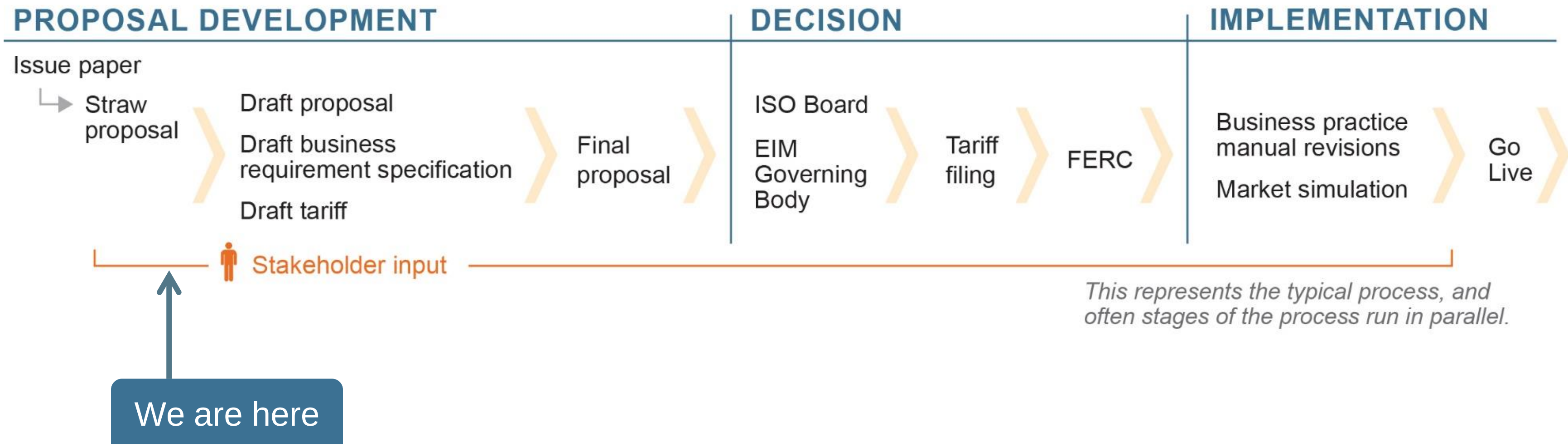
California ISO

Energy Storage and Distributed Energy Resources Initiative: Second Revised Straw Proposal, Day 2

March 3, 2020

ISO Policy Initiative Stakeholder Process



Day 2 Agenda – March 3

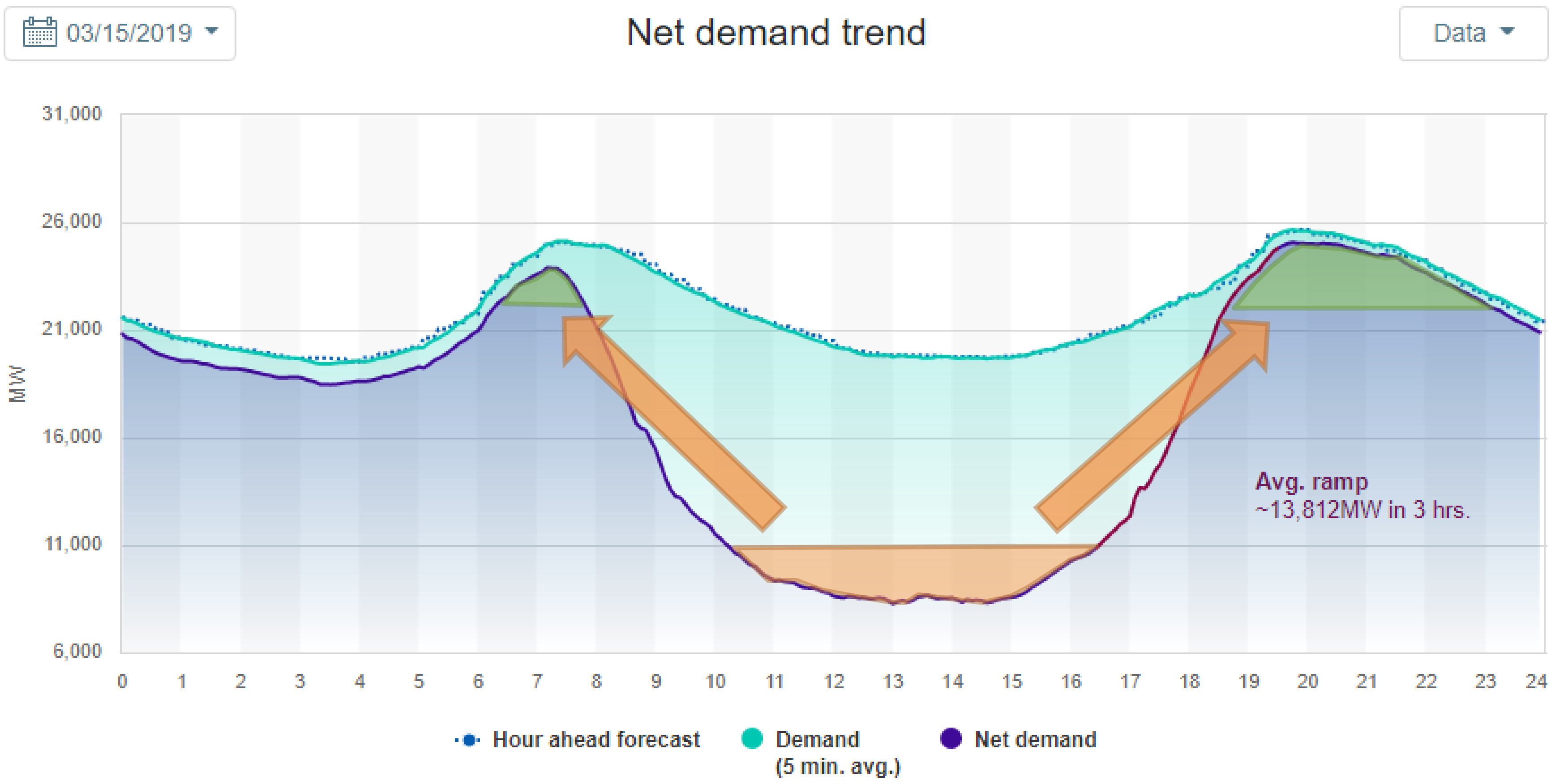
Time	Agenda Topic	Presenter
10:00 - 10:05	Welcome and Introduction	James Bishara
10:05 - 10:10	Background	Gabe Murtaugh
10:10 - 10:45	Bidding for storage resources	Gabe Murtaugh
10:45 - 11:15	End-of-day state of charge parameter	Gabe Murtaugh
11:15 - 11:45	End-of-hour state of charge parameter	Jill Powers
11:45 - 12:45	Lunch	
12:45 - 2:15	Minimum charge requirement	Gabe Murtaugh
2:15 - 3:20	Default energy bid for storage resources	Gabe Murtaugh
3:20 - 3:30	Next Steps	James Bishara

