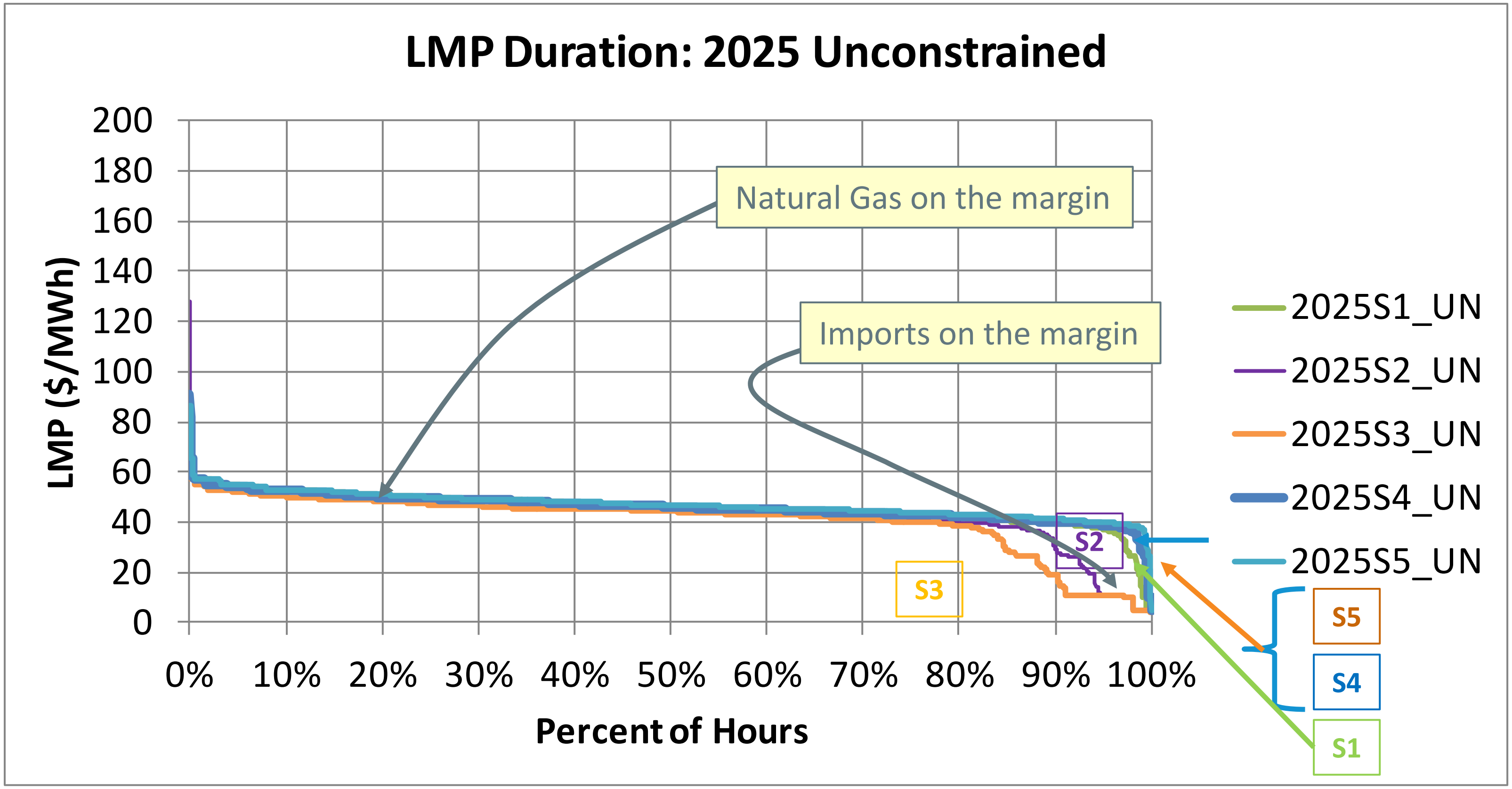


Annual Systemwide LSE Energy Expenses ($M/Year) - 2030 Transmission Interfaces Unconstrained



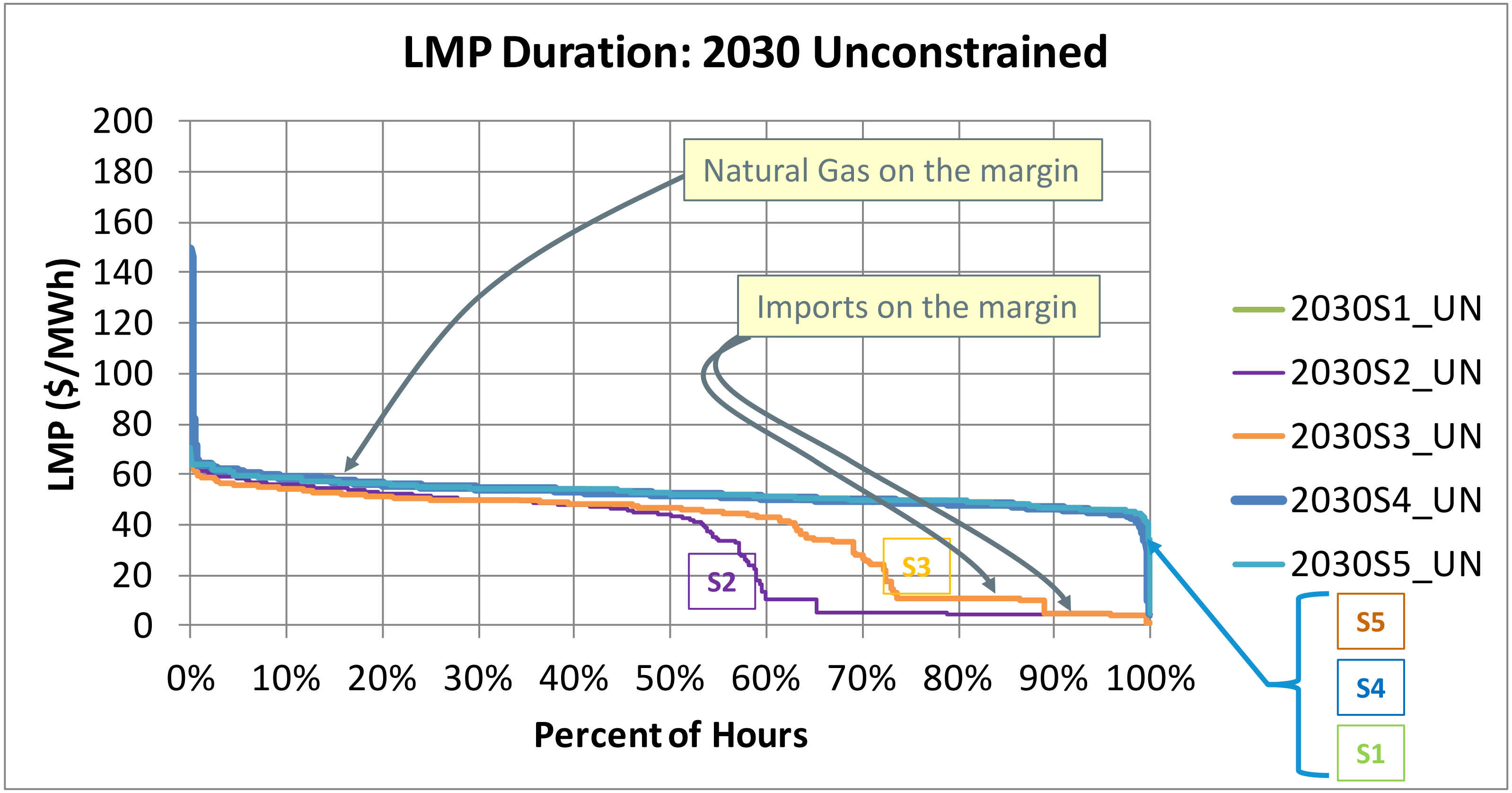
LMPs for 2025 Scenarios Typically Set by Natural Gas

