California ISO

Energy Storage and Distributed Energy Resources Phase 4

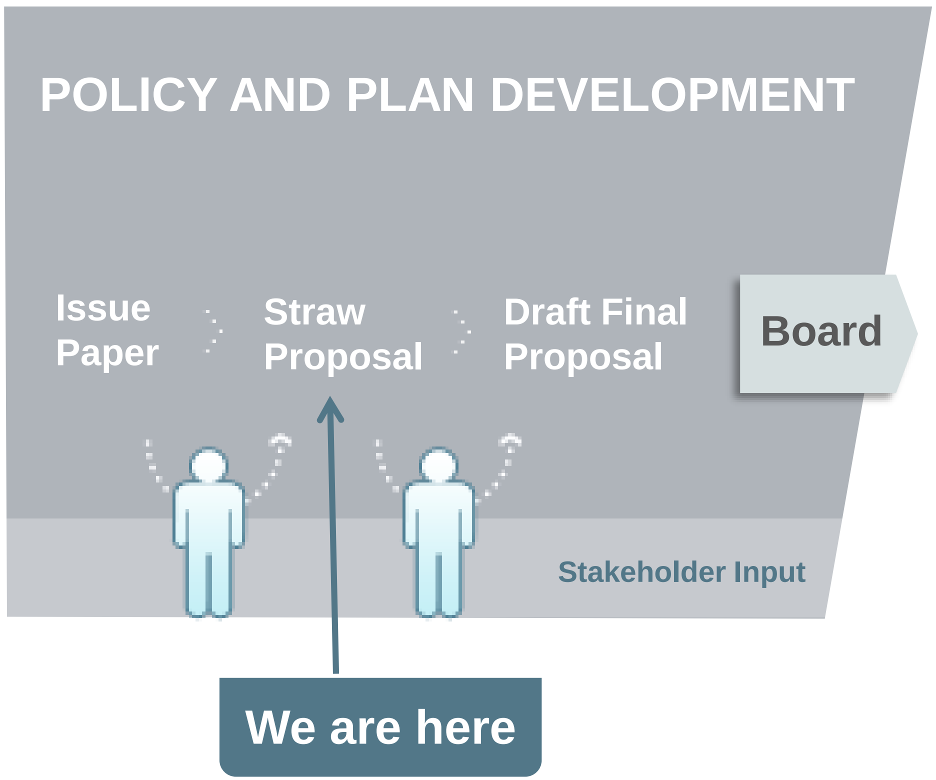
Revised Straw Proposal
October 28, 2019
10:00 a.m. – 3:00 p.m. (Pacific Time)

Agenda

Time	Item	Speaker
10:00 - 10:05	Stakeholder Process and Schedule	James Bishara
10:05 – 10:10	Objectives and Scope	Eric Kim
10:10 – 10:45	End-of-Hour SOC	Eric Kim
10:45 – 12:00	Market Power Mitigation for Storage Resources	Gabe Murtaugh
12:00 – 1:00	*Lunch Break*	
1:00 – 1:45	Variable Output Demand Response	Lauren Carr
1:45 – 2:15	Parameters to Reflect DR Operational Characteristics	Eric Kim
2:15 – 2:55	Non-24x7 Settlement Discussion	Eric Kim
2:55 – 3:00	Next Steps	James Bishara

STAKEHOLDER PROCESS

CAISO Policy Initiative Stakeholder Process



OBJECTIVES / SCOPE

Scope

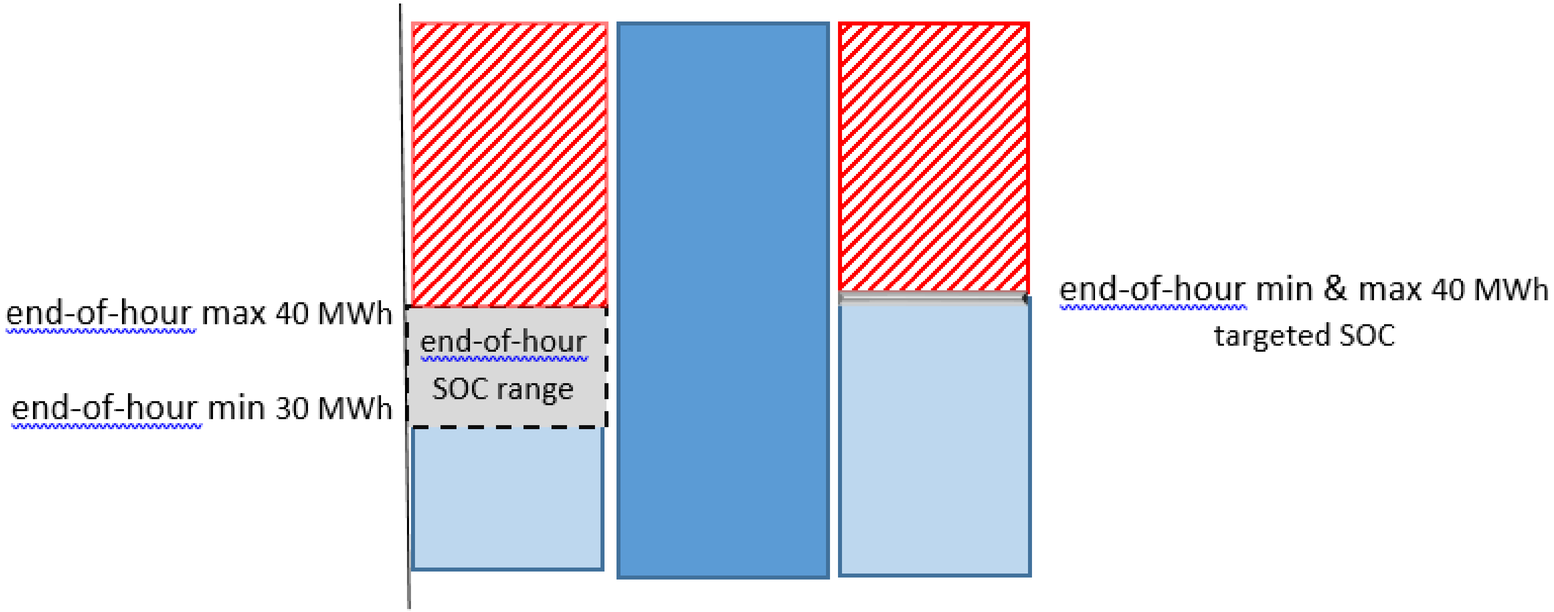
1. NGR state of charge parameter
2. Market power mitigation measures for energy storage resources
3. Streamlining interconnection agreements for NGR participants
4. Demand response maximum run time parameter
5. Operational process for variable-output demand response resources
6. Consideration of the non-24x7 settlement of behind the meter resources utilizing NGR model*