BACKGROUND

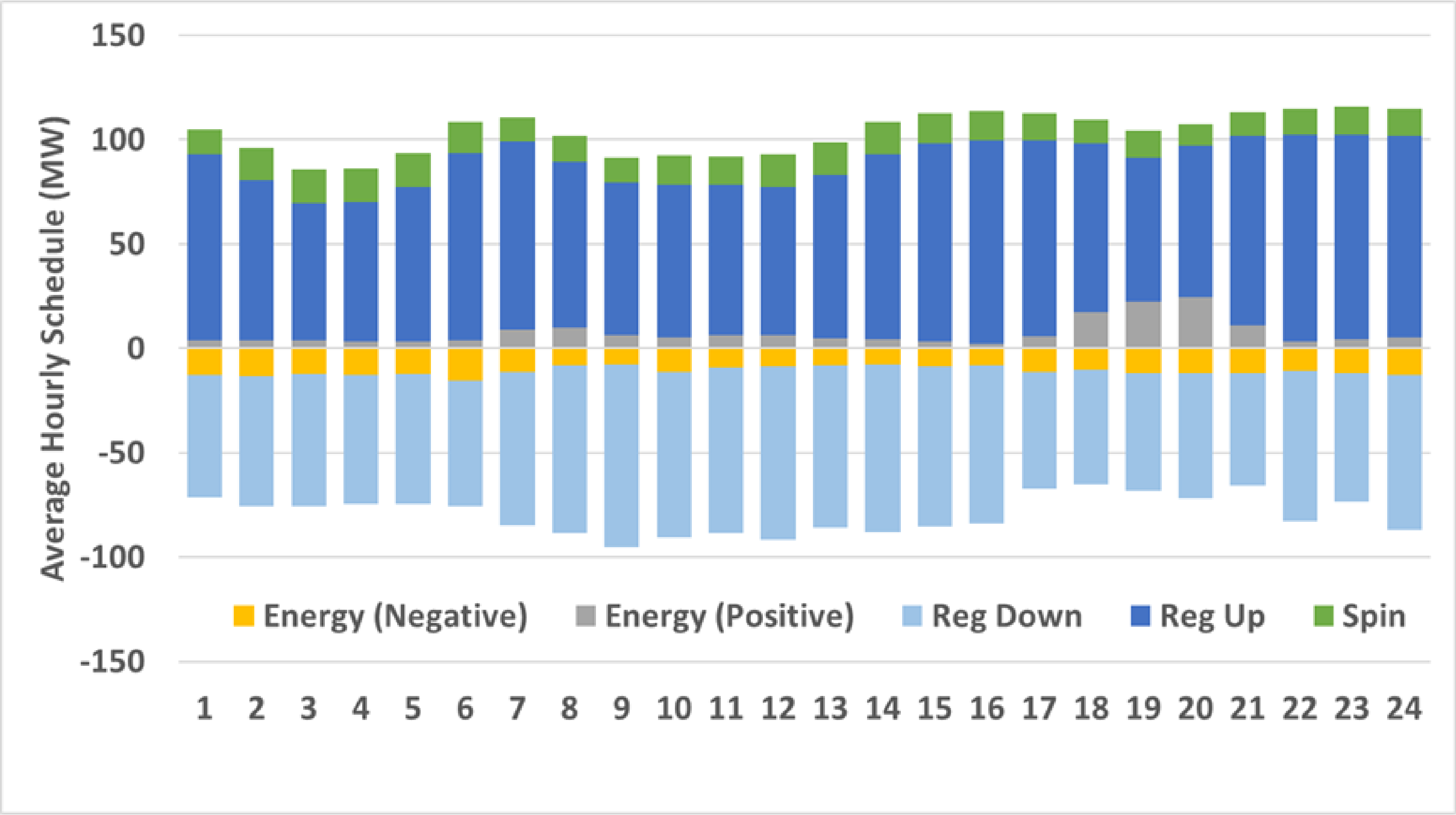
Storage is expected to be integral for California to produce energy with less greenhouse gas emissions

- The CPUC is ordering new resource procurement to replace older steam resources over the next 3 years
  - The retirement of a large nuclear resource in 2024 will likely require additional procurement
- Today there are about 150 MW of storage online, but the (ISO ?)will be dispatching thousands of MW in the future
- Much of the new procurement may come in the form of battery storage and hybrid (solar + storage) resources
- These resources bring new integration challenges
  - Market power mitigation is not currently applied to storage resources
  - CAISO does not (currently) have a tool to compel a storage resource to charge and be “ready” for discharge
  - Storage resources have limited energy

Planning for storage resources has assumed 'arbitrage' of day-ahead energy prices



Today storage resources are not moving significant amounts of energy across different hours of the day

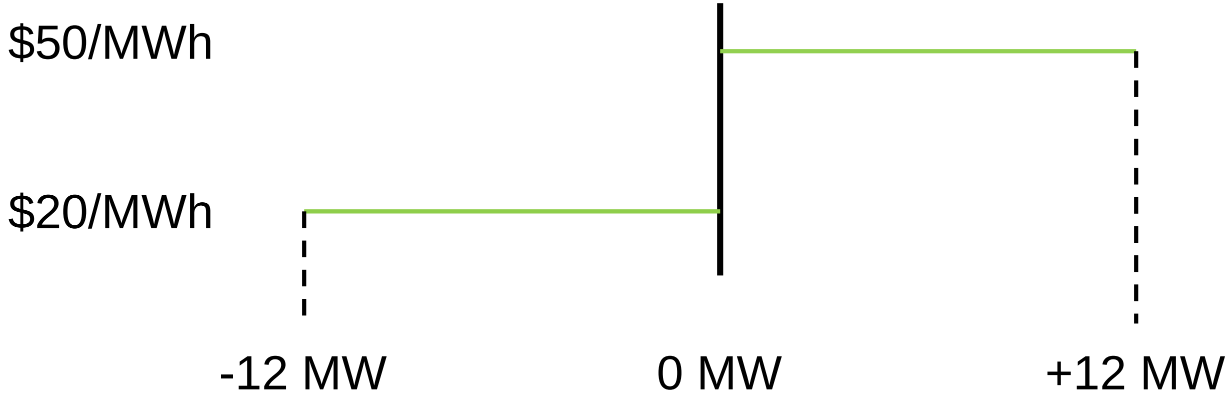


BIDDING FOR STORAGE RESOURCES

Bids for storage resources work similarly to bids for conventional resources

- The day-ahead market may schedule a resource based on: bids to charge, bids to discharge, and ‘spread bids’
- Similar to most resources participating in the market, storage resources can bid their capacity from Pmin to Pmax, for dispatch at price/quantity pairs

Example bid curve for a +/- 12 MW resource:



In the day-ahead market, storage resources may receive schedules based on spread bids

- The day-ahead market may schedule the example resource to charge if prices are $50/MWh, however this would only occur if there was another interval where prices were $80/MWh of greater where the resource was scheduled to discharge
  - In this way, the day-ahead market already observes spreads between positive and negative energy bids
  - This is different than the treatment of conventional resources
- The day-ahead market will schedule the resource to charge when prices are below $20/MWh, and to discharge when prices are above $50/MWh
- This is possible since the day-ahead solution evaluates all 24 hours at once, where all hours bind

The "spread" in the real-time market may cause resources to be uneconomically dispatched

- RT markets consider binding and advisory intervals
  - Advisory intervals can impact binding dispatch instructions and cause adverse outcomes for storage resources
  - Bid cost recovery relieves financial implications

	B1	A1	A2	A3	A4	A5	A6	A7	...
Expected Price:	$25	$30	$30	$30	$800	$30	$30	$30	...
Current SOC:	0 MWh								
Dispatch:	-12 MW	0	0	0	+12	0	0	0	...
Expected SOC:	1 MWh	1	1	1	0	0	0	0	...

...

	B1	A1	A2	A3	...
Expected Price:	$30	$30	$30	$30	...
Current SOC:	1				
Dispatch:	0	0	0	0	...
Expected SOC:	1	1	1	1	...

The "spread" in the real-time market may cause resources to be uneconomically dispatched

- Advisory intervals may result in uneconomic discharges
  - Generally advisory intervals are not this volatile

	B1	A1	A2	A3	A4	A5	A6	A7	...
Expected Price:	$35	$30	$30	$30	-$100	$30	$30	$30	...
Current SOC:	48 MWh								
Dispatch:	+12 MW	0	0	0	-12	0	0	0	...
Expected SOC:	47 MWh	47	47	47	48	48	48	48	...

...

	B1	A1	A2	A3	...
Expected Price:	$30	$30	$30	$30	...
Current SOC:	47				
Dispatch:	0	0	0	0	...
Expected SOC:	47	47	47	47	...