Transmission Interfaces Unconstrained



LMPs for 2030 Are Lower for Scenarios 2 and 3

Transmission Interfaces Unconstrained

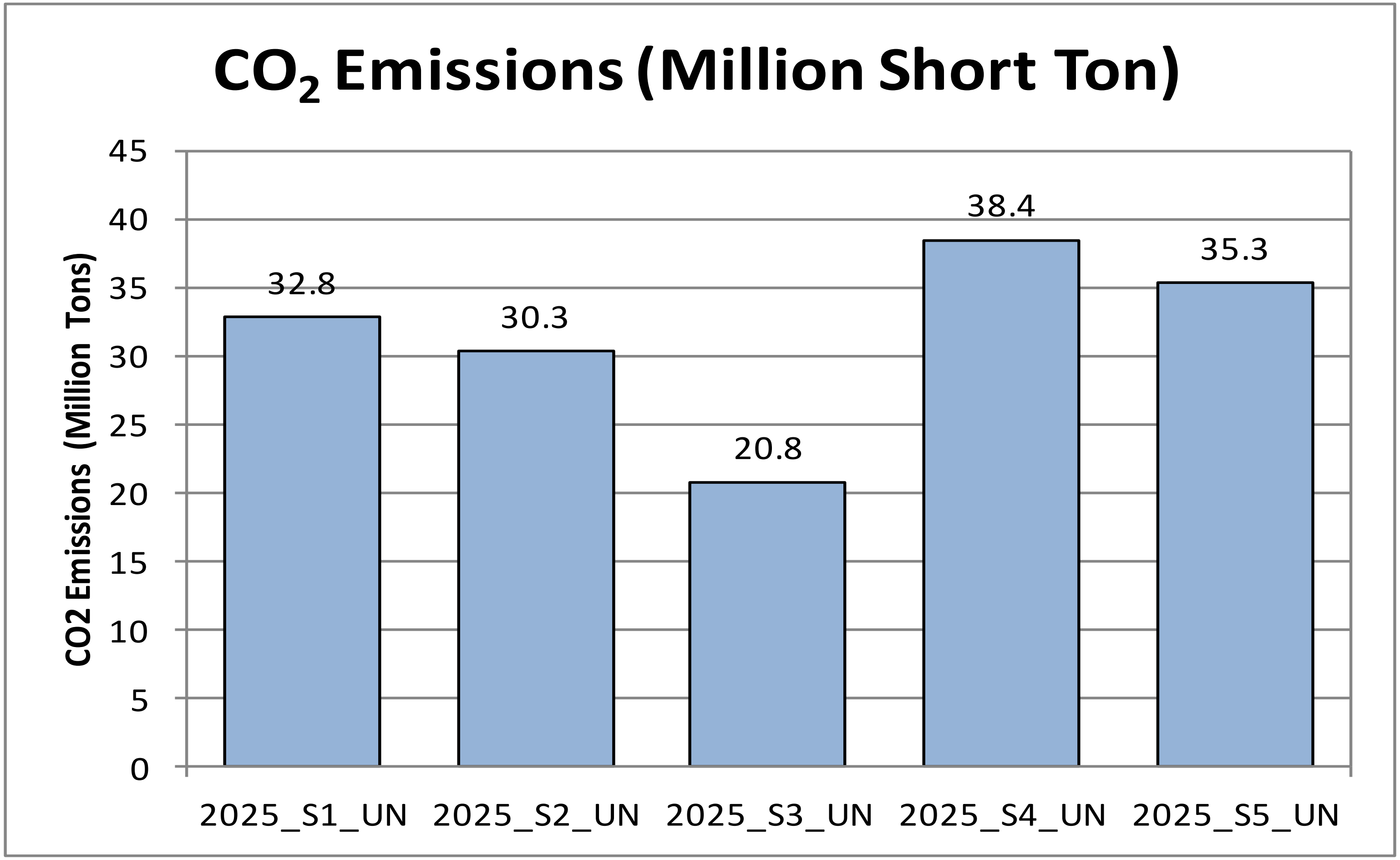


Emissions
Transmission Interfaces Unconstrained

- Coal is competitive with NGCC in Scenario 4, which lowers use of natural gas but increases emissions
    - SO_2 emissions are approximately 8,000 short tons for Scenario 4 and under 2,500 short tons for all other cases
- Scenarios with the large scale development of zero emitting resources lower CO_2 emissions
    - Scenarios 3 results in the lowest overall emissions
- The Regional Greenhouse Gas Initiative (RGGI) is currently reviewing its draft goals that may
    - Apply to units larger than 25 MW
    - Result in New England allowances between 21.6 and 24 million short tons for 2025 and between 16.7 and 21.1 million short tons for 2030
    - Permit the use of banked allowances, allowances from neighboring states, offsets, and cost containment reserves
- The total emissions for Scenario 3, including units under 25 MW, are well below the RGGI goals

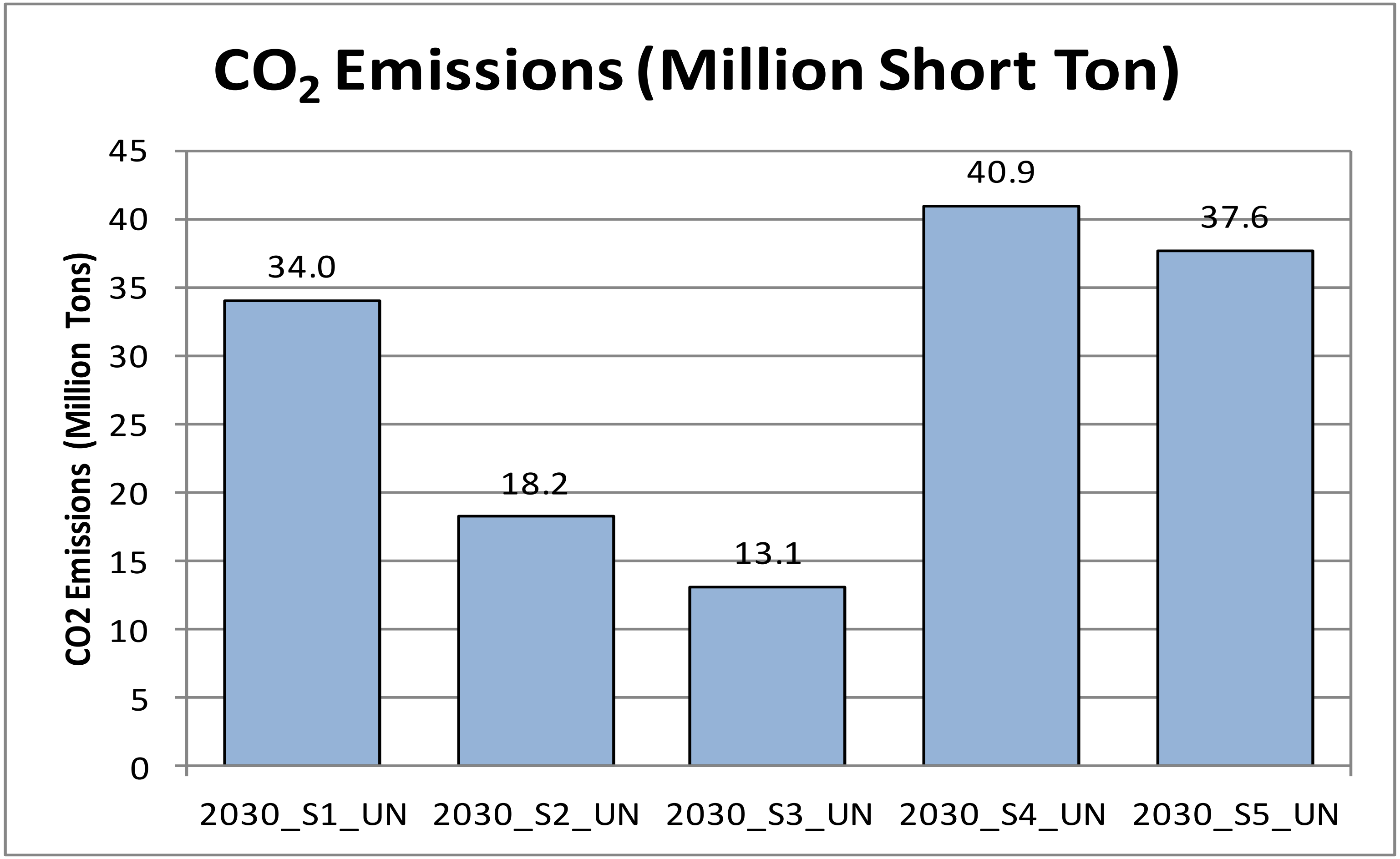
Annual Systemwide CO2 Emissions (Million Short Tons) – 2025

