California ISO

Energy Storage Enhancements
Final Proposal

Gabe Murtaugh

October 31, 2022

Agenda

Time	Item	Speaker
9:00-9:10	Introductions and Stakeholder Process	Brenda Corona
9:10-9:55	Policy Summary	Gabe Murtaugh
9:55-11:55	Additional Q&A	Gabe Murtaugh
11:55-12:00	Next Steps	Brenda Corona

Initiative Stakeholder Process

The final proposal continues to includes the same 6 main areas for changes as the previous proposal

Enhancements for reliability:

1. Improved accounting for state of charge while providing regulation
2. *Enhanced bidding requirements for resources providing ancillary services*
3. Exceptional dispatch tools for storage resources to hold state of charge and opportunity cost compensation

Enhancements to co-located model:

4. Electable mechanism to prevent 'grid charging'
5. Extension of the co-located model to pseudo-tie resources

Improvements to the storage default energy bid:

6. Add an opportunity cost component into the day-ahead default energy bid

The proposal includes two provisions to help ensure storage availability while providing ancillary services

1. Update the state of charge equation so that it reflects regulation awards
   - Enhance accuracy of the state of charge formulation
   - Use a formula that includes different hourly multipliers
   - Resource specific multipliers are not included and may be hard to estimate because of limited historical data

2. Require bids alongside ancillary service awards
   - Ensure that storage resources can always provide ancillary service
   - *The requirement for bids will only apply in the real-time markets*
   - In the future, the policy may consider tailoring requirements to specific hours, or specific conditions

- Both solutions may be necessary for reliability

3. The proposal includes new exceptional dispatch tools for storage resources to hold state of charge

- The proposal includes a new form of exceptional dispatch to hold state of charge
  - Today the exceptionally dispatch tool only specifies a certain power (MW) output form resources
  - This exceptional dispatch can require storage resources to hold charge
  - This tool will only apply in the real-time market

- The proposal develops an opportunity cost methodology to compensate storage resources
  - The market compares two counterfactual energy schedules, based on bids, one with the dispatch and one without, to determine lost opportunity

4. The proposal includes an operation mode for co-located storage to avoid grid charging

- Resources will only charge when generation is scheduled from on-site resources
  - The market will insert a constraint ensuring that storage charging schedules do not exceed co-located renewable output schedules
  - Functionality will apply in the day-ahead and real-time market
  - Functionality is specific to a certain hour (i.e. may be turned on or off)
  - *Co-located renewables that are not scheduled in the day-ahead market will have forecasts used in lieu of schedules*
  - Functionality would not preclude self-schedules

- Includes the ability for storage to “back down” when energy from renewables does not meet schedule

5. The proposal will extend co-located features to pseudo-tie resources

- Pseudo-tie resources will be allowed to participate in the market similar to co-located resources today
  - The market will allow co-located resources outside of the ISO balancing area to utilize “undersized” transmission and interconnection when modeled as a pseudo-tie resource
  - These pseudo-tie resources will have access to newly proposed features as well as existing features
  - Resources are required to receive approval from balancing area they are located in for this treatment

6. The proposal makes a small change to the day-ahead default energy bid

- The day-ahead default energy bid will be expanded to include an opportunity cost adder
  - The market will use prices from the market power mitigation run in the day-ahead market to formulate these opportunity costs
  - There could be other sources of input to formulate these values, these may be considered in the future

- Some stakeholder identified other concerns current default energy bids, and these may be addressed in future stakeholder initiatives

NEXT STEPS

Next Steps

- All related information for the Energy Storage Enhancements initiative is available at: https://stakeholdercenter.caiso.com/StakeholderInitiatives/Energy-storage-enhancements

- Please submit stakeholder written comments on today's discussion and the storage enhancements issue paper by Nov 15, 2022, through the ISO's commenting tool
  - The commenting tool is located on the Stakeholder Initiatives landing page (click on the "commenting tool" icon): https://stakeholdercenter.caiso.com/StakeholderInitiatives


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APPENDIX

Appendix: Ancillary Service Proposal

- Today the formula that governs state of charge is:

$$SOC_{i,t} = SOC_{i,t-1} - \left(P_{i,t}^{(+)} + \eta_i P_{i,t}^{(-)}\right)$$

- This proposal updates the formula to:

$$SOC_{i,t} = SOC_{i,t-1} - \left(P_{i,t}^{(+)} + \eta_i P_{i,t}^{(-)} + \mu_1 RU_{i,t} - \mu_2 \eta_i RD_{i,t}\right)$$