*Removing from scope

END-OF-HOUR SOC PROPOSAL

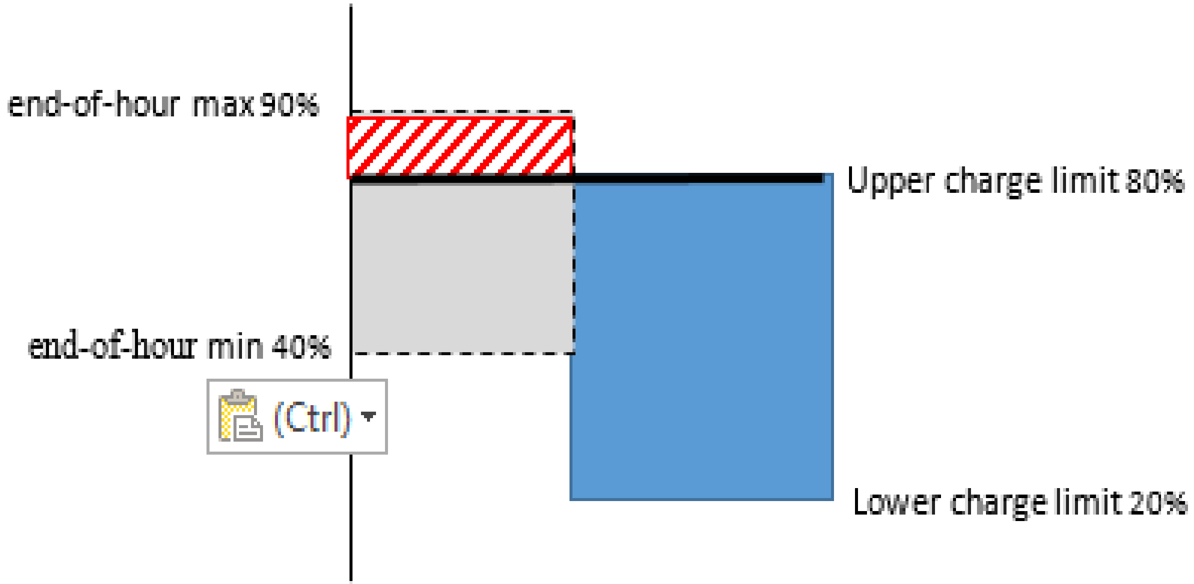
The ISO is proposing an end-of-hour SOC parameter in the real-time market

- Gives scheduling coordinators the option to manage the optimal use of their energy storage resource
- Scheduling coordinators can submit the end-of-hour SOC parameter as a MWh range



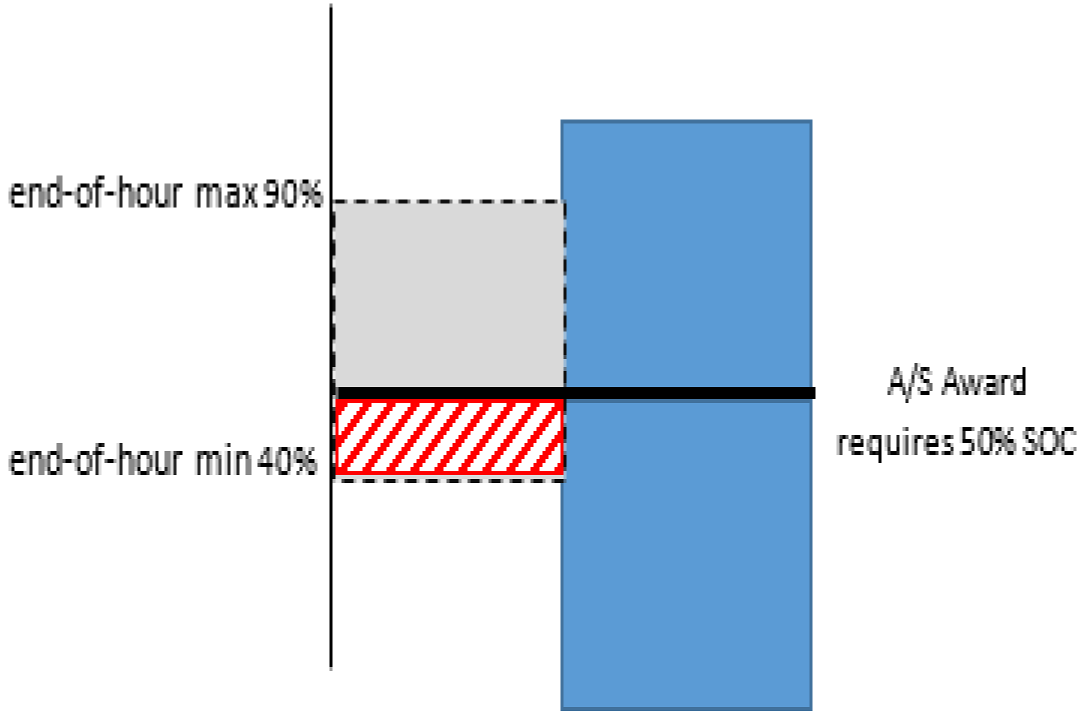
Upper and Lower Charge Limits

- *End-of-hour SOC will prioritize upper and lower charge limits*



Ancillary Service Award

Market will maintain SOC to meet A/S awards



Bid Cost Recovery

- The ISO is proposing to exclude bid cost recovery in intervals with an end-of-hour SOC bid
- Additionally, non-generator resources with a self-schedule in a preceding hour will be ineligible for BCR.
  - Non-generator resources utilizing self-schedules will be ineligible for BCR because the market must optimize around the self schedule
  - For example, an upcoming self-schedule may require the market to charge or discharge uneconomically

END-OF-DAY SOC PROPOSAL

The ISO received requests to consider spread bidding, and an end-of-day state of charge parameter in DAM

- The day-ahead market respects: bids to charge, bids to discharge, and ‘spreads’
- Resources receiving day-ahead schedules could receive instructions which have the resource at a non-neutral position on quantity of energy
- This parameter may allow storage resources to bid “true spreads” into the market
  - May prevent resources from buying at a ‘high’ price, adjusting bids then selling at a ‘low’ price at a later day due to volatility
- Resource operators may have other concerns regarding availability of spread bids in the market

