Energy storage enhancements discussion

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Energy storage enhancements includes changes to ensure reliable storage operation and modeling

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 ISO is proposing policy to help ensure storage resource availability while providing ancillary service

The ISO has two proposals to address resources:

1. Update the state of charge equation so that it reflects regulation awards
   - Will make the estimated state of charge is more accurate
   - Will use a formula that includes different hourly multipliers
2. Require bids alongside ancillary service awards
   - Will ensure that storage resources can always provide ancillary service
   - Will apply in the day-ahead and real-time markets

- ISO proposes both tools, because they provide different functions, which will help address each concerns

1. Update the state of charge formula

- Today the formula that governs state of charge is:

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

- The ISO proposes to update the formula as follows:

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

$SOC_{i,t}$	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

- The value of the multipliers will change each hour

Preliminary analysis shows potential differences in multipliers across hours

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%

2. Require energy bids alongside ancillary service awards

- 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
  - Bids would be required in the real-time market, not in the day-ahead market
  - Energy bids cannot be overlapping with ancillary service awards, this may limit the amount of ancillary services storage can qualify for
- This rule ensures that the ISO can schedule a resource for <u>energy</u> during hours when they are providing regulation

Example: A ±12 MW storage 48 MWh resource

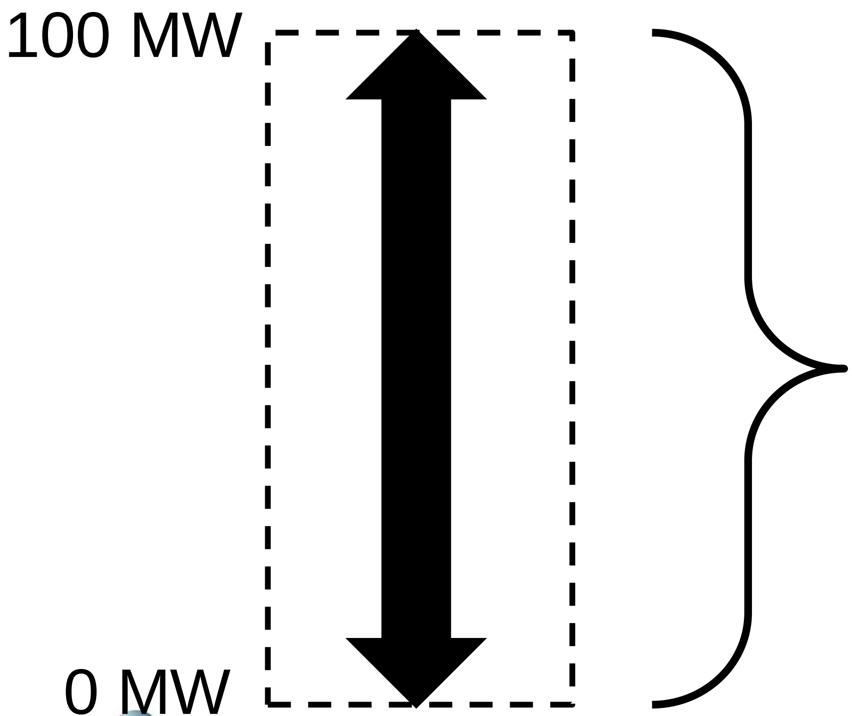
- In the day-ahead market the resource could be awarded:
  - Up to 12 MW of regulation up,
  - Up to 12 MW of regulation down,
  - Up to 8 MW of Regulation up and 8 MW of regulation down, or
  - Another combination still allowing energy bids in the real-time market
  - There would be no new bidding requirement 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

Ancillary services are awarded in the day-ahead market and are carried over to the real-time market

- 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 be awarded 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

Resources can provide capacity for ancillary services or energy, but not both simultaneously

