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Enabling Resources Program: Storage and Hybrid Integration Project

Optimization Design Engagement

Memo 2.0

Engagement Topic: Optimization Design Element for Storage Resources

Date: October 16, 2025

Purpose

The purpose of this document is to provide detail on the IESO's market design work with respect to the 'Optimization Design Element' for the storage resource participation model. It articulates how the IESO undertook the optimization design and the decisions that are relevant to stakeholders for the enhanced storage participation model.

Initial decisions on 'Optimization' were made and presented in the external stakeholder engagement session held on Jul 24, 2025. The objective of this design memo is to tentatively conclude decisions on those design topics and supplement the information presented on the stakeholder engagement session held on Oct 16, 2025.

The IESO will utilize this document and materials from subsequent design phases to support the implementation of the design work for the Storage and Hybrid Integration Project. This will be captured in future changes to Market Rules, Market Manuals, software interfaces with the IESO, and internal IESO systems and processes. These external changes will be reviewed for input with stakeholders. Any material changes to this design as a result of implementation discovery will be discussed with stakeholders.

Table of Contents

List of Abbreviations

Abbreviation	Definition
ADE	Availability Declaration Envelope
BESS	Battery Energy Storage System
CROW	Control Room Operations Window
CycleDEL	Cycling Daily Energy Limit
DA	Day Ahead
DAM	Day-Ahead Market
DSO	Dispatch Scheduling and Optimization
EOP	Economic Operating Point
ESR	Energy Storage Resource
HOL	High Operating Limit
ISL	Internal Service Load
LOL	Low Operating Limit
MaxSoC	Maximum State of Charge
MinSoC	Minimum State of Charge
MIO	Multi-Interval Optimization
MF&I	Market Forecasts and Integration
MPM	Market Power Mitigation
NCED	Network Constrained Economic Dispatch
NCUC	Network Constrained Unit Commitment
NSA	Network Security Assessment
PD	Pre-Dispatch
PD-INI	Pre-Dispatch Initialization
RT	Real-Time
RTE	Round-Trip Efficiency
SoC	State of Charge

Background

ERP's Storage and Hybrid Implementation Project is focused on developing an enhanced participation model for storage resources and co-located hybrid facilities. During the design phase, the IESO is first proceeding with the core 'Optimization' element within the 'Grid and Market Operations' module, which is a main precursor to design decisions to support other design modules and elements. The design elements under 'Grid and Market Operations' module clarify how the storage facility participates in energy and Operating Reserve (OR) markets. This includes what the IESO needs to dispatch resources and consider them in the optimization engine across all timeframes.

Phased Approach

The Storage and Hybrid Implementation Project is adopting a phased delivery approach to expedite and prioritize the implementation of essential functionalities, including:

- Bi-directional single resource model
- State of Charge (SoC) Management

As seen in **Figure 1**, subsequent design phases will implement:

- Regulation service
- Uplift exemptions
- Any required enhancement resulting from Phase 1 implementation

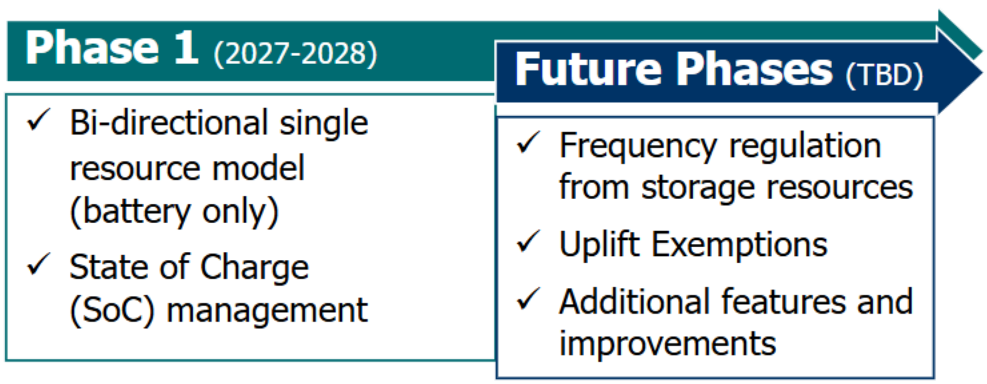


Figure 1: Project Scope

The IESO is targeting a 2027-2028 Phase 1 implementation date.

Scope of Impact for Phase 1

For Phase 1 of the enhanced market design, the IESO will focus on Battery Energy Storage Systems (BESS), i.e., resources that have the sole purpose of withdrawing electricity from the electricity system, storing that electricity, and re-injecting it into the electricity system. In subsequent phases, the IESO will consider the applicability of other types of storage technologies and potential nuances that could require additional/different parameters.

The IESO's focus is on single-site, dispatchable storage resources greater 1 MW. As registered facilities in the IESO-Administered Markets, each BESS facility should directly interface with the IESO and may be transmission or distribution connected.

This enhanced market design will support recent storage procurements, including the Oneida facility and those procured via Long-Term 1 (LT1) and Expedited Long-Term (ELT) procurements. Some of these BESS facilities are/will have achieved their Commercial Operation

Date before the enhanced participation model is live; the transition of these facilities to the enhanced model will be discussed with stakeholders at a later date. Further assessment is required for existing resources that have Energy Storage Facility Agreement (ESFA) contracts if they will be subject to the new storage design or will continue participating as with the foundational two-resource model in the IESO Administered Markets (IAMs) until their contracts expire.

Design Methods and Outcomes

Principles

The ERP market design principles guide decision criterion and help to verify the design meets the needs of the IESO and market participants. These principles were utilized for the Market Renewal Program (MRP) and were considered as part of the long-term vision for storage:

- Efficiency - Lower out-of-market payments and focus on delivering efficient outcomes to reduce system costs
- Competition - Provide open, fair, non-discriminatory competitive opportunities for participants to help meet evolving system needs
- Implementation - Work together with our stakeholders to evolve the market in a feasible and practical manner
- Certainty - Establish stable, enduring market-based mechanisms that send clear, efficient price signals
- Transparency - Accurate, timely and relevant information is available and accessible to market participants to enable their effective participation in the market
- Operability – Based on the decisions for this model, can the IESO plan/ forecast the operational needs of the grid, and continue to have the ability to manage the grid, without detriment

Method

The design and integration of storage will be organized in a 'build-to-bill' format called 'modules' (representing larger functions) and 'elements' (more specific functions within a module). The build-to-bill modules and elements are specific to the market participant and IESO processes to bring new resources onto the grid and facilitate their participation in markets and services. Design modules and elements will be engaged on based on project dependencies and priorities (i.e. not in a chronological format regarding a typical build-to-bill decision-making process).

The first and most complex design element that will drive all other design is the Optimization element.

Optimization Element

Figure 2 shows the scope of Phase 1 of the Storage and Hybrid Integration Project, with the focus of this design memo on the 'Optimization' design element for storage.

The IESO is first proceeding with the 'Optimization' element within the 'Grid and Market Operations' module, which is the core design element and a necessary precursor to design decisions to support other design modules and elements. The design elements under 'Grid and Market Operations' module clarify how storage resources participate in the IAMs within energy and Operating Reserve (OR) markets or other functions that support the reliable operation of the grid. The Optimization element explicitly deals with the requirements needed by the IESO's calculation engines across all timeframes - Day-Ahead (DA), Pre-Dispatch (PD) and Real-Time (RT) - to be able to effectively dispatch resources

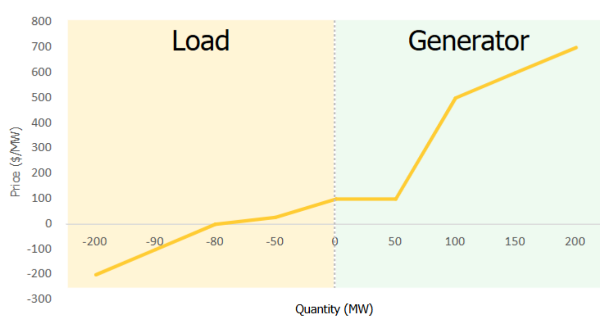
	Design Module	Design Element
Batch 1	**Grid and Market Operations**	• Optimization (Energy & Operating Reserve)
Batch 2	**Connection and Registration**	• Connection Assessment and Approval • Market Registration
	Grid and Market Operations	• Dispatch Data and Other Inputs • Operations Integration
	Market Power Mitigation	• Ex-Ante • Ex-Post
	Settlements	• Market Settlement
	Contracts	• Contract Impacts
Batch 3	**Hybrids**	• Market rules need to be adjusted for the co-located hybrid model with the integration of the new storage model

Figure 2: Market Design Modules in Phase 1

Outcomes of Optimization Design

The anticipated outcome of the Optimization design is the cost-effective use of battery storage resources to support system reliability, utilizing the unique capabilities of storage. The outcomes of optimization will support key decision-making across all other design elements and modules. The optimization design will implement its key decisions through:

- **A Single Resource Model** – The IESO will implement a single-resource model for energy storage which means that the load (withdrawal/charging) and generation (injection/discharging) aspects of the storage resource will be modeled as a single resource. Specifically, the IESO will implement a 'bi-directional generator model' meaning that a single resource can provide positive MWs, as an injection, and negative MWs, as a withdrawal. The single-resource model will be utilized by the IESO's optimization tool, the Dispatch Scheduling Optimization (DSO) tool and other supporting tools. **Figure 3** shows an example of a bid-offer curve of a hypothetical battery storage resource.



Example: Capacity 200 MW, Energy Limit 800MWh

Figure 3: Example Bid-Offer Curve for a Storage Resource under the Single Resource Model

State of Charge (SoC) Management – SoC information will be collected, initialized, calculated, and incorporated as a constraint into the optimization processes for all market timeframes, namely, Day Ahead Market (DAM), Pre-Dispatch (PD) and Real-Time (RT). Seamless SoC management will support feasible scheduling & dispatch, and the IESO's awareness of the storage's operational capability. To verify SoC across the different engines and passes the IESO will utilize various estimates or telemetered values.

Optimization Background

Optimization refers to the process of making something as efficient as possible, improving performance, and achieving the best possible outcome. More specifically, in the case of a wholesale electricity market, optimization functions to maximize the gain from trade, which is the difference between the value to consumers of the electricity consumed and the cost to suppliers of electricity. The IESO optimizes its system using three calculation engines, Day-Ahead Market (DAM), Pre-Dispatch (PD), and Real Time (RT) to achieve economic dispatch. The IESO uses resource data inputs, future-looking and RT operating conditions to optimize the grid. The IESO's calculation engines set the schedules, economic dispatch, and Locational Marginal Prices (LMPs).

Optimization Process

Not only does the IESO optimize over different time periods, but it also must optimize between markets while respecting various other commitments for services. The IESO co-optimizes between energy and OR, where it simultaneously determines the most optimal set of resources to be utilized in both energy and OR markets.

Figure 4 shows the overall optimization execution process where the calculation engines receive inputs from the market participants and from other internal tools to produce schedules, prices, and commitments.

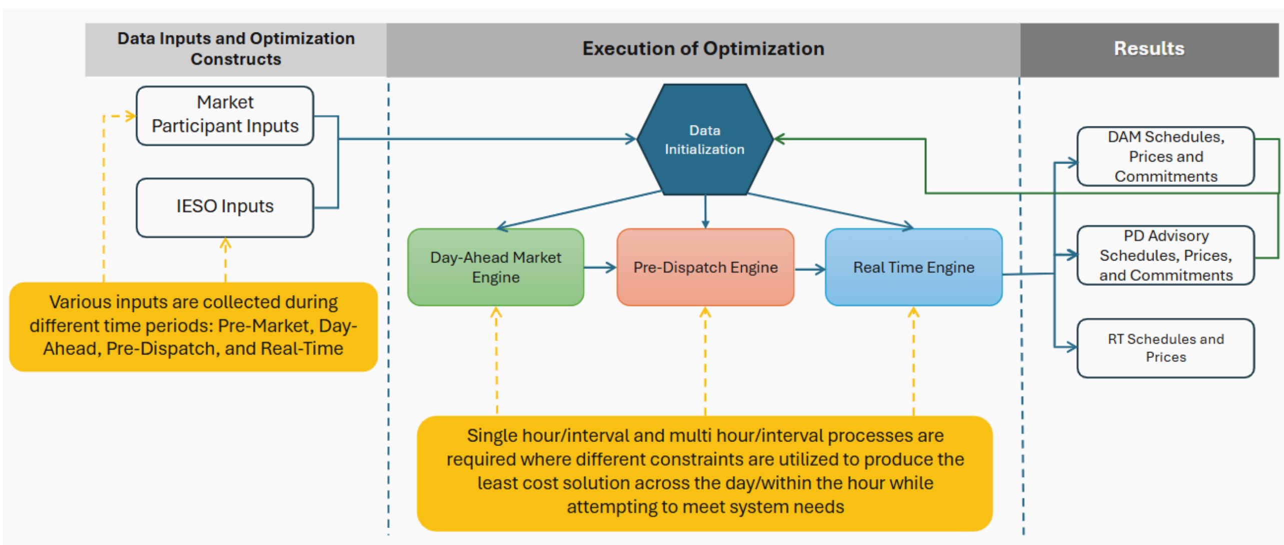


Figure 4: Optimization Process

Optimization design decisions described are required across the following time periods:

- **Pre-Market** to understand impacts to premarket requirements that are needed to support optimization;
- **DAM** to collect relevant data, determine constraints that will impact hourly scheduling and produce DAM financially binding results;
- **PD** to collect relevant data, determine constraints that will impact hourly scheduling and produce PD advisory schedules and that may impact commitments; and
- **RT** to collect relevant data, determine constraints that will impact 5-min interval scheduling and produce dispatch instructions and LMPs that will eventually be used downstream settlement purposes.