Transmission Interfaces Unconstrained



Annual Systemwide CO2 Emissions (Million Short Tons) – 2030

Transmission Interfaces Unconstrained



OBSERVATIONS

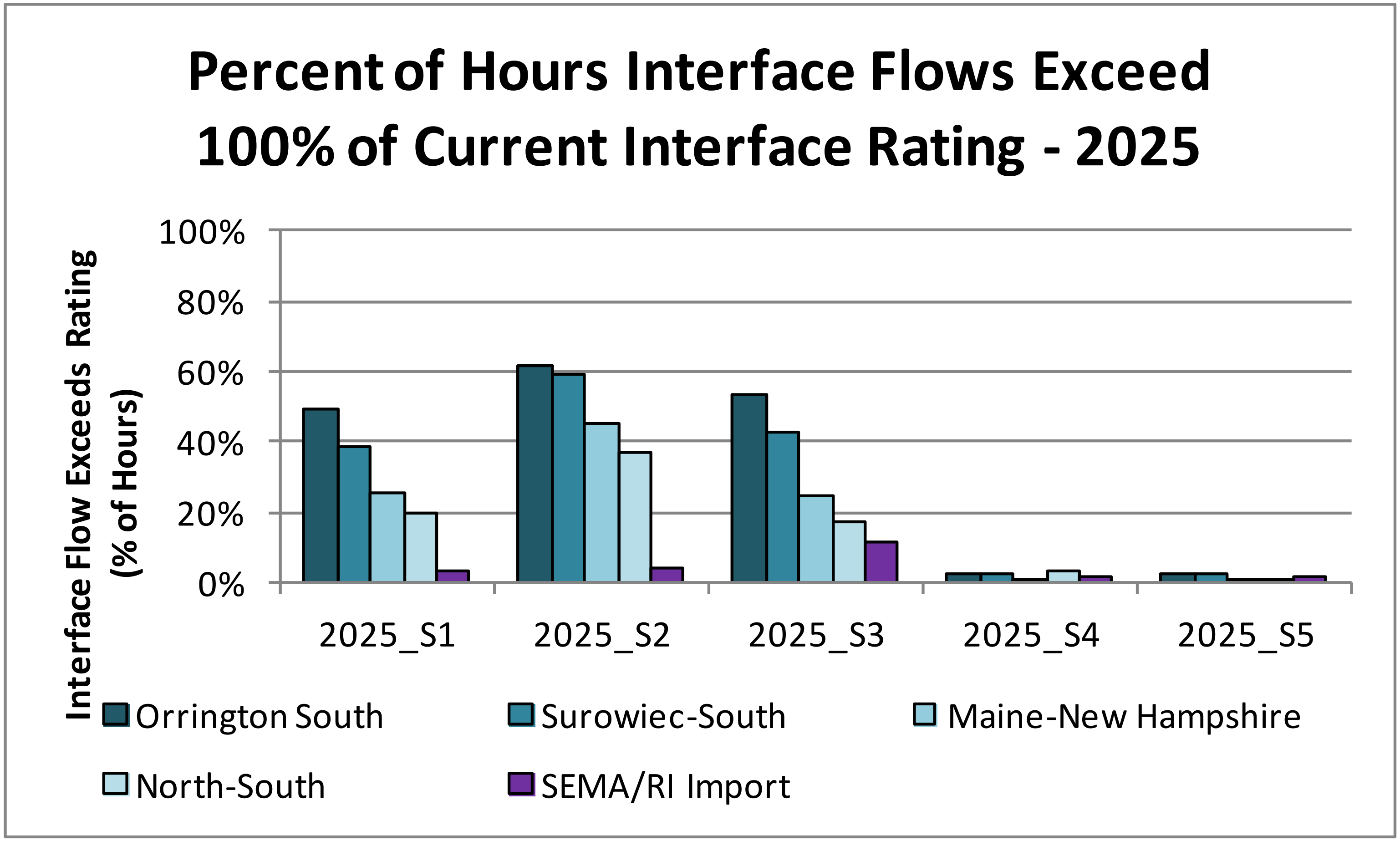
TRANSMISSION INTERFACE FLOWS AS COMPARED WITH TRANSFER LIMITS

Transmission Interface Flows

- The addition of large amounts of onshore wind generation in Northern New England results in higher flows from north to south
- The addition of relatively inexpensive resources in other areas increases flows on the SEMA/RI Import interface
- The development of resources in existing locations minimizes the potential need for transmission expansion
- Note: Interface metric graphs used the following limits
  - 1325 MW - Orrington South
  - 1500 MW - Surowiec South
  - 1900 MW - Maine – New Hampshire
  - 2725 MW - North-South
  - 1280 MW - SEMA/RI Import