Both real-time examples were extreme cases where the resource was either fully charged or discharged

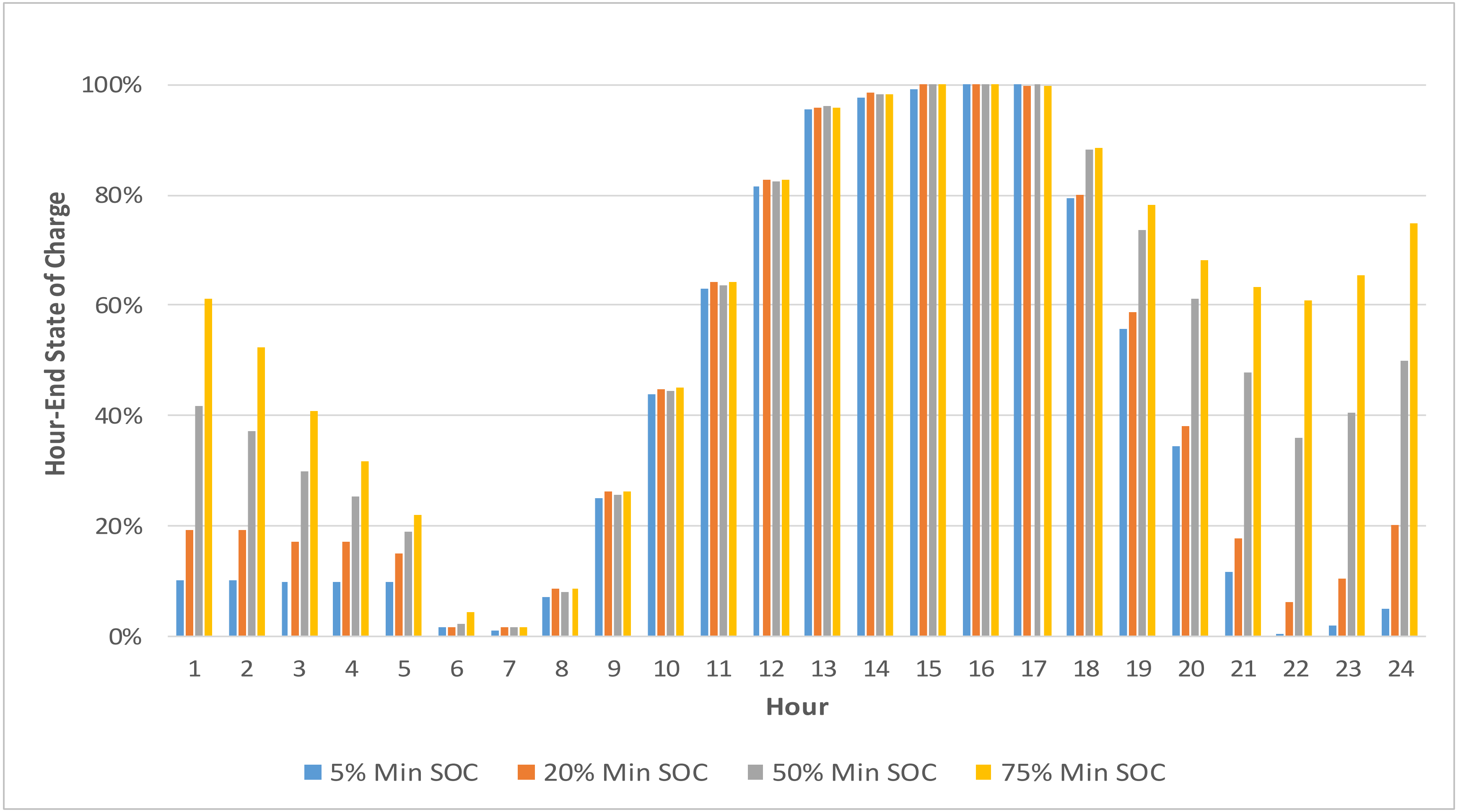
- When resources have a state of charge near their midpoint, these outcomes are less likely
  - These uneconomic outcomes may never happen for 4 hour batteries if the resource is operating between 25%-75% state of charge
- These examples are simplified
  - Actual dispatch for storage resource includes calculation of losses
  - Resources are also co-optimized between energy and ancillary services
  - Bids and spreads can change from hour to hour (within one RTD solution set), but the same process is followed to arrive at dispatch instructions
- STUC has an indirect influence on dispatch instructions for storage resources
  - STUC is only used to commit resources, not to dispatch resources

END-OF-DAY STATE OF CHARGE PARAMETER

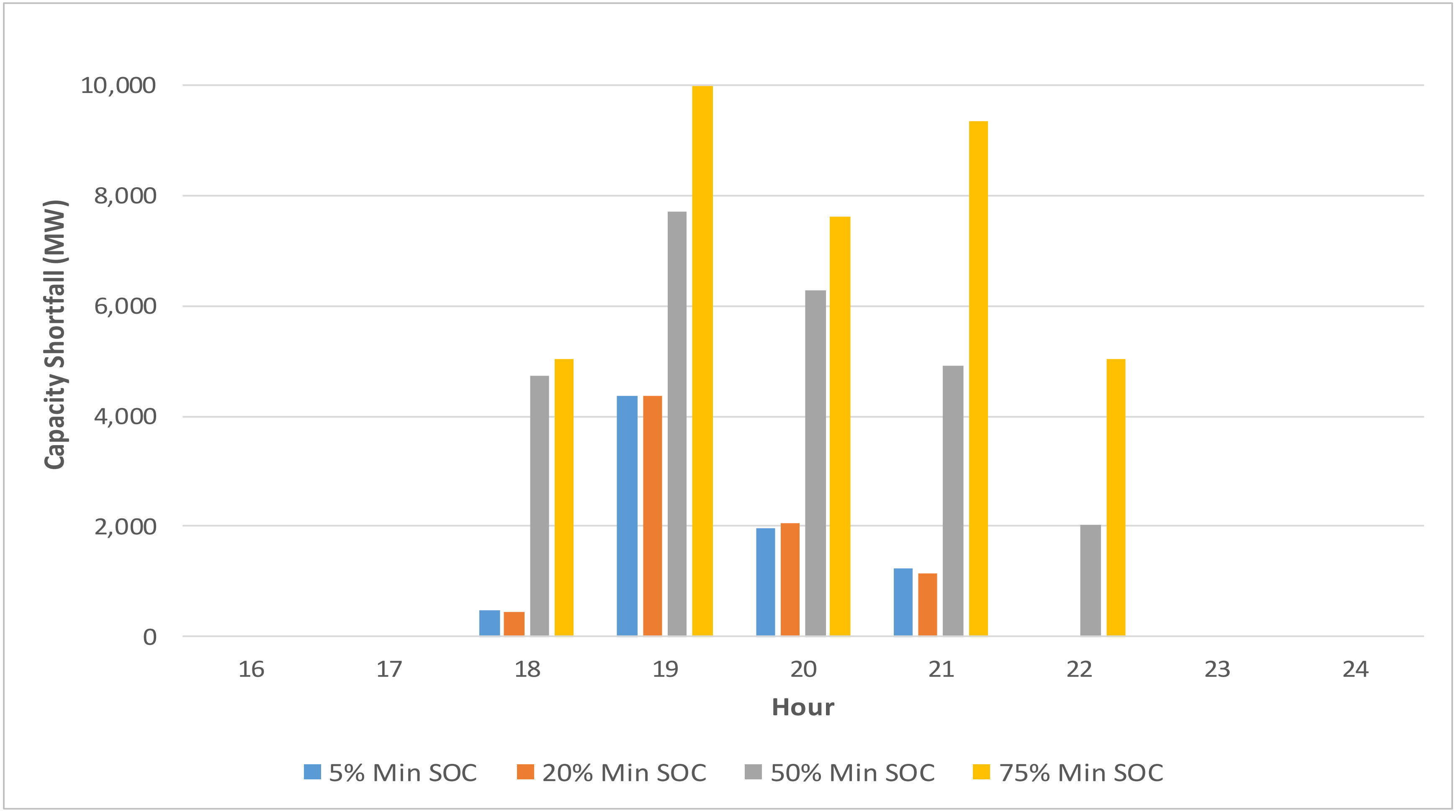
The ISO received requests to include an end-of-day state of charge parameter in the day-ahead market

