ANALYSIS GROUP

NYISO 2025-2029 ICAP Demand Curve Reset (DCR)

Preliminary Net EAS Results, 5-Minute Battery Modeling, and Technology Selection Factors

ICAP Working Group

March 25, 2024

Agenda

- Preliminary Net Energy and Ancillary Services (EAS) Revenue Results
- 5-Minute Real-Time Battery Modeling
- Technology Selection Considerations

ANALYSIS GROUP

Preliminary Net EAS Results

ANALYSIS GROUP

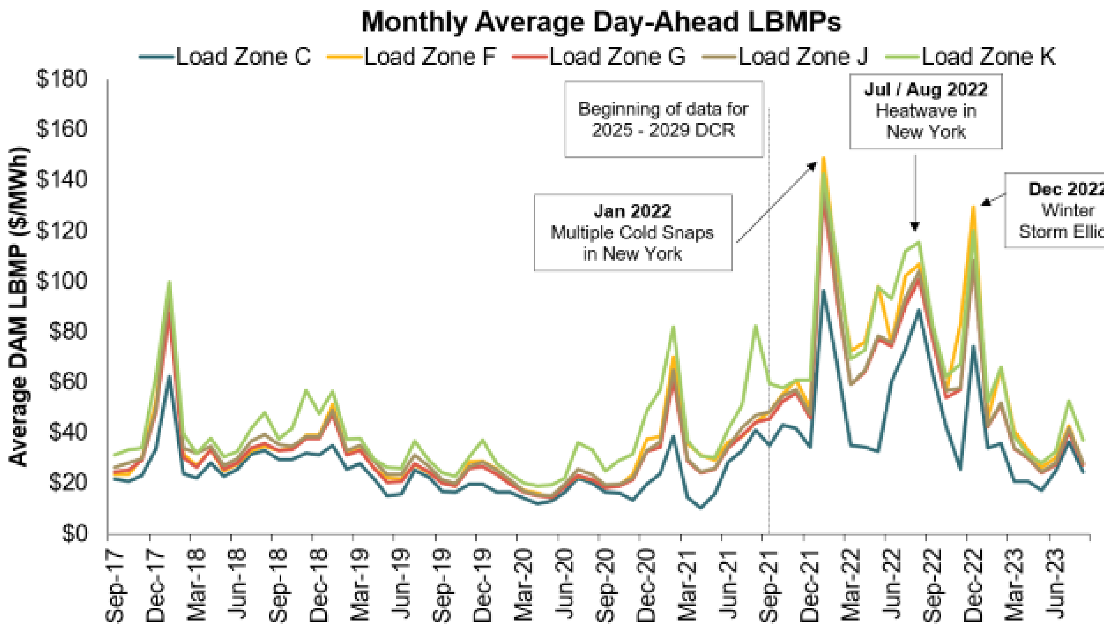
Preliminary Net EAS Results

- AG has developed illustrative net EAS results using the following preliminary assumptions:
  - H/J-class Simple Cycle Gas Turbine ("SCGT") represented by GE 7HA.03
  - Historical data period: September 1, 2020 – August 31, 2023
  - Updated operating characteristics and variable operating cost estimates from 1898&Co for SCGT and battery energy storage system (BESS) technologies
  - Updated natural gas pricing hubs consistent with the preliminary recommendations presented at the February 29th ICAPWG meeting
    - Load Zone C: Dawn Ontario (December-March) and Tennessee Zone 4 200 leg (April-November)
    - Load Zone F: Iroquois Zone 2
    - Load Zone G (Dutchess and Rockland): Tennessee Zone 5 200 leg
    - Load Zone J: Transco Zone 6 NY
    - Load Zone K: Iroquois Zone 2
  - Selective catalytic reduction (SCR) emissions control technology and dual fuel capability for SCGT in all locations
  - Hourly battery model with runtime enhancements previously discussed at the January 25th ICAPWG meeting
- Otherwise, the methodological approach is identical to the previous DCR
- Later, we will compare the preliminary net EAS outcomes for battery storage to results using the 5-minute real-time interval modeling enhancement

