AGO Alternative Storage EAS Revenue Estimates

NEPOOL Markets Committee

November 9-10, 2020

Summary & Key Takeaways

- Final AGO proposed EAS revenue offsets are 6% higher than CEA assuming FRM is maintained and 19% higher assuming FRM is sunset.

  Assuming FRM Maintained (2025$): $8,812,453 ($58.75/kW-year)

  Assuming FRM Sunset (2025$): $8,177,487 ($54.52/kW-year)

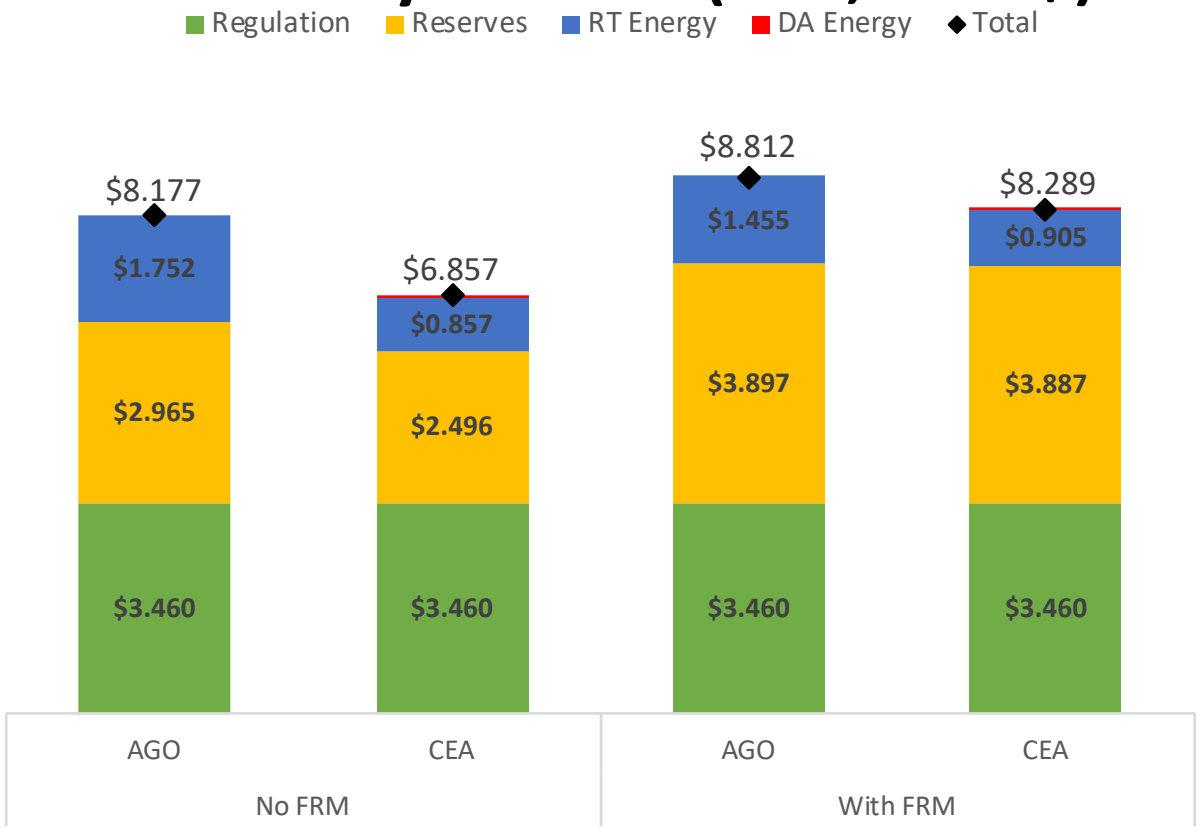
- AGO revenue estimates have been updated since last month to adjust regulation revenues down (and align AGO, ISO-NE/CEA estimates for that product).
  - AGO regulation revenues reduced by $54k/year in FRM and No FRM cases.
  - AGO estimates for energy and TMSR sales are unchanged from last month.
- AGO approach comports with revenues available to a “reasonably competent” storage operator and improves on CEA’s simple model.

AGO revenues are down by $54k due to changes to regulation revenues

- Last month, AGO had to slightly scale-up the CEA regulation revenues due to assuming a slightly different regulation dispatch methodology.
  - AGO assumed regulation was provided in all hours while CEA previously assumed that provided when battery was not charging or discharging (*see* Draft Report at 55).
- CEA has adjusted their regulation dispatch to assume, like AGO, that this product is provided in all hours.
- Now that CEA and AGO assume same regulation dispatch methodology, AGO can adopt the CEA regulation revenue estimate.
  - AGO regulation revenue has been revised down to $3.46mm/year from last month's estimate of $3.51mm/year.