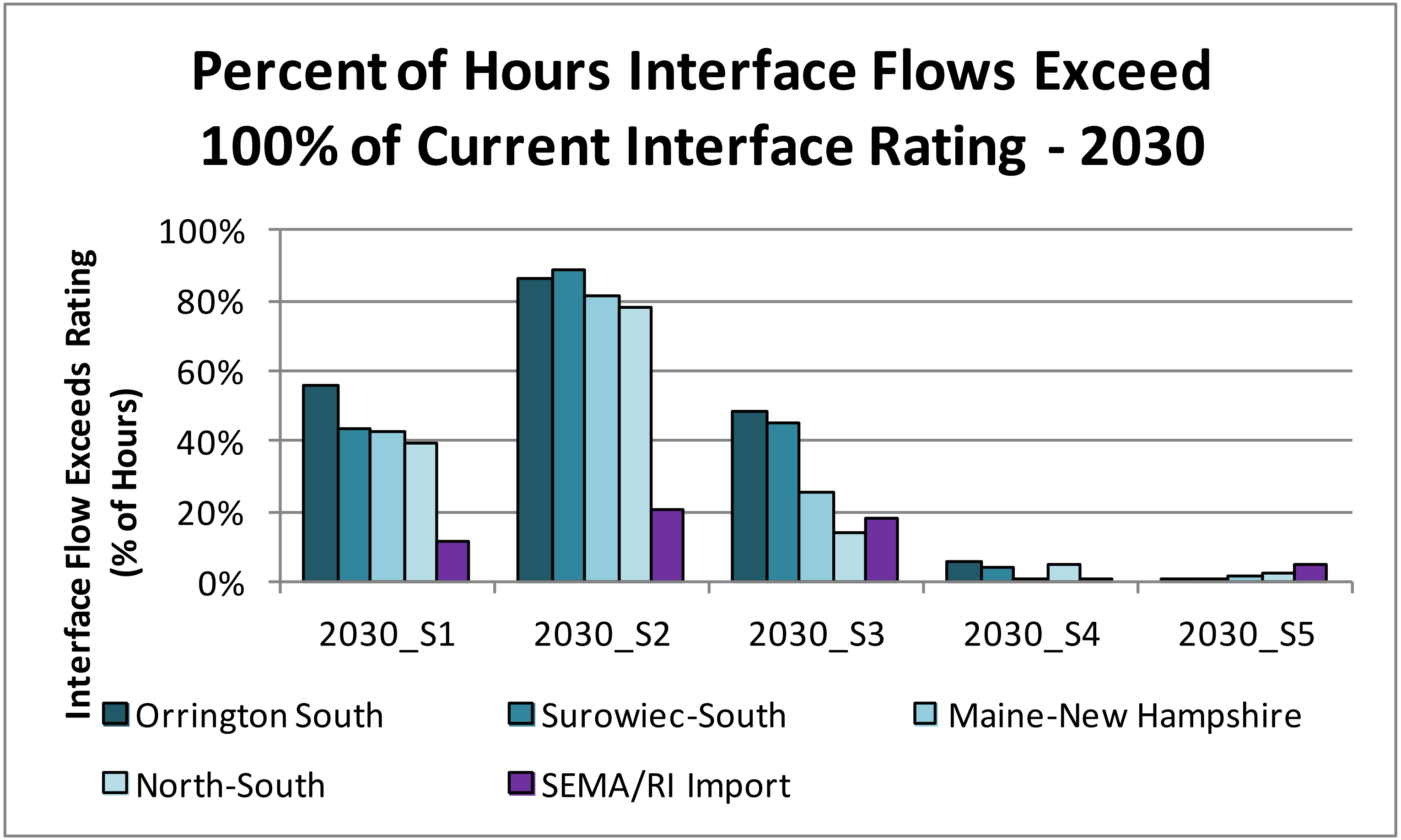
Interface Flow Metric - 2025

Transmission Interfaces Unconstrained



Interface Flow Metric - 2030

Transmission Interfaces Unconstrained



OBSERVATIONS

EFFECT OF TRANSMISSION CONSTRAINTS ON METRICS AND COMPARISON WITH UNCONSTRAINED RESULTS

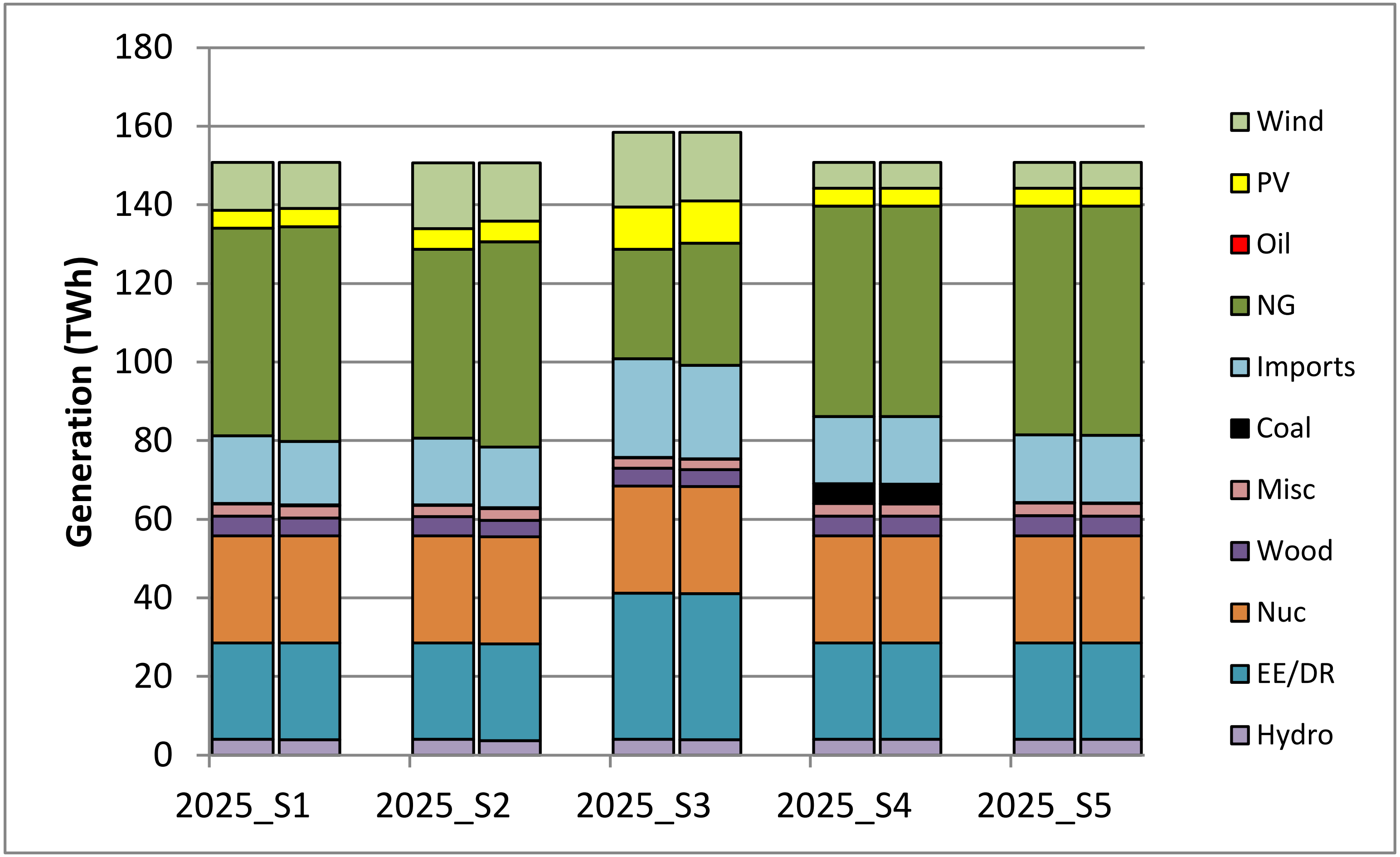
Effect of Congestion

- Low dispatch cost resource additions close to load centers significantly reduce congestion
  - The dispatch of large amounts of remote wind resources, particularly in Northern ME, are limited by transmission system constraints
  - Higher cost units in SEMA/RI and retirements cause some congestion, especially for scenarios with larger scale additions of renewable resources
- Scenarios 4 and 5 experience little congestion because resource locations are close to the load centers
- Congestion in Scenarios 1 and 2 is greater for 2030 as the result of additional development of remote wind resources