- Some stakeholders offer that this tool would allow for storage to access to true spread bidding
  - Resources would have balanced charge and discharge schedules
  - Revenues from all (combined) sales and purchases would have a positive value
  - Resources will not move from a low state of charge at the beginning of a day, to a high states of charge at the end of the day
- Ask for continued dialogue to determine if this tool is necessary
- In the last stakeholder initiative we brought up a number of potential concerns regarding this tool
  - Ensure that these concerns are still addressed as we move forward

The ISO performed analysis to determine impacts of this parameter on dispatch in the day-ahead market



Higher parameter values implied additional probability that the ISO would drop load in critical hours



The allowable end-of-day state of charge will be very low for resources that opt to use it

- This analysis shows that particularly high end of day SOC values severely impact efficient market outcomes
  - Resources that have a minimum requirement for a state of charge at 75%, will never discharge energy below 60%, during the evening
  - This could impede grid reliability and the ISO’s ability to manage evening peak loads
  - Lower minimum states of charge values have much less impact on estimated optimal dispatch
- Asking stakeholder feedback on making this a minimum value, rather than a specific target
  - Minimum values may not ensure the balance of charge and discharge positions to ensure storage has true spread bidding

This parameter would be biddable in the day-ahead market with other bid components

- If proposed, the end-of-day state of charge parameter could be a specific target value that the market optimization would have to impose in a solution set
- Storage resources would have the ability to bid this value into the day-ahead market
  - Values for this parameter and the expected start of day values would be included in day-ahead bids for storage resources
- ISO will likely restrict state of charge to values at 10% full state of charge or less

End-of-Hour State of Charge Parameter

End-Of-Hour State-of-Charge Biddable Parameter

Option for a non-generator resource (NGR) to manage its use in real-time market to achieve a desired state-of-charge

- Enhance real-time market to accept state-of-charge values for future hours and constrain the NGR output to meet those values
  - Submitted as a MWh range with min and max SOC
  - Targeted SOC accommodated with min = max
- Allow end-of-hour state-of-charge parameter to take precedence over economic outcomes in the market optimization
- Allow the market to dispatch non-generator resources economically or uneconomically to achieve a preferred hourly end-of-hour state-of-charge

Resource Constraints Prioritized Above EOH SOC

Constraints that will be respected before the end-of-hour state-of-charge effecting its achievability

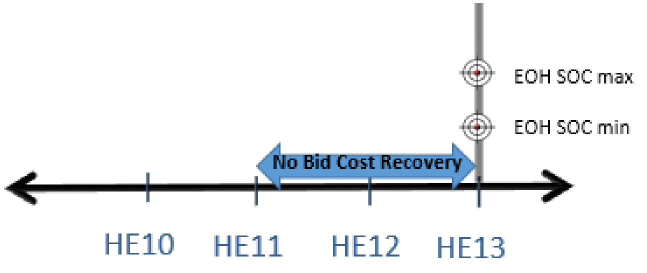
- The max/min continuous energy limits in the Masterfile or upper/lower charge limit that are bid
- A state-of-charge needed to meet an ancillary service award
  - stakeholder comments suggested that an end-of-hour state-of-charge bid not be allowed in hours the resource has received a day-ahead ancillary service award. At this time, the CAISO is not proposing to restrict the use of an end-of-hour state-of-charge continuing to allow it as an option with recognition of the known impact of a simultaneous ancillary service award.

- (*Under further consideration) Self-schedule in future hours*

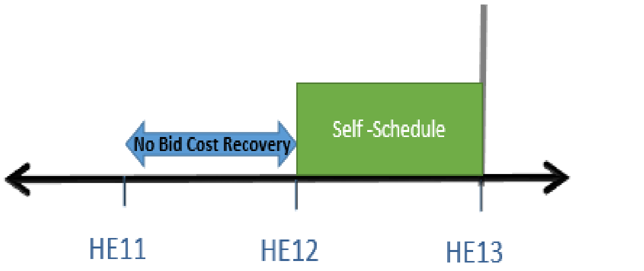
Changes to Eligibility for Bid Cost Recovery Supported by Stakeholder Comments

Proposal excludes a non-generator resource's bid cost recovery settlement in hours when end-of-hour state-of-charge bid parameter or self-schedule has the potential to create an uneconomic dispatch.

- Ineligible to receive bid-cost recovery for both the hour preceding AND for the hour in which an end-of-hour state-of-charge is bid



- Ineligible to receive bid-cost recovery in the hour preceding the self-scheduled hour



Market Application of the end-of-hour SOC bid

- Real-time bidding parameters are submitted to the market 75 minutes prior to the start of the hour.
  - ✓ Applies to when market will see resources submitted end-of-hour state-of-charge minimum and maximum parameters.
- Once received these values will be used to inform dispatch instructions for resources in the successive 15-minute market (RTPD) interval and the corresponding 5-minute interval.

CAISO proposes to align visibility of the end-of hour state-of-charge bid constraint to the same binding intervals for both the 5-minute (RTD) and 15-minute real-time (RTPD) markets.

- ✓ An implied end of hour constraint will be applied at the end of the time horizon for 5-minute (RTD) runs.
- ✓ The end of horizon constraint will be set to the end of hour constraint, adjusted for the resources full charging capability between the end of horizon and end of hour.

Example: RT Market Application for the EOH SOC

Resource submits a min EOH SOC for HE10 due at 07:45

RTPD:

At 07:50 the binding market run begins for 08:30 interval **(First RTPD market run with EOH SOC)**

Binding instructions for 08:30-08:45, Advisory for 08:45-10:00 **(EOH SOC respected for each of the Adv & Bind ints)**

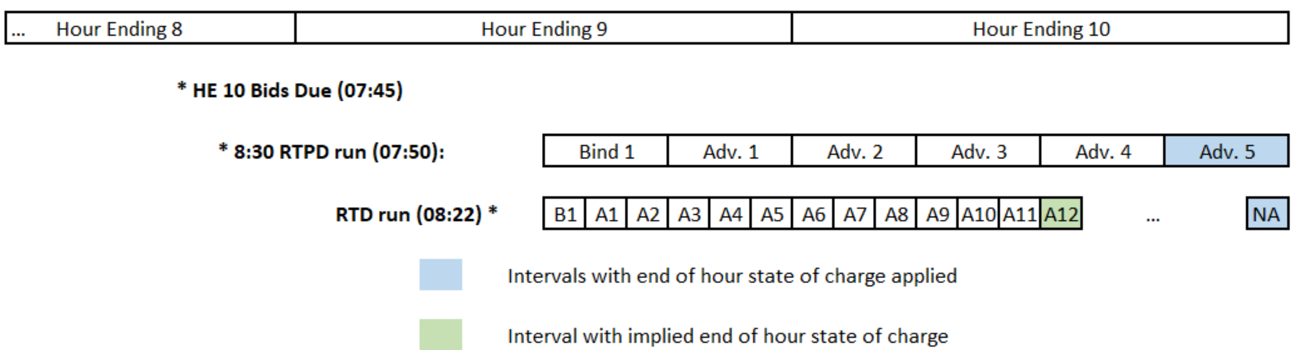
✓ **From this point, as needed, all RTPD intervals will be used to achieve the resources EOH SOC**

RTD: *Market runs 7.5 minutes prior to the start of a specific 5-min interval with 65 minute look out 1 binding and 12 advisory 5-minute intervals*

At 08:07:30 binding market run begins for 08:15-08:20 **(EOH SOC is in market for RTD run – but will not be considered)**

At 08:57:30 binding market run begins for 09:05-09:10 **(First RTD market run to see EOH SOC)**

✓ **EOH SOC bid is not considered until the last interval of the 5-minute (RTD) run time horizon reaches the end of the hour**



- Due to EOH SOC time horizon visibility differences between RTPD & RTD there may be a sub-optimal situation where RTD could undo planned RTPD actions not dispatching to charge the resource until it is too late.