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



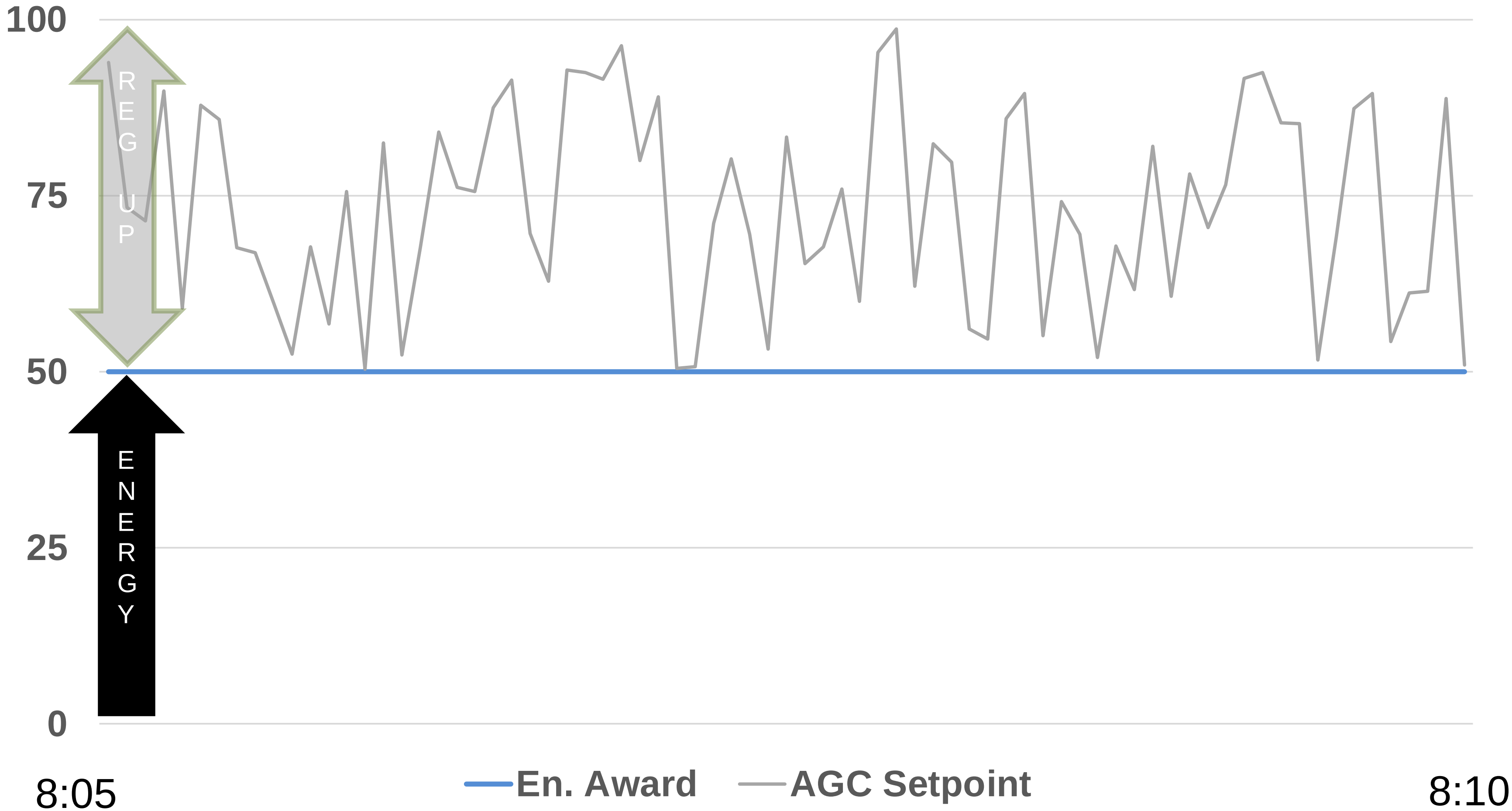
Potential Outcomes:

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

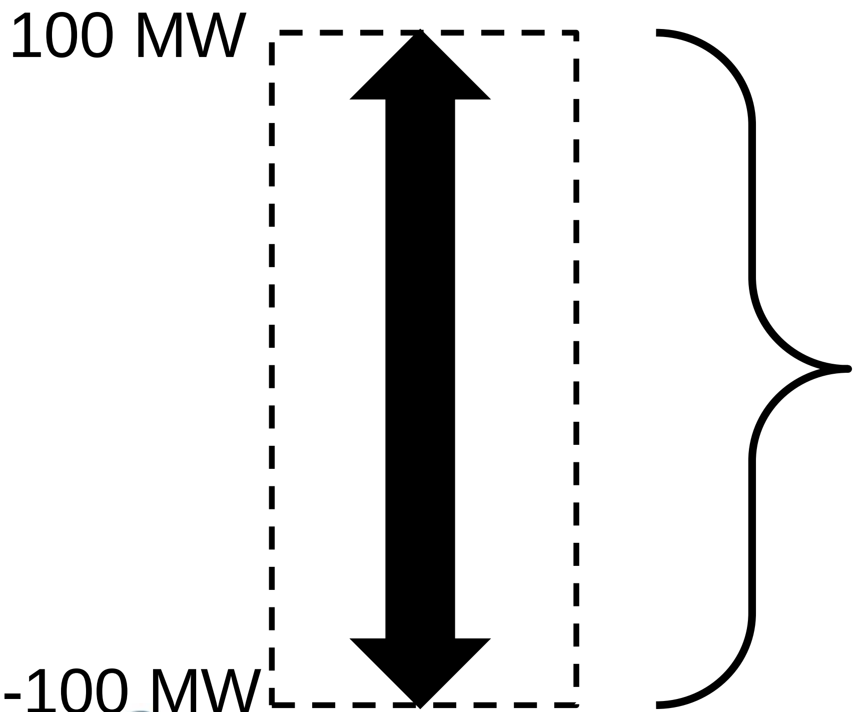
P = 100 MW	RU = 100 MW
P = 70 MW	RU = 70 MW

Suppose a resource receives a RT energy award for 50 MW, and has a 50 MW award for regulation up



Storage also can provide capacity for ancillary services or energy, but not both simultaneously

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



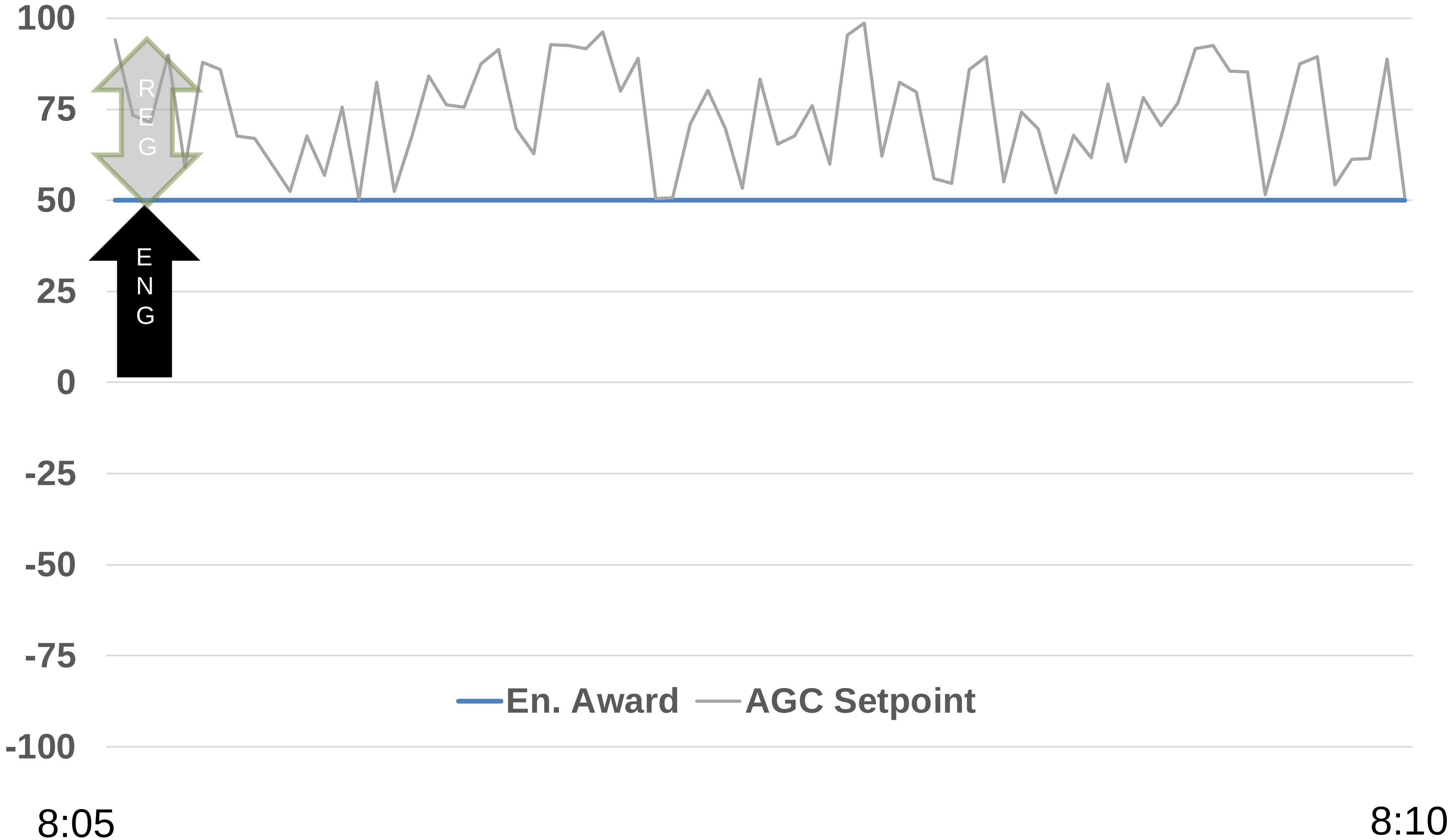
Potential Outcomes:

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

Rules for dispatch for storage resources are similar to traditional resources



Constraints the ISO employs in the real-time market:

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

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

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

3. Bidding Requirement

- Ensures bids paired with AS awards

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

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

These rules will change the awards that storage resources can receive in the day-ahead market

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 > 50 MWh = 100 MWh * .5 (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 MW – 50 * .11

  144.5 MWh > 25MWh = 50 MWh * .5 (ASSOC check)

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

- 100 MW of energy and 200 MW of regulation down

  SOC = 142 MWh = 200 MWh – 100 MWh + 200 MWh * .21

  142 MWh < 300 MWh = 400 MWh - 200 MWh * .5 (ASSOC check)

  100 MW = 100 MW = 200 MW * .5 (Bidding check)

Some outcomes are not feasible with the proposed rules

Suppose a +/- 100 MW 400 MWh, HE 14, 60 MWh SOC

- 0 MW of energy and 100 MW of regulation up

  SOC = 49 MWh = 60 MWh – 100 MW * .11

  49 MWh < 50 MWh = 100 MWh * .5 (ASSOC check)

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

- 50 MW of energy and 50 MW of regulation up

  SOC = -1 MWh = 60 MWh – 50 MWh * .11

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

  SOC = 110 MWh = 60 MWh – 100 MW * .11 + 100 * .21

  110 MWh > 50 MWh = 100 MWh * .5 (ASSOC check)

  110 MWh < 350 MWh = 400 MWh - 100 MWh * .5 (ASSOC check)

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

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

3. The ISO proposes to expand exceptional dispatch tools for storage resources to hold state of charge

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

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

4. The ISO proposes an operation mode to allow co-located storage the ability to avoid grid charging

- Resources will only charge when generation is scheduled form on-site resources
  - ISO will insert a constraint ensuring that storage charging schedules do not exceed output from other co-located resources
  - Functionality will apply in the day-ahead and real-time market
  - Functionality would not preclude self-schedules in the day-ahead market
  - ISO plans to develop this with functionality to be toggled on/off for specific hours
- Functionality will be electable on an hourly basis
- Offer the ability for storage to “back down” when energy from renewables does not meet schedule

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

- Pseudo-tie resources will be allowed to participate in the market similar to co-located resources today
  - ISO 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

6. The ISO uses a default energy bid for storage resources in the day-ahead market

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

En:	Estimated cost for resource to buy energy
δ:	Energy duration
η:	Round-trip efficiency
ρ:	Variable cost
OC:	Opportunity 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 differences between expected values and actuals

The ISO calculations for the day-ahead default energy bid using prices from the market power mitigation run

- The ISO uses prices from the market power mitigation run to determine expected costs to buy energy
  - Input from the market power mitigation run of the day-ahead market is used to inform estimated cost to buy energy
  - The ISO proposes to use the same series of costs (form the market power mitigation run) to generate the opportunity cost term

- Some market participants raised a concerns that market power mitigation run values might be inflated
  - Prices from the market power mitigation run inherently could be inflated because market power mitigation has not yet been applied
  - The ISO is considering how this could be accounted for and the potential for using the day-ahead market results from the previous day