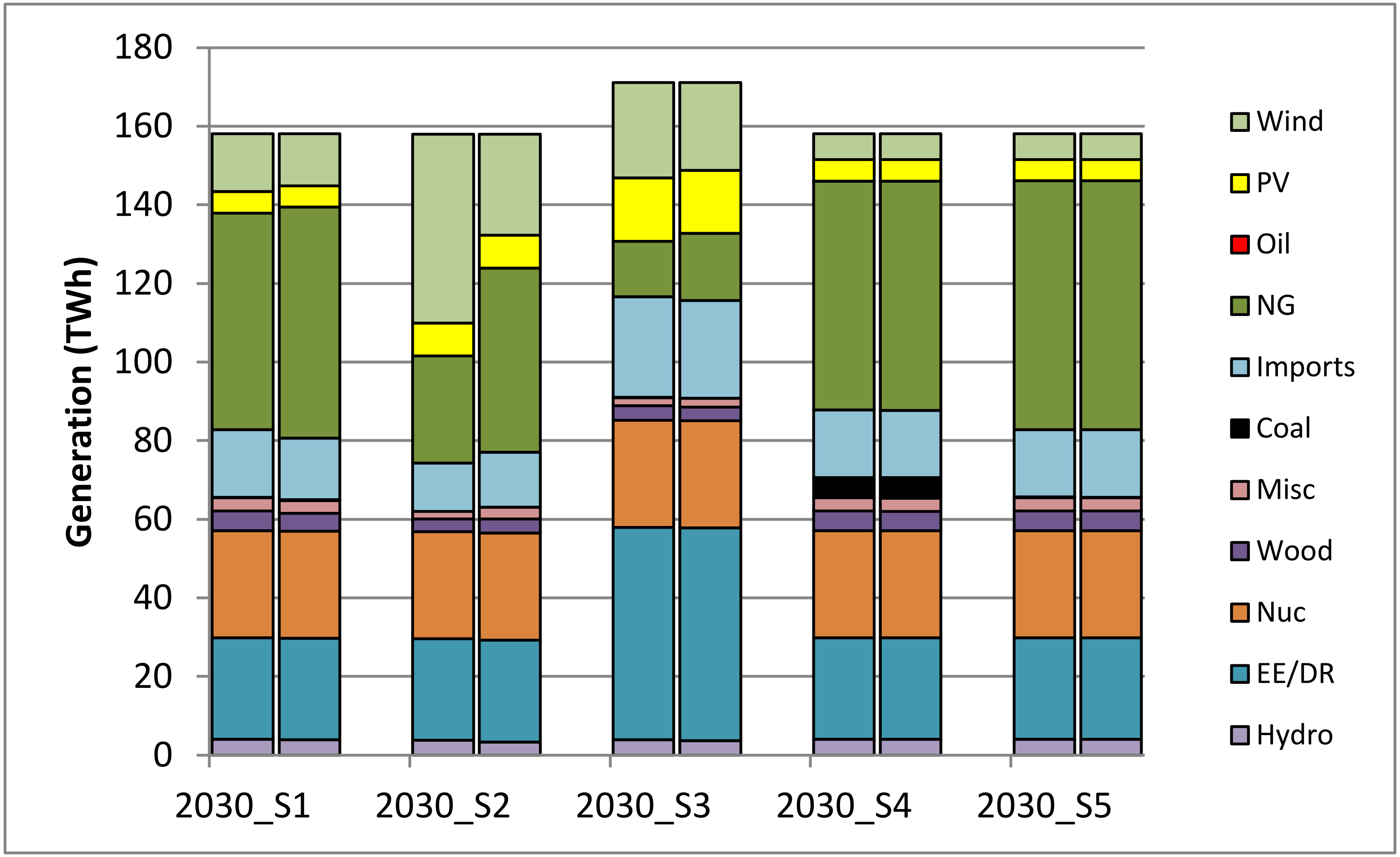
Effect of Congestion, continued

- Congestion for Scenario 3 is lower in 2030 as the result of relatively inexpensive resource additions south of the North-South interface
- Emissions for scenarios with high penetrations of wind are further reduced by eliminating transmission constraints
- Congestion increases the use of natural gas across all scenarios and the use of coal in Scenario 4
- Wind displaces imports from New Brunswick and other more expensive resources in Northern New England
  - RPS goals are physically met in Scenarios 1, 2, and 3 for both 2025 and 2030

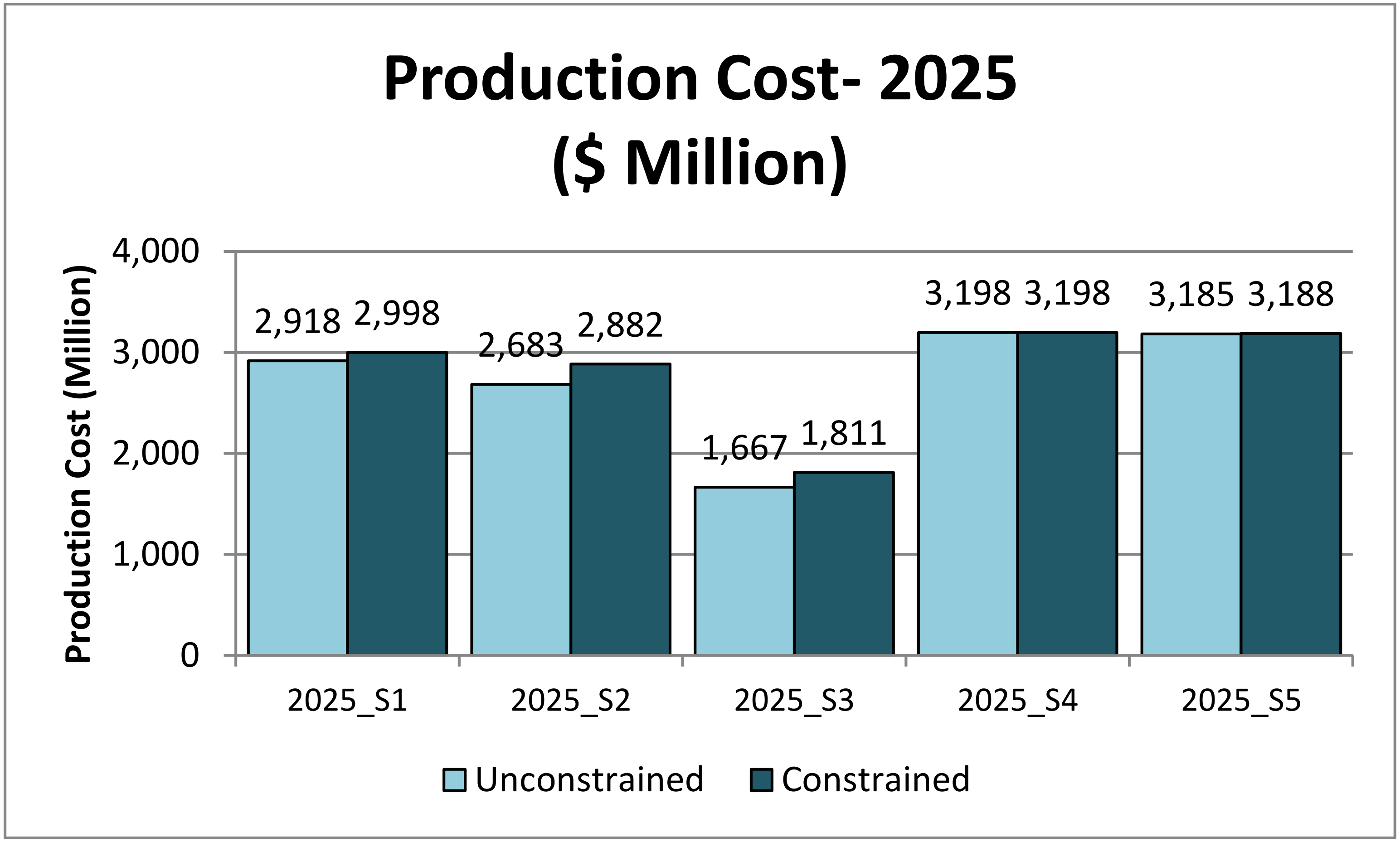
Energy By Source 2025 (TWh) Unconstrained (Left) vs. Constrained (Right)