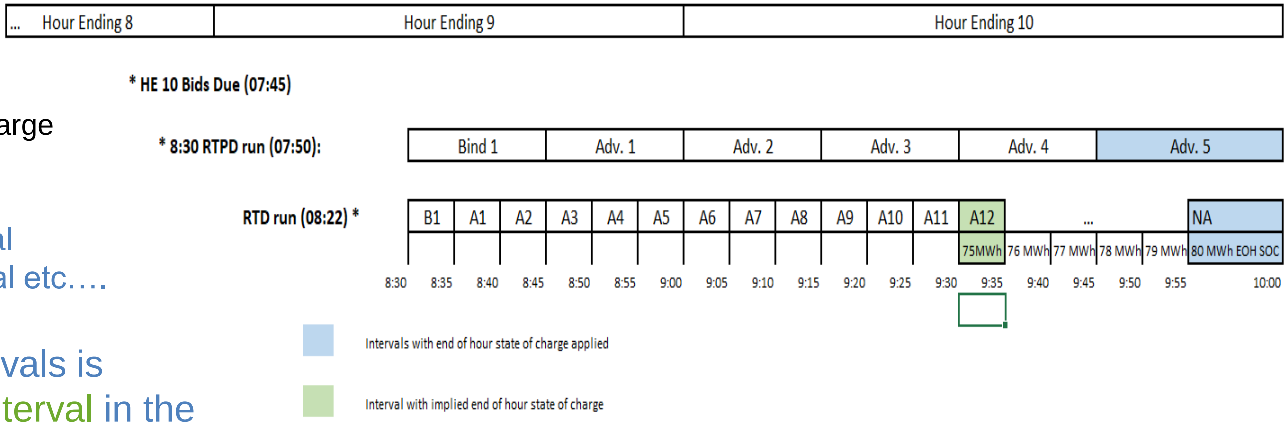
Example: RT Market Application for the EOH SOC

- Propose to align visibility of the end-of hour state-of-charge bid constraint to the same binding intervals for both the RTD and RTPD
- An implied end of hour constraint will be applied at the end of the time horizon for RTD runs for binding intervals (starting 8:30 to 09:00 in this example)
- This end of <u>horizon</u> constraint will be set to the end-of-hour constraint, adjusted for the resources full charging capability between the end of horizon and end of hour

Example:
100 MWh resource
  1 MW/5 min (12 MW/hour) charge/discharge
 80 MWh min SOC for HE10

✓ 79 MWh implied req for 11th interval
✓ 78 MWh implied req for 10th interval etc.…

Imposed when each of these intervals is considered as the final advisory interval in the current 5-minute market run.



- CAISO is considering other approaches in developing the most refined proposal to the end of horizon constraint calculation.

MINIMUM CHARGE REQUIREMENT

We envision a number of challenges as storage resources are integrated onto the grid

- Renewable and storage resources are key to operating the California the grid with less GHG emission
  - Retirement of OTC resources, with 3,300 MW of procurement by 2023
  - Retirement of large nuclear resource in 2024
  - Additional solar, wind, and storage resources developed by 2030
- Storage is different than traditional generation
  - Storage is a net consumer of energy; it moves energy inter-temporally
  - There are opportunity costs whenever storage discharges, which considers the lost potential for selling energy at a later time in the day
  - With current bidding tools, it may be challenging for resources to manage state of charge
    - High real-time prices for bid storage resources will result in discharge schedules awarded to these resources, regardless of day-ahead or even RTPD prices
    - Financially challenging for storage resources
    - Reliability challenges for grid operators

Example: Gas resources do not face the same bidding challenges as storage resources

- The real-time market is set up to accommodate traditional (gas) resources
- Suppose a resource's true cost is $30/MWh, and that cost is bid into the market

	...	HE7	HE8	HE9	HE10	HE11	HE12	HE13	HE14	HE15	HE16	...
DA Bid:		$30	$30	$30	$30	$30	$30	$30	$30	$30	$30	
DA Price:		$40	$35	$28	$25	$20	$22	$27	$29	$32	$40	
DA MW:		12 MW	12	0	0	0	0	0	0	12	12	

Example: Gas resources do not face the same bidding challenges as storage resources

- The real-time market is set up to accommodate traditional (gas) resources
- Suppose a resource's true cost is $30/MWh, and that cost is bid into the market

	...	HE7	HE8	HE9	HE10	HE11	HE12	HE13	HE14	HE15	HE16	...
DA Bid:		$30	$30	$30	$30	$30	$30	$30	$30	$30	$30	
DA Price:		$40	$35	$28	$25	$20	$22	$27	$29	$32	$40	
DA MW:		12 MW	12	0	0	0	0	0	0	12	12	
RT Bid:		$30	$30	$30	$30	$30	$30	$30	$30	$30	$30	
RT Price:		$29	$28	$28	$25	$20	$22	$27	$35	$36	$37	
RT MW:		0	0	0	0	0	0	0	12	12	12	

- In the real-time market, storage resources bidding identical prices, at cost, are generally better off

Example: Gas resources do not face the same bidding challenges as storage resources

- Suppose a very simple storage resource has a full (4 hour) charge at the start of the day, and only wants to sell energy
  - Scheduler's goal is to estimate the four highest priced hours

	...	7	8	9	10	11	12	13	14	15	16	17	18	19	20	...
	...	HE7	HE8	HE9	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20	...
DA Discharge Bid:		$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	
DA Price:		$42	$35	$28	$25	$20	$22	$27	$29	$32	$37	$52	$55	$50	$38	
DA MW:		12 MW	0	0	0	0	0	0	0	0	0	12	12	12	0	

Example: Gas resources do not face the same bidding challenges as storage resources

- Suppose a very simple storage resource has a full (4 hour) charge at the start of the day, and only wants to sell that capacity
  - Scheduler’s goal is to estimate the four highest priced hours

	...	7	8	9	10	11	12	13	14	15	16	17	18	19	20	...
	...	HE7	HE8	HE9	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20	...
DA Discharge Bid:		$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	
DA Price:		$42	$35	$28	$25	$20	$22	$27	$29	$32	$37	$52	$55	$50	$38	
DA MW:		12 MW	0	0	0	0	0	0	0	0	0	12	12	12	0	
RT Bid:		$41	$41	$41	$41	$41	$41	$41	$41	$41	$41					
RT Price:		$29	$32	$28	$25	$20	$22	$27	$45	$46	$47					
RT MW:		0	0	0	0	0	0	0	12	12	12					

- Bidding similar to gas resources, storage can increase revenues in the real-time market

Example: Gas resources do not face the same bidding challenges as storage resources

- Suppose a very simple storage resource has a full (4 hour) charge at the start of the day, and only wants to sell that capacity
  - Scheduler's goal is to estimate the four highest priced hours

	...	7	8	9	10	11	12	13	14	15	16	17	18	19	20	...
	...	HE7	HE8	HE9	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20	...
DA Discharge Bid:		$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	
DA Price:		$42	$35	$28	$25	$20	$22	$27	$29	$32	$37	$52	$55	$50	$38	
DA MW:		12 MW	0	0	0	0	0	0	0	0	0	12	12	12	0	
RT Bid:		$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	$41	
RT Price:		$29	$32	$28	$25	$20	$22	$27	$45	$46	$47	$49	$999	$999	$999	
RT MW:		0	0	0	0	0	0	0	12	12	12	12	0	0	0	

- Bidding similar to gas resources, storage can increase revenues in the real-time market
- Resources may be exposed to severe penalties if they cannot meet day-ahead schedules