An end-of-day state of charge parameter may have unintended consequences

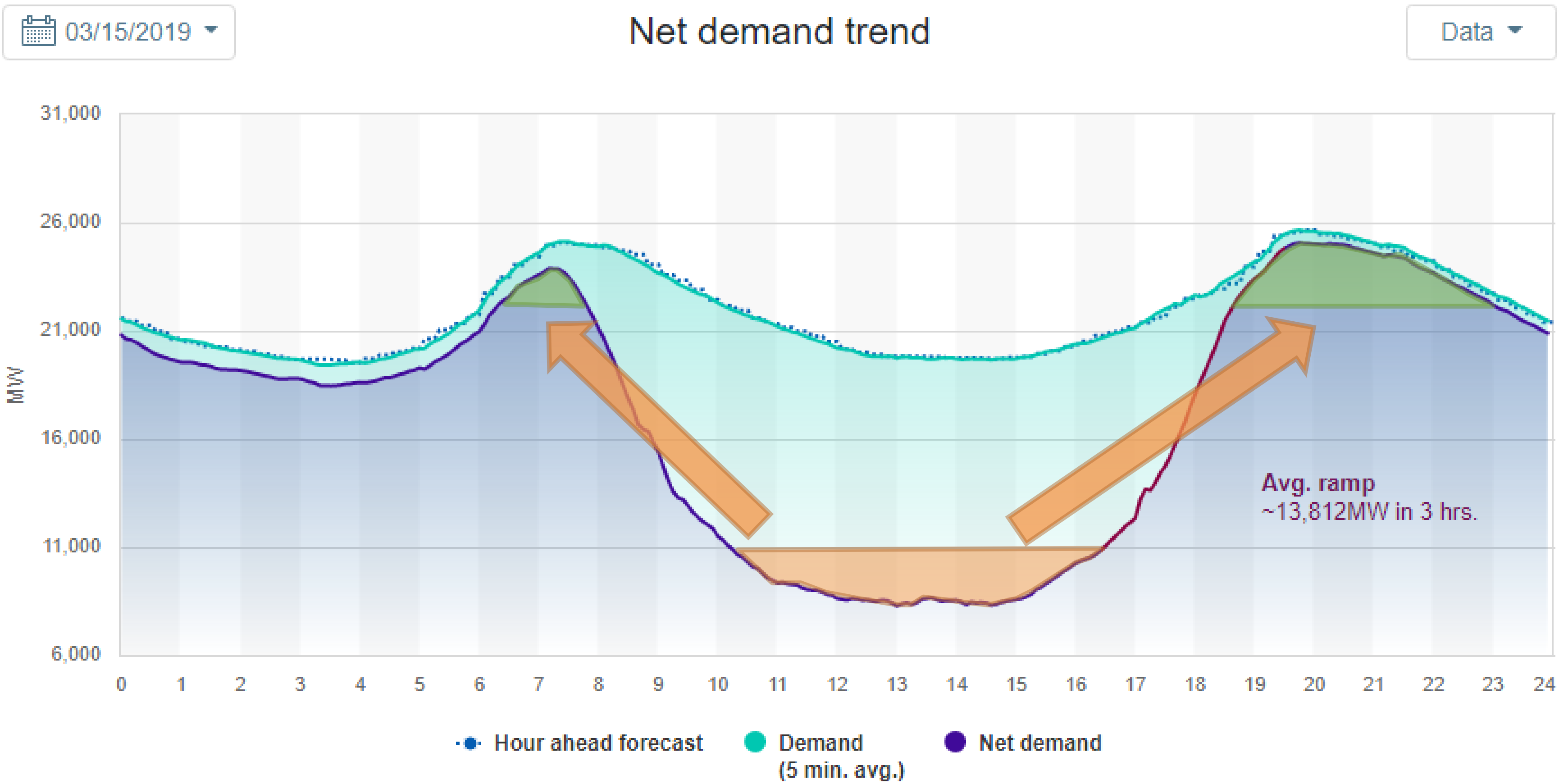
- Resources with an end of day state of charge parameter may miss opportunities to buy energy at relatively low prices when the parameter is close to 100%, or miss opportunities to sell when prices are high is parameter is close to 0%
- Particularly high state of charge values may prevent the resource from receiving energy awards because prices and ideal hours for discharging energy tend to occur toward the end of the day
- The ISO would like to consider opportunities to mitigate these consequences

MARKET POWER MITIGATION FOR ENERGY STORAGE

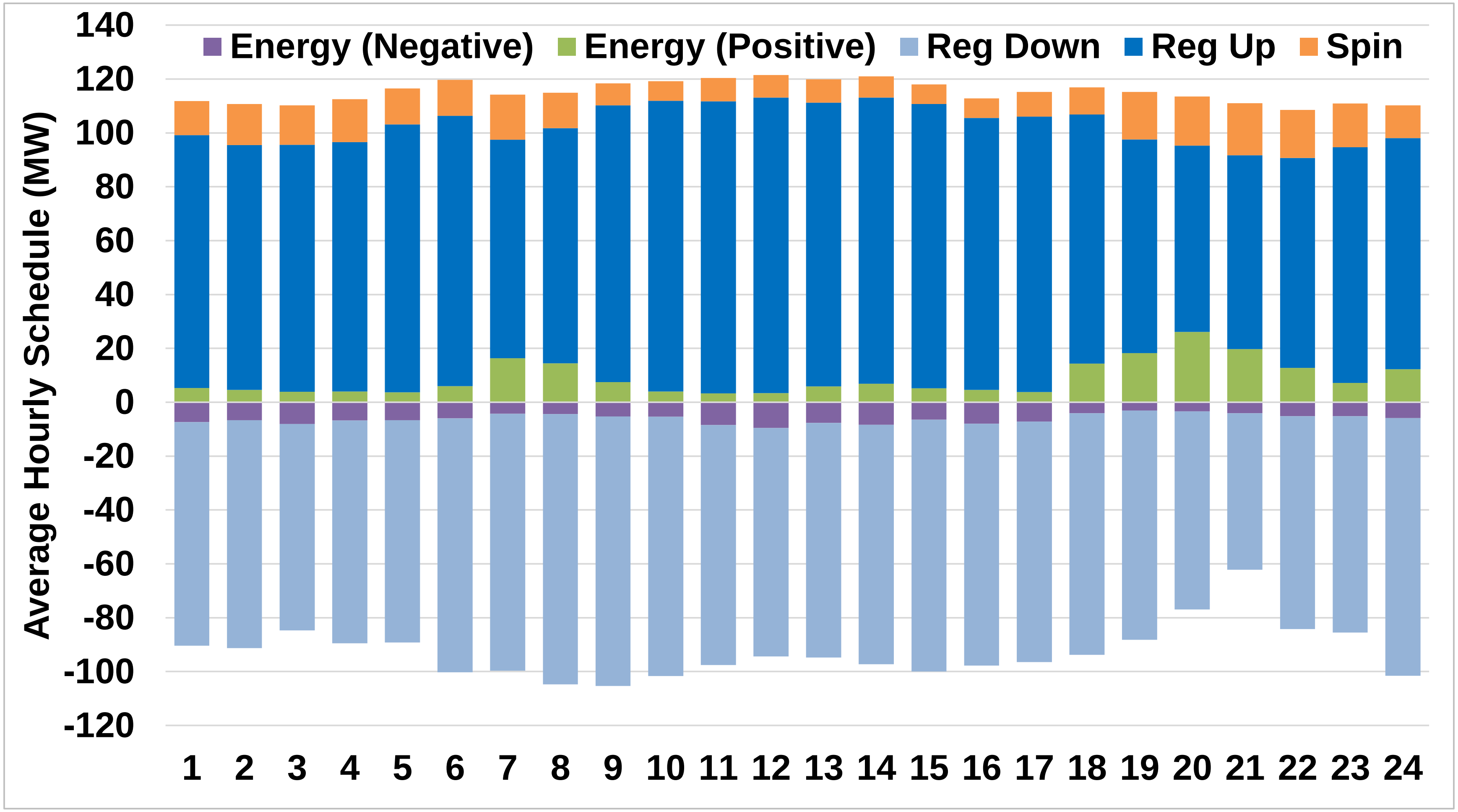
The ISO is proposing a methodology to calculate default energy bids for storage resources in ESDER 4