High Level Storage Optimization Design Decisions

The following decisions for the Optimization design element of Phase 1 will be valid for providing Energy and OR services:

i) Storage will be able to participate in energy and OR from both the injection and withdrawal side of the resource, given that they have sufficient capability. Branching from withdrawal to injection within an OR offer will be permitted, under feasible circumstances.
   a. Optimization will include the entire offer range to schedule charging and discharging of storage resources for energy and OR. For energy, the offer curve will start from a negative quantity for charging and increase towards the positive direction for discharging. For OR, the offer will span from 0 MWs to positive MWs. OR offer quantities will never be negative because when the storage is discharging, it increases its MWs further to provide OR; and when it is charging, it must decrease its charging MWs or stop charging to provide OR.

ii) The IESO will utilize the following variables to set SoC constraints:
   a. SoC Tracker – a rolling total of SoC across hours or intervals,
   b. Initial SoC – PD estimate to the next dispatch day, or MP submitted
   c. Min/Max SoC limits – Max and min that a battery resource may be scheduled or dispatched to
   d. Internal Service Load – to track various facility loads that discount from the battery SoC calculation
   e. Cycle / round-trip efficiency – energy losses resulting from dispatching the battery; applied on withdrawals

Figure 5 shows the high-level information on impacts/design for storage resources across the day as well as within various calculation engines and processes.

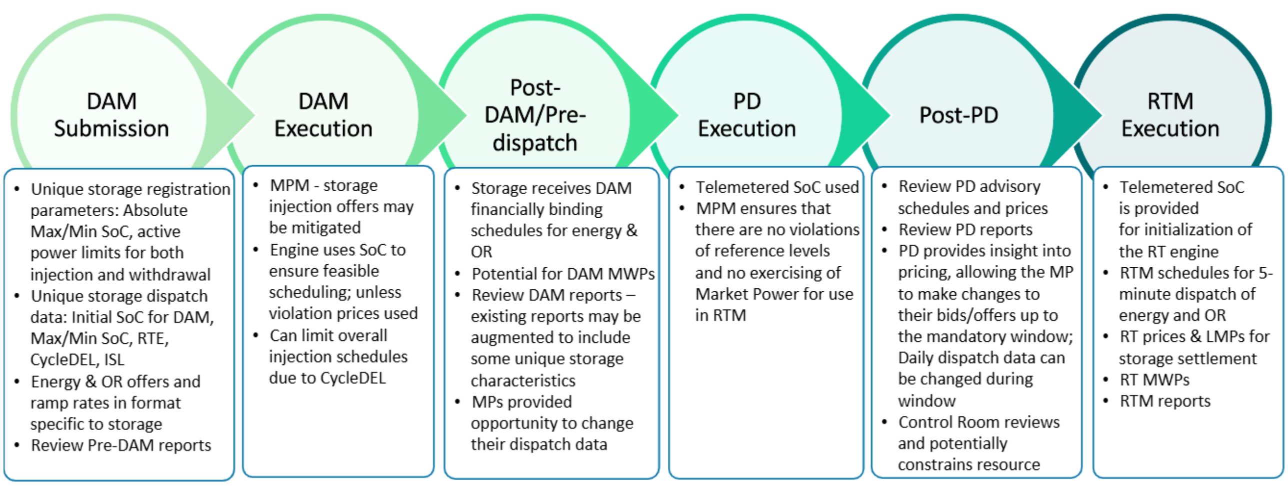


Figure 5: Storage-specific optimization process

Pre-Market

Many decisions within optimization are not necessarily made for specific engines but are general requirements that are impactful to all engines or to optimization generally. Pre-market decisions are focused on static input needs, meaning they do not change frequently, and consistent features applied to any of the engines. It also helps clarify general design requirements that must be collected or determined early in the process and can provide the additional clarity needed on how it will impact various IESO and MP value chains specified in subsequent design elements and modules.

MP Requirements

Below represents pre-market decisions related to the optimization design. Further assessments and refinement will be conducted in subsequent registration and connection design modules:

- **Registration** – Participant will register a facility as an 'Energy Storage Facility'; the IESO will then allow the participant to select the bi-directional generator resource model. This registration process will allow the resource the capability to branch from withdrawal to injection, represented as a single resource. This will require a consolidation of the generator and load requirements that were previously separated by these individual resource type. The process will consider the registration needs of both generator and load in aggregate.
- **Quick-start (QS) Generator Characteristics** – This new energy storage model will be classified as a quick-start generator that can produce positive or negative energy, as well as participate in reserves. This entails the same treatment within the calculation engines as existing quick-start resources, where: (1) there are no commitments made for schedules that carry forward into various scheduling timeframes and; (2) certain non-quick start parameters are not available, such as minimum loading point (MLP), minimum generation block run time (MGBRT), minimum generation block down time (MGBDT), thermal states, startup costs, lead time, ramp to MLP profile, etc.
- **Internal Service Load** – The IESO will request all storage MPs to provide the MW impact on the bi-directional generator resource from other facility operations such as station service and auxiliary load (if applicable), to ensure the accuracy of SoC calculations within the optimization engines. During registration, the Maximum Internal Service Load (ISL) parameter will represent the maximum hourly forecast impact on the SoC of the battery (in MW) to meet internal resource needs. It will account for the Auxiliary, Station Service, and any other marginal loads that are directly impact the resources SoC. For day-to-day operation, ISL will be a daily dispatch parameter representing the average estimated hourly MW draw on the batteries SoC to supply the same loads. ISL is considered in DAM and PD engine runs to ensure the resources are not overcommitted. The ISL is discounted from the SoC in the hourly SoC calculations. Please note, treatment of these loads is unique to each facility where different site configurations could impact various registration requirements which are outside the scope of optimization.
- **Commissioning of the new model** – When commissioning the resource, the resource will operate under a single resource model meaning that the IESO's online model requirements will apply, although the resource will participate as a self-scheduler during this period. There will be certain exclusions and requirements to support this period of the resource's operation and to adapt the self-scheduling model for the single resource model, these include:

- The resource will participate like a self-scheduling generator under existing requirements but utilizing negative generator characteristics. When injecting they will provide their self-schedule with a positive MW quantity, when withdrawing they will provide their self-schedule with negative MW quantity.
- LMP pricing will apply whether injecting or withdrawing during all time frames.
- SoC will not be modelled when entering self-schedules, the resource will manage these and must submit self-schedules that respects its own state of charge limitations.

For clarity, the IESO will need to develop a new self-scheduling model for commissioning of resources under the new bi-directional generator model. Existing storage resources that are currently operating under the two-resource self-scheduling model will not be impacted and the existing model will persist as-is.

Registration Parameters

In addition to energy and OR offer curves, the IESO is intending to utilize new and modified existing parameters to support feasible scheduling and dispatch of the resource. Static registration parameters are provided prior to DAM and are collected or set up within the registration phase for the market participant. Static registration parameters unique to storage and expected from the storage MPs during registration are as listed in **Table 1**.

Note - parameters whose 'Timeframe' is denoted as 'Registration / Daily Dispatch' are meant for registering default/initial or validation values where market participants have an opportunity to update them (within reasonable ranges and due to genuine causes) during DAM data submission as daily dispatch parameters. Additionally, like other daily dispatch parameters, they may be updated at any time and are not restricted by the mandatory window., If they are updated prior to a new engine run being initialized, the updated parameters will be utilized by the engine. **Table 1** below shows the daily dispatch data parameters used by the DSO to calculate sate of charge and enforce state of charge limits.

Table 1 – Registration Parameters

Parameter	**Unit**	**Timeframe**	**Definition**
Maximum Generator Resource Active Power Capability (PMax)	MW	Registration	Existing parameter for dispatchable generators, but in this case refers to the maximum active **injection** capability of the resource to validate the submission of offers for energy or Operative Reserves as dispatch data (note – MPs can use a combination of PMax and PMin for a lamination into OR; referred to as 'branching')
Maximum Negative Generator Resource Active Power Capability (PMin)	MW	Registration	The maximum **withdrawal** active power capability of the resource to validate the submission of offers for energy or Operative Reserves as dispatch data
Absolute MaxSoC	MWh	Registration	The maximum SoC availability of the battery that could be utilized by the IESO. Indicates the MWh max that

			the battery will ever be charged to. Generally needed access for maintenance. Value will be used to validate MaxSoC submission.
Absolute MinSOC	MWh	Registration	The minimum SoC availability of the battery that could be utilized by the IESO. Indicates the MWh min that the battery will ever be discharged to. Generally needed access for maintenance. Value will be used to validate MinSoC submission. Can be zero or another value as determined by MP.
Lower Energy Limit (MinSoC)	MWh	Registration / Daily Dispatch	The lowest energy amount that the electricity storage system can consistently be discharged beyond expected degradation from standard operation.
Upper Energy Limit (MaxSoC)	MWh	Registration / Daily Dispatch	The maximum energy amount that the electricity storage system can be consistently charged beyond expected degradation from standard operation.
Maximum Internal Service Load (ISL)	MW	Registration	The maximum amount of load consumed from the battery bank to service the resource. Expected to account for Auxiliary Load or Station Service Load that will impact IESO's SoC calculations; Submission should be a maximum value that will be utilized to validate ISL daily dispatch submission. ISL is only used in DAM and PD.
Cycle/Round-trip efficiency (RTE)[1]	% or decimal	Registration / Daily Dispatch	The ratio of energy discharged to the energy charged at the resource level. Applied at time of withdrawal and used to discount the SoC based on total efficiency losses to reinject energy at the resource. This should not account for ISL related items to avoid double counting impacting on SoC.

[1] Please note, this value does not correspond to RTE related to payment mechanisms in the procurements. This value is for the operation timeframe to appropriately account for losses on the SoC of the resource during the operational timeframe.

Data Monitoring/Telemetering Requirements

All facilities must comply with the applicable data monitoring requirements, which are listed in the IESO Market Rules (Chapter 0.4 Appendices, Section 4.24), and are used to ensure reliability of the grid by monitoring system conditions and resource response as well as to support DSO calculations. **Table 2** describes telemetry requirements for energy storage resources that should be available to the IESO on a continual basis, in accordance with the Market Rules.

Table 2 - Data Telemetering Requirements

Attribute	Units of Measure	Description	Note
Active Power	MW	1) MW (withdrawn or injected) on the low side of each transformer (dependent on the number of resources in the facility) 2) MW (withdrawn or injected) on the high side of each transformer (dependent on the number of resources in the facility) 3) MW telemetry from each feeder. For electricity storage facilities that have been aggregated, the standard requirement shall be provided as an aggregated total.	One value for active power injection and one for withdrawal (required for DSO and state estimator), net or gross depending on configuration relative to station service and auxiliary load.
Reactive Power	MVAR	1) MVAR (withdrawn or injected) on the low side of each transformer (dependent on the number of resources in the facility) 2) MVAR (withdrawn or injected) on the high side of each transformer (dependent on the number of resources in the facility) 3) MVAR telemetry from each feeder. For electricity storage facilities that have been aggregated, the standard requirement shall be provided as an aggregated total.	One value for reactive power injection and one for withdrawal (only for state estimator), net or gross depending on configuration relative to station service and auxiliary load.
State of Charge	MWh	The amount of energy available that can be injected into the grid. This is an existing parameter for storage resources currently participating in the IAMs; however, it is monitored in	To avoid discrepancy between scheduling / dispatch and actual SoC, telemetered SoC should account for all losses and reflect MWh that could be

		%. The unit of measure will be updated to be in MWh.	injected into the grid. In addition, this SoC should reflect any outages towards its energy capability, in other words it should offer a true reflection of available MWh as a result of outages or derates.