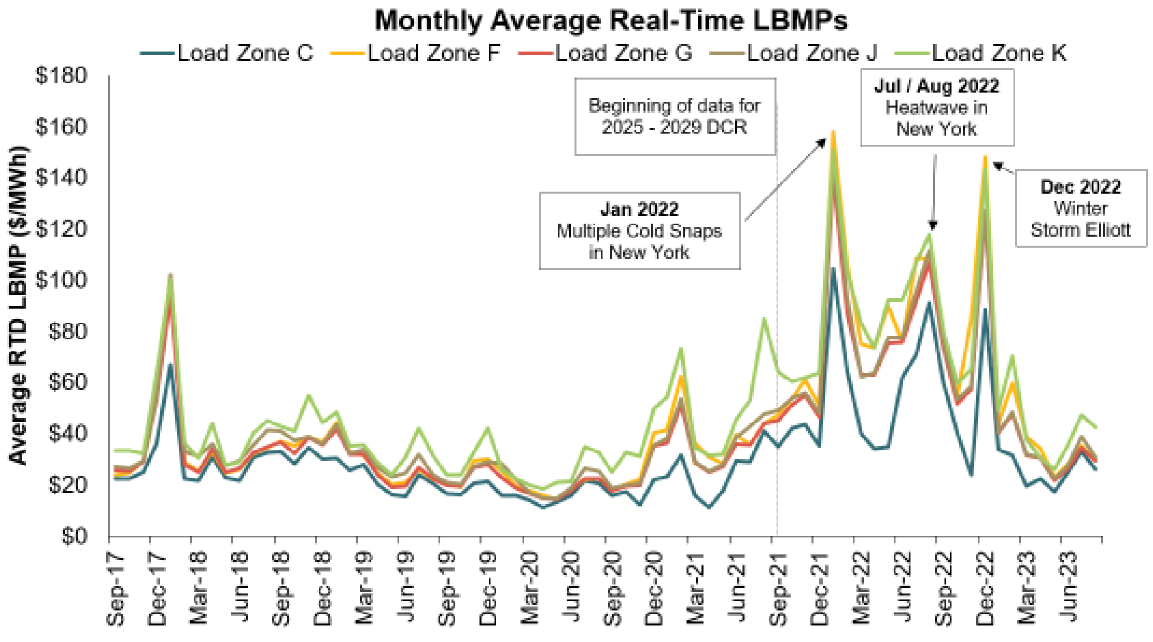
ANALYSIS GROUP

Summary of LBMPs, September 2017 – August 2023

Day-Ahead and Real-Time LBMPs by Load Zone



Source: NYISO Pricing Data.



Note: Underlying data are Time-Weighted/Integrated hourly Real-Time prices. **Source:** NYISO Pricing Data.

ANALYSIS GROUP

Preliminary Net EAS Results

Preliminary Net EAS Results for Fossil-Fuel-Fired Generators

Technology	Zone C	Zone F	Zone G (Rockland)	Zone G (Dutchess)	Zone J	Zone K
Preliminary Net EAS Results						
SCGT J-Class	$63.37	$85.50	$68.55	$68.55	$78.57	$117.10
2024-2025 Raw Net EAS Results (Annual Update)						
GE 7HA.02 – H Class Frame	$52.38	-	$84.04	-	$68.10	$110.29
Percentage Difference						
	20.98%	-	-18.43%	-	15.38%	6.18%

Preliminary Net EAS Results for Battery Energy Storage Systems

Technology	Zone C	Zone F	Zone G (Rockland)	Zone G (Dutchess)	Zone J	Zone K
BESS 4-hour	$61.57	$78.93	$68.39	$70.12	$71.56	$97.33
BESS 6-hour	$66.00	$83.35	$71.09	$73.58	$74.15	$108.62
BESS 8-hour	$67.45	$86.05	$71.89	$75.18	$75.37	$113.73

Note: All dollar values are nominal (i.e. prior to escalation). Preliminary net EAS results and 2024-2025 raw net EAS results are both based on September 1, 2020 – August 31, 2023 data. Values do not reflect a voltage support service (VSS) revenue adder of $2.04/kW-year. 2024-2025 Raw Net EAS Results (Annual Update) were previously presented in the 11/17/2023 ICAPWG meeting.

Observations

- Due to higher natural gas prices over the past three years resulting in higher LBMPs, net EAS revenues are consistently higher than the previous results for year one of the 2021-2025 DCR (i.e., 2021-2022 Capability Year) for all technologies.
- Higher net EAS revenues are already incorporated into current reference point prices through the annual update process
  - The changes relative to the net EAS revenues used in establishing the 2024-2025 ICAP Demand Curves represent differences resulting from the preliminary assumptions and the operating characteristics of the J class turbine compared to the H class turbine selected for the 2021-2025 DCR
- Over time, net EAS revenues may rise or fall as the historical three-year lookback period moves beyond the 2020-2023 period reflecting changes in market prices over time
  - The historical data period that will be used in determining the year one curves for the 2025-2029 DCR (i.e., the 2025-2026 Capability Year) is September 1, 2021 through August 31, 2024
- Net EAS revenues for batteries do not increase proportionally with duration
  - *Incremental* revenues (relative to 4-hour batteries) range from 3.5%-11.4% across all locations for 6-hour batteries, and 5.0%-16.5% across all locations for 8-hour batteries