$SOC_{i,t}$	State of charge for resource *i* at time *t*
$P_{i,t}^{()}$	Dis/Charge (+/-) instruction for resource *i* at time *t*
η_i	Round trip efficiency for resource *i*
$RU_{i,t}$	Regulation up awarded to resource *i* at time *t*
$RD_{i,t}$	Regulation down awarded to resource *i* at time *t*
μ	Multiplier

- Analysis shows μ_1=.08 and μ_2=.19 across all hours

Appendix: Preliminary analysis for AS multipliers

Hour	Reg Up	Reg Down
1	6%	12%
2	2%	10%
3	2%	13%
4	7%	18%
5	6%	11%
6	8%	13%
7	12%	24%
8	6%	22%
9	3%	13%
10	8%	13%
11	4%	13%
12	6%	18%
13	7%	20%
14	11%	21%
15	8%	21%
16	9%	21%
17	16%	25%
18	16%	35%
19	12%	21%
20	7%	35%
21	6%	37%
22	8%	23%
23	3%	26%
24	5%	25%

Appendix: Ancillary Service Proposal

- Operators noted storage resources can run out of SOC, resulting in an inability to provide ancillary services
  - Storage schedules with ancillary services may become infeasible
- ISO proposes that upward/downward ancillary services awards have accompanying energy bids
  - Storage resources are required to have energy bids in the opposite direction of ancillary service awards, at 50% of the award

EXAMPLE: A ±12 MW storage resource

- Award: 12 MW regulation up (i.e., regulation will discharge the resource)
  - Must bid a 6 MW (0 MW to -6 MW) range of charging energy
- Award: 12 MW regulation down (i.e., regulation will charge the resource)
  - Must bid a 6 MW (0 MW to +6 MW) of discharging energy
- Award: 8 MW of regulation up and 8 MW of regulation down
  - Must bid 4 MW of charging and discharging energy (-12 MW to 12 MW)

Appendix: Exceptional Dispatch

- The ISO proposes to run two very simple counterfactuals to determine payment to storage resources:
  1. Profit maximizing energy schedule without ED
  2. Profit maximizing energy schedule with ED

- Counterfactuals will be based on actual prices realized at the location of the resource
  - Stakeholders requested that there should be no counterfactual dispatch if bids are not economic

- The timeframe used to construct counterfactuals will run through the end of the operating day

Appendix Example: AS ±12 MW storage resource

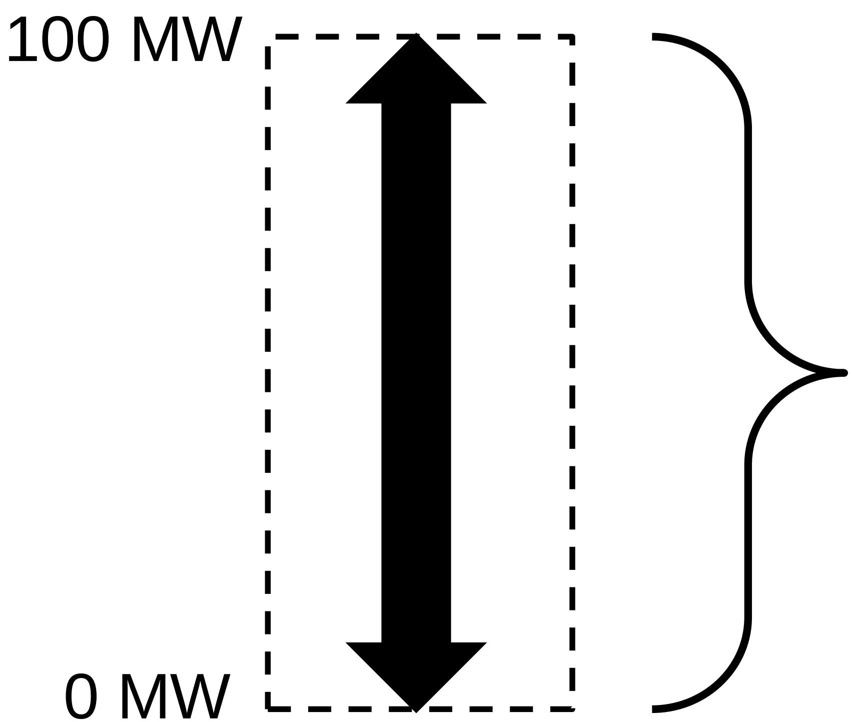
- In the day-ahead market the resource could be awarded:
  - Up to 12 MW of regulation up,
  - Up to 12 MW of regulation down,
  - Up to 8 MW of Regulation up and 8 MW of regulation down, or
  - Another combination still allowing energy bids in the real-time market
  - There would be no new bidding requirement in the day-ahead market
- In the real-time market:
  - If awarded 12 MW of regulation up, the requirement would be to bid at least 6 MW of energy in the charging (negative) range
  - If awarded 12 MW of regulation down, the requirement would be to bid at least 6 MW of energy in the discharging (positive) range
  - If awarded 8 MW of regulation up and 8 MW of regulation down, the requirement would be to bid the remaining 4 MW of discharging and charging range as energy
- This rule makes no requirements on energy that will or will not clear in the market