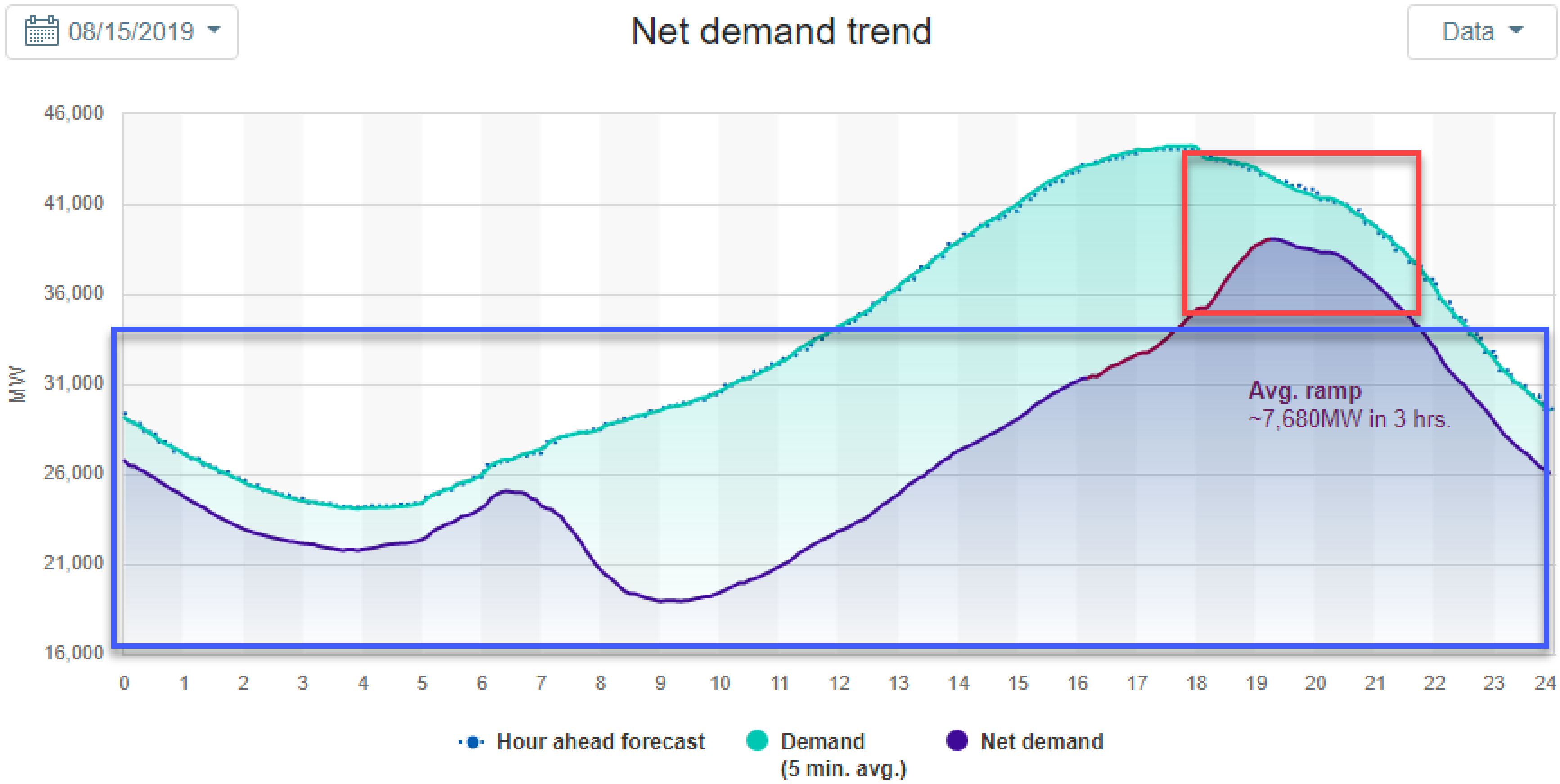
The example outlines a number of problems for storage resources

- The storage resource would have preferred to discharge at hour ending 18, 19, and 20 when prices were close to $1,000/MWh
- Storage must consider the probable price distribution in future intervals
- To optimally operate, storage may need to update bids throughout the day since these probability distributions change

$$Max_{Bid_h} \sum_{i} Bid_h * \Pr(Price)_i * Bool(\Pr(Price) > Bid)_i$$

- The ability for resources to charge makes this problem even more challenging

Energy limited resources may be critical for reliability on the system as gas resources retire



The ISO proposed a minimum charge requirement (MCR) to help resolve some of these concerns

- In the RA Enhancements initiative the ISO proposed the minimum charge requirement to:
  - Relieve resources of inability to meet day-ahead schedules and exposure to shortage prices if limited energy was depleted in RT
  - Ensure that the ISO has resources charged and ready to meet expected net load needs, resulting from day-ahead market outcomes
- This is an important discussion within ESDER
  - The ISO will continue to discuss this policy with stakeholders in both initiatives, regardless of where it is actually proposed
  - Some stakeholders suggested moving this topic to the ESDER initiative
  - ISO may reconsider where the policy development fits best

Example where resource has a rational DA bid, with unexpected results in the RT market

Hour	9	10	11	12	...	17	18	19	20	21	22	23	24
Load	190 MW	190	190	200	...	300	330	335	345	350	340	280	210
DA Bid ↓	$30/MWh	$30	$30	$30		$30	$30	$30	$30	$30	$30	$30	$30
DA Bid ↑	$60/MWh	$60	$60	$60		$60	$60	$60	$60	$60	$60	$60	$60
DA Price	$50/MWh	$50	$50	$50		$60	$100	$100	$100	$100	$100	$80	$70
DA Sched	-50 MW	-50	-50	-50		0	30	35	45	50	40	0	0
DA SOC	50 MWh	100	150	200		200	170	135	90	40	0	0	0

The necessary prices may not materialize in the real-time market to charge the storage resource

Hour	9	10	11	12	...	17	18	19	20	21	22	23	24
Load	190 MW	190	190	200	...	300	330	335	345	350	340	280	210
DA Bid ↓	$30/MWh	$30	$30	$30		$30	$30	$30	$30	$30	$30	$30	$30
DA Bid ↑	$60/MWh	$60	$60	$60		$60	$60	$60	$60	$60	$60	$60	$60
DA Price	$50/MWh	$50	$50	$50		$60	$100	$100	$100	$100	$100	$80	$70
DA Sched	-50 MW	-50	-50	-50		0	30	35	45	50	40	0	0
DA SOC	50 MWh	100	150	200		200	170	135	90	40	0	0	0
RT Bid ↓	$50/MWh	$50	$50	$50		$50	$50	$50	$50	$50	$50	$50	$50
RT Bid ↑	$100/MWh	$100	$100	$100		$100	$100	$100	$100	$100	$100	$100	$100
RT Price	$60/MWh	$60	$60	$60			$1,000						
RT Sched	0 MW	0	0	0	0								
RT SOC	0 MWh	0	0	0	0								