5-Minute Real-Time Battery Modeling

ANALYSIS GROUP

Sequential Methodology for 5-Minute Interval Real-Time Model

For each interval without a day-ahead (DA) energy position, the model performs the following steps:

Step 1: Assess the *expected* incremental revenues of taking a real-time (RT) energy position in that interval, and an offsetting RT energy position later in the day (using the DA price as the expected RT price for the offsetting position), net of any buyouts of DA reserve positions. If those revenues exceed the specified hurdle rate, commit the RT energy positions.

- The use of DA prices as expected RT price for future hours *eliminates* perfect foresight in the scheduling of RT energy positions.

Step 2: Assess whether specific actions are required to ensure the model does not violate physical feasibility constraints (i.e., charging with state of charge ("SOC") of 100%, or discharging with SOC of 0%).

a. Even if the potential incremental revenues outlined in **Step 1** exceed the specified hurdle rate, the model will not dispatch in RT if physical feasibility is violated.
b. If RT energy positions change the state of charge such that meeting DA energy or reserve commitments are no longer physically feasible, the model buys out of the affected DA positions.

Step 3: Assess whether specific actions are required to ensure the model ends the cycle day with the SOC implied by the DA commitment schedule. This is necessary because the DA model optimizes over multi-day horizons.

a. For intervals where the model took a RT energy position based on the calculation of potential incremental revenues, the model takes the assumed offsetting energy position later in the day, unless subsequent RT positions (and/or DA buyouts) obviate the need for that offsetting energy position.
b. If the model reaches the end of the cycle day with a SOC deviation from the DA schedule, it will take the required positions at the end of the cycle day to achieve the required SOC.

5-Minute Sequential Methodology

Illustration of Model Logic: No Physical Feasibility Constraints

- At 11:05 AM, the model calculates RT discharge revenues of $100/MWh, based on the RT LBMP.
  - For simplicity, assume the model did not take a DA reserve position at 11:00 AM.
- The model uses the *lowest DA LBMP for the remaining hours in the day* to estimate a proxy for the costs of recharging later in the day.
  - In this case, assume the lowest DA LBMP occurs at 8:00 PM, with an associated *expected* charge cost of $50/MWh.
- The model compares the spread between the two components above to a specified hurdle rate (in this example, assume a hurdle rate of $30/MWh).
- Ultimately, revenues for these RT energy positions are calculated based on *realized* RT prices in all cases (and do not include the hurdle rate as an offsetting cost).

RT Dispatch Decision based on Expected RT Prices

$100/MWh - $50/MWh > $30/MWh → Discharge

Physical Feasibility Check

SOC of 50% → No Violation

Realized Revenues from RT Energy Positions

$100/MWh - $75/MWh = $25/MWh

SOC: 50%

11:05 AM
RT Discharge Revenues: $100/MWh

8:00 PM
Expected Charge Cost from DA Price: $50/MWh
Realized Charge Cost from RT Price: $75/MWh

5-Minute Sequential Methodology

Illustration of Model Logic: Physical Feasibility Violated

- Assume identical conditions to the prior example, except that the model enters 11:05 AM with no stored energy.
- Even though the expected incremental revenues associated with the RT energy positions exceed the specified hurdle rate, the model will not pursue a discharge position for this interval because it would violate a physical feasibility constraint.

RT Dispatch Decision based on Expected RT Prices
$100/MWh - $50/MWh > $30/MWh → Discharge

Physical Feasibility Check
SOC of 0% → **Violation**

Realized Revenues from RT Energy Positions
n/a

SOC: 0%

11:05 AM
RT Discharge Revenues: $100/MWh

8:00 PM
Expected Charge Cost from DA Price: $50/MWh
Realized Charge Cost from RT Price: $75/MWh

ANALYSIS GROUP

5-Minute Sequential Methodology

Illustration of Model Logic: DA Energy Buyout

- Assume now that the RT LBMP remains at a constant level from 11:00 AM – 12:00 PM, such that the 5-minute model discharges in RT for the entire hour.
- The model has sufficient stored energy to discharge for an hour in RT, but it does not have sufficient energy to meet a previously scheduled DA discharge commitment at 2:00 PM.
- To offset the RT discharge, the model buys out of the DA position.
- Assuming for simplicity that the RT LBMP at 2:00 PM is equal to the DA LBMP at 2:00 PM such that the net buyout cost is zero, RT revenues increase by $100/MWh, offset in part by a decrease in revenues of $80/MWh due to the buyout of the DA position.