Outage Information

MPs must provide outage information that accurately reflects the operational capability of resources. This impacts the high operating limit (HOL) and low operating limit (LOL) of the resource. Currently storage resources can submit outages/derates for generation resources only. Outages will need to account for the capacity of the bi-directional generator for both the injection and withdrawal ranges. The IESO will allow the resource to submit information that would independently reduce either the injection or withdrawal capacity of the resource. Specifically, this will impact the high and low operating limits of the resource. For example, a storage facility rated at +/- 200 MW may submit a derate to the maximum capability down to + 185 MW impacting the HOL and at the same time submit a derate to the minimum capability up to -190 MW impacting the LOL.

IESO Inputs Impacted by the new Storage Model

IESO system inputs set the bounds for what the DAM engine needs to solve for and set system constraints to avoid operational issues from scheduling. Below are IESO data inputs impacted by the new storage model:

Fundamental Sets and Location Identifiers

Set of buses and delivery points within Ontario corresponding to bids and offers at locations on the IESO-controlled grid:

- Bus and Delivery Point Considerations - The IESO will model at a single delivery point and bus to support a single resource model. This is to ensure pricing is consistent whether injecting or withdrawing.
  - The IESO will utilize a generator bus and delivery point to support storage in the commercial model. As described above, the IESO will consider storage to be a 'bi-directional generator'; when injecting the resource is a "positive generator", and when withdrawing the resource is a "negative generator". Therefore, a generator bus and delivery point can be applicable and provide the single pricing location.
- Within a facility, there could be multiple resources. Each dispatchable bi-directional resource would be considered a "single resource" with injection and withdrawal capability, depending on the configuration of the facility.

Demand Forecasts

In DAM and PD, the IESO uses hourly average demand forecasts and hourly peak demand forecasts. In RT, forecasts represent actual total system consumption plus losses (actual demand). The IESO must ensure that demand forecasts and associated calculations accurately apply data related to a bi-directional generator when the resource is expected to withdraw.

Resource Minimum and Maximum Constraints

Constraints applied by IESO in IESO systems must allow negative and positive ranges of the resource to be constrained by the DSO.

- The IESO uses a tool to enter constraints on the resource to restrict the high and low operating limits of the resource:
  - Minimum, Maximum and Fixed constraints may be applied to storage resources in the injection and withdrawal ranges. In the withdrawal range a Max constraint will impact the high operating limit, and a Min constraint will impact the low operating limit. (For example, for a +/- 200 MW resource with a Max constraint of -50 MW and a Min constraint of -150 MW the generator may operate between -50 MW and -150 MW.)
  - Overlapping constraint rules remain unchanged.
- These changes also apply when an OR activation is set for the resource and must consider how branching will be implemented.
  - The IESO Control Room (CR) will set the minimum operating limit to the maximum injection range that is applicable to the OR offer.

Tie-Breaking Rules

When applicable and when scheduling storage, the standard tie breaking rules will apply (standard tie breaking for dispatchable generators/loads).

Market Power Mitigation

Reference levels and reference quantities are a set of mandatory registration requirements that the IESO determines in consultation with market participants. These are used to support the Ex-Ante, Settlement and Ex-post Market Power Mitigation (MPM) processes in the market. Ex-ante mitigation of financial dispatch data parameters takes place within the DAM and PD calculation engines. Initial decisions were made for ex-ante mitigation as it occurs within some of the optimization timeframes:

- Energy offers from the storage resource will be mitigated on the injection side only. There will be no mitigation on the load side of the energy offer submitted for consumption, except where necessary to support monotonic offer curves. For clarity, the IESO will ensure a mitigated offer meets non-decreasing price requirement across the entire range. This specifically entails ensuring that mitigated offers do not conflict in the withdrawal side of the offer curve and create non-viable offers for the engine to consider for scheduling. e.g., if a withdrawal bid overlaps with the first injection reference pricing, when mitigated, it will be reduced to $0.01 below the mitigated injection offer to ensure a monotonic offer curve.
- Generators and dispatchable loads are mitigated for providing OR on their OR supply offers for each applicable class of OR. Storage resources will have their OR supply offers mitigated, whether they are charging, discharging, or bridging an OR offer between withdrawal to injection. MPM will need to support the transition to the single resource model where existing storage resource OR reference level requirements will be adapted to a single resource model. Additional changes will be considered in subsequent implementation phases of the ERP. The IESO will review its OR reference level curve per class of OR for the single resource storage model to consider all methods that a storage resource could provide OR.

Violation Pricing

Below describes the constraint violation penalty curves that this resource model will utilize (specific penalty price to be determined).

- Typical violation pricing that are used in the network constrained unit commitment will apply to support the scheduling of the storage resource when they are necessary.
- For CycleDEL a similar approach for storage resources will be utilized as for existing hydroelectric resources (which use the MaxDEL constraint).
- A violation price will be utilized to bypass MaxSoC, MinSoC.
- A violation price to bypass when MaxSoC, MinSoC are set to Absolute MaxSoC and Absolute MinSoC will be set to a value higher than the standard MaxSoC and MinSoC values.

DAM

Overview

The DAM engine is the first of the three optimization engines that is run by the IESO. At a high level, all engines operate in the same manner where data comes in, is initialized, and run in one or more "passes" that comprise multiple steps to generate the results. As seen in **Figure 6**, DAM data inputs come from the Market Participants and IESO. MP inputs include static parameters from the registration process (described in the Pre-Market Section), dynamic dispatch data submitted by the MP, or outage information. The IESO's inputs incorporate the Pre-market data, in addition to relevant grid operational conditions used as constraints, various forecasts, and any other IESO-submitted resource constraints. Data is initialized and passed into three different passes to execute the optimization.

This execution of the optimization in DAM produces financially binding day-ahead schedules and day-ahead prices that are used for settling the financially binding schedules and setting commitment decisions for some resources that are required to operate efficiently.

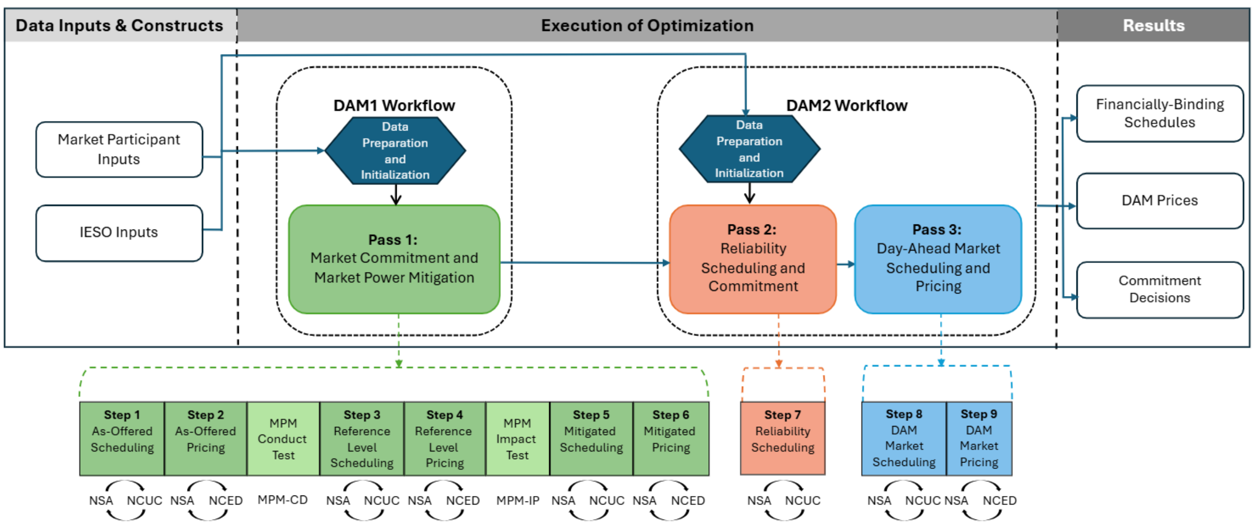


Figure 6: DAM Optimization Process

Optimization Initialization, Passes and Steps

The engines utilize passes and steps to execute the optimization. DAM utilizes three passes that support: the production of initial scheduling, initial commitments, assessing and implementing ex-ante mitigation, additional commitments to support reliability, and final scheduling and pricing. Below are the specific passes:

1. Market Commitment and MPM
2. Reliability Scheduling and Commitment
3. Scheduling and Pricing

Each pass has multiple steps to complete the objectives of each pass. These steps utilize functions such as algorithms, assessments, unit commitments, economic dispatches, conduct tests, and impact tests; all of which vary depending on the objectives of each step within the pass.

The following algorithms are generally utilized within various passes of all engines:

- **Scheduling algorithm:** Generates optimal solution for commitment statuses and schedules
- **Pricing algorithm:** Uses the commitment statuses and resource schedules from the scheduling algorithm to calculate LMPs

These require utilizing optimization functions the Network Constrained Unit Commitment (NCUC), Network Constrained Economic Dispatch (NCED), and a security assessment called the Network Security Assessment (NSA).

For engines that require MPM, there is the MPM Conduct Test (MPM-CD) and the MPM Impact Tests (MPM-IP). Conduct tests are done first where additional scheduling and pricing is done, then an impact test is conducted.

Figure 6 shows how these passes, and steps run with the various other functions in the DAM engine. Each subsequent calculation engine will show its unique requirements to produce their results.

The following sections describes the design decisions valid and relevant to MPs for the DAM timeframe. They are separated into the Data Inputs, Optimization execution, and Results sections.

Data Inputs

DAM Submission Window: 06:00 EPT – 10:00 EPT: MPs utilizing the bi-directional generator model can submit, revise or withdraw hourly and daily dispatch data without restriction. Offers can be standing offers, where the initial state of charge will be updated based on PD schedules.

Daily Dispatch Data Parameters

Table 3 shows the daily dispatch parameters specific to the new bi-directional storage model. Some parameters may be repeated from the 'Registration Parameters' section as the MPs can override them.

Table 3 - New Bi-Directional Generator Daily Dispatch Data Parameters

Attribute	**Unit of Measure**	**Description**	**Note**
ISoC *Initial State of Charge*	MWh	Represents the total forecasted state of charge, which corresponds to the amount of MWh available to inject into the grid.	Optional submission used by DAM only. IESO will utilize the last available PD forecast prior to the end of bid submission window if nothing submitted by the MP. If submitted it should not include any ISL reductions.
RTE *Round-trip Efficiency*	% or decimal value; TBD	A multiplier applied to withdrawals used to update the calculated state of charge;	Optional submission. Supersedes the default registered RTE

		Represents the combined injection and withdrawal efficiencies.	value when submitted.
MaxSoC *Maximum State of Charge*	MWh	The maximum energy amount to which the electricity storage system can be consistently charged without damage beyond expected degradation from normal use.	Optional submission. Supersedes the default registered MaxSoC value when submitted. Can enter up to Absolute MaxSoC.
MinSoC *Minimum State of Charge*	MWh	The lowest energy amount to which the electricity storage system can be consistently discharged without damage beyond expected degradation from normal use.	Optional submission. Supersedes the default registered MinSoC value when submitted. Can enter to the Absolute MinSoC
ISL *Internal Service Load*	MW (to one decimal place)	The average estimated hourly MW draw on the batteries SoC to supply its auxiliary load or other service loads. This discounts the calculated SoC at the beginning of each hour.	Optional submission between zero and the maximum ISL submitted during registration.
CycleDEL *Cycling Daily Energy Limit*	MWh (to one decimal place)	The maximum amount of daily injections that may be scheduled for energy across all hours and for feasibility on OR scheduled from the injection side. To assist the MP to avoid over cycling their battery if deemed necessary to avoid degradation.	Optional submission used by DAM and PD. In the absence of a submission the default value will be 99,999.0 (consistent with Max DEL). CycleDEL is not utilized in RT to restrict dispatch and scheduling.