Appendix: Ancillary services market awards

- Ancillary services and energy awards are co-optimized in the day-ahead market
  - The DAM performs produces a least-cost solution across all 24 hours
  - The market ensures the total energy awards plus ancillary service awards do not exceed the total capacity for any resource
- Ancillary service awards are carried over from the day-ahead market to the real-time market
  - If a resource is unavailable, or unable to support ancillary services in the real-time market, it may receive no-pay for the ancillary service award in the 15-minute real-time market
- Ancillary service awards will impact potential energy awards in the real-time market
  - E.g., a 100 MW resource, with a 100 MW award for regulation up, must receive a 0 MW energy award

Appendix: Energy and ancillary service example

- Traditional resources have capacity and can be awarded energy or ancillary services (or nothing), but cannot have overlapping awards for the same capacity



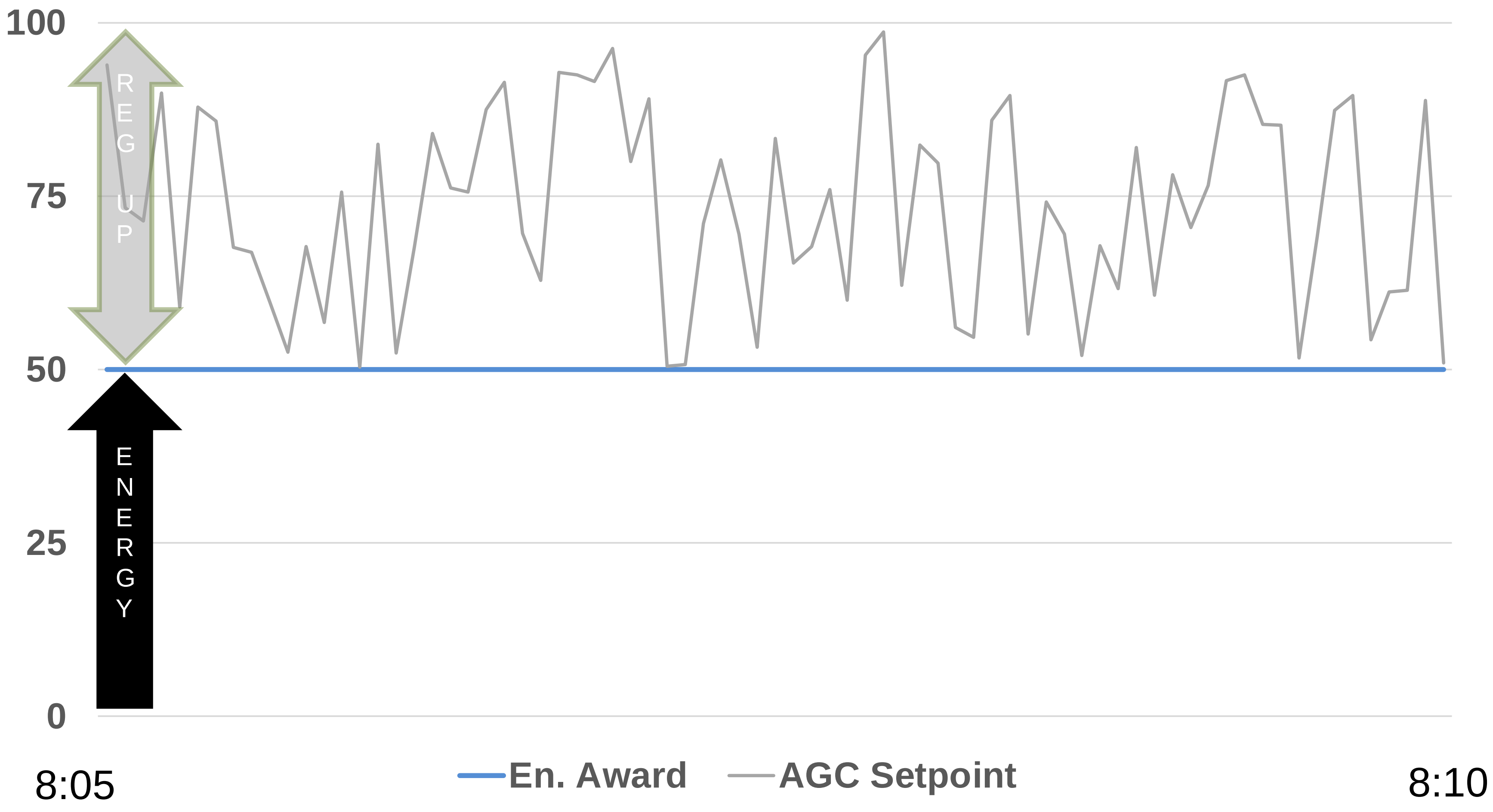
Potential Outcomes:

P = 100 MW	RU = 0 MW
P = 0 MW	RU = 100 MW
P = 50 MW	RU = 50 MW
P = 50 MW	RD = 50 MW

Infeasible Outcomes

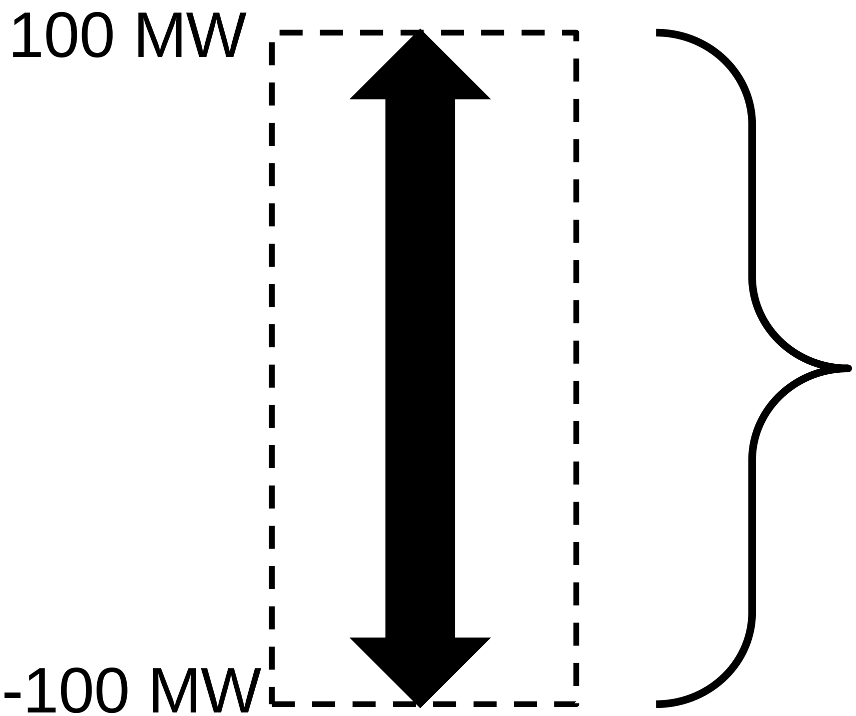
P = 100 MW	RU = 100 MW
P = 70 MW	RU = 70 MW

Appendix: Energy and ancillary service example



Appendix: Energy and ancillary service for storage

- Storage capacity can be awarded energy or ancillary services(or nothing), but cannot have overlapping awards for the same capacity