RT Dispatch Decision based on Expected RT Prices
$100/MWh - $50/MWh > $30/MWh → Discharge

Physical Feasibility Check
SOC of 0% for DA Discharge → Violation

Realized Revenues from RT Energy Positions
$100/MWh

Change in Revenues From DA Positions
-$80/MWh

Net Change in Revenues From RT Energy Positions and DA Buyout
+$20/MWh

SOC: 25%

SOC: 0%

11:00 AM – 12:00 PM
RT Discharge Revenues: $100/MWh

2:00 PM – 3:00 PM
DA Discharge Expected Revenues: $80/MWh

8:00 PM
Expected Charge Cost from DA Price: $50/MWh
Realized Charge Cost from RT Price: $75/MWh

5-Minute Sequential Methodology

Other Issues

- Because of imperfect foresight in RT prices, it is possible for realized revenues on an RT dispatch decision to be negative in any given interval (for example if realized RT charging costs were higher than those implied by DA prices ex-ante).
- AG believes that battery storage operators which elect to “self manage” the SOC of their resources will be sufficiently sophisticated to dynamically update market offers to account for various factors.
  - These factors include, *inter alia*, physical feasibility limitations and relevant market information, such as forecasts of market prices.
- AG continues to review certain NYISO market rules which may impact the 5-minute modeling approach, such as:
  - Ramping limitations within 5-minute intervals.
  - Battery storage’s ability to earn additional revenues from intervals less than 5 minutes long (i.e., those that occur due to RTD Corrective Action Mode), subject to relevant constraints.
- Note that the impact of 5-minute interval pricing on net EAS revenues will result in changes due to both *methodology* and changes due to *pricing frequency*
  - To assess the extent to which the 5-minute interval modeling results are driven by differences in modeling logic, the “sequential” RT model logic was applied to hourly intervals.
  - The sequential hourly RT model serves as an “apples-to-apples” comparison to the sequential 5-minute RT model results.

5-Minute Real-Time Interval Analysis

Sequential 5-Minute RT Model Results: Total Net EAS Revenues

- Both the change in methodology and the change in pricing interval impact total net EAS revenues for battery technologies, but in opposite directions:
  - The change in methodology removes a degree of perfect foresight from the real-time energy market storage model, ***lowering net EAS revenues***
  - The change in pricing intervals increases potential opportunities for gains from energy arbitrage through increased price volatility, ***increasing net EAS revenues***
- The total impact on net EAS revenues of switching from the hour pair to sequential 5-minute model for real-time appears to be material but relatively small with the largest impact observed in Load Zone K