- Initial State of Charge (ISoC)
    - Pass 1 and 3 – PD populated/ MP submitted -– the DAM engine will utilize the last valid PD run prior to DAM submission window closing. This will pull the HE24

SoC which will then be adjusted to the hour ending SoC based on the schedule of HE24. This value denotes the estimated state of charge in MWh of the battery resource that they must inject into the grid and will be used as the initial value for scheduling of the first hour in the DAM. The expectation is that this would be similar to what the IESO would telemeter from the resource. The market participants can override this value during the DAM offer submission window, where they can provide their own estimate with the assumed SoC they will have at the end of the previous dispatch day and expected initial value for their dispatch data in DAM.
    - Pass 2 – the IESO will only utilize the SoC from the PD advisory schedule as described above.
- Internal Service Load (ISL)
    - Considering that the calculation methodology for station service and auxiliary loads varies significantly according to several factors (e.g., season, temperature, aging), the IESO requests market participants to submit an 'internal service load' parameter information to support MPs not having to include it in the Round-Trip Efficiency (RTE) calculation and to support an accurate SoC calculation. This is an estimate from the MP and will be subtracted from each hour's SoC at the beginning of each hour. MPs are expected to change this value if they determine a different draw on the batteries SoC as a result of various ISLs.
- Cycling Daily Energy Limit (CycleDEL)
    - This will be entered as a daily dispatch parameter. There will not be any restrictions in increase or decrease of this value.
- MaxSoC
    - Enter a MaxSoC up to its Absolute MaxSoC.
    - When submitting a high MaxSoC that could limit the MPs to comply with dispatch, it should be scheduled with the IESO i.e. due to foldback and to perform maintenance. When submitting a lower MaxSoC up to a certain threshold (to be determined by the IESO), the IESO will request MPs to inform the IESO to verify this entry. The IESO will provide further details in later design elements on how this process will be implemented, and the thresholds / conditions that will require such requirements.
- MinSoC
    - Enter a MinSoC up to its Absolute MinSoC.
    - When submitting a low MinSoC that could limit the MPs to comply with dispatch, it should be scheduled with the IESO, i.e. due to foldback and to perform maintenance. When submitting a higher MaxSoC up to a certain threshold (TBD by the IESO), the IESO will request MPs to inform the IESO to verify this entry. The IESO will provide further details in later design elements on how this process will be implemented, and the thresholds / conditions that will require such requirements.

Figure 7 below depicts the design for min/max SoC limits, assuming an 800 MWh battery.

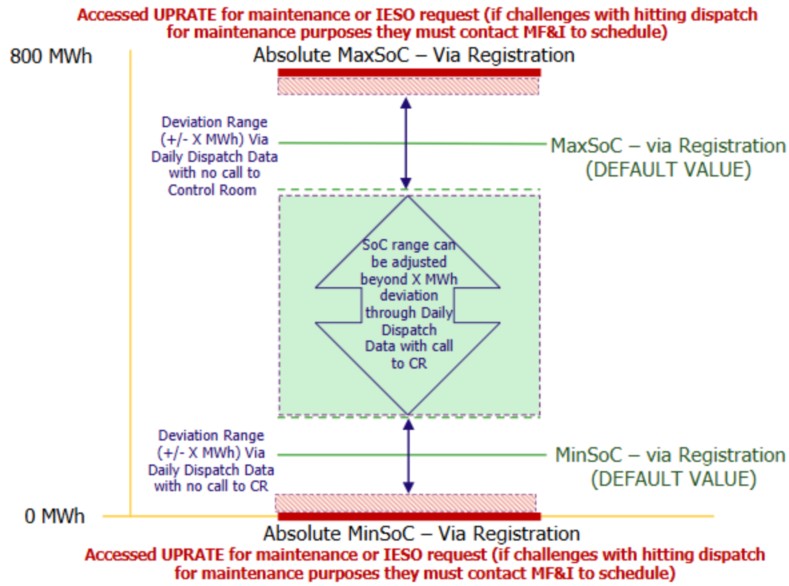


Figure 7: Design for minimum and maximum State of Charge limits

Hourly Dispatch Data Parameters

Hourly Energy Dispatch Data Parameters:

- Energy Offer:
  - Currently, resources are allowed to submit between 2 to 20 price-quantity (P-Q) pairs ($/MW) for energy, which will continue to be the case for storage resources. The unique feature of an energy offer curve for single-resource storage model will be that it will be a single continuous offer curve, representing both offers for charging (withdrawal) and for discharging (injection).
  - The first lamination for the storage participant's will indicate the largest MW quantity withdrawal, utilize a negative MW value, as well as have their lowest (highest in the negative direction) price in $/MW as the part of the same lamination. Each subsequent lamination will have a monotonically increasing MW quantity, and a monotonically non-decreasing $/MW price. After expressing all withdrawals, the participant must enter a zero MW quantity to denote the cut over point to injections, which will share the same $/MW value as the participants next injection lamination (the lowest price the market participant is willing to accept for an injection). Each injection will be denoted by a positive MW quantity and will also have monotonically increasing MW quantities and monotonically non-decreasing prices in $/MW. If just withdrawing, the curve goes from the largest withdrawal to zero. If just injecting, it starts at zero and goes to highest injection capability they want to express in the market.
    - The existing offer requirements for dispatchable generators that may not apply for a storage offer curve are: i) The first quantity must equal 0.0 MW. ii) Prices on the first and second price-quantity pairs must be the same.
  - Accounting for Station Service and Auxiliary Load – There should be minimal to no error between how a resource is being dispatched, what response the IESO sees onto the grid (via the resource's telemeter), and how the IESO should add or subtract from the state of charge of the resource.

    - ADE based on the MPs' energy offer - Energy storage resources will continue to be subject to ADE requirement. The ADE is the hourly injection or withdrawal capacity offered day-ahead for dispatchable resources. Energy storage resources must submit their maximum injection, and maximum withdrawal offers to fully utilize that range in PD and RT through their continuous offer.

Table 4 - Example of Energy Offer Laminations

Example Energy offer with 9 laminations				
P/Q Pair	Price ($/MW)	Quantity (MW)	Price to Schedule ($/MW)	MW that could be scheduled
Pair 1	-200	-200	-200 or less (more negative)	Withdrawal 90.1 to 200
Pair 2	-100	-90	-199.99 to -100	Withdrawal 80.1 to 90
Pair 3	0	-80	-99.99 to 0	Withdrawal 50.1 to 80
Pair 4	25	-50	0.01 to 25	Withdrawal 0.1 to 50
Pair 5	100	0	25.01 to 99.99	Idle
Pair 6	100	50	100 to 499.99	Inject 0.1 to 50
Pair 7	500	100	500 to 599.99	Inject 50.1 to 100
Pair 8	600	150	600 to 699.99	Inject 100.1 to 150
Pair 9	700	200	700	Inject 150.1 to 200

    - In the example shown in **Table 4**, the MP submits 9 laminations. The MP is showing a maximum withdrawal capability of 200 MW (denoted by the -200 MW quantity) and a maximum injection capability of 200 MW (denoted by the +200 MW quantity). The MP will be able to provide up to these values in PD and RT as per the ADE requirement. The zero quantity in the laminations is indicative that this market participant will not be scheduled economically between market prices of $25.01 to $99.99. Their withdrawals will start at a $25/MW market price, and their injections will start at the $100/MW market price.
    - Generation without Offer - If the resource does not enter any offer, the generator will be assigned a value of zero MW based on the assumption that the generator is offline and will not be charging nor injecting.
- Energy Ramp Rate
    - Energy ramp-up rate will refer to increasing generation or decreasing withdrawal (MW moving in the positive direction) and will be validated against registered energy ramp rate Non-Financial Reference Levels (NFRL).
    - Energy ramp-down rate will refer to decreasing generation or increasing consumption (MW moving in the negative direction) and will be validated against registered energy ramp rate NFRL. **Figure 8** depicts the energy ramp-up and ramp-down rates.
    - The IESO will look to set a 100 MW/Min max requirement on its ramp rate to be utilized by storage resources for injection and withdrawal when scheduled for energy. Although this value will be entered at a resource level, based on current precedence the IESO expects storage facilities operate their resources in combination no higher than 100 MW/min.

- Note: This 100 MW/min requirement will support more stable grid performance and supports SoC calculations throughout the different engines.
    - The MP is not required to adhere to the 100MW/Min max ramping requirement when activated for OR, frequency excursions, voltage changes, or equipment protection operations including Remedial Action Scheme (RAS) runbacks.
    - MPs can submit up to 5 ramp rates that are equal to or below 100 MW/Min.

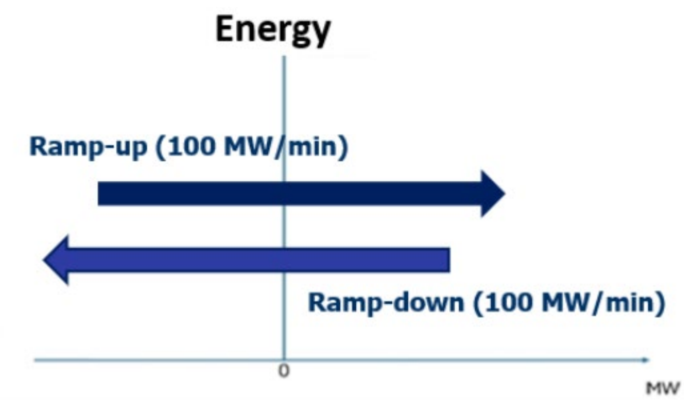


Figure 8: Energy Ramp Rates Design

Hourly OR Dispatch Data Parameters:

- Operating Reserve Offer
    - OR offers will primarily be consistent with other resource types where:
        - Participants are allowed to submit between two to five P-Q pairs / laminations for each class of operating reserve (10S, 10N, 30R) for each dispatch hour with their OR MW quantity and $/MW price.
        - OR offer is always either 0 or positive for MW quantities.
    - Storage resources can offer the full operating range of the storage resource as a net positive value. Specifically, this means that they can submit a combination of the absolute values of the withdrawal MW range and injection MW range as a single lamination into OR. This will support the resource in providing an OR activation by reducing charging and then immediately discharging; referred to as "branching".

Table 5 - Example of Operating Reserve Offer Laminations

Example OR offer with 5 laminations		
P/Q Pair	Price ($/MW)	Quantity (MW)
Pair 1	0.1	0
Pair 2	0.1	50
Pair 3	5	80
Pair 4	10	200
Pair 5	10.01	400

- The above example in **Table 5** has 5 laminations where the first OR offer is 50 MW and the last offer is 400 MW. If correlated to the MP's energy offer in the previous energy offer example, the MP submitted a -200 MW and +200 MW quantity offers into the market. This 400 MW OR offer accounts for the resources capability to be consuming for 200 MW and immediately provide injection capability of 200 MW if activated. To simulate this action the MP would stop their consumption and immediately inject the 200 MW for a 400 MW swing of response.
- The optimization engine will determine the correlation between energy offers and OR to support co-optimization efforts due to OR offers expressing withdrawal, injection, and branching opportunities.

- OR Ramp Rate (MW/min)
    - Design for storage will be consistent with other resources where only one value is permitted.
    - It will be validated against registered OR ramp rate NFRL.
    - Unlike energy ramp up/down rates, the OR ramp rate will not be limited by the 100 MW/Min requirement but must respect the resource's registered maximum ramp rate value, as depicted in **Figure 9**.

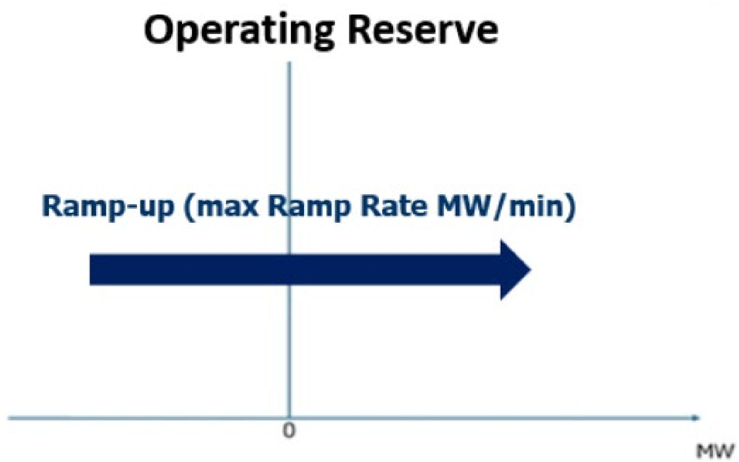


Figure 9: Operating Reserve Ramp Rate Design

- Reserve Loading Point:
    - This denotes the minimum generation level in MW at which a resource associated with a dispatchable generation facility can provide the maximum operating reserve of the class of operating reserve being offered.
    - A reserve loading point must be zero for a single resource model. This will accommodate the resource providing OR from a static state, the complete operational range of the resource (withdrawal to injection), while injecting, or only withdrawing.

Optimization Execution

Single-hour and multi-hour processes are required where different constraints are utilized to produce the least-cost solution across the day while attempting to meet system needs.