- The ISO currently does not calculate default energy bids for storage resources
- There is a considerable amount of storage in the new generation queue for the system
- Storage is often suggested as a solution for local issues to mitigate for retirement of essential resources
- Planning models used by the CPUC and the ISO tend to include 4-hour storage ‘moving’ generation from peak solar hours to peak net load hours
  - Generally the existing battery fleet is not doing this

Batteries might be used to ‘shift’ energy from one time of the day to another



Battery dispatch data shows storage was scheduled for regulation and not energy in the first half of 2019



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

Energy costs are built to measure the expected cost for resources to buy energy

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

- Energy Costs (*En*) – Calculated based on relevant bilateral index prices (DAB) from previous day to current day
- Energy costs will estimate the cost for a storage resource to charge
- 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
- The ISO is not carrying out any supply and demand analysis to forecast anticipated prices

Cycling costs are an important component of cost for storage resources

- As a storage resource operates, the metal making up the battery cells degrades and eventually requires replacement
  - The cost for battery replacement is directly related to battery operation and should be considered in marginal cost
- Cells degrade more when resources perform ‘deeper’ cycles

Cycle Cepth (CD)	Total Cost ($)	Marginal Cost ($)
10%	1	1
20%	4	3
30%	9	5
40%	16	7
50%	25	9
60%	36	11
70%	49	13

- Cells may also degrade faster based on current rate, ambient temperature, over charge/discharge, and average state of charge

Cycling costs may be accrued over a short period of time or a long period of time

- Generally storage resources that discharge at the same depth over a short period of time or long period of time experience about the same amount of cell degradation

Hour	P (MW)	SOC (MWh)	SOC (%)	Cost
1	0	7	70%	0
2	4	3	30%	16
3	0	3	30%	0
4	0	3	30%	0
5	0	3	30%	0
6	0	3	30%	0
				16

Hour	P (MW)	SOC (MWh)	SOC (%)	Cost
1	0	7	70%	0
2	1	6	60%	1
3	1	5	50%	3
4	1	4	40%	5
5	1	3	30%	7
6	0	3	30%	0
				16

Modelling depth of discharge can be complicated

- Xu et al. uses a 'rainflow' model to estimate cell degradation and associated costs
- This model effectively tracks when every discharge period starts and ends, and tracks 'nested' discharge periods

Hour	P (MW)	SOC (MWh)	SOC (%)	Cost ($)
1	0	7	70%	0
2	4	3	30%	16
3	-2	5	50%	0
4	2	3	30%	4
5	1	2	20%	9
6	1	1	10%	11
				40

- This model is difficult to implement in a nodal market because of modelling complexity

Xu, et al. Factoring the Cycle Aging Cost of Batteries Participating in Electricity Markets: https://arxiv.org/pdf/1707.04567.pdf.

The rainflow model tracks charge and cost for a storage resource

- Each portion of the battery has a flag to determine if charged or discharged
  - Cheapest segments are charged first, before more expensive segments

Segment	0.1	0.2	0.3	0.4	0.5	0.6	…
	↓	↓	↓	↓	↓	↓	
Marginal Cost	1	3	5	7	9	11	…
Charge?	0/1	0/1	0/1	0/1	0/1	0/1	…

- Model may accurately tracks costs for resources, but can be computationally intensive to model for many resources
- A model would need many more discrete intervals for RT markets.

The first model includes a multiplier applied to the ‘distance’ dispatch SOC is below maximum SOC

- Model energy with the state of charge

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

where:

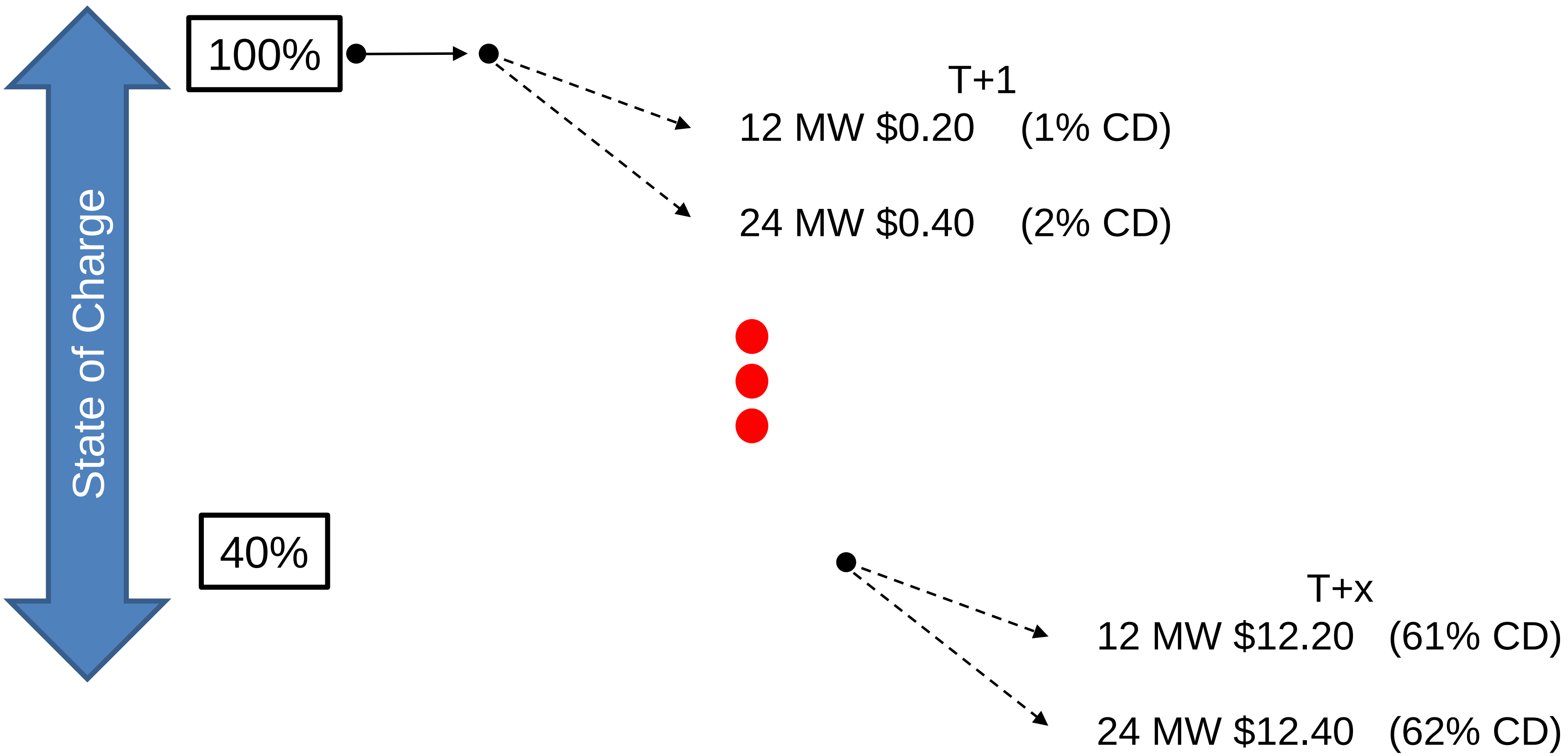
v: Binary = 1 when the state of charge is decreasing
ρ: Constant