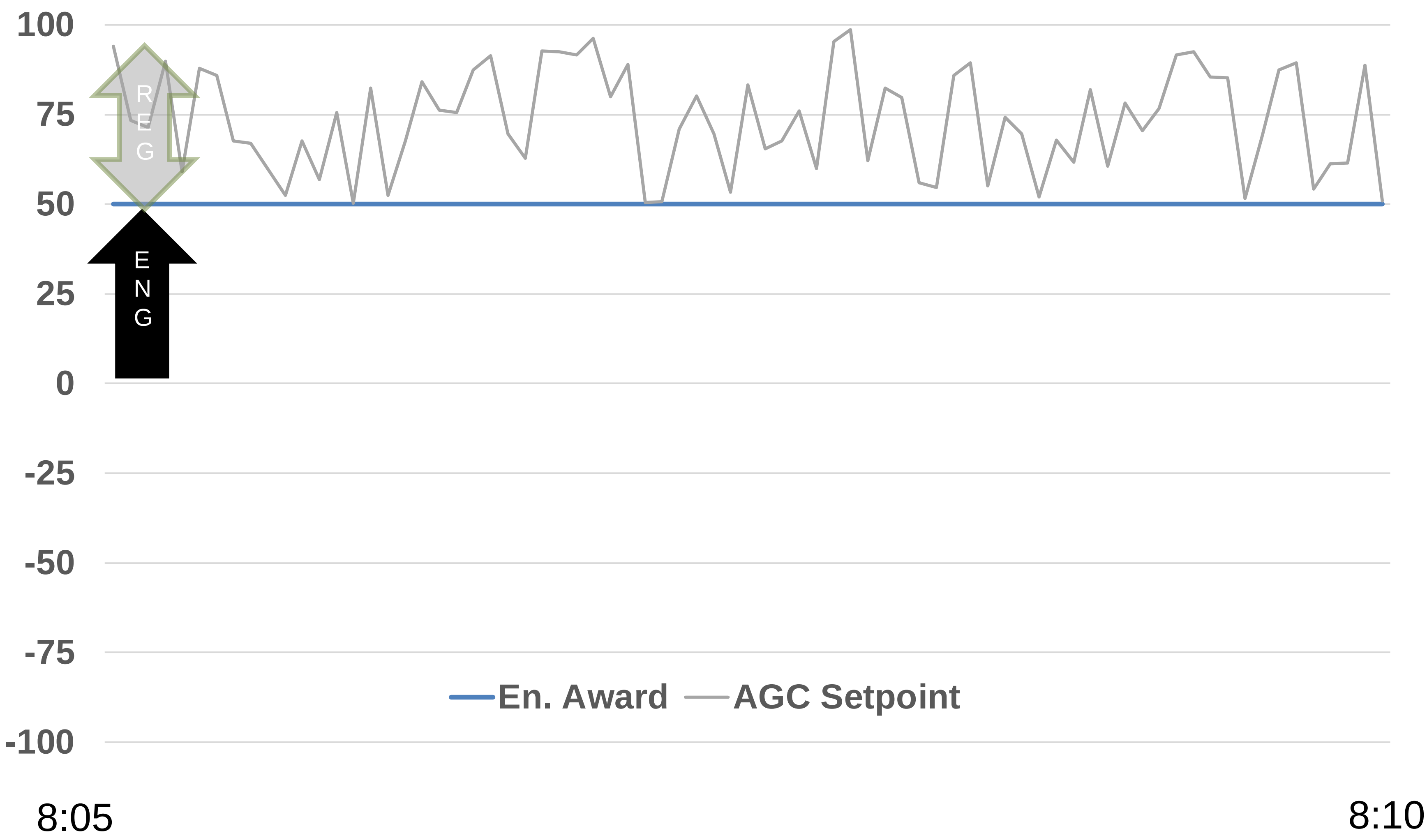
Potential Outcomes:

P = 100 MW	RU = 0 MW
P = 0 MW	RU = 100 MW
P = 50 MW	RU = 50 MW
P = 100 MW	RD = -200 MW

Infeasible Outcomes

P = 100 MW	RU = 100 MW
P = 70 MW	RU = 70 MW

Appendix: Energy and ancillary service for storage



Appendix: Storage constraints

1. State of Charge

- Models how SOC changes based on awards

$$SOC_{i,t} = SOC_{i,t-1} - \left(P_{i,t}^{(+)} + \eta_i P_{i,t}^{(-)} + \mu_1 RU_{i,t} - \mu_2 \eta_i RD_{i,t}\right)$$