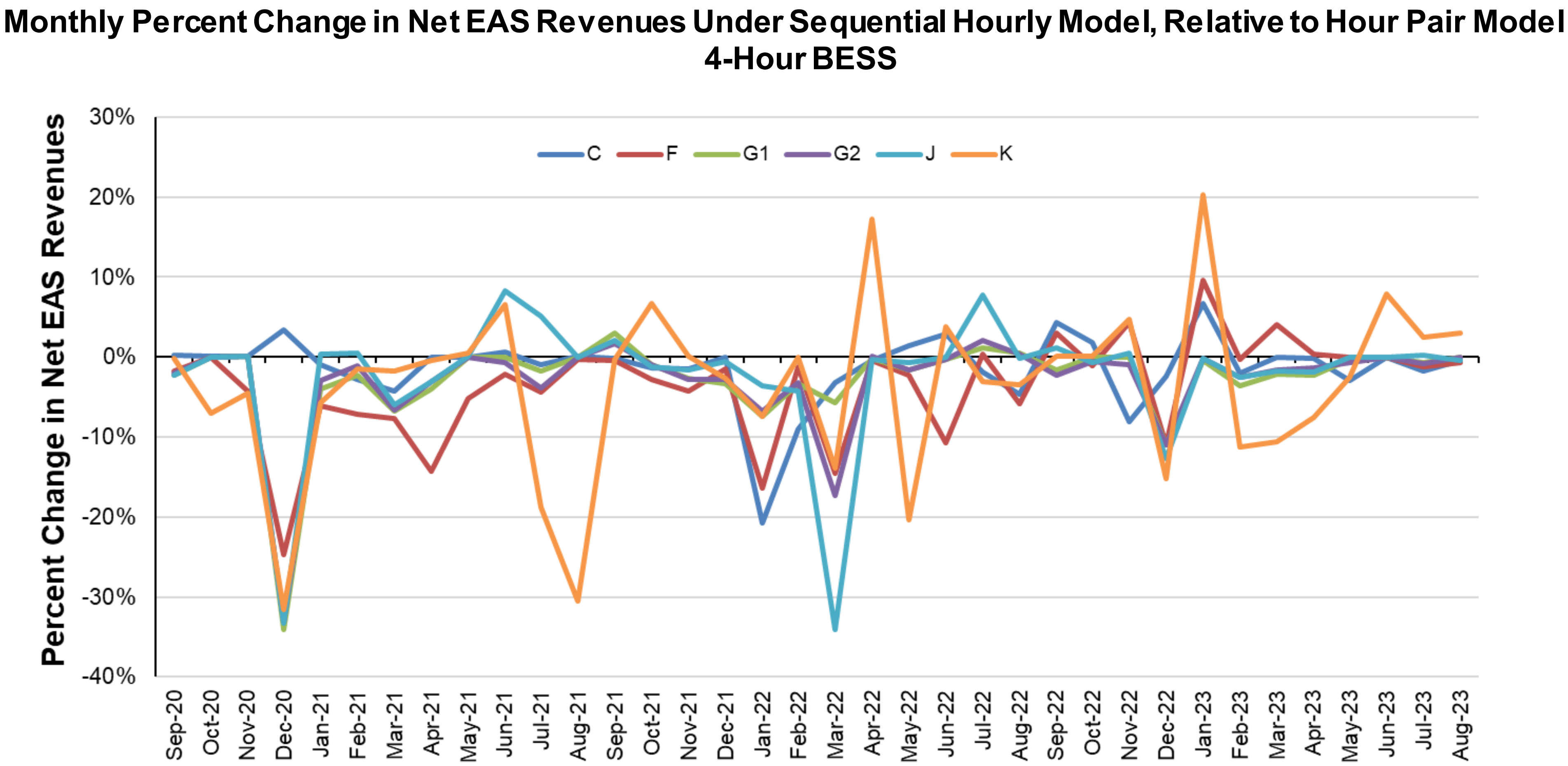
Percent Change in Net EAS Revenues by Model
4-Hour BESS

Zone	5-Minute Optimal Hurdle Rate ($/MWh)	Hour Pair to Sequential 5-Minute
C	20	4%
F	60	4%
G1	70	0%
G2	60	0%
J	65	2%
K	30	8%

Note: Based on September 1, 2020 – August 31, 2023 data. G1 corresponds to Load Zone G (Dutchess), and G2 corresponds to Load Zone G (Rockland)