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

i: Resource
t: Interval

Example Resource: Assume a +/-24 MW storage resource with 100 MWh of capacity and ***ρ* = 20**. Max SOC = 100%

Proposed dynamic DEBs (and bids) reflecting marginal costs of cycle depths in the real-time market



There are several pros and cons to modelling resources based on maximum cycle depth

Pros

- This model will always be greater than or equal to the cost to operate the battery
  - Aligns with increasing marginal costs
- Price for any discharge increases as state of charge decreases
  - Market outcomes will tend to charge the battery

Cons

- The model may grossly overestimate the cost to produce
  - Assumes costs at maximum cycle depth
  - This happens if there are ‘nested’ resource charges
  - Does not account for ‘rainflow’ methodology

The second model includes a multiplier applied to the difference in SOC from one interval to the next

- Model energy with the state of charge

$$CD_{i,t} = u_{i,t}\, \rho_i \left(SOC_{i,t-1} - SOC_{i,t}\right)$$

$$= u_{i,t}\, \rho_i \, \frac{P_{i,t-1} + P_{i,t}}{2} \, \frac{\Delta T}{T}$$

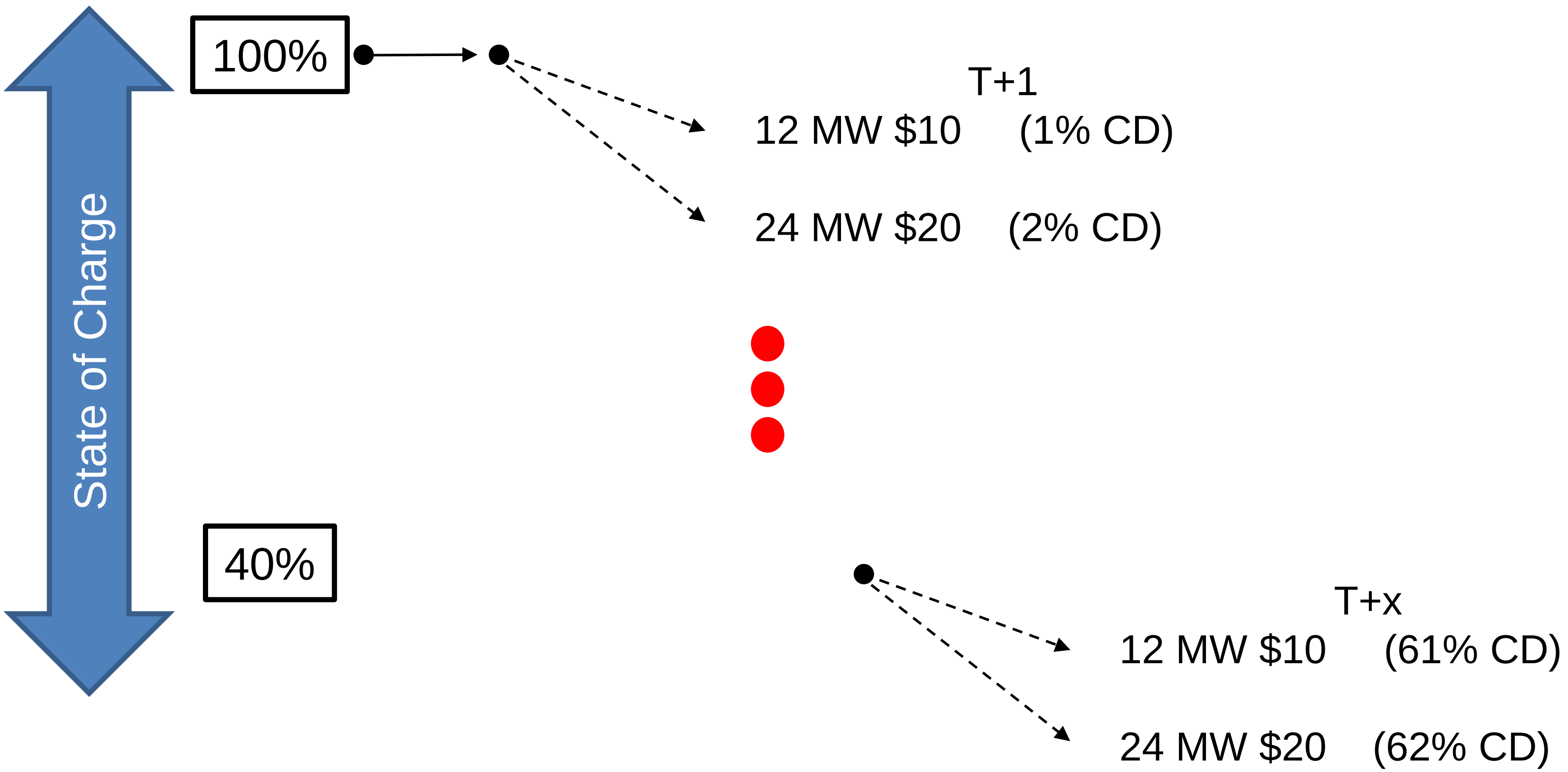
where:

u: Binary = 1 when the state of charge is decreasing

P: Dispatch instruction (Market decision variable)

Assume a +/-24 MW storage resource with 100 MWh of capacity and **ρ = 1000**

This cost characterization causes all individual interval deeper discharges to be more expensive



There are several pros and cons to modelling resources based on total costs for cycle depth

Pros

- May more efficiently dispatch resources for energy (MWh)
- May more consistently produce the correct price on average
- May be more simplistic for implementation/settlement

Cons

- – Overestimates costs for large dispatches when cycle depth is thin and under estimates costs for small dispatches when cycle depth is deep
- – May cause round-trip efficiency to be underestimated

Opportunity costs are built to match the expected peak prices that resources will be able to sell energy

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

- 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 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 cost (ρ): Estimates for cell degradation costs
  - Will differ with discharge cost model ultimately implemented
  - May differ with expected cost date
  - May differ with facility/vendor/market participant
- ISO may use collected values and industry data to develop DEBs

Other concerns about storage resources have been raised during this initiative

- If such a default energy bid is adopted resources will have the ability to bid in at values that match the default energy bid
  - These values can vary from one interval to the next and change with state of charge or dispatch
- 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 completion
  - 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 an negotiated default energy bid with the ISO

VARIABLE-OUTPUT DEMAND RESPONSE

By definition, variable-output DR may be unable to deliver its shown NQC value in real-time due to its variable nature

- CAISO defines variable-output DR as DR whose maximum output can vary over the course of a day, month, or season due to production schedules, seasonality, temperature, occupancy, etc.