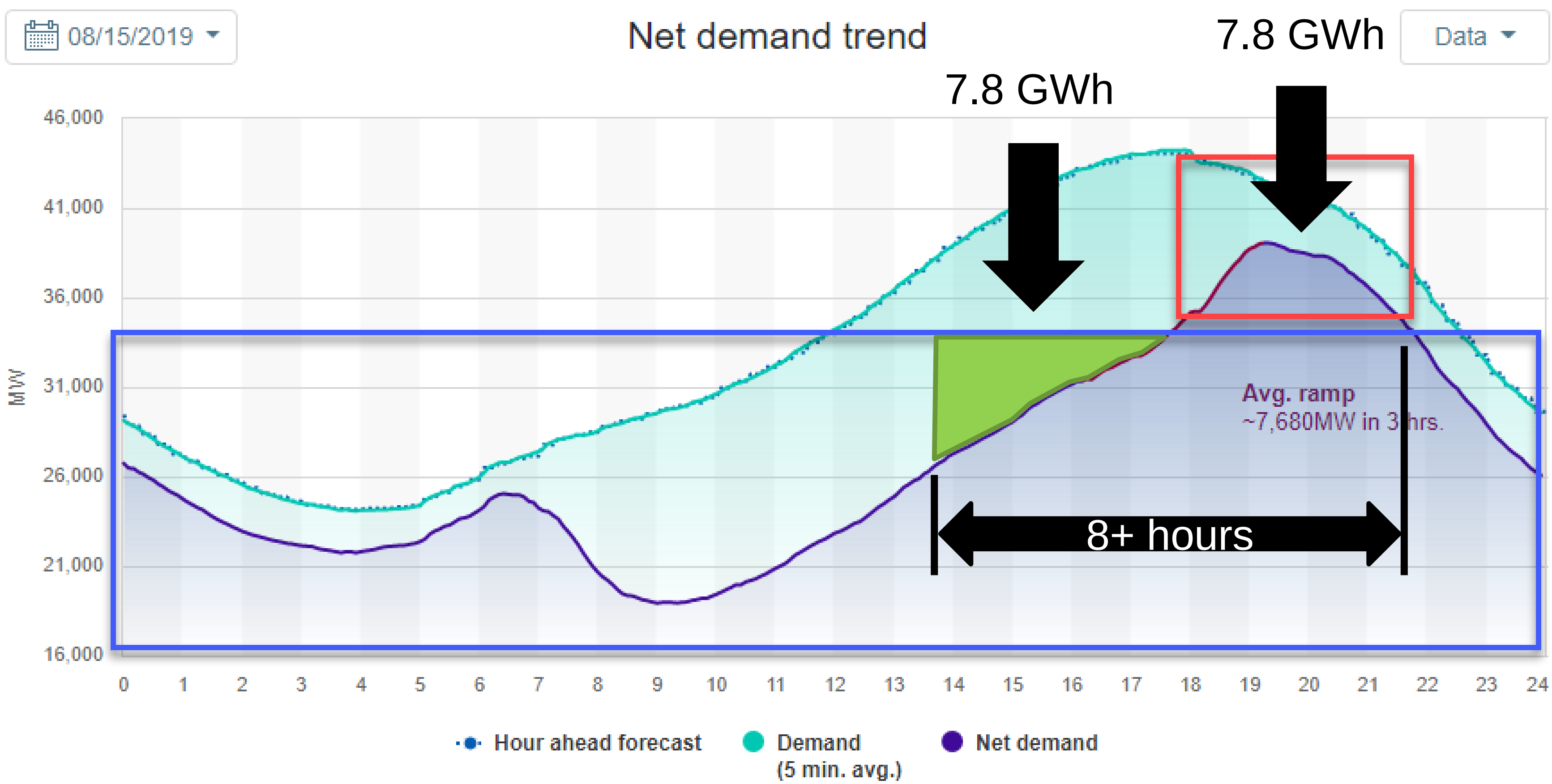
There are a number of potential ways to resolve problems outlined in these examples

1. Require day-ahead schedules to be completely self-scheduled into the real-time market
   - Lose all flexibility from resources
   - Hourly block scheduling in the real-time must be scheduled around
   - Resources miss opportunities to respond to real-time price spikes
2. Minimum charge requirement based on day-ahead schedules for energy limited resources
   - Restrain resources from using energy that the day-ahead market requires for use during later hours
   - Allow resources to still respond to price spikes if requirement is met
   - Imposes a new constraint that could alter ‘efficient’ dispatch signals
3. Additional tool to ‘override’ economic RTD instructions if energy limited resources are required
   - Tool more similar to exceptional dispatch
   - Would require sophisticated logic to implement
4. Extend real-time market to look 16+ hours ahead
   - Solution may not be technologically feasible at this time

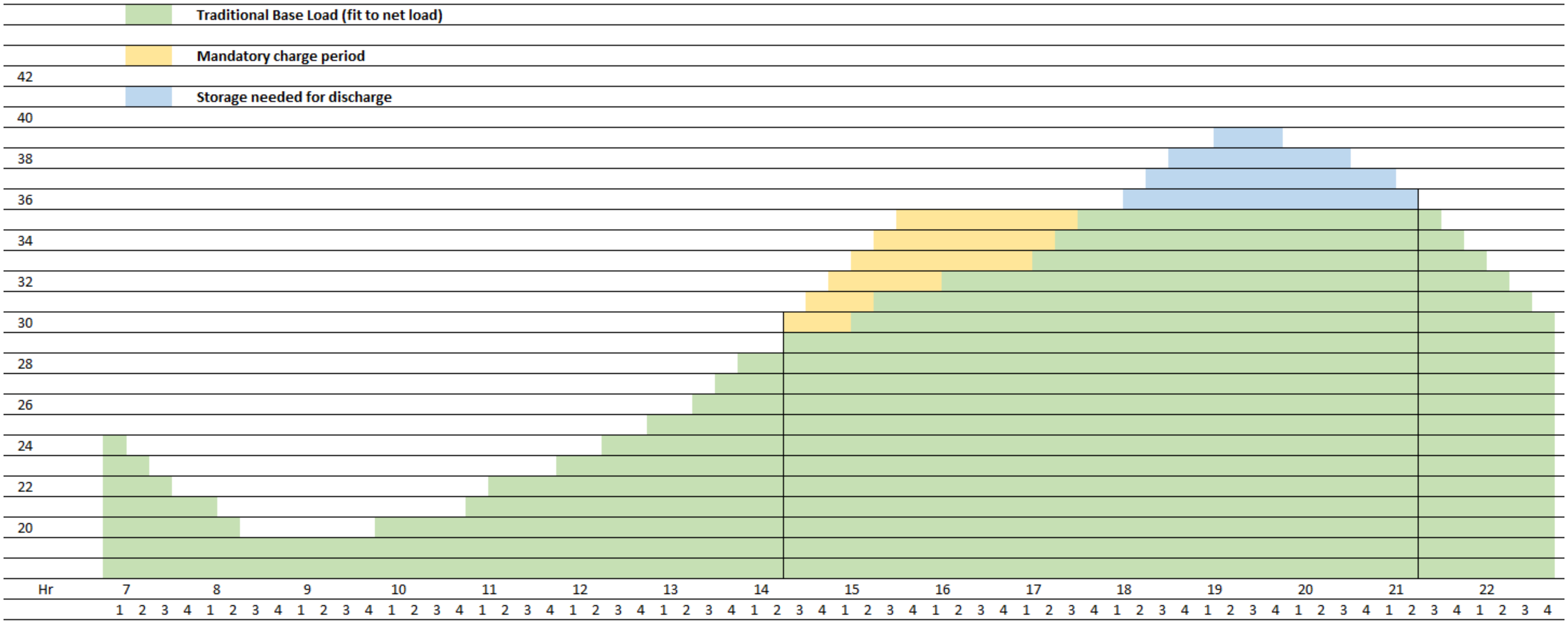
A signal 'override' tool may be possible for applications to energy limited resources for peak energy needs

- A tool that looks ahead multiple hours is conceptually possible
  - Likely would have to look ahead many hours (~14+)
  - Storage resources may prefer this solution as it gives maximum latitude for bidding and dispatch in the real-time market
  - May not be able to meet day-ahead schedules, which could expose resource to large financial implications
- Tool would need to ensure there is enough time, energy and ramp capability to meet needs
  - Gas (reliable) resources that are online their ramp/generation capability
  - Calculate the energy needs beyond those capabilities
  - Model state of charge for storage accurately
  - Calculate appropriate schedule to achieve necessary state of charge
- Compensation for these dispatches could be challenging
  - Compensation may need to be treated similar to exceptional dispatch

A tool applied to energy limited resources would have to look over a long horizon



In reality, the tool would need to account for ramping constraints and other market restrictions



It may be technologically challenging for the ISO to implement such a tool

- Although such a tool may be theoretically possible, it may not be practical to implement
  - It may need to run on a 5-minute basis for a 10+ hour horizon, this would be computationally burdensome
  - We have STUC today that works about 4 hours in advance of the current interval for unit commitment; this tool is run only every hour

- The ISO is not inclined to move forward on a proposal for such a tool at this time

Propose to implement a minimum charge requirement for energy limited resources with day-ahead schedules

- The state of charge is currently maintained for storage resources on the system
- Resources that are scheduled in the day-ahead marker will have a minimum charge requirement applied
- The constraint ensures that the day-ahead discharge schedule can be met for the resource
- Considers expected energy at the beginning of the day and day-ahead energy schedules awarded to the resource
  - Minimums will be 0 MWh if there is no DA discharge schedule
- The following two examples illustrate how this constraint will work

The same hypothetical resource is charged partially in the morning and discharged in the evening