Single Hour Constraints:

- The bi-directional generator will be able to operate at any level between their HOL and LOL. There will be no forbidden regions applied to the resource. When dispatched to 0

MWs, the resource is expected to not be operating/providing energy/withdrawing from the grid but can be scheduled for OR up to the HOL and depending on the various limiting factors described in this section. The HOL and LOL is based on:

  - Offer quantities – a resource's schedule will not exceed offer quantities submitted by the market participant through their dispatch data for energy and cannot exceed the combination of the absolute values of max withdrawal quantity (the largest negative offer) and the max injection quantity (the largest positive number).
  - Derates - The market participant can submit a derate on their maximum injection or withdrawal capability and scheduling will not exceed these limits.
  - Constraints entered by other IESO systems and tools that feed into the DSO. The IESO shall be able to submit Min/Max or Fix constraints in the positive or negative range of the resource. This can be entered in one hour or multiple hours.

- The above can be further constrained by:
  - CycleDEL – This could limit the schedule based on the availability of the daily energy limit value. The market participant cannot be scheduled beyond this limit on the injection side only, unless Violation Pricing is utilized. This will apply for each hour and over the entire multi hour scheduling. CycleDEL should not impact scheduling the resource for withdrawals.
    - E.g. A resource that is economic to inject up to its HOL of 200 MW but with a remaining CycleDEL of less than 200 MWh will be limited by the CycleDEL for both energy as well as operating reserve scheduled in the injection range.
  - Ramp rate – ramp can constrain a schedule like other quick start resources. For schedules that will utilize branching the resource, where it will utilize both withdrawal and injection capability of the resource for energy and OR; when withdrawing it will be limited by ramp for energy schedules like other quick start/dispatchable load resources. For OR the amount of 10 min or 30 minute operating reserve cannot exceed the amount by which the resource can decrease and then increase its output over 10 or 30 minutes, as limited by its operating reserve ramp rate which is indicative of a positive swing (moving in the net positive direction from the negative withdrawal, to the positive injection).
  - State of charge/ Min and Max SoC, where they must be scheduled within these limits. Unless violation pricing is utilized the SoC can reduced by:
    - RTE - losses submitted by the MP. This will be applied only on the withdrawals, even though it accounts for all losses from withdrawing and injecting.
    - Internal Service Load – SoC will be discounted by the ISL estimate that was submitted by the MP at the beginning of each hour. This is required prior to any additional SoC related calculations.

- Additional SoC Considerations:
  - Energy (no reserves scheduled)
    - In any given hour, a storage resource's SoC, considering its energy schedule for the hour, should always be less than or equal to its maximum energy storage capacity and greater than its minimum energy storage capacity.
    - The SoC capability must ensure that the resource can feasibly provide energy for the full hour scheduled for injection or withdrawal. The highest

economic energy offer will set the initial limit unless SoC is not available for injection or SoC is too high to support a withdrawal for a full hour based on this offer, they can be scheduled for the max of their SoC/energy capability for the hour (i.e. if SoC available is 100 MWh, they but their power capability is 200 MWs the resource is available to only inject 100 MWs for the hour). For injection, this will be SoC availability up to the Min SoC, for withdrawal this is difference between the Max SoC and existing SoC.

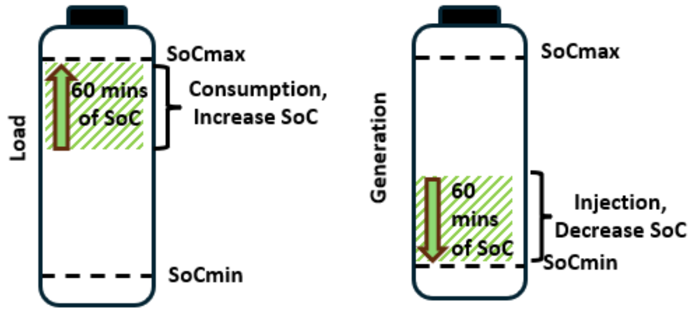


Figure 10: SoC requirement for energy in DAM

- Operating Reserve (no energy schedules)
    - OR-only schedules can only be achieved by the injection capability of the storage resource. Therefore, to provide OR only the resource must have a zero-energy schedule and to achieve the OR activation it would require the resource to inject energy to the grid.
    - As there is no energy schedule, the expectation is that a storage resource can have their OR schedule limited to a value to ensure 60 mins of SoC availability and this value cannot exceed the MinSoC. This is to simulate the ability to have an OR activation that can be met at any point over the hour without bypassing the lower SoC limit set by the MP.

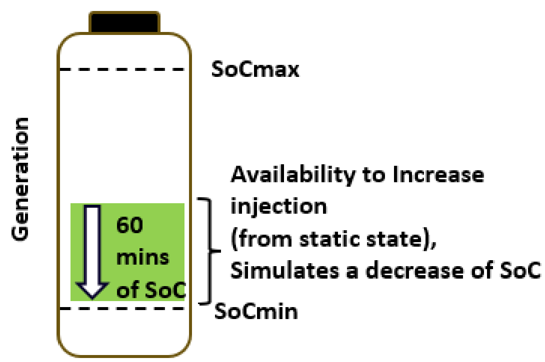


Figure 11: SoC requirement for OR in DAM

- Energy and Operating Reserve Schedules
    - Withdrawal based energy and OR - To be scheduled to consume energy it must ensure the resource's schedule can receive energy/can consume for a 60 min period without bypassing the MaxSoC of the resource. OR is provided by reducing consumption, therefore will not exceed what can be consumed over a 60 min period; same limit as energy withdrawal
    - Injection based energy and OR – to be scheduled to inject energy it must ensure that resource's schedule is capable of injecting energy for 60 mins

as well as have a further 60 mins of stored energy to simulate an incremental increase in energy from an OR activation, in addition to not exceeding the SoC Min.

- Withdrawal based energy and branching OR – To be scheduled to consume energy it must ensure the resource's schedule can receive energy/can consume for a 60 min period without bypassing the MaxSoC of the resource. OR is provided by reducing consumption and then immediately injecting (branching from withdrawal to injection), therefore will not exceed what can be consumed over a 60 min period, which is same limit as energy withdrawal, but must also have a 60 minute of injection capability without exceeding the MinSoC. The energy schedule is limited to this withdrawal capability, and the OR schedule is limited to both the withdrawal and injection requirements stated.

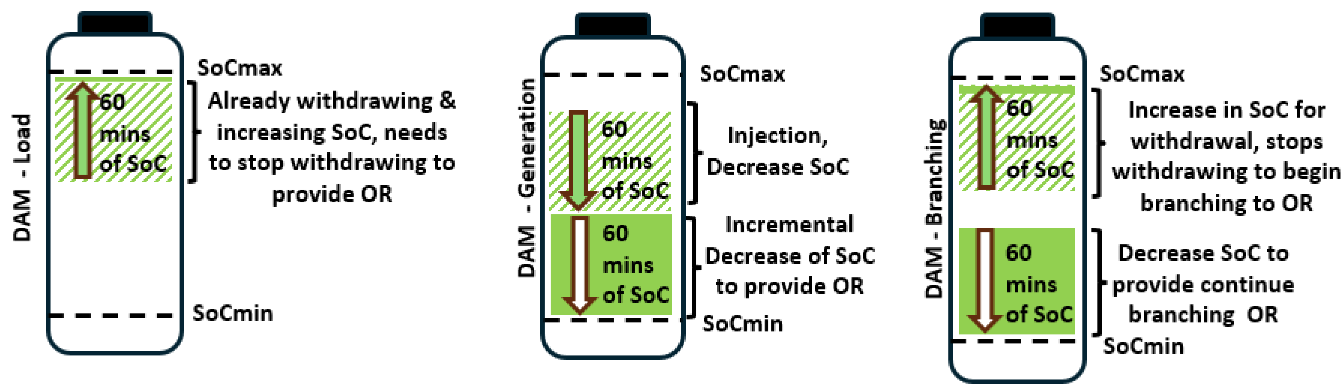


Figure *12*: SoC requirement for energy and OR in DAM

- Energy and OR Joint Optimization Considerations
  - Energy offers and OR offers will be co-optimized. OR offers will only be scheduled if the corresponding energy offers will promote a feasible action by the MP. In other OR quantities must be achieved by having the corresponding energy MW schedule, a specific example is branching in OR, where the MP must be scheduled to withdraw by a certain MW quantity to enable this action.

Figure 10, **Figure 11** and **Figure 12** depict the SoC requirements in DAM of a battery while providing energy only, OR only, and co-optimized energy and OR, respectively.

Results

Results for the resource in DAM include typical financially binding DAM schedules for energy and OR, based on LMPs. In addition, the IESO has made the following decisions that will impact the results:

- Since storage is being modelled as a QS generator, storage will not receive commitments.
- Price setting eligibility:
  - Bi-directional generator resources with a binding CycleDEL, will have their price-setting eligibility requirements treated the same as energy limit resources with a binding MaxDEL.
  - When scheduled up to the Max/MinSoC will also limit a resource's ability to set prices.

    - The same price-setting requirements should be leveraged for bi-directional generator resources as other resources on the following constraints:
        - Ramping Constraints
        - Manual Constraints applied by the IESO (via contract manager) or from derates submitted by the MP (via CROW)
- Make Whole payments will be determined in upcoming settlements design module.

Pre-Dispatch

Overview

The Pre-Dispatch engine is the second of the three engines that is run by the IESO and is run once every hour. Data inputs come from the Market Participants, the IESO, and commitment decisions from the DAM engine. MP inputs are static parameters from the MP from registration (described in the Pre-Market Section), or dynamic dispatch data submitted by market participant. The IESO's inputs incorporate the Pre-market data inputs, in addition to relevant grid operational conditions, various updated forecasts, as well as real time operational telemetry from relevant market participants. After the initialization is done, these inputs are integrated into the specific pre-dispatch hours and input into the singular pass of the pre-dispatch engine to execute the optimization. This execution of the optimization in pre-dispatch produces advisory schedules and prices for market participants to plan their operations and the IESO to plan the grid for the future hours; it also includes schedules for intertie resources 1 hour prior to real time, as well as preparing and scheduling hourly demand response resources; finally the PD engine also produces additional commitment decisions needed for specific resources to prepare their operations for real time.

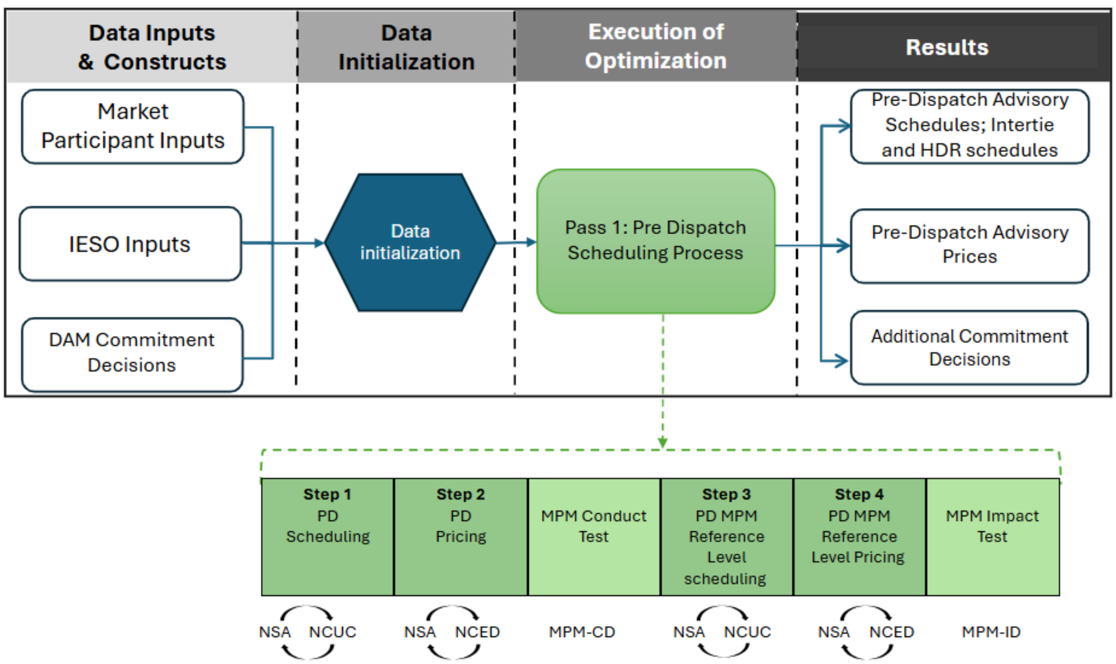


Figure 13: Pre-Dispatch Optimization Process

Optimization Initialization, Passes and Steps

There is a significant data initialization phase conducted for this engine. This is referred to as Pre-dispatch initialization (PD-INI), where it the initialization process requires a simulation of the RT hour; mimicking a RT-MIO calculation engine. This estimate could be different than the RT-MIO engine as they are run considering slightly different information. PD-INI runs 7-minutes before Pre-dispatch at xx:55, calculates resource initial schedules for the hour preceding the Pre-dispatch study period, and uses the output to determine the Pre-dispatch initial conditions.