5-Minute Real-Time Interval Analysis

Time Series of Revenue Impacts Due to Change In Methodology

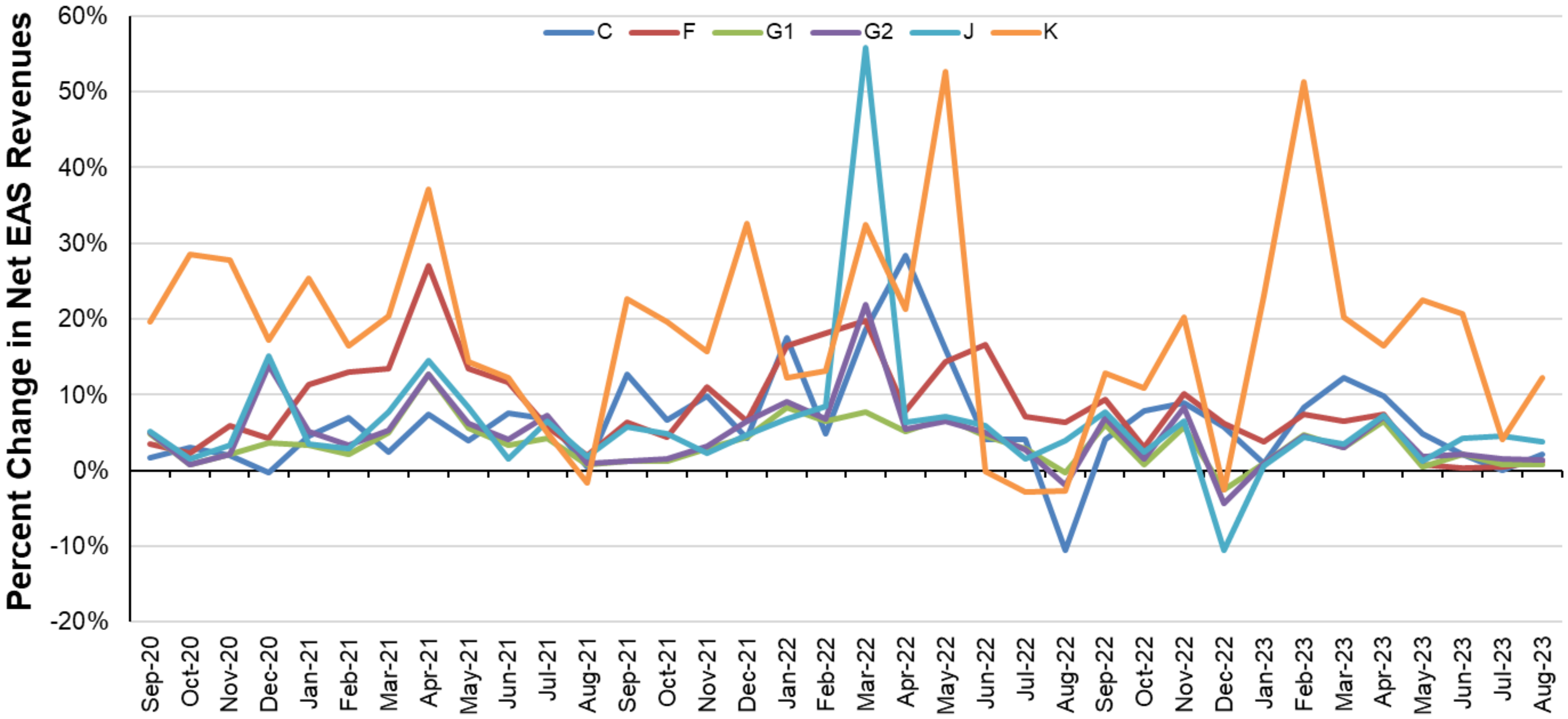


ANALYSIS GROUP

5-Minute Real-Time Interval Analysis

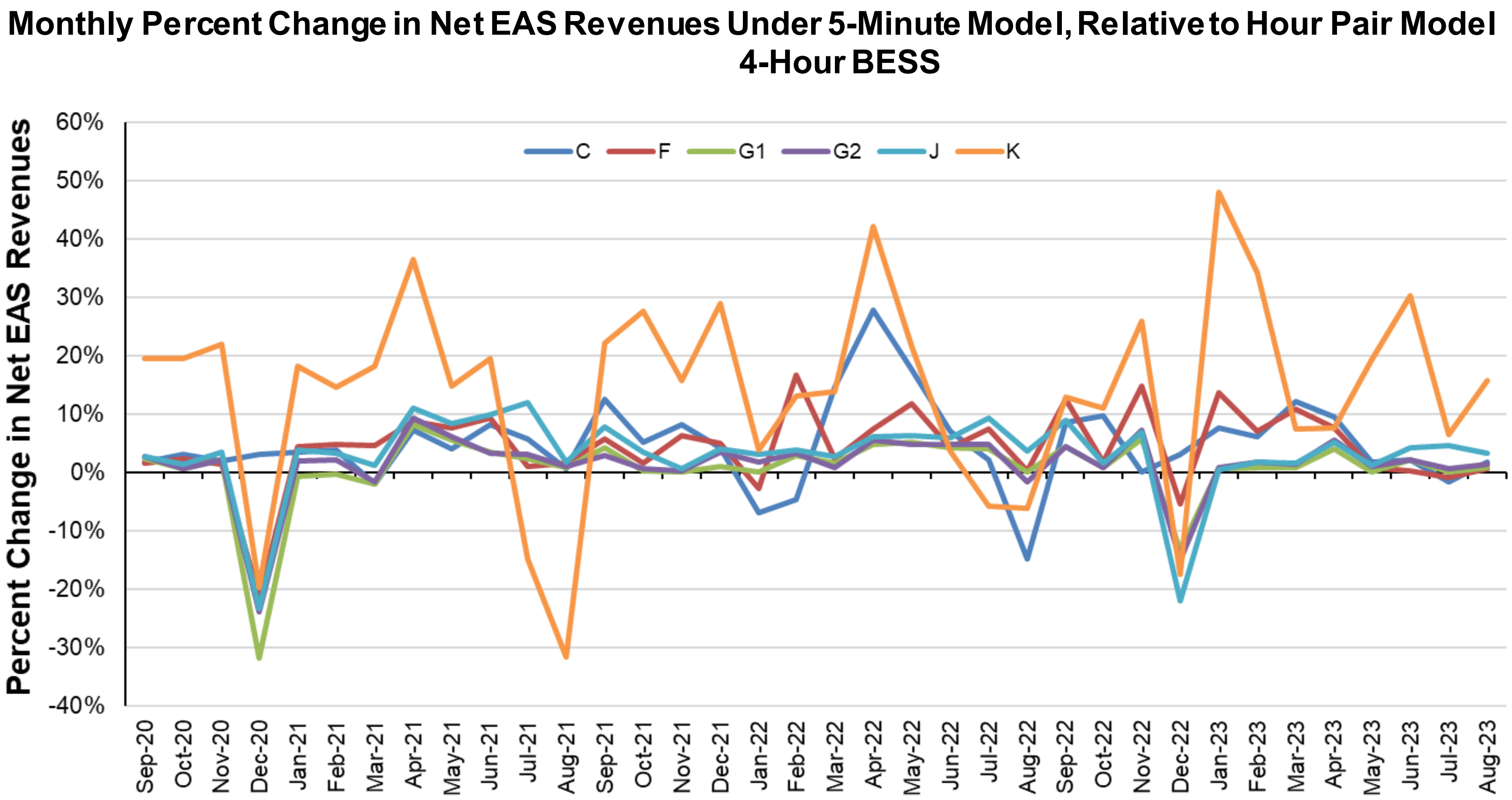
Time Series of Revenue Impacts Due to Change In Pricing Intervals