Improved storage dispatch increases annual revenues by up to $1.32 million

Revenue by Product (mm, 2025$)



Observations

- AGO values are 19% higher assuming FRM is sunset and 6% higher assuming FRM maintained.
- AGO revenue estimates for energy and reserves are higher than the equivalent CEA values:
  - TMSR higher because AGO model reflects opportunity costs and will try to keep battery full so it can receive a TMSR designation. (CEA's will not recharge until early morning hours if discharged the previous day.)
  - Energy higher because it charges and discharges during optimally based on the DA price curves. (CEA discharges battery whenever prices exceed an annual threshold, even if a higher-priced hour follows.)
  - Regulation revenues for AGO match ISO-NE / CEA values because dispatch for that product is the same.

Key Model Results (*from Oct MC*)

1. AGO battery primarily used for reserves & regulation, like CEA.
   - Cycles less than once per day on average (incl. effective cycling for reg.)
2. AGO dispatch increases overall revenue compared CEA, because:
   a) AGO model discharges storage when DA prices indicate highest profits.
   b) AGO model cycles more frequently, whenever DA prices indicate that cycling is cost effective.
   c) AGO model includes opportunity costs which allow storage to maximize revenues across products and across time.

Details on AGO dispatch modeling and discussion of why the AGO approach yields more reasonable results are provided in the Appendix.

- *The substance of these results was presented at the October MC, but the examples have been updated to reflect the change in regulation dispatch to all hours .*

AGO estimates reflect revenues available to a reasonably competent storage operator.

- AGO concludes that no reasonable operator would operate a battery for energy and reserves in the manner proposed by CEA, given ease by which more revenue could be earned.
- AGO approach comports with revenues available to a "reasonably competent" storage operator.
  - It reflects both cross-product and intertemporal opportunity costs.
  - It does not require sophisticated intra-day dispatch strategies or complex forecasting; just the DAM price curves and estimated TMSR opportunity costs.
  - More advanced dispatch schemes could yield revenues in excess of AGO values.
- Final AGO proposed EAS revenue offsets are 6% higher than CEA assuming FRM is maintained and 19% higher assuming FRM is sunset.

Assuming FRM Maintained (2025$): **$8,812,453 ($58.75/kW-year)**
Assuming FRM Sunset (2025$): **$8,177,487 ($54.52/kW-year)**

Appendix:
Methods & Updated Results

AGO optimization model is a more reasonable approach to calculate EAS revenue offsets