- The central tenet of the RA program is to ensure sufficient energy is available and deliverable when and where needed

- If a DR resource cannot bid its full RA capacity and deliver it under its must offer obligation (MOO) due to its variable nature, the resource may be assessed RAAIM penalties

Many DR resources also have availability limitations

- Availability limitations are significant dispatch limitations such as limited duration hours or event calls that could affect a resource’s ability to provide energy associated with the RA capacity a resource provides
- CAISO will rely more heavily on both variable and availability-limited resources in the future
- It is critical to assess the ability of the new resource fleet to displace carbon-emitting generation while maintaining system reliability and serving energy needs every hour of the year

The CAISO will advance the variable-output demand response issue following two key principles

1. The qualifying capacity (QC) valuation must consider variable-output and availability-limited DR resources' reliability contribution to system resource adequacy needs
   – To help inform and advance CPUC/LRA consideration, the CAISO will discuss how to perform a Loss of Load Expectation (LOLE) study and establish an Effective Load Carrying Capability (ELCC) value for demand response
2. Market participation and Must Offer Obligations (MOOs) must align with demand response resource capabilities
   – The CAISO will explore altering market participation rules for variable-output DR to allow must offer obligation fulfillment by bidding their full capability

The ELCC method can and should be applied to variable-output and availability-limited DR

- ELCC is a probabilistic approach used to quantify the contribution of the resources or group of resources to resource adequacy by assessing the resource’s ability to avoid LOLE
- The ELCC can compare the reliability contribution of different variable resources (i.e., other DR programs or other technology types)
- ELCC can capture the incremental benefit and saturation rate of demand response to system reliability given program design configurations

CAISO has contracted with E3 to develop methodology and provide ELCC values for DR

- Analysis will consider inputs that inform DR resources' availability including:
  - Number of Calls (calls/month, calls/year, number of consecutive days)
  - Maximum call duration
  - Hourly availability profile (to reflect variability by hour, season, weather, etc.)
- The CAISO and E3 will collaborate and review results with stakeholders in the ESDER process

In conjunction with the adoption of ELCC, CAISO could modify must offer obligations for variable-output demand response

- Variable-output demand response resources could fulfill their must offer obligation by bidding the amount they are physically capable of providing
- Resources without intra-hour variability may be able to reflect variability through their bids
  - Bids submitted on an hourly basis, 75-minutes prior to operating interval
  - If capability will not change between when bids are submitted and the operating interval, resources could reflect variability through their bids

Resources with variability intra-hour must submit capability in real-time to ensure feasible dispatches

- CAISO proposes SC provide their own forecasted capability on a 5 or 15 minute basis
  - SC-provided capability would set the upper economic limit on bids
    - Ensures feasible dispatches if capability changes after bids are submitted
- Proposes resources meet their must offer obligation by bidding the amount they are physically capable of providing per their most recent forecasted capability
- CAISO is considering the timing of must offer obligations for all demand response
  - Stakeholders suggested DR resources have differing degrees variability which may impact obligations
  - Must consider developments in Day-Ahead Market Enhancements and RA Enhancements

CAISO must ensure there are no disincentives for submitting full capability

- It is important to establish adequate controls to ensure the forecast/bids reflect full capability
- The CAISO is considering ways to eliminate any disincentives for submitting or bidding in full capability including auditing provisions, testing procedures, and performance penalties

The CAISO welcomes stakeholder feedback on such controls that should be put in place

OPTIONS TO REFLECT OPERATIONAL CHARACTERISTICS OF DEMAND RESPONSE RESOURCES

Proposals recognize program design impacts on demand response resource characteristics

DR Resources may have various characteristics that are set by their underlying demand response programs including:

- minimum length of time it must respond to a dispatch
- maximum number of hours it can respond to a dispatch
- maximum number of hours within a day available for dispatch
- response requiring contiguous dispatch
- multiple starts per day but differ with CAISO's start-up definition to Pmin
  - problematic with Pmin = 0 MW
- may not be capable to vary response once dispatched
  - once dispatched to curtail, the resource will respond to its MW bid qty, even if the market dispatch quantity is below that qty or changes between intervals

DR resources can utilize existing parameters to represent their unique operating characteristics

Register start up costs

- Hourly and 15-min bid options will extend notification times and dispatch durations
- Resource will no longer be a $0 and 0 MW resource in RUC

Minimum load costs with a Pmin > 0 MW

- Register a Pmin close to its Pmax
- Register minimum load cost
- DR will only be committed to its Pmin if the market determines it is economic to do so

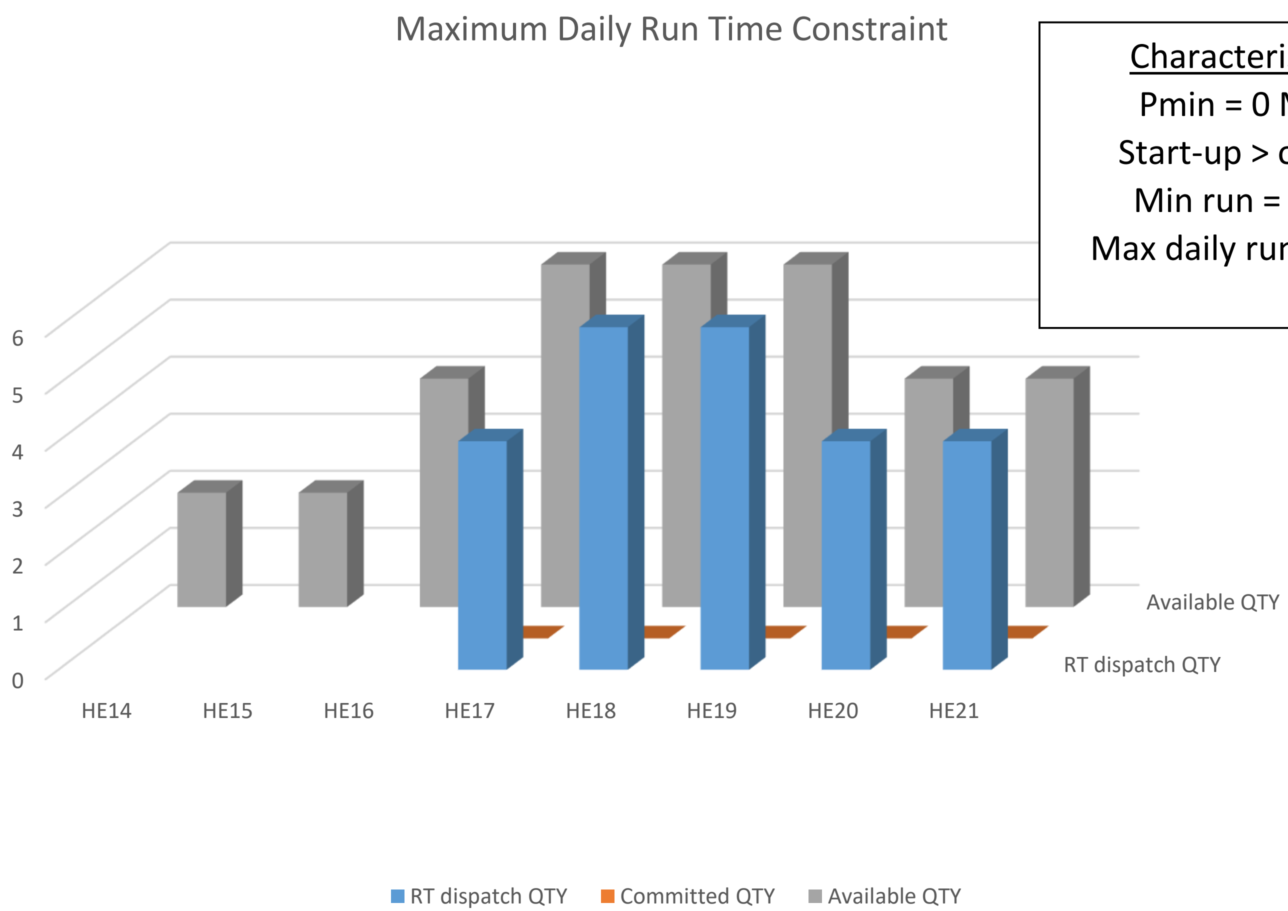
The proposed Maximum Daily Run Time constraint allows a demand response resource to identify the maximum number of hours the resource could be “on” over the course of a day