Monthly Percent Change in Net EAS Revenues Under 5-Minute Model, Relative to Sequential Hourly Model
4-Hour BESS



5-Minute Real-Time Interval Analysis

Time Series of Overall Revenue Impacts Due to Change to 5-Minute Pricing



Preliminary Observations and Next Steps

- The impacts of switching to 5-minute real-time intervals on net EAS revenues appear significant enough to warrant inclusion in storage net EAS model
  - The net impact on net EAS revenues ranges from 0% to 8% for 4-hour batteries
  - Results are similar, but smaller in magnitude, for 6-hour and 8-hour batteries
- These results use a single, static hurdle rate. AG is continuing to investigate the potential impact of using some degree of varying (e.g., seasonal) hurdle rates per stakeholder feedback.
  - The sequential 5-minute real-time model runs much faster than previous battery model iterations, making it easy to test various combinations of hurdle rates
  - We would only include varying hurdle rates to the extent they capture realistic opportunities to earn incremental net revenues in the real-time market

ANALYSIS GROUP

Technology Selection Considerations

Background on ICAP/UCAP Reference Point Prices

- AG will calculate seasonal monthly ICAP/UCAP reference point prices consistent with the methodology filed with FERC by NYISO in December 2023
- The metric actually transacted in the ICAP market is UCAP
- ICAP to UCAP translation methodology, as specified in the Installed Capacity Manual:

  "[E]ach price on each ICAP Demand Curve shall be converted into a price on the corresponding UCAP Demand Curve by dividing it by the product of: (a) the Capacity Accreditation Factor of the peaking plant used to establish the applicable ICAP Demand Curve, and (b) one minus the applicable derating factor of such peaking plant."
- Selection of the peaking technology by minimizing the cost of ICAP would fail to account for variation in Capacity Accreditation Factors (CAFs) or derating factors across technologies, and thus could result in selecting a technology that does not supply UCAP at the lowest cost
- AG proposes to consider the relevant UCAP reference point prices for each technology option in selecting the appropriate peaking unit technology for each demand curve

ANALYSIS GROUP

Variation in Capacity Accreditation Factors (CAFs) by Technology

Final CAFs for the 2024/2025 Capability Year

	Zone C	Zone F	Zone G - Rockland	Zone G - Dutchess	Zone J	Zone K
4-Hour Energy Duration Limited	64.5%	64.5%	68.0%	68.0%	68.8%	78.9%
6-Hour Energy Duration Limited	91.8%	91.8%	91.9%	91.9%	90.4%	91.5%
8-Hour Energy Duration Limited	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%
SCGT J-Class	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Final capacity accreditation factors for the 2024/2025 capability year were previously presented in the 2/29/2024 ICAPWG meeting.