There is only one pass in the PD engine. Meaning that within the steps of this single pass there is the scheduling, pricing, and MPM. Like DAM, for each scheduling/pricing step during PD execution, the NSA and NCUC/NCED functions iterate until convergence and MPM conduct test and impact test ensure that there are no violations of reference levels and no exercising of Market Power. Real-Time Multi-Interval Optimization (RT-MIO) engine uses mitigated-for-impact offers produced by the PD engine. **Figure 13** shows how these passes, and steps run with the various other functions in the PD engine.

Considering that DAM's first pass and PD's only pass have similar steps, and both are hourly, much of the relevant information collected from the MPs, the IESO and the DAM engine requires the same design to consider storage in the PD engine. The below information provides the relevant differences in design from DAM.

Data Inputs

- Initial State of Charge
    - No longer will be an MP submitted estimate, but will utilize the last telemetered SoC prior to the start of the PD engine run to set the initial value
- The MP can update their daily dispatch data at any point; and will be utilized in the PD run if entered prior to the engine starting its run. This specifically includes the Min/MaxSoC; RTE, ISL, and CycleDEL.
- Offers:
    - The MP will be subject to the mandatory window, where updates are limited to PD-2 (two hours prior to RT).
    - Availability Declaration Envelope (ADE) Based on the MPs' energy bid and offer - The MP will not be permitted submit any laminations that will exceed the max and min MW quantities in their offers that were submitted in DAM. I.e. if submitting a 200 MW injection offer and a -200 MW withdrawal offer, they will not be able to submit an injection offer in excess of 200 MW, or withdrawal below -200 MW.

Optimization Execution

- PD-Initialization – the initial value is the telemetered SoC but PD-INI does not use this value directly since bi-directional storage facilities are by default energy limited by CycleDEL and SoC. As a result, the initialization of these parameters will follow similar methods as MaxDEL where it will take schedules based on the average of the RT-MIO advisory schedules to reduce the CycleDEL and either add or subtract from the SoC. In addition, considering CycleDEL is not enforced in RT, it will not be enforced in the initialization so that the starting value for PD-1 (one hour prior to RT) is as accurate as possible with the best available information.

Results

- Like most other resources, storage will receive advisory schedules and forecasted LMPs.
- Storage is being modelled as a QS generator; therefore, they will not receive commitments from PD decisions. Considering that there are no commitments and PD produces advisory decisions, this can result in the IESO taking actions, as required, to ensure that the energy limitations of storage are managed, and so that there is resource availability for situations the control room deems necessary. Make whole payment considerations of these actions will be discussed in the settlement module of the Phase 1 design.

Real-Time

Overview

The real-time engine is the third of the three engines that is run by the IESO. Data inputs come from the Market Participants, the IESO, and commitment decisions from the DAM and PD engines, and the pre-dispatch intertie schedules (from PD-1). MP inputs are static parameters from the MP from registration (described in the Pre-Market Section), or dynamic dispatch data submitted by market participant which were submitted prior to the mandatory window during pre-dispatch (PD-2 specifically).

The IESO's inputs incorporate the Pre-market data inputs, in addition to relevant grid operational conditions, various updated forecasts, as well as real time operational telemetry from relevant market participants. Data is initialized where it is adapted for specific intervals and input into one pass to execute the optimization. This execution of the optimization in real-time produces real-time dispatch schedules for the next interval, and advisory interval schedules for the next 11 intervals. This also includes prices for each interval at each location.

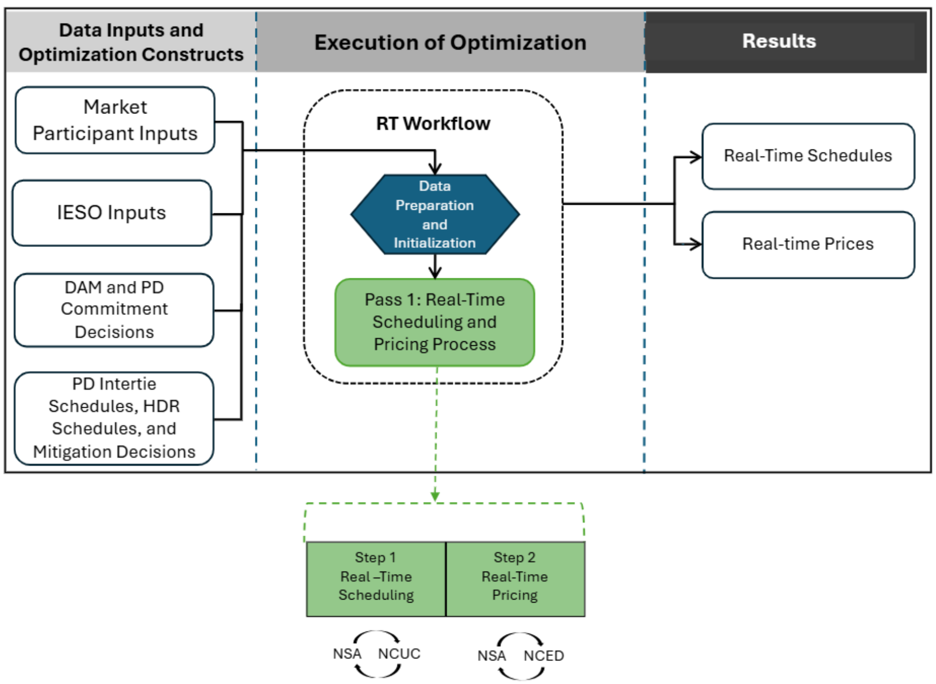


Figure 14: Real-Time Optimization Process

Optimization Initialization, Passes and Steps

The initialization is focused on the next 5-minute intervals and the immediate study horizon of the engine. Some initializations must happen to account for the previous 5 min dispatch that occurred. Many inputs are also created during the PD timeframe and used as initial information.

The RT engine is composed of a single pass, Real-Time Scheduling and Pricing, that calculates both dispatch schedules and LMPs, utilizing the same algorithms as the DAM and PD engines. **Figure 14** shows how these passes, and steps run with the various other functions in the RT engine. The first step isa scheduling step that finds the optimal resource dispatch schedules and the second step is a pricing step that calculates the LMP for each interval. Similar to DAM and

PD, for the scheduling step, the NSA and NCUC functions iterate until convergence and for the pricing step, the NSA and NCED functions iterate until convergence.

RT execution engine collects relevant information that is utilized to produce 5-minute dispatch schedules and prices that will eventually be used additional settlement purposes.

This section discusses the incremental changes that are required for the RT engine. From a storage MP's perspective, RT requires that they prepare for physical dispatches and other actions required by the IESO to support reliability. Many of the actions outside of this requirement are generally the same. The RT engine considers offers that were submitted during PD prior to the mandatory window. Although offers are hourly, they are utilized for the 5 min interval dispatches and advisory schedules.

Data Inputs

- CycleDEL - will not be used to constrain the resource of its scheduling in RT. MPs are responsible for having their dispatch data submitted in a way that can support limitations in operation.
- Internal Service Load (ISL) – this estimate will not be utilized by the RT engine to account for service loads that would impact the bi-directional generators SoC. This is because the IESO will collect telemetered SoC for each run of the RT engine, therefore this will avoid potentially double counting service load.
- Other daily dispatch parameters that have been submitted prior to any run of the RT engine, and pass validations in MIM, must be applied.
- Will utilize telemetered SoC to constrain the resource. It will take the latest telemetered value prior to any run in the RT engine.
- RT-MIO engine will use mitigated for impact offers produced by the PD pre-process module.

Optimization Execution

- Storage resources that are economic in RT intervals will be dispatched regardless of their DAM or PD schedules as it does not have any commitments
- Initialization of the SoC - RT-MIO uses the telemetered state of charge (SoC) and will calculate the interval ending SoC for the interval prior to the target interval. This value will be used by the target interval to constrain energy and operating reserve scheduled in the injection range to the MinSoC and to prevent withdrawals scheduled to exceed the MaxSoC
- SoC calculations will be adjusted to support interval to interval calculations. This will also include ramping impacts of the resource based on the submitted ramp rate as part of the dispatch data.

Constraints:

- Ramp constraints:
    - Energy and OR ramp rates can be limiting factors in the RT engine like other quick start resources.
    - The amount of 10 or 30 minute (injecting or withdrawing) operating reserve cannot exceed the amount by which it can increase its output over 10 or 30 minutes, and operating reserve ramp rate for its additional reserve schedule.
    - Dispatch will utilize branching the resource, as the tools it will utilize both withdrawal and injection capability of the resource for energy and OR; when

withdrawing the schedule will be limited by ramp for energy schedules like other quick start/dispatchable load resources. The branching OR mechanism is indicative of a positive swing (moving in the net positive direction, from negative withdrawal to the positive injection).

- Energy (no reserves schedule)
    - In any given 5-minute interval, a storage resource's SoC should always be less than or equal to its maximum energy storage capacity and greater than its minimum energy storage capacity.
    - The SoC capability must ensure that the resource can feasibly provide energy for the interval when it is activated for injection or withdrawal. If the SoC available is 100 MWh, and the power capability is 200 MW, the resource is available to inject 200 MW for the interval. If they have a 5 MWh SoC, they would not be able to feasibly be able to inject 200 MW for the interval, and therefore their injection should be limited to how much can be feasibly achieved for that 5 min interval and considering the ramp rate of the resource to get up to that injection. For injection this will be SoC availability up to the Min SoC, for withdrawal this is difference between the Max SoC and existing SoC.

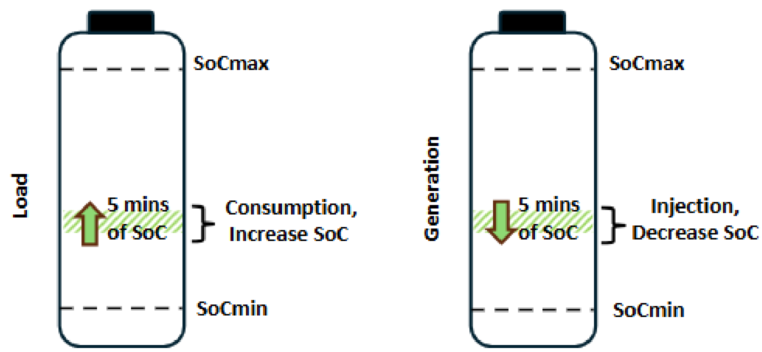


Figure 15: SoC requirement for energy in RT

- Operating Reserve (no energy schedules):
    - Like DAM and PD, OR only activation can only be achieved by the injection capability of the storage resource. Therefore, to provide OR only, the resource must have a zero-energy dispatch. To achieve OR activation, it would require the resource to inject energy to the grid.
    - As there is no energy dispatch, the expectation is that a storage resource can have their OR schedule limited to a value to ensure 60 mins of SoC availability (as in the case of DAM and PD timeframes) and this value cannot exceed the MinSoC.

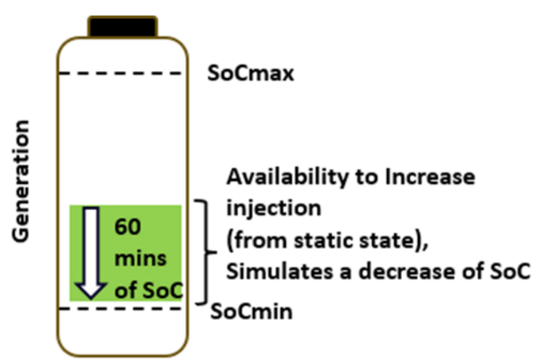


Figure 16: SoC requirement for OR in RT

- Energy and Operating Reserve Schedules
    - Withdrawal based energy and OR - To be dispatched for withdrawing energy, it must ensure the resource's schedule can receive energy/can consume for a 5 min period without bypassing the MaxSoC of the resource. OR is provided by reducing consumption, therefore will not exceed what can be consumed over a 5 min interval; same limit as energy withdrawal
    - Injection based energy and OR – To be dispatched for injecting energy, it must ensure that resource's schedule is capable of injecting energy for 5 mins as well as have a further 60 mins of stored energy to simulate an incremental increase in energy from an OR activation, in addition to not exceeding the SoC Min.
    - Withdrawal based energy and branching OR – To be scheduled to consume energy it must ensure the resource's schedule can receive energy/can consume for a 5 min period without bypassing the MaxSoC of the resource. OR is provided by reducing consumption and then immediately injecting (branching from withdrawal to injection), therefore will not exceed what can be consumed over a 5 min period, which is same limit as energy withdrawal, but must also have a 60 minute of injection capability without exceeding the MinSoC.