- A Masterfile parameter representing the maximum number of hours a DR resource can be committed and/or dispatched in one day
- Applicable for both PDR and RDRR.
- Must be a resource with 1 MW or greater capacity (Pmax >= 1 MW).
  - *Note: the CAISO is currently considering additional resource requirements for use of this parameter*

The CAISO will limit the number of DR resources utilizing maximum daily run time

- Concerns with overloading market systems with an increasing number of market participants and resource IDs
- Currently, there are upwards of 800 PDRs bidding into the day-ahead market
  - Adding the maximum daily run time for all resources would impact market performance and jeopardize the 1PM day-ahead market publishing deadline

Example 1: Max daily run with Day Ahead Commitments



<u>Characteristics</u>

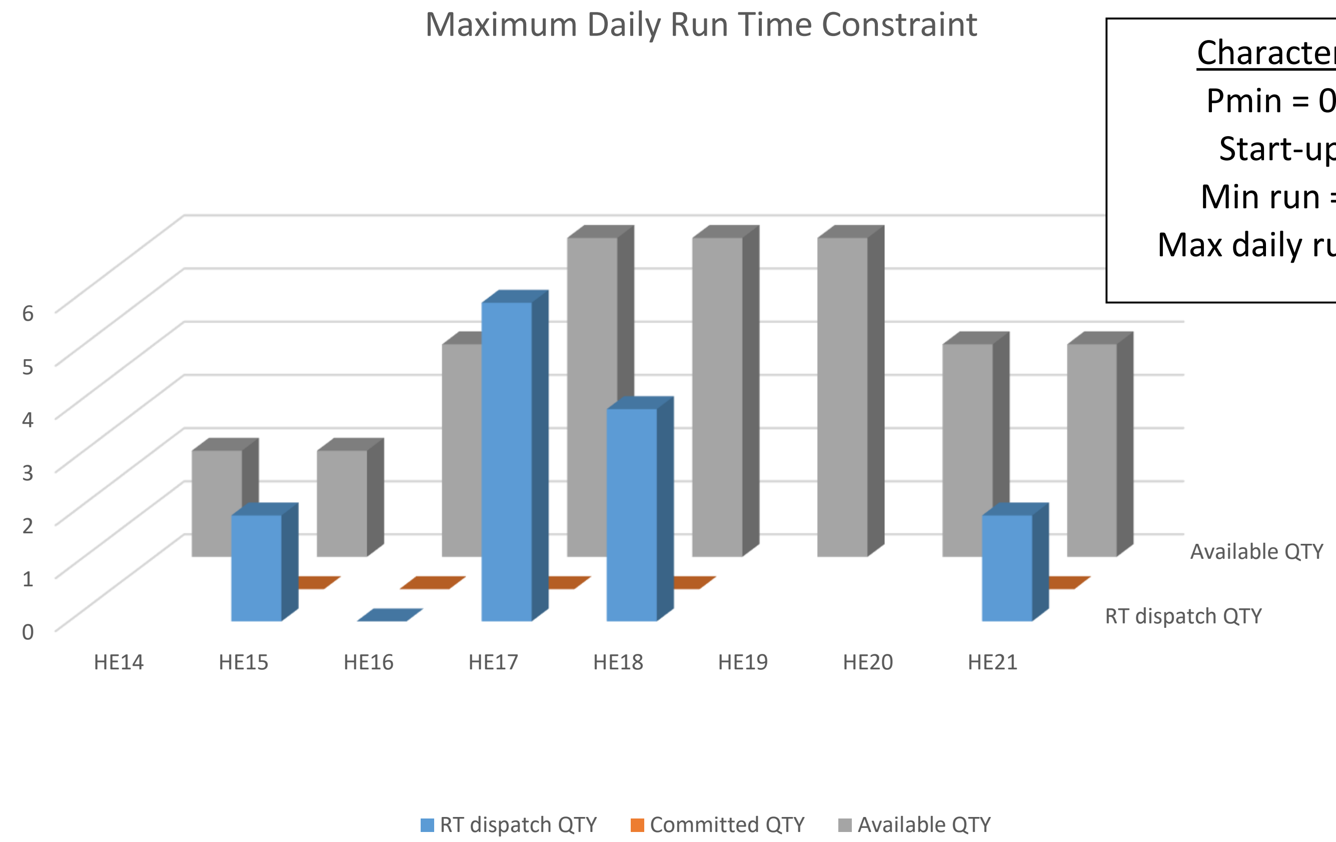
Pmin = 0 MW

Start-up > or = 1

Min run = 1 hr

Max daily run = 5 hr

Example 2: Noncontiguous dispatch in real-time market



Characteristics

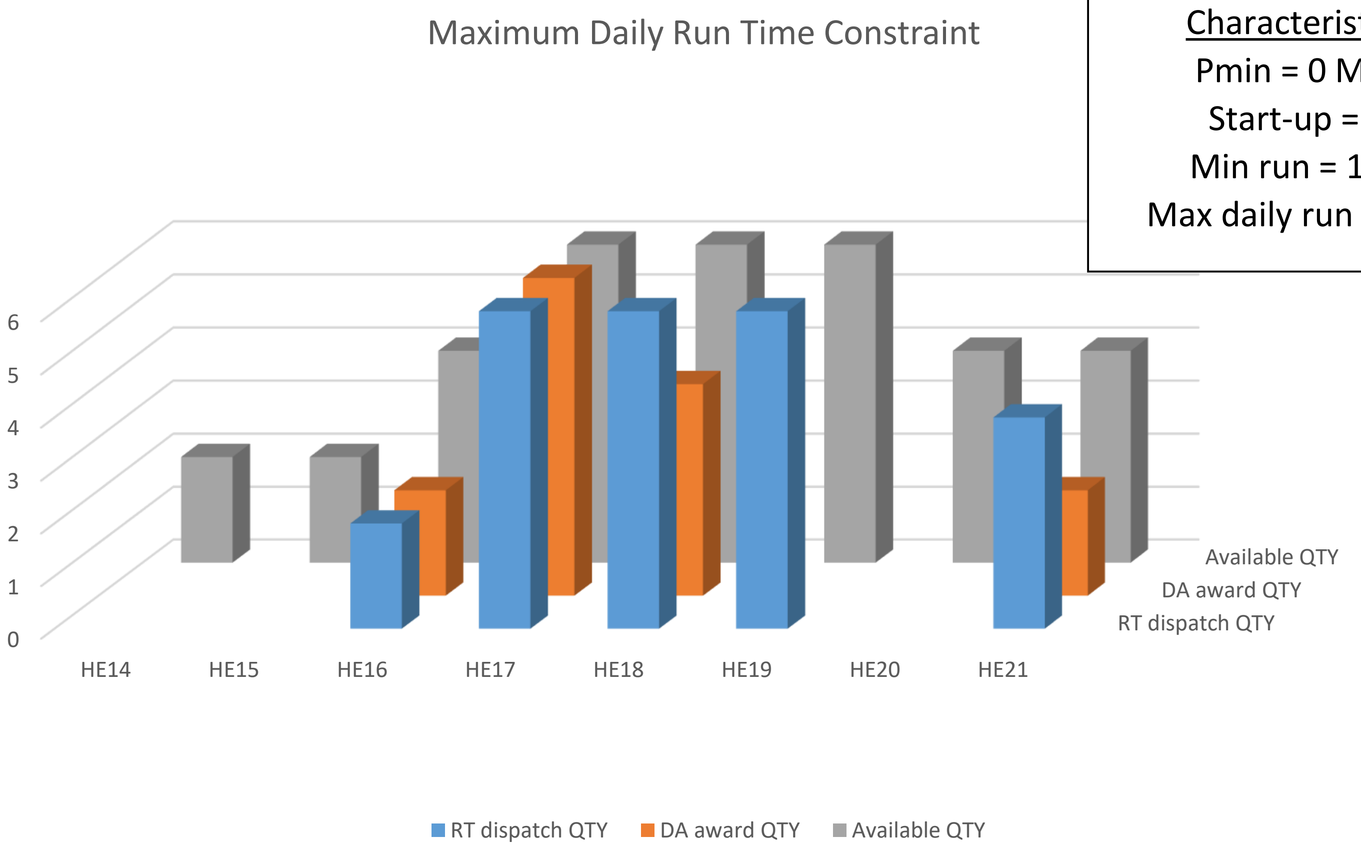
Pmin = 0 MW

Start-up = 2

Min run = 1 hr

Max daily run = 5 hr

Example 3: Interaction between day-ahead and real-time market awards



Characteristics

Pmin = 0 MW

Start-up = 2

Min run = 1 hr

Max daily run = 5 hr

DISCUSSION OF DER MULTI-USE APPLICATION NON-24x7 SETTLEMENT

The ISO has explored the settlement of behind the meter DERs participating in the wholesale market under a multi-use application.

The CAISO has determined, and stakeholders comments confirm, that there are precursor issues needing to be resolved to accommodate multi use application prior to considering a non-24x7 wholesale market settlement:

- There is no definitive solution with how LSEs will forecast and bid load with behind-the-meter DER participation.
- There are several solutions presented by stakeholders to account for both retail and wholesale settlement that require clarification from the local regulatory authority.

Utility stakeholders detailed cross-jurisdictional requirements needed to effectuate multi-use applications for a BTM resource.

1. **Rules & Standards**
   - UDCs and LSEs need jurisdictional clarity when a CPUC jurisdictional BTM resource participates by exporting into the ISO.
2. **Support Systems**
   - Separate metering is needed to understand wholesale vs. retail.
   - Accounting methodology for when sub-meter is behind a retail meter and service is provided in different intervals.
   - IT and billing systems to support these new proposals
3. **Operations and Communication**
   - Communication protocols or standards for DER providers to inform LSEs of their operational configuration for a given day/season.