Dual Fuel Capability

- AG's preliminary recommendation is to include dual fuel (DF) capability in all locations based on economic and capacity accreditation factor considerations
- Focus is on the tradeoffs a developer would consider when evaluating the added expense vs. future cost risks and opportunities, and whether the developer more likely than not would decide to include DF capability
- Load Zones G-K factors continue to support recommendation of DF capability as in prior DCRs – these factors remain at least, if not more, relevant, including:
  - Local electric reliability rules (Load Zones J and K)
  - Connections of most generation to local distribution company (LDC) gas systems, some requiring fuel switching under certain conditions
  - Challenged gas availability under winter peak conditions and potential for higher revenues when price of gas exceeds oil or opportunities to operate on gas are limited
- In previous DCRs, similar potentially important considerations have been noted in Load Zones C and F, but ultimately it was concluded that a developer may, on balance, be likely to choose gas-only construction given associated costs
- In our view, the risks associated with lower capacity accreditation factors for generators without firm fuel (or alternatively, the risks of penalties if firm fuel is not acquired) amplify the rationale for DF in Load Zones G-K, and swing the balance in Load Zones C and F
  - In our view, with firm fuel and capacity accreditation rules in place, in addition to other risks associated with gas-only peaking operation, developers in Load Zones C and F may be more likely than not to decide to include DF capability

Contact

Analysis Group

Paul Hibbard, Principal
617-425-8171
paul.hibbard@analysisgroup.com

Todd Schatzki, Principal
617-425-8250
todd.schatzki@analysisgroup.com

Joe Cavicchi, Vice President
617-425-8233
joe.cavicchi@analysisgroup.com

Charles Wu, Vice President
617-425-8342
charles.wu@analysisgroup.com

Daniel Stuart, Manager
617-425-8196
daniel.stuart@analysisgroup.com

Appendix

5-Minute Real-Time Interval Analysis

Sequential Hourly RT Model Results: Total Net EAS Revenues

- Both the change in methodology and the change in pricing interval impact total net EAS revenues for battery technologies, but in opposite directions:
  - The change in methodology removes a degree of perfect foresight from the real-time energy market storage model, ***lowering net EAS revenues***
  - The change in pricing intervals increases potential opportunities for gains from energy arbitrage through increased price volatility, ***increasing net EAS revenues***
- The total impact on net EAS revenues of switching from the hour pair to sequential 5-minute model appears to be material but relatively small with the largest impact observed in Load Zone K

Percent Change in Net EAS Revenues by Model
4-Hour BESS

Zone	5-Minute Optimal Hurdle Rate ($/MWh)	Methodology Impact: Hour Pair to Sequential Hourly	5-Minute Interval Impact: Sequential Hourly to Sequential 5-Minute	Total Impact of Switching to New 5-Minute Modeling Approach: Hour Pair to Sequential 5-Minute
C	20	-3%	7%	4%
F	60	-4%	9%	4%
G1	70	-3%	3%	0%
G2	60	-4%	4%	0%
J	65	-3%	5%	2%
K	30	-6%	15%	8%

Note: Based on September 1, 2020 – August 31, 2023 data. G1 corresponds to Load Zone G (Dutchess), and G2 corresponds to Load Zone G (Rockland)

ANALYSIS GROUP

5-Minute Real-Time Interval Analysis

Sequential Hourly RT Model Results: Total Net EAS Revenues

Percent Change in Net EAS Revenues by Model 6-Hour BESS

		Methodology Impact	5-Minute Interval Impact	Total Impact of Switching to New 5-Minute Modeling Approach
Zone	5-Minute Optimal Hurdle Rate ($/MWh)	Hour Pair to Sequential Hourly	Sequential Hourly to Sequential 5-Minute	Hour Pair to Sequential 5-Minute
C	15	-6%	8%	2%
F	20	-5%	10%	4%
G1	30	-5%	5%	0%
G2	25	-5%	5%	0%
J	50	-4%	5%	0%
K	25	-6%	13%	6%

Percent Change in Net EAS Revenues by Model 8-Hour BESS

		Methodology Impact	5-Minute Interval Impact	Total Impact of Switching to New 5-Minute Modeling Approach
Zone	5-Minute Optimal Hurdle Rate ($/MWh)	Hour Pair to Sequential Hourly	Sequential Hourly to Sequential 5-Minute	Hour Pair to Sequential 5-Minute
C	15	-5%	8%	2%
F	25	-7%	9%	2%
G1	25	-5%	5%	0%
G2	25	-5%	5%	0%
J	25	-5%	5%	1%
K	20	-5%	11%	5%

Note: Based on September 1, 2020 – August 31, 2023 data. G1 corresponds to Load Zone G (Dutchess), and G2 corresponds to Load Zone G (Rockland).