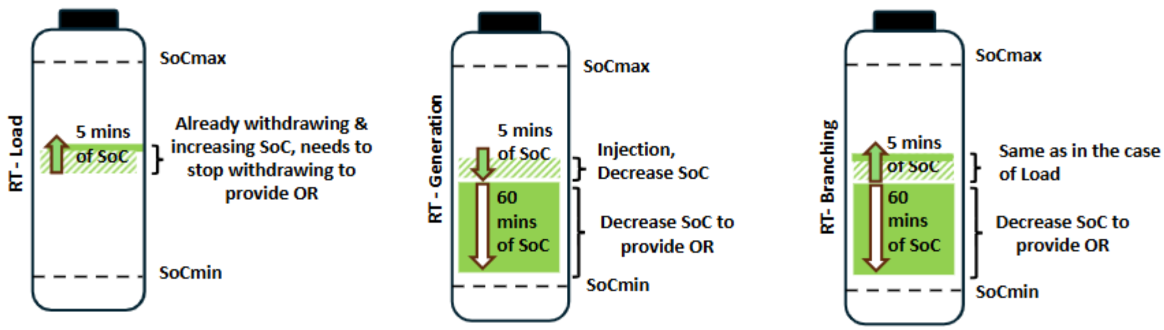


Figure 17: SoC requirement for energy and OR in RT

Figure 15, **Figure 16** and **Figure 17** depict the SoC requirements in RT of a battery while providing energy only, OR only, and co-optimized energy and OR, respectively.

Results

- The results include the RT dispatch and advisory schedules for the next 11 intervals.
- MWP and EOP considerations will be determined in the 'Settlements' module of design.

Day in the Life

This section illustrates how key features of the 'Optimization' market design are intended to function together in the 'day in the life' of a battery storage market participant, commencing with DAM submission and concluding with RTM execution. The examples here are intended to mimic various situations to demonstrate impacts of the design. These examples are for illustrative purposes only; the scenarios in the upcoming section may be unrealistic and are being presented for educational purposes to better demonstrate key concepts of the optimization design features.

For examples we are consider a resource with the following characteristics in **Table 6** below.

Table 6 - Example Resource Characteristics

Parameter Name	Short Name	Unit	Parameter Value
Maximum Injection Rating	Pmax	MW	200
Maximum Withdrawal Rating	Pmin	MW	-200
Maximum State of Charge	MaxSoC	MWh	900
Minimum State of Charge	MinSoC	MWh	50
Round-trip Efficiency	RTE	% or decimal	0.9
Initial State of Charge	Initial SoC	MWh	50
Internal Service Load	ISL	MW	3
Ramp Rate	Ramp Rate	MW/min	100
Cycling Daily Energy Limit	CycleDEL	MWh	700

Consider this resource submits the following energy offer for all hours of the day in **Table 7** below.

Table 7 - Example of Energy Offer Laminations All Hours of Day

Example Energy offer with 9 laminations				
P/Q Pair	**Price ($/MW)**	**Quantity (MW)**	**Price to Schedule ($/MW)**	**MP's Intended Action**
Pair 1	-200	-200	-200 or less (more negative)	Charge 200MW if price is -$200 or below
Pair 2	-100	-90	-199.99 to -100	Charge 90MW if the price is between-$100 and -$199.99
Pair 3	0	-80	-99.99 to 0	Charge 80MW if the price is between -$99.99 and $0
Pair 4	25	-50	0.01 to 25	Charge 50MW if the price is between $0.01 and $25
Pair 5	100	0	25.01 to 99.99	Do nothing if price is between $25.01 and $99.99
Pair 6	100	50	100 to 499.99	Inject 50MW if price is between $100 and $499.99
Pair 7	500	100	500 to 599.99	Inject 100MW if price is between $500 and $599.99
Pair 8	600	150	600 to 699.99	Inject 150MW if price is between $600 and $699.99

Pair 9	700	200	700	Inject 200MW if price is $700 or above

Table 8 outlines the DAM Prices to show how the various features will be utilized for scheduling purposes:

Table 8 - Example of DAM prices

Hour Ending (HE)	DAM LMP
HE1	$-10.00
HE2	$0.06
HE3	$-200.00
HE4	$-200.00
HE5	$-200.00
HE6	$5.00
HE7	$10.00
HE8	$15.00
HE9	$15.00
HE10	$30.00
HE11	$500.00
HE12	$500.00
HE13	$550.00
HE14	$550.00
HE15	$600.00
HE16	$650.00
HE17	$710.00
HE18	$100.00
HE19	-$250.00
HE20	$500.00
HE21	$20.00
HE22	$10.00
HE23	$5.00
HE24	$5.00

DAM Scheduling

Based on the aforementioned offers and the posted DAM prices, this resource will receive the following 'DAM Energy Schedule'. Red values indicate a withdrawal; green indicates an injection. Note how CycleDEL decreases throughout periods of injection. Also note that in HE18 to 19 the MP has a reduction of 3 MW to account for the ISL. HE20's available SoC also shows that the RTE and ISL have been calculated -200 MW is discounted by 0.9 (83 MW + 200 MW (0.9) – 3 MW = 260 MW).

Hour Ending	HE1	HE2	HE3	HE4	HE5	HE6	HE7	HE8	HE9	HE10
DAM LMP	-$ 10.00	-$ 0.06	-$ 200.00	-$ 200.00	-$ 200.00	$ 5.00	$ 10.00	$ 15.00	$ 15.00	$ 30.00
	HE01	HE02	HE03	HE04	HE05	HE06	HE07	HE08	HE09	HE10
DAM ENERGY SCHEDULE	-80.0	-50.0	-200.0	-200.0	-200.0	-50.0	-50.0	-50.0	-50.0	0.0
**STATE OF CHARGE (SoC) (beginning of hour)	50.0	119.0	161.0	338.0	515.0	692.0	734.0	776.0	818.0	860.0
*AVAILABLE SoC (beginning of hour)	0.0	69.0	111.0	288.0	465.0	642.0	684.0	726.0	768.0	810.0
Daily injection	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CycleDEL Tracker (End of Hour)	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0

Hour Ending	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM LMP	$ 500.00	$ 500.00	$ 550.00	$ 550.00	$ 600.00	$ 650.00	$ 710.00	$ 100.00	-$ 250.00	$ 500.00
	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM ENERGY SCHEDULE	0.0	0.0	100.0	100.0	150.0	150.0	200.0	0.0	-200.0	0.0
**STATE OF CHARGE (SoC) (beginning of hour)	857.0	854.0	851.0	748.0	645.0	492.0	339.0	136.0	133.0	310.0
*AVAILABLE SoC (beginning of hour)	807.0	804.0	801.0	698.0	595.0	442.0	289.0	86.0	83.0	260.0
Daily injection	0.0	0.0	100.0	200.0	350.0	500.0	700.0	700.0	700.0	700.0
CycleDEL Tracker (End of Hour)	700.0	700.0	600.0	500.0	350.0	200.0	0.0	0.0	0.0	0.0

Hour Ending	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM LMP	$ 500.00	$ 500.00	$ 550.00	$ 550.00	$ 600.00	$ 650.00	$ 710.00	$ 100.00	-$ 250.00	$ 500.00
DAM OR LMP	$ 10.00	$ 15.00	$ 15.00	$ 4.00	$ 15.00	$ 10.00	$ 10.00	$ 4.00	$ 4.00	$ 4.00
	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM ENERGY SCHEDULE	0.0	0.0	100.0	100.0	150.0	150.0	200.0	0.0	-200.0	0.0
DAM OR SCHEDULE	200	200	100	50	50	50	0	0	0	0
**STATE OF CHARGE (SoC) (beginning of hour)	857.0	854.0	851.0	748.0	645.0	492.0	339.0	136.0	133.0	310.0
*AVAILABLE SoC (beginning of hour)	807.0	804.0	801.0	698.0	595.0	442.0	289.0	86.0	83.0	260.0
Daily injection	0.0	0.0	100.0	200.0	350.0	500.0	700.0	700.0	700.0	700.0
CycleDEL Tracker (End of Hour)	700.0	700.0	600.0	500.0	350.0	200.0	0.0	0.0	0.0	0.0

Figure 18: DAM Scheduling example for Energy

The snapshot below shows HE11 and 12. Although the resource is economic and has adequate SoC in these hours for a 100 MW injection, the engine recognizes that there are greater economic opportunities in later hours and will preserve the SoC of the battery for those hours.

Hour Ending	HE11	HE12
DAM LMP	$ 500.00	$ 500.00
	HE11	HE12
DAM ENERGY SCHEDULE	0.0	0.0
*STATE OF CHARGE (SoC) (beginning of hour)	857.0	854.0
*AVAILABLE SoC (beginning of hour)	807.0	804.0
Daily injection	0.0	0.0
CycleDEL Tracker (End of Hour)	700.0	700.0

Figure 19: Snapshot of HE11 and HE12 in DAM Scheduling example (Energy)

Furthermore, see HE18 below. Although the resource is economic for a 50 MW injection, and has adequate SoC for a 29 MW injection, the engine realizes that the CycleDEL for the day has been fulfilled, and it will not schedule any more injections in the DAM. Note that though the resource withdrawals 200 MW to charge in HE19, the CycleDEL does not increase as outlined in **Figure 20** below.

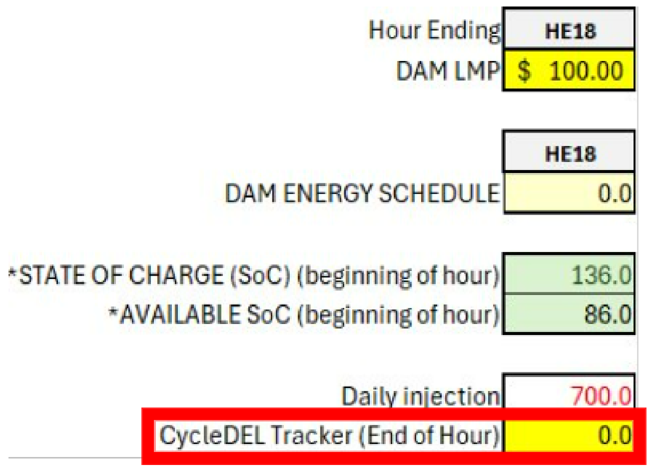


Figure 20: Snapshot of HE18 in DAM Scheduling example (Energy)

The following examples will now discuss the co-optimization of the resource. **Table 9** below dictates the OR offer laminations submitted by the resource.

Table 9 - Example of Operating Reserve Offer Laminations

Example OR offer with 5 laminations		
P/Q Pair	Price ($/MW)	Quantity (MW)
Pair 1	0.1	0
Pair 2	0.1	50
Pair 3	5	80
Pair 4	10	200
Pair 5	10.01	400

Energy and OR co-optimization: When co-optimizing for OR, the engine looks at the OR offers submitted and schedules the resource based on their SoC and scheduled action for that hour. Based on the OR offers submitted as above, co-optimized with our Energy offers, we receive the following Energy and OR schedule in the DAM in **Figure 21**.

