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Connecting Today.
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Enabling Resources Program: Storage and Hybrid Integration Project

Market Power Mitigation

Memo 2.0

Engagement Topic: MPM Design Element for Storage Resources

Date: May 6, 2026

Purpose

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

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.

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List of Abbreviations

Abbreviation	Definition
BCA	Broad Constrained Area
BSOC	Battery Storage Opportunity Cost
DA	Day-Ahead
DAM	Day-Ahead Market
DMSR	Dual Model Storage Resource
DSO	Dispatch Scheduling and Optimization
ESR	Energy Storage Resource
FRL	Financial Reference Level
GMP	Global Market Power
IAM	IESO-administered market
LMP	Locational Marginal Price
MAPC	Maximum Generator Resource Active Power Capability
MaxSoC	Maximum State of Charge
MinSoC	Minimum State of Charge
MP	Market Participant
MPM	Market Power Mitigation
MRP	Market Renewal Program
MW	Megawatt
NCA	Narrow Constrained Area
NFRL	Non-Financial Reference Level
OR	Operating Reserve
PD	Pre-Dispatch
PQ	Price-Quantity
RQ	Reference Quantity
RT	Real-Time
RTE	Round-Trip Efficiency
SoC	State of Charge
SMSR	Single-Model Storage Resource

Background

This Phase 1 design document provides information to update the market power mitigation (MPM) framework and processes to incrementally incorporate changes relating to the new single model storage resource (SMSR) as part of the Enabling Resources Program (ERP).

Phased Approach

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

- Single model storage resource (SMSR (battery) with bi-directional offers;
- State of Charge (SoC) Management.

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

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

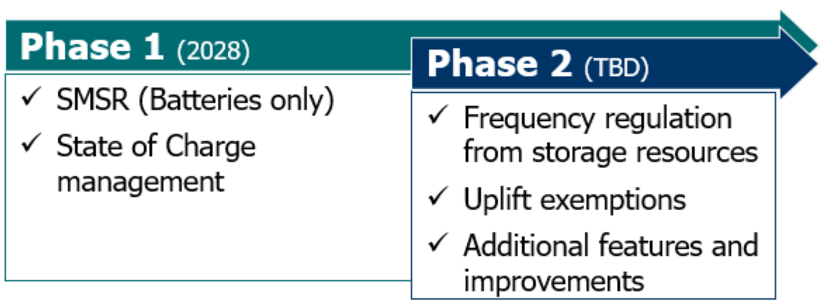