2. Ancillary Service State of Charge

- Ensures storage has 30 minutes of SOC for AS awards

$$SOC_{i,t-1} \geq \underline{SOC}_{i,t} + 0.5 * RU_{i,t} + 0.5 * SR_{i,t} + 0.5 * NR_{i,t}$$

$$SOC_{i,t-1} \leq \overline{SOC}_{i,t} - 0.5 * RD_{i,t}$$

3. Bidding Requirement

- Ensures bids paired with AS awards

$$\overline{P_{i,t}^{(-)}} \geq \left(RU_{i,t} + SR_{i,t} + NR_{i,t}\right) * .5$$

$$\overline{P_{i,t}^{(+)}} \geq \left(RD_{i,t}\right) * .5$$

Appendix: Storage constraints and DA examples

Suppose a +/- 100 MW 400 MWh, HE 14, 200 MWh SOC

- 0 MW of energy and 100 MW of regulation up is feasible

  SOC = 189 MWh = 200 MWh – 100 MWh * .11

  189 MWh > 100 MWh = 100 MW * 1 h (ASSOC check)

  100 MW > 50 MW = 100 MW * .5 (Bidding check)

- 50 MW of energy and 50 MW of regulation up is feasible

  SOC = 144.5 MWh = 200 MWh – 50 MWh – 50 * .11

  144.5 MWh > 50 MWh = 50 MW * 1 h (ASSOC check)

  100 MW > 25 MW = 50 MW * .5 (Bidding check)

- 100 MW of energy and 100 MW of regulation down

  SOC = 121 MWh = 200 MWh – 100 MWh + 100 MWh * .21

  121 MWh < 300 MWh = 400 MWh - 100 MW * 1 h (ASSOC check)

  100 MW > 50 MW = 100 MW * .5 (Bidding check)

Appendix: Storage constraints and DA examples

Suppose a +/- 100 MW 400 MWh, HE 14, 50 MWh SOC

- 0 MW of energy and 100 MW of regulation up

    SOC = 39 MWh = 50 MWh – 100 MWh * .11

    49 MWh < 100 MWh = 100 MW * 1 h (ASSOC check)

    100 MW > 50 MW = 100 MW * .5 (Bidding check)

- 50 MW of energy and 50 MW of regulation up

    SOC = -5.5 MWh = 50 MWh – 50 MWh – 50 MWh * .11

- 100 MW of regulation up and 100 MW of reg down

    SOC = 60 MWh = 50 MWh – 100 MWh * .11 + 100 MWh * .21

    60 MWh < 100 MWh = 100 MW * 1 h (ASSOC check)

    60 MWh < 300 MWh = 400 MWh - 100 MW * 1 h (ASSOC check)

    0 MW < 50 MW = 100 MW * .5 (Bidding check)

    0 MW < 50 MW = 100 MW * .5 (Bidding check)

Appendix: Current default day-ahead energy bid

$$DA\ Storage\ DEB = \left(MAX\left(En_{\delta/\eta}, 0\right) + \rho\right) * 1.1$$

En: Estimated cost for resource to buy energy

δ: Energy duration

η: Round-trip efficiency

ρ: Variable cost

This default energy bids includes three components:

- Energy: Expected cost to charge the storage resource considering duration (Max SOC/Pmax) and round-trip efficiency of the resource
- Variable: Wear and tear the resource incurs from charging and discharging
  - This component is not included in the discharge portion of the resource
- Multiplier: Accommodates some differences between expectations and actual outcomes

Appendix: Proposed day-ahead default energy bid

$$DA\ Storage\ DEB = MAX\left[\left(MAX\left(En_{\delta/\eta}, 0\right) + \rho\right), \boldsymbol{OC_{\delta}}\right] * 1.1$$

En: Estimated cost for resource to buy energy
δ: Energy duration
η: Round-trip efficiency
ρ: Variable cost
OC: Opportunity Cost

- Opportunity costs are a function of the duration of the storage resource
  - A four hour resource will receive an opportunity cost equal to the fourth highest priced hour of the day
- This proposed formulation aligns with the RT DEB
- The opportunity cost will ensure that storage resources are not dispatched prematurely