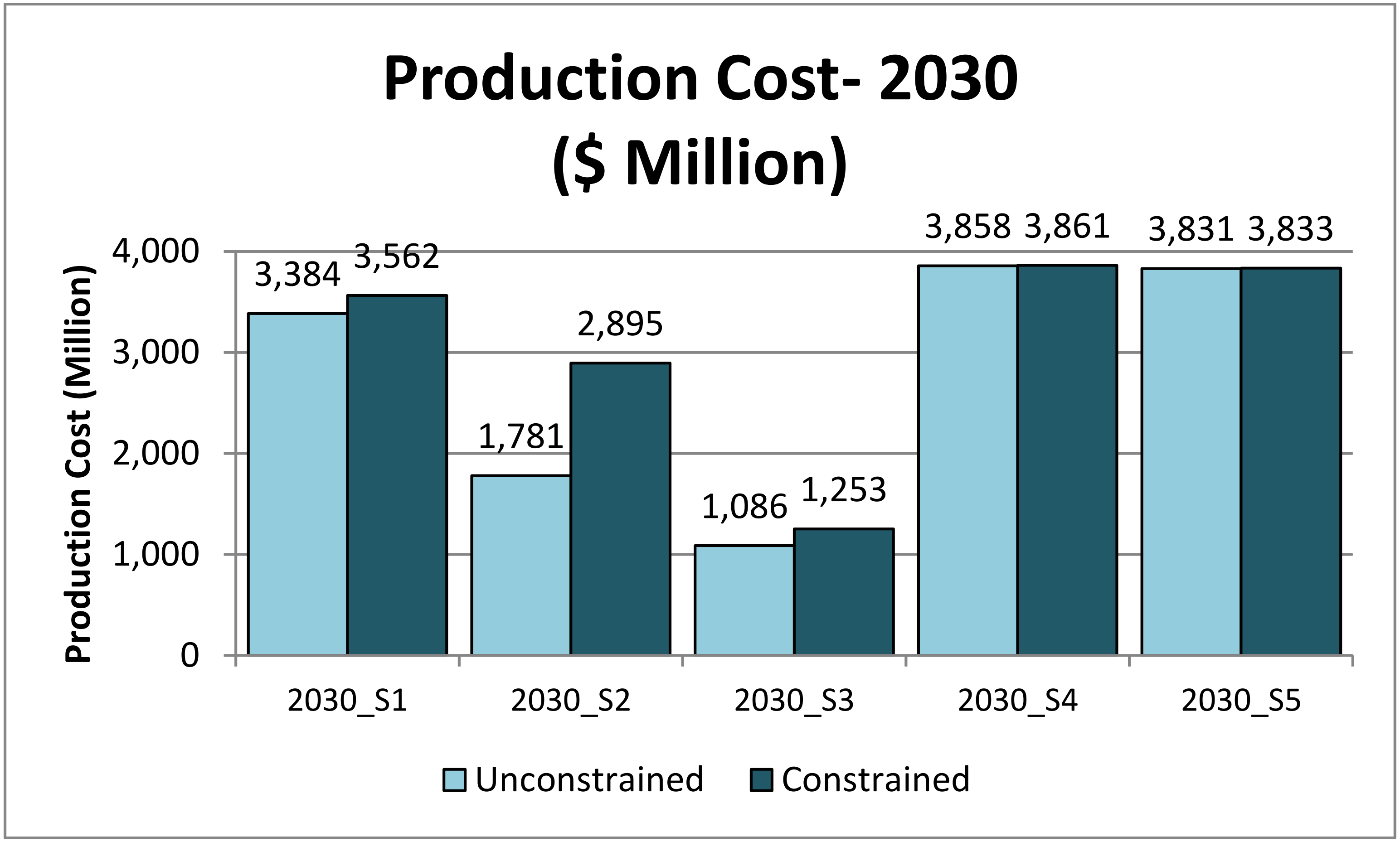
Energy By Source 2030 (TWh) Unconstrained (Left) vs. Constrained (Right)



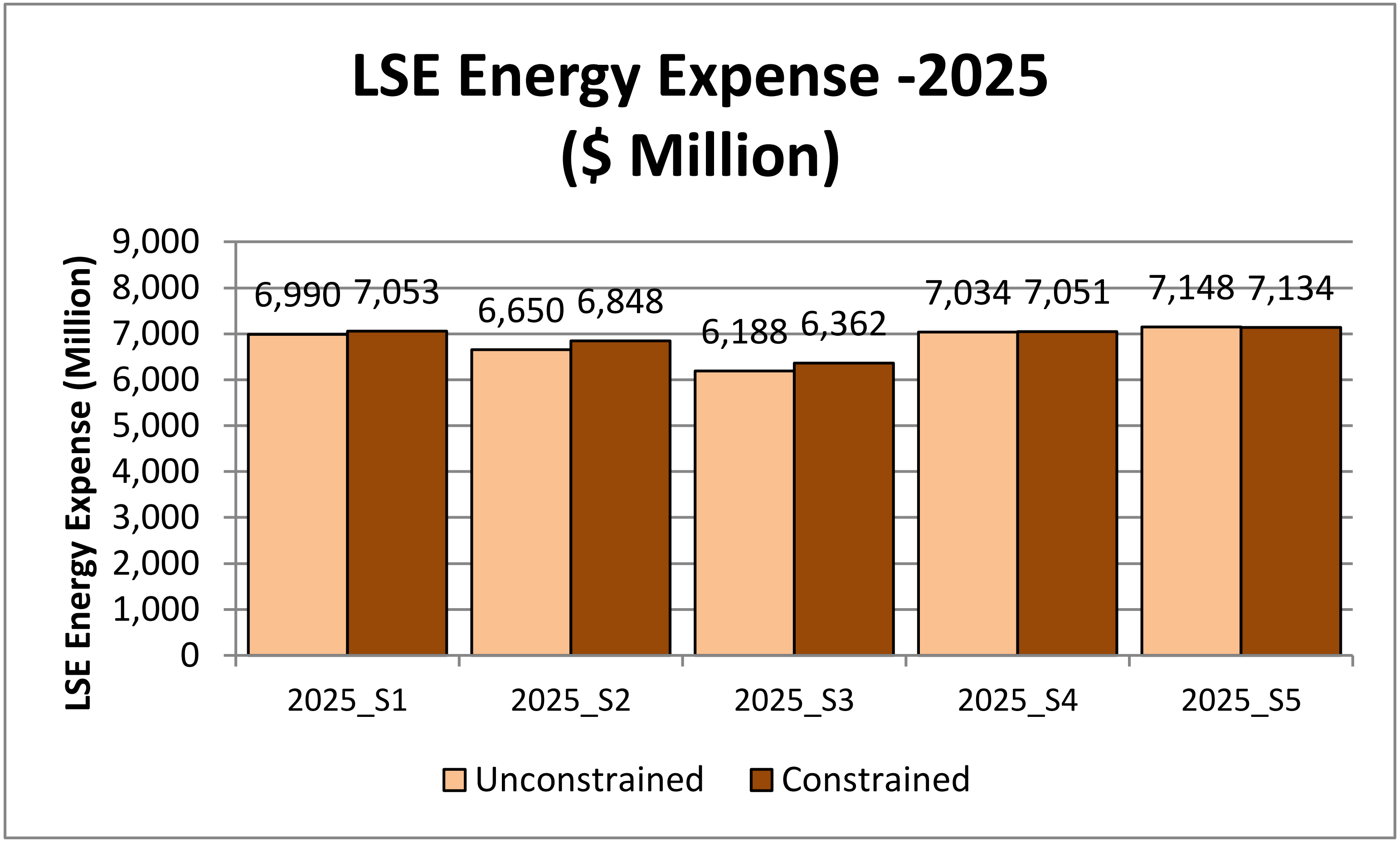
Annual Systemwide Production Costs ($M/Year) – 2025 Transmission Interfaces Unconstrained and Constrained