Hour Ending	HE1	HE2	HE3	HE4	HE5	HE6	HE7	HE8	HE9	HE10
DAM LMP	-$ 10.00	-$ 0.06	-$ 200.00	-$ 200.00	-$ 200.00	$ 5.00	$ 10.00	$ 15.00	$ 15.00	$ 30.00
DAM OR LMP	$ 0.10	$ 15.00	$ 0.10	$ 0.10	$ 15.00	$ 15.00	$ 1.00	$ 1.00	$ 1.00	$ 10.00
	HE01	HE02	HE03	HE04	HE05	HE06	HE07	HE08	HE09	HE10
DAM ENERGY SCHEDULE	-80.0	-50.0	-200.0	-200.0	-200.0	-50.0	-50.0	-50.0	-50.0	0.0
DAM OR SCHEDULE	50	116	50	50	400	250	50	50	50	200
*STATE OF CHARGE (SoC) (beginning of hour)	50.0	119.0	161.0	338.0	515.0	692.0	734.0	776.0	818.0	860.0
*AVAILABLE SoC (beginning of hour)	0.0	69.0	111.0	288.0	465.0	642.0	684.0	726.0	768.0	810.0
Daily injection	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CycleDEL Tracker (End of Hour)	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0

Hour Ending	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM LMP	$ 500.00	$ 500.00	$ 550.00	$ 550.00	$ 600.00	$ 650.00	$ 710.00	$ 100.00	-$ 250.00	$ 500.00
DAM OR LMP	$ 10.00	$ 15.00	$ 15.00	$ 4.00	$ 15.00	$ 10.00	$ 10.00	$ 4.00	$ 4.00	$ 4.00
	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM ENERGY SCHEDULE	0.0	0.0	100.0	100.0	150.0	150.0	200.0	0.0	-200.0	0.0
DAM OR SCHEDULE	200	200	100	50	50	50	0	0	0	0
*STATE OF CHARGE (SoC) (beginning of hour)	857.0	854.0	851.0	748.0	645.0	492.0	339.0	136.0	133.0	310.0
*AVAILABLE SoC (beginning of hour)	807.0	804.0	801.0	698.0	595.0	442.0	289.0	86.0	83.0	260.0
Daily injection	0.0	0.0	100.0	200.0	350.0	500.0	700.0	700.0	700.0	700.0
CycleDEL Tracker (End of Hour)	700.0	700.0	600.0	500.0	350.0	200.0	0.0	0.0	0.0	0.0

Figure 21: DAM Scheduling example for Energy and OR

See **Figure 22** below for 3 examples of branching for OR:

Hour Ending	HE1	HE2	HE3	HE4	HE5	HE6
DAM LMP	-$ 10.00	$ 0.06	$ 200.00	-$ 200.00	-$ 200.00	$ 5.00
DAM OR LMP	$ 0.10	$ 15.00	$ 0.10	$ 0.10	$ 15.00	$ 15.00
	HE01	HE02	HE03	HE04	HE05	HE06
DAM ENERGY SCHEDULE	-80.0	-50.0	-200.0	-200.0	-200.0	-50.0
DAM OR SCHEDULE	50	116	50	50	400	250
*STATE OF CHARGE (SoC) (beginning of hour)	50.0	119.0	161.0	338.0	515.0	692.0
*AVAILABLE SoC (beginning of hour)	0.0	69.0	111.0	288.0	465.0	642.0
Daily injection	0.0	0.0	0.0	0.0	0.0	0.0
CycleDEL Tracker (End of Hour)	700.0	700.0	700.0	700.0	700.0	700.0

Figure 22: Snapshot of HE2, HE5 and HE6 in DAM Scheduling example (Energy and OR)

In HE2 the resource is dispatched for a 50 MW withdrawal and is their OR offer is eligible for branching. However, since the resource is only withdrawing 50MW and only has 72 MWh available in the battery, the total branch from withdrawal to injection is 122 MW which is what the resource can be scheduled for.

HE5 demonstrates a full branch from the resource. They are scheduled for a 200MW withdrawal, with an economic OR offer for branching. They also have adequate SoC to inject 200 MW. Therefore, the resource can be scheduled for a full 400 MW of OR.

In HE6 the resource has adequate SoC for a 200 MW inject of OR but is only withdrawing 50 MW. The engines recognizes that the resource can branch for 250 MW of OR.

RT Dispatch

Consider the period below (HE9 INT11 – HE11 INT5) in **Figure 23**.

DAM Schedule

DAM Schedule

Hour Ending	HE9	HE10	HE11
DAM LMP	$ 15.00	$ 30.00	$ 500.00
DAM OR LMP	$ 1.00	$ 10.00	$ 10.00

	HE09	HE10	HE11
DAM ENERGY SCHEDULE	-50.[illegible]	0.0	0.0
DAM OR SCHEDULE	50	200	200
*STATE OF CHARGE (SoC) (beginning of hour)	818.0	860.0	857.0
*AVAILABLE SoC (beginning of hour)	768.0	810.0	807.0

RT Snapshot

	HE9		HE10											HE11				
Hour Ending	INT11	INT12	INT1	INT2	INT3	INT4	INT5	INT6	INT7	INT8	INT9	INT10	INT11	INT12	INT1	INT2	INT3	INT4	INT5
RT LMP	$ 15.00	$ 15.00	$ 30.00	$ 30.00	$ 30.00	$ 30.00	$ 30.00	$ 30.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00
RT OR LMP	$ 1.00	$ 1.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00

	INT11	INT12	INT1	INT2	INT3	INT4	INT5	INT6	INT7	INT8	INT9	INT10	INT11	INT12	INT1	INT2	INT3	INT4	INT5
ENERGY SCHEDULE	-50.0	-50.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
OR SCHEDULE	50	50	200	200	200	200	200	200	100	100	100	100	100	100	100	100	100	100	100
**STATE OF CHARGE (SoC)	771.5	775.0	778.5	778.3	778.0	777.8	777.5	777.3	777.0	768.4	759.8	751.3	742.7	734.1	725.5	716.9	708.3	699.8	691.2
*AVAILABLE SoC (beginning of Interval)	721.5	725.0	728.5	728.3	728.0	727.8	727.5	727.3	727.0	718.4	709.8	701.3	692.7	684.1	675.5	666.9	658.3	649.8	641.2

Figure 23: RT example 1 for Energy and OR

Assume in this situation the resource has not updated their offers in the PD window, and the original energy offer is still being used. Though the resource was not scheduled to inject in HE10 and HE11 in the DAM, since storage resources are not committed, the RT engine does not respect this DAM schedule. In HE10 INT7 we see the price spike to $500, making the resource's offer economic. This will result a dispatch being sent to the resource, triggering a 100 MW dispatch. Since the price stays elevated into HE11, the dispatch will remain at 100 MW.

DAM Schedule

DAM Schedule

Hour Ending	HE15	HE16	HE17
DAM LMP	$ 600.00	$ 650.00	$ 710.00
DAM OR LMP	$ 15.00	$ 10.00	$ 10.00

	HE15	HE16	HE17
DAM ENERGY SCHEDUL	150.0	150.0	200.0
DAM OR SCHEDULE	50	50	0
*STATE OF CHARGE (SoC) (beginning of hour	645.0	492.0	339.0
*AVAILABLE SoC (beginning of hour	595.0	442.0	289.0

RT Snapshot

	HE15		HE16											HE17				
Hour Ending	INT11	INT12	INT1	INT2	INT3	INT4	INT5	INT6	INT7	INT8	INT9	INT10	INT11	INT12	INT1	INT2	INT3	INT4	INT5
RT LMP	$ 600.00	$ 600.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 710.00	$ 710.00	$ 710.00	$ 710.00	$ 710.00
RT OR LMP	$ 1.00	$ 1.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00

	INT11	INT12	INT1	INT2	INT3	INT4	INT5	INT6	INT7	INT8	INT9	INT10	INT11	INT12	INT1	INT2	INT3	INT4	INT5
ENERGY SCHEDUL	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	200.[illegible]	148.0	0.0	0.0	0.0
OR SCHEDULE	50	50	50	50	50	50	50	50	50	50	50	50	50	50	0	0	0	0	0
**STATE OF CHARGE (SoC)	254.0	241.3	228.[illegible]	215.8	203.0	190.3	177.5	164.8	152.0	139.3	126.5	113.8	101.0	88.3	75.5	58.6	46.0	45.8	45.5
*AVAILABLE SoC (beginning of Interval)	204.0	191.3	178.[illegible]	165.8	153.0	140.3	127.5	114.8	102.0	89.3	76.5	63.8	51.0	38.3	25.5	8.6	-4.0	-4.3	-4.5

Figure 24: RT example 2 for Energy and OR

Consider that the resource realized they did not update their offers but wanted to respect their DAM schedule. In the PD window they have gone in and updated their offers to make themselves uneconomic for all hours except those they were scheduled for in the DAM.

See **Figure 24**, in HE15 and HE16 the resource is dispatched to 150 MW, and it has sufficient SoC to meet these dispatches. However, note the SoC at the beginning of HE16, and compare it to what the SoC was expected to be per the DAM; the dispatch in HE10 and HE11 has negated the ability of the resource to inject after INT2 in HE17, so the resource has not received a dispatch for that hour even though they had a DAM position. This failure to inject will be settled at the RT price in the settlement process.

To mitigate this situation, the resource could had updated their offers to become economic to withdraw prior to HE15, so that they would have adequate SoC to discharge in later hours. This would be allowed since CycleDEL does not apply in RT.

Next Steps

The IESO has begun work on the Phase 1 Batch 2 design work which will support decision-making across numerous modules and elements. Future engagements will take place on topics related to the Batch 2 design modules that the IESO will require feedback on to continue forward with the design work.

Phase 1 Design Scope

The scope of design modules and elements for Phase 1 design is depicted in **Table 10**.

Table 10 - Scope of Design Modules and Elements

<table>
<tr><th>Batch #</th><th>Design Module</th><th>Design Element</th></tr>
<tr><td>1</td><td>Grid and Market Operations</td><td>Optimization (Energy & Operating Reserves)</td></tr>
<tr><td rowspan="8">2*</td><td>Grid and Market Operations</td><td>Dispatch data and other inputs</td></tr>
<tr><td>Grid and Market Operations</td><td>Operations Integration</td></tr>
<tr><td rowspan="2">Connection and Registration</td><td>Market Registration</td></tr>
<tr><td>Connection Assessment and Approval</td></tr>
<tr><td>Settlements</td><td>Market Settlement</td></tr>
<tr><td>Contracts</td><td>Contract Impacts</td></tr>
<tr><td rowspan="2">Market Power Mitigation (MPM)</td><td>Exante</td></tr>
<tr><td>Expost</td></tr>
<tr><td>3</td><td>Hybrid</td><td>All modules</td></tr>
</table>

***The IESO will run all other design elements in parallel with an attempt to expedite delivery. Where possible, the IESO will attempt to consolidate design memos and multiple engagements moving forward.**

The outcomes of design Elements such as 'Dispatch data and other inputs', 'Market Registration' and 'Exante Mitigation' feed in to the 'Optimization' design element and have been explored, to an extent, due to their high correlation with 'Optimization' design.

'Optimization' Design Element Dependencies

Other Design Elements that the 'Optimization' Design Element is dependent on are:

Dispatch data and other inputs:

This refers to daily and hourly dispatch data submitted in DAM. As described through this document, the dispatch data may be updated after submission up till 10 minutes before real time dispatch. Basic decisions related to this design element (e.g. dispatch parameters unique to storage, energy/offer curves, ramp rates) were necessary for the 'Optimization' design element. Further enhancements or more specific requirements to this element will be investigated during Batch 2 design.

Market Registration:

i) Resource Registration: This refers to constant values recorded during registration of the facility and utilized by the engines for scheduling, dispatch, and settlement. This combines existing static registration data list required for dispatchable resources and new proposed static registration parameters only required for energy storage (as described in the 'Pre-Market' section).

ii) Telemetry: All facilities must comply with the applicable data monitoring requirements, which are listed in the IESO Market Rules (Chapter 0.4 Appendices, Section 4.24), and are used to monitor system conditions, resource response, and to support DSO calculations. Some of these parameters are not required by the optimization engines but may be required for operational purposes. The IESO will continue to consider further telemetering requirements that may be required as part of subsequent modules of design including other needs to support reliability of the grid.

iii) Commissioning: For commissioning purposes only, this new storage will participate as a self-scheduling storage resource. MPs will participate in the DAM by submitting self-schedules for each hour they intend to inject or consume; they may submit either an injection schedule or a withdrawal schedule for each hour. No SoC will be modelled or submitted by MPs during this commissioning period. MPs will pay or be paid LMP. This will still utilize the negative generator model that positive is indicative of injections and negative of withdrawals. This model will mimic the existing self-scheduling generator model.

Market Power Mitigation:

Initial decisions for ex-ante mitigation were described earlier as it occurs within some of the optimization timeframes. Like ex-ante design, non-decreasing price requirement of enhanced mitigated-for-conduct offers will be respected for settlement mitigation. Ex-post mitigation for physical withholding takes place after market clearing and settlement of a dispatch day to assess potential instances of physical withholding using reference quantities. This occurs outside of the optimization engine, and it is expected that minimal changes will be made to ex-post mitigation for storage for this phase of ERP, and existing requirements will be adapted to the single resource model. Ex-post and settlement mitigation will be further explored in Batch 2 of Phase 1 design along with scenario analysis that may challenge the initial decisions made for ex-ante mitigation.

Other Impacted Design Elements:

i) Connection Assessment and Approval – Modelling of the new storage model have a limited impact with the single-resource design feature. There will be no change to completed studies and assessments.

ii) Operations Integration – Forecasting is not considered for a load in the traditional sense; therefore, modifications are required.

iii) Market Settlement:

   a. Settlement outcomes are managed through the Settlements process and tools, but Economic Operating Point (EOP) tool used to facilitate Make Whole Payments (MWPs) is designed to mimic the DSO.
   b. EOP tool is not currently designed to consider resources with a single bid-offer curve.
   c. Scenario analysis will be conducted to determine where storage resources should receive make-whole payments based on the new design. This may require MWP changes or additional optimization changes (if necessary).