Several questions remain on differentiating retail versus wholesale settlement.

1. Should there be a demarcation of hours when behind-the-meter resources can provide either a wholesale or retail level service?

2. With regards to metering standards, which entity owns and controls the meter and meter data to account for separation of retail and wholesale transactions and settlement?

3. Does there need to be a new retail rate for resources participating partially in the wholesale market?

4. How should UDCs separate retail charges or payments when the resource is settled in the wholesale market?

Several stakeholders offered potential accounting solutions to the discussion.

- LRAs would set standards for UDCs to net out any wholesale activity from a customer's bill while DER owners would be responsible to communicate load or generation for correct accounting.
- All export of energy from the behind-the-meter resource would be settled as wholesale while all load is charged as retail.
  - For example, a BTM battery discharging into the wholesale market will be settled by CAISO, while the UDC or LSE would assess retail rates for all load including when the battery is charging (even if it is for wholesale discharging purposes).

Several stakeholders offered potential accounting solutions to the discussion. (Cont'd.)

- Allow for the settlement of net export under proxy demand resource model.

- Create a similar construct to the load shift resource model with no symmetric dispatchability requirements.
  - With bidding rules to bid above the net benefits test price threshold to provide energy and bid below $0 for charging.

The CAISO has decided not to continue development of a proposal for a non-24x7 settlement for DERs.

- Because DERs are physically located in the distribution system, the Local Regulatory Authority must provide jurisdictional clarity.
  - Retail settlement rules
  - Metering and visibility requirements
  - Distribution system impacts and planning
  - Address operational and forecasting concerns

- The CAISO supports moving forward in coordination with LRAs.

NEXT STEPS

Next Steps

Milestone	Date
Revised Straw Proposal posted	October 21, 2019
Stakeholder web conference	October 28, 2019
Stakeholder comments due	November 12, 2019

Written stakeholder comments on today's discussion are due by COB November 12 to InitiativeComments@caiso.com.

All material for the ESDER initiative is available on the ISO website at: http://www.caiso.com/informed/Pages/StakeholderProcesses/EnergyStorage_DistributedEnergyResources.aspx.