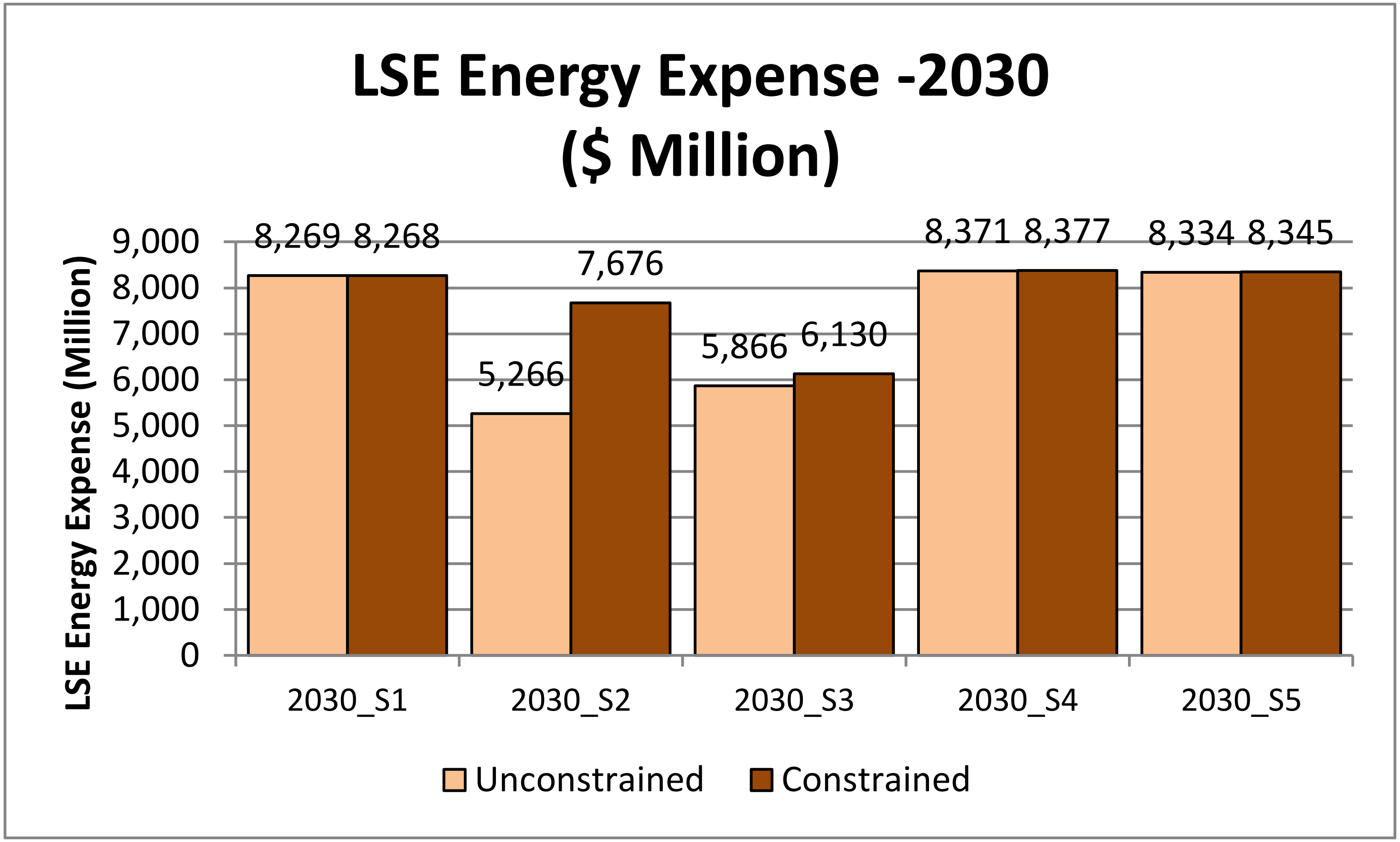
Annual Systemwide Production Costs ($M/Year) – 2030 Transmission Interfaces Unconstrained and Constrained



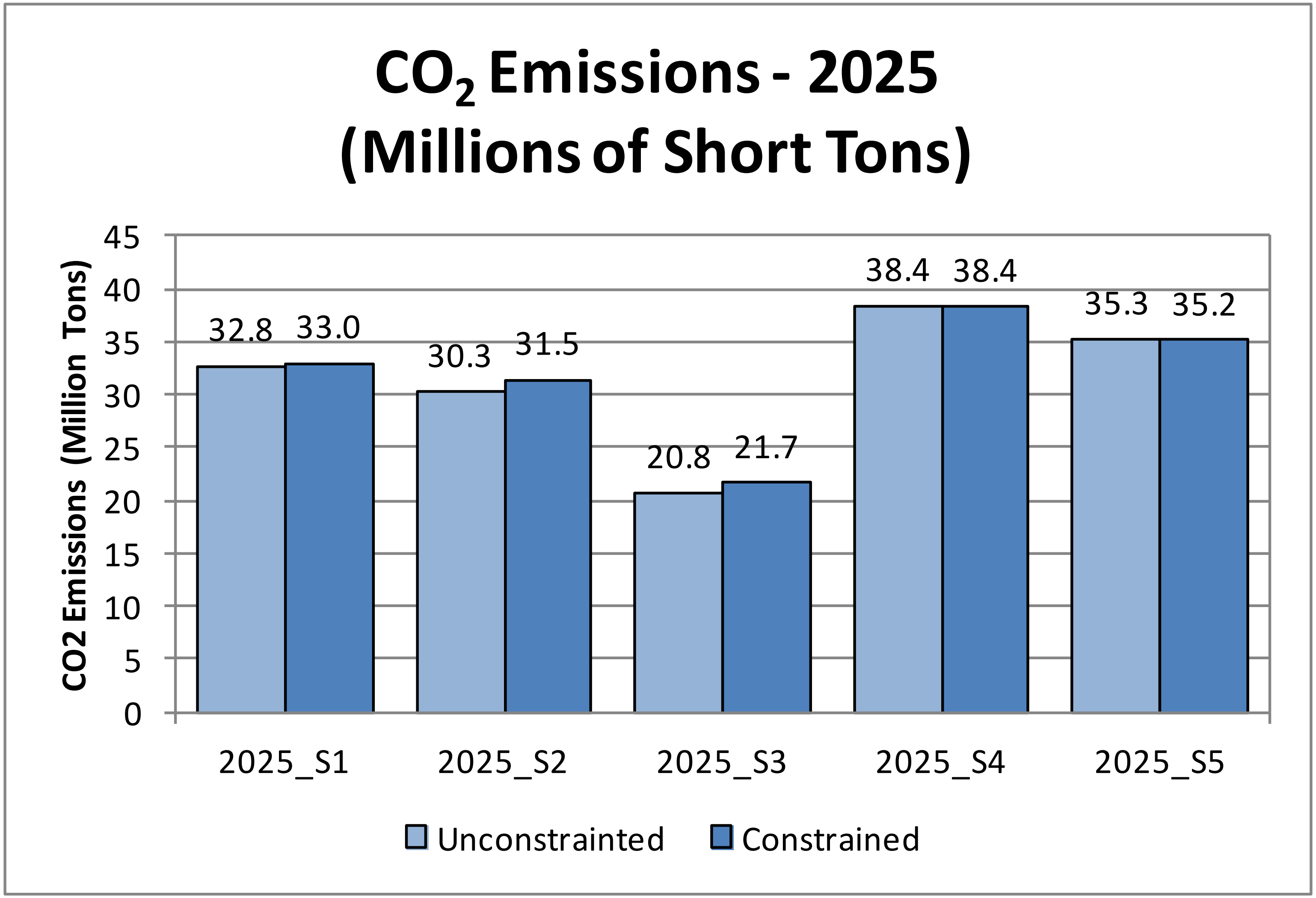
Annual Systemwide LSE Energy Expenses ($M/Year) - 2025 Transmission Interfaces Unconstrained and Constrained