Hour	9	10	11	12	...	17	18	19	20	21	22	23	24
Load	190 MW	190	190	200	...	300	330	335	345	350	340	280	210
DA Bid ↓	$30/MWh	$30	$30	$30		$30	$30	$30	$30	$30	$30	$30	$30
DA Bid ↑	$60/MWh	$60	$60	$60		$60	$60	$60	$60	$60	$60	$60	$60
DA Price	$50/MWh	$50	$25	$50		$60	$60	$60	$70	$70	$60	$60	$60
DA Sched	0	0	-50	0		0	0	0	30	50	0	0	0
DA SOC	30 MWh	30	80	80		80	80	80	50	0	0	0	0

- The discharge is less than the full capacity of the resource, which implies that the minimum state of charge is also less than the full capacity
- In this case, the minimum charge requirement begins at 30 MWh and never exceeds 80 MWh
- The resource continues to be allowed to update bids in the real-time market to maximize potential earnings

In the real-time, the resource charges to meet the increasing minimum charge requirements

Hour	9	10	11	12	…	17	18	19	20	21	22	23	24
Load	190 MW	190	190	200	…	300	330	335	345	350	340	280	210
DA Bid ↓	$30/MWh	$30	$30	$30		$30	$30	$30	$30	$30	$30	$30	$30
DA Bid ↑	$60/MWh	$60	$60	$60		$60	$60	$60	$60	$60	$60	$60	$60
DA Price	$50/MWh	$50	$25	$50		$60	$60	$60	$70	$70	$60	$60	$60
DA Sched	0	0	-50	0		0	0	0	30	50	0	0	0
DA SOC	30 MWh	30	80	80		80	80	80	50	0	0	0	0
RT Bid ↓	$25/MWh	$25	$30	$25		$25	$25	$25	$25	$25	$25	$25	$25
RT Bid ↑	$70/MWh	$70	$75	$72		$72	$72	$72	$72	$72	$72	$72	$72
RT Price	$60/MWh	$20	$27	$60		$60	$200	$60	$60	$60	$60	$60	$60
RT Sched	0 MW	-50	-50	0		0	50	0	0	0	0	0	0
RT SOC	30 MWh	80	130	130		130	80	80	80	80	80	80	80
Min Chrg	30 MWh	30	80	80		80	80	80	50	0	0	0	0

- HE 11: Update RT bids to charge further above MCR
  - Impacts potential sell prices later in the day
- HE 18: Resource captures high real-time price, not in DA market
- HE 20-21: Resource may not be discharged, based on realized DA prices, but resource remains charged and able to meet DA schedule

This tool will limit dispatch for energy limited resources, but actual economic impacts may be low

- Energy limited resources will have full ability to bid economically into the day-ahead market as desired
  - Aggressive bidding strategies in the day-ahead market may result in no schedule awarded
    - This implies no minimum charge requirement will be observed
- Prices in the day-ahead market are generally aligned with prices in the real-time markets
  - Day-ahead awards likely align with the highest priced intervals in the 5-minute market, when resources would optimally choose to operate
- Granularity of the 5-minute market may make it easy for flexible resources to earn additional revenue
  - Price spikes in the 5-minute market are infrequent
  - A resource with a state of charge slightly above the minimum will likely have ample opportunity to capture most or all price spikes
  - Real-time price spikes in the negative direction may also be beneficial to energy limited resources

DEFAULT ENERGY BID FOR STORAGE RESOURCES

The ISO identified four primary cost categories for storage resources

- Energy
  - Energy likely procured through the energy market
- Losses
  - Round trip efficiency losses
  - Parasitic losses
- Cycling costs
  - Battery cells degrade with each “cycle” they run
  - Cells may degrade faster with “deeper” cycles
  - Cycling costs should be included in the DEBs, as they are directly related to storage resource operation
  - It is expensive for these resources to capture current spreads
- Opportunity costs

Several factors contribute to the proposed default energy bid for storage resources

$$Storage\ DEB = Max\left[\left(\frac{En}{\lambda} + CD\right), OC\right] * 1.1$$

- Energy Costs (*En*) – Cost or expected cost for the resource to purchase energy
- Losses (λ) – Round-trip efficiency losses currently impact lithium-ion storage resources. Would like to include parasitic losses in the model in the future
- Cycle Costs (CD) – Cost, in terms of cell degradation represented in $/MWh, to operate the storage resource
- Opportunity Cost (OC) – An adder to ensure that resources with limited energy are not prematurely dispatched, before the highest priced hours of the day

- Bid is calculated daily, according to the formula, for each resource that selects this default energy bid option

Energy costs are designed to match the expected energy prices that resources could buy energy at

$$En_t^{\delta} = En_{t-1}^{\delta} * Max\left(\frac{DAB_t}{DAB_{t-1}}, 1\right)$$

- Energy Costs (*En*) – Calculated based on relevant bilateral index prices (DAB) from previous day to current day
- Energy costs will estimate expected prices that a resource may be able to buy energy at, if charging
- Storage duration (δ) – Represent the amount of storage a resource has, in hours and will be used to determine the estimated energy price that a resource would pay to charge
- Each resource will be mapped to a single representative bilateral hub, which will scale prior day prices – similar to expectations for energy prices

Opportunity costs are designed to match the expected peak energy prices resources can sell

$$OC_t^{\delta} = OC_{t-1}^{\delta} * Max\left(\frac{DAB_t}{DAB_{t-1}}, 1\right)$$

- Opportunity Costs (*OC*) – Calculated based on relevant bilateral index prices (DAB) from previous day to current day
- Opportunity costs will estimate estimated the expected price that a resource could discharge at, if fully charged
- Storage duration (δ) – Represent the amount of storage a resource has, in hours and will be used to determine the estimated energy price that a resource would pay to charge
- Each resource will be mapped to a single representative bilateral hub, which will scale prior day prices – similar to expectations for energy prices

The last version of the proposal included a relatively complex model for cycling costs

- Model energy with the state of charge

$$CD_{i,t} = v_{i,t}\,\rho_i\left(Max\,SOC\ - SOC_{i,t}\right)$$

where:

v: Binary = 1 when the state of charge is decreasing
ρ: Constant

Max SOC: Maximum SOC available for dispatch (generally 100%)
SOC: State of charge (Market decision variable)

i: Resource
t: Interval

In this version, the ISO applied a significantly simpler approach to cycle depth costs

- Generally storage resources are designed and built to a specification for average working conditions
  – Actual resources entering the market anticipate the ability to provide one cycle per day (and operate for a four hour duration)
  – These resources may operate beyond these specifications, but costs may be significantly higher
- These resources have an estimate from manufacturers about how much cell degradation costs will be for running up to that one cycle, and beyond that level
- The ISO intends to solicit documentation from storage resources on both costs, and apply the higher value to the ‘CD’ component of the DEB
  – This may be refined as more resources interconnect

The ISO will need to collect additional information in Master File and storage bids to construct DEBs

- Losses (λ): Expected round trip efficiency losses
- Storage Duration (δ): Amount of time the resource is capable of discharging for, given energy (MWh) capacity at full output
- Cell degradation costs: Estimates for cell degradation costs
  - Will require documentation prior to implementation
  - May be reviewed by actual costs incurred (or anticipated) after the resources establish a track record of participations
  - General values may be applied to the variable energy default energy bids as the ISO gains more experience
- ISO may use collected values and industry data to develop DEBs

Other concerns about storage resources have been raised during this initiative

- ISO is balancing the needs to derive a default energy bid that does not understate costs with the need to mitigate for market power
  - Understating costs could reduce market participation and competition
  - Market power could have far reaching impacts to rate payers and lead to potential reliability impacts

- Resources will always have the ability to file for a negotiated default energy bid with the ISO

NEXT STEPS

Next steps

- All related information for the Resource Adequacy Enhancements initiative is located at http://www.caiso.com/StakeholderProcesses/Resource-Adequacy-Enhancements

- Please submit stakeholder written comments on today's discussion and the ESDER4 second revised straw proposal by end of day March 16, 2020

  – Submit to initiativecomments@caiso.com

  – Comments template will be available on the ESDER4 initiative webpage under today's meeting header, at http://www.caiso.com/StakeholderProcesses/Energy-storage-and-distributed-energy-resources