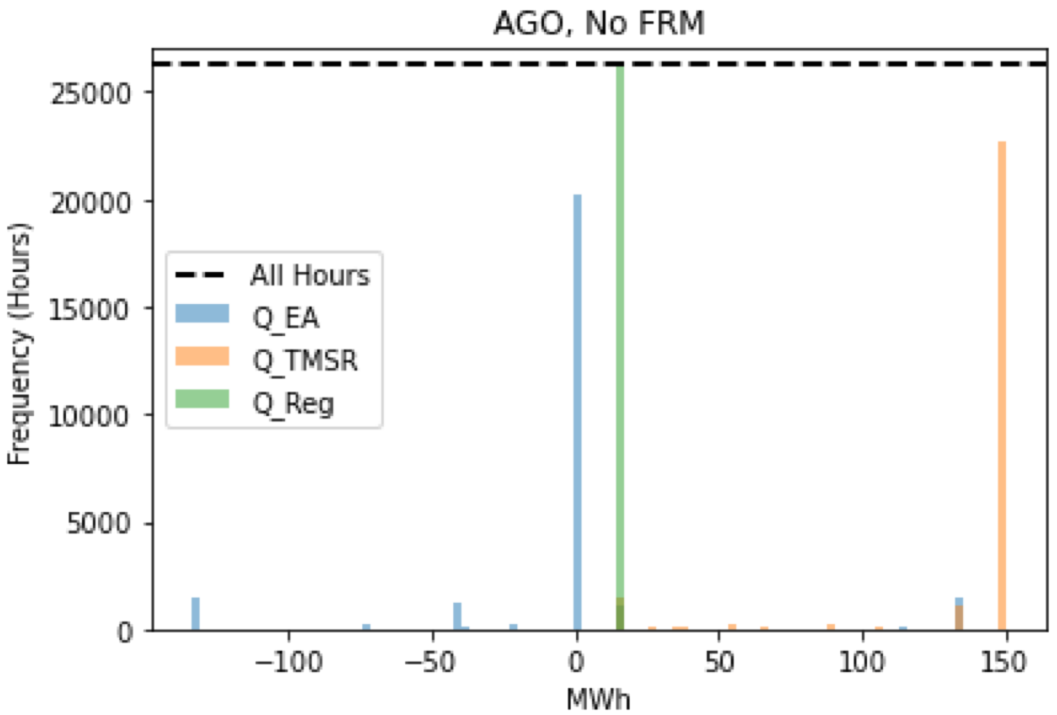
Modeling Framework

- MA AGO developed a linear optimization model to simulate hourly battery operation.
  - Developed in Python 3 using PYOMO library and GLPK to solve the problem.
- Inputs: CEA pricing data and battery parameterization
- Outputs: Efficient dispatch schedules and EAS revenues.
- EAS revenues designed to be directly substituted into CEA's DCF model.
- AGO offers the model itself, model outputs, and a memorandum summarizing the model's formulation for committee review.

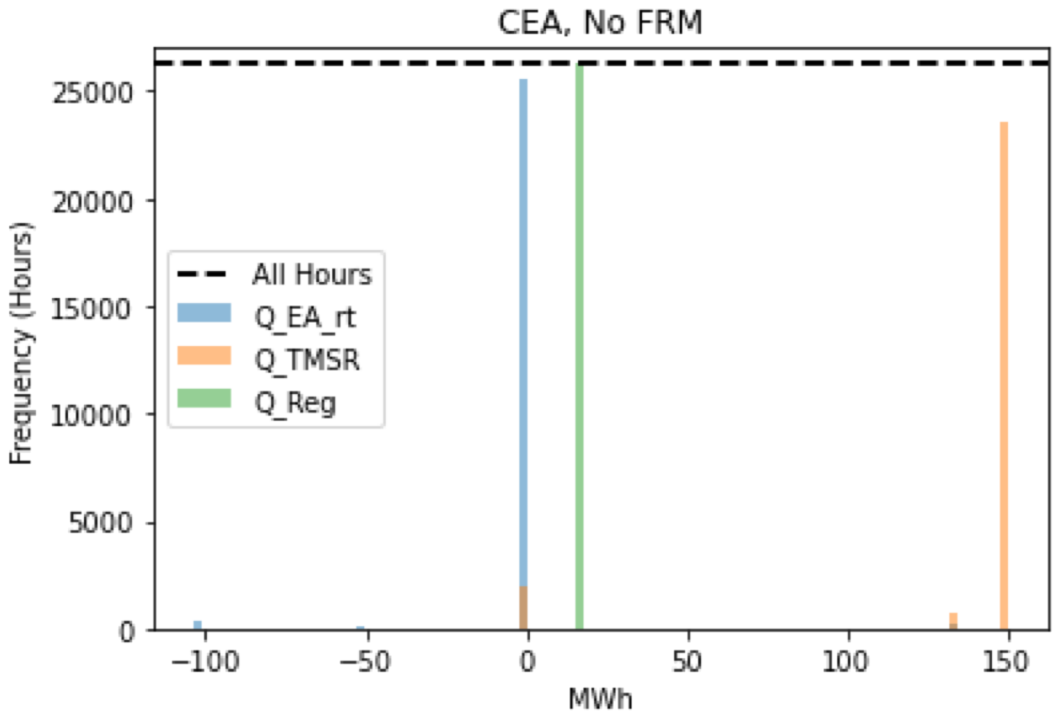
Model Dispatch Strategy

- Dispatch schedule is developed to maximize revenues from Energy, Regulation, and TMSR (including FRM), based on:
  - (a) known DA energy price curves,
  - (b) an exogenous estimate of TMSR opportunity costs ($5/MWh),
  - (c) the assumption that battery provides 16.5 MW of regulation in all hours.
- Battery is operated in RT market and earns revenue based on actual RT prices for LMP, TMSR, and Reg.
- Battery does not have foresight of actual RT prices when developing its dispatch and does not update its dispatch based on prevailing RT market conditions.
- Incorporation of *expected* future TMSR revenue allows storage to reflect cross-product and intertemporal opportunity costs.

Optimized dispatch primarily provides regulation and reserves; < 1 cycle per day.



- Battery provides Reg in all hours.
- Battery has 150 MW TMSR designation in 86.5% hours.
- Battery averages 0.75 cycles per day.