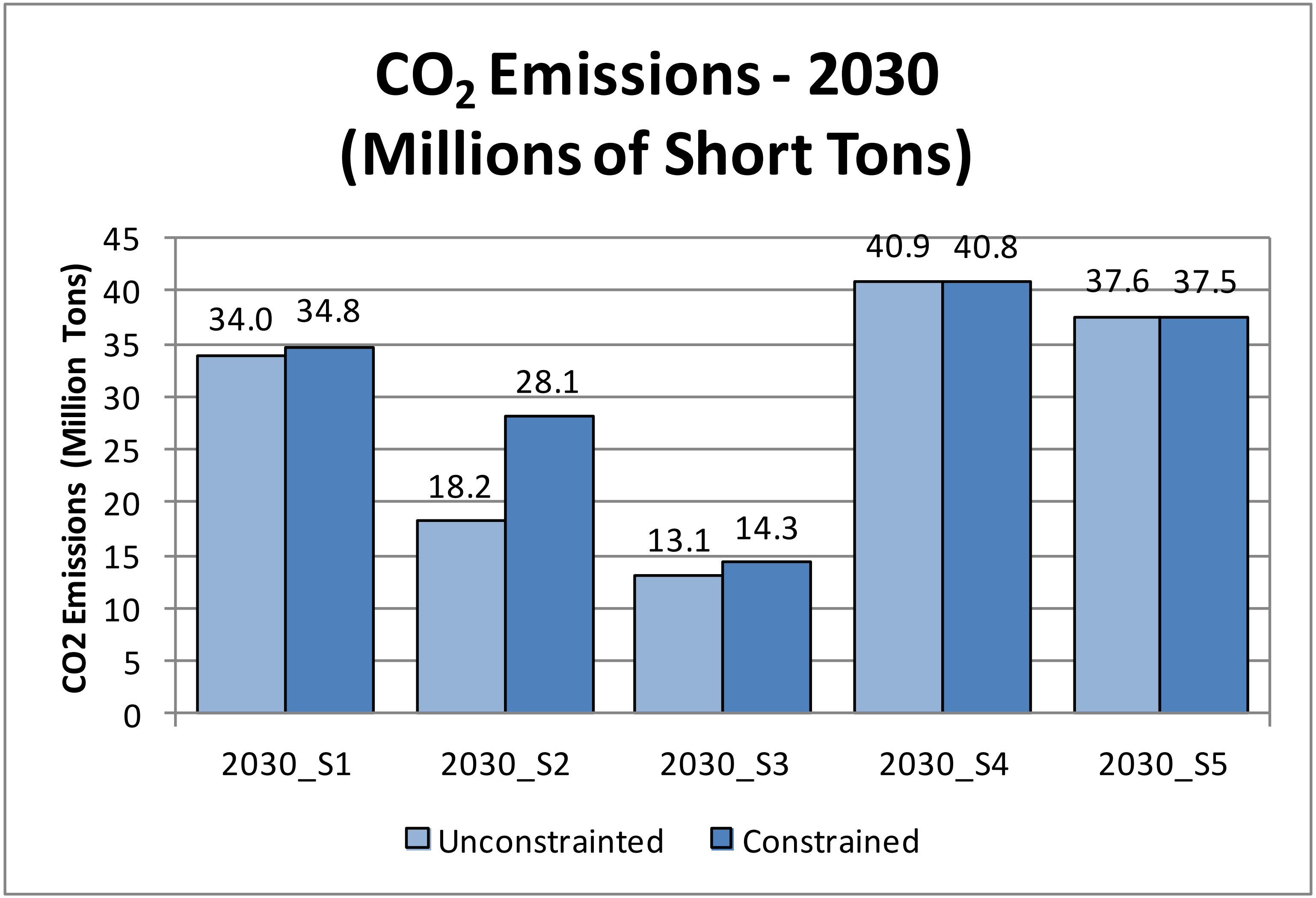
Annual Systemwide LSE Energy Expenses ($M/Year) - 2030 Transmission Interfaces Unconstrained and Constrained



Annual Systemwide CO_2 Emissions - (Million Short Tons) - 2025 Transmission Interfaces Unconstrained and Constrained



Annual Systemwide CO_2 Emissions - (Million Short Tons) - 2030 Transmission Interfaces Unconstrained and Constrained



TRANSMISSION EXPANSION ISSUES

Transmission Expansion Challenges

- The large scale addition of asynchronous resources (EE, PV, wind, and HVDC imports) poses physical challenges
  - Special control systems may be required, especially to stabilize the system and provide frequency control
  - Protection system issues resulting from lack of short circuit availability could require major capital investment
  - Many other issues with power quality, voltage regulation, etc.
- The ISO is currently conducting a literature search on planning techniques for systems with high penetrations of asynchronous resources
  - Rules of thumb do not exist for systems with large amounts of asynchronous resources
- Loads net of wind, PV, EE, hydro, and nuclear may be exceedingly low
  - Presents voltage and stability issues
- Guest speakers have been invited to discuss issues at the October PAC meeting

Transmission Expansion Challenges, continued

- It may be impossible to accurately estimate transmission system and related special control system costs for scenarios 1, 2, and 3
  - However, work is proceeding on the 2016 Maine Resource Integration Study that is scheduled for discussion at the PAC this fall
  - The total justified transmission investment can be estimated as:
    - Taking the difference between the production cost of the unconstrained case minus the constrained case
    - Dividing the above difference by the annual carrying costs of transmission investment (estimated at 15%)

NEXT STEPS

Summary of Metrics for Comparing Scenarios

Graphical and Tabular Format [√ discussed today]

Systemwide production costs ($) √	Total production in GWh and percent for each resource type, including imports √	Total air emissions of CO_2 (Compare with RGGI regional goal) √
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Congestion ($) √	Hours where the spinning reserve requirements are not met	
Percent of time that interfaces exceed 100% of limit for unconstrained cases √ (See Appendix)		
Chronological curves for interface flows that are above 90% of limit		
Diurnal flows of interfaces		
Seasonal flow duration curves for interfaces		
Interface flows on representative summer and winter days		
The fuel that sets the marginal clearing price summarized annually √		
Wholesale energy market revenues and contributions to fixed cost by resource type		

Next Step: Summarize Additional Metrics

- Average Locational Marginal Prices by RSP bubble ($/MWh)
- Wholesale energy market revenues and contributions to fixed cost by resource type
- Energy revenue contributions to fixed costs of resources
- Capacity factors by unit types
- Capacity factors of units that suggest the need for other types of units
- Chronological curves for interface flows that are above 90% of limit
- Diurnal flows of interfaces
- Seasonal flow duration curves for interfaces
- Interface flows on representative summer and winter days
- Hourly ramps
- Ramp rates over hourly periods
- Hourly operating reserve requirements
- Hours where the spinning reserve requirements are not met – May be deferred to Phase II
- Unit commitment and dispatch issues under light load conditions - New issue to be presented

PAC Comments Requested

- This presentation discusses several high level observations
- Stakeholders are invited to examine detailed results (posted separately)
- Please provide the ISO with additional observations, requests for information, and desire for sensitivity cases by 9/1
- Kindly submit comments to PACmatters@iso-ne.com

Schedule

- September 21 PAC
  - Continued discussion of draft results
  - Sensitivity analyses
  - 2016 Maine Resource Integration Study
- 4th Quarter
  - Discussion of transmission planning issues with integrating large amounts of asynchronous resources
  - Final results (based on limited number of additional sensitivity cases)
  - Draft report for stakeholder discussion
  - Final report (target)
  - Discussion of Phase II Scope of Work

Schedule, cont.

- Phase II Analysis to be conducted in 2017
  - Examine representative Forward Capacity Auction (FCA) clearing prices for several scenarios
  - Analyze hourly and intra-hourly ramping, regulation, and reserve requirements
  - Assess natural gas system deliverability issues
  - Can be achieved with the help of consultants

Questions