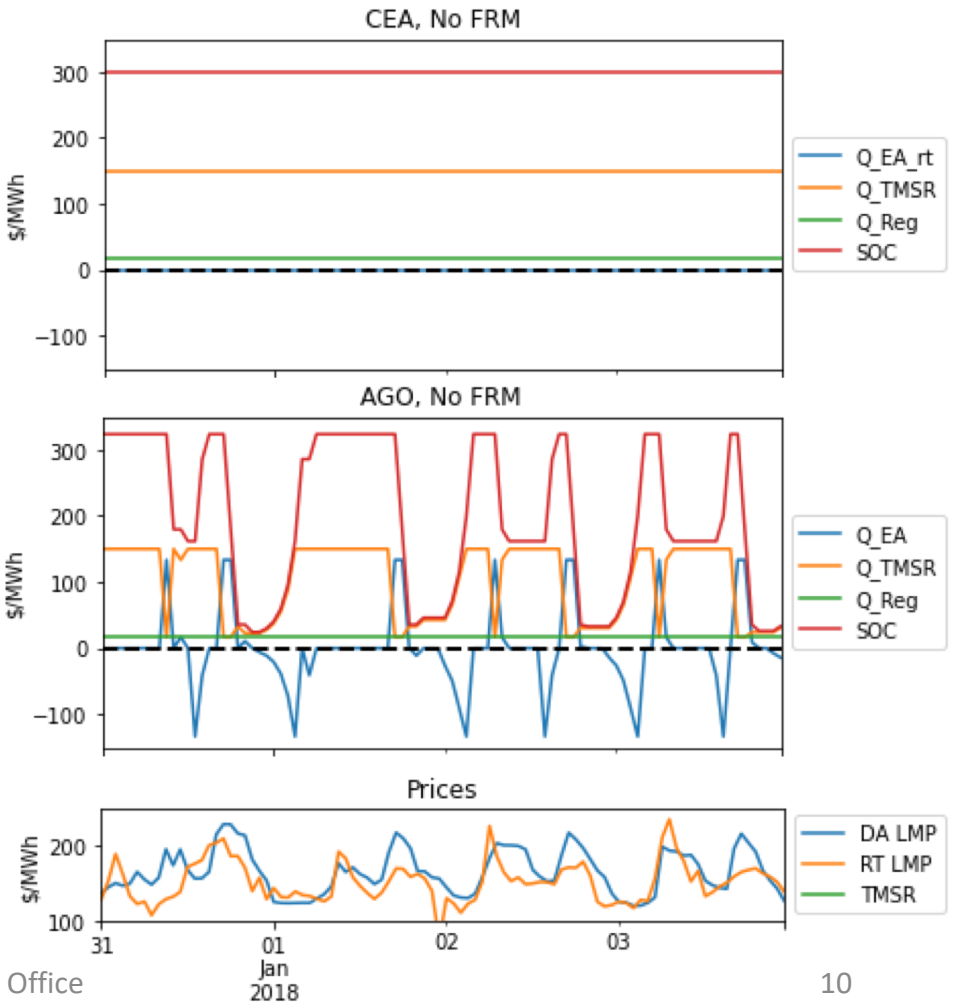


- Battery provides Reg in all hours.
- Battery has 150 MW TMSR designation in 89.4% hours.
- Battery averages 0.1 cycles per day.

CEA battery rarely discharges, so it foregoes many opportunities for incremental revenue.

- AGO optimizes dispatch based on the day-ahead price curves (even though it operates in the RT market).
  - AGO battery discharges during higher priced periods.
- Over a four-day period, 12/31/2017 through 1/3/2018, CEA unit never dispatches.
- AGO unit cycles about once per day in this period.
  - This period does not even include a period where RT prices diverge from DA.
  - When prices happen to diverge, significant revenue potential. E.g., dispatch on 1/4-5/2018 earns ESR $74.2k.
  - Incidentally, there are instances where AGO battery is dispatched based on DA prices but RT prices are unprofitable. Intraday updating of dispatch should help an ESR owner avoid these losses.

Revenue Comparison for 96 Hour Period ($000)				
	RT Energy	**TMSR**	**Reg**	**Total**
AGO	$65.1	$0	$33.7	$98.8
CEA	$0	$0	$33.7	$33.7
Dif.	$65.1	$0	$0	$65.1



CEA's lack of opportunity costs leaves battery empty after discharge, foregoing TMSR revenues

- Because AGO model recognizes cross-product and intertemporal opportunity costs, it will dispatch in ways that maximize *expected* revenues between all products.
- Over a sample 48-hour period, AGO dispatch nearly doubles overall revenues, even though it earns slightly less energy revenue.
- Distribution of TMSR revenues is right skewed, so there is significant optionality associated with a full battery.
  - While AGO *median* daily TMSR revenue is just $22/day higher than CEA, *mean* revenue is $1,167/day higher.

Revenue Comparison for 48 Hour Period ($000)				
	RT Energy	**TMSR**	**Reg**	**Total**
AGO	$35.0	$141.7	$17.2	$193.8
CEA	$38.9	$44.2	$17.2	$100.3
Dif.	-$3.9	$97.5	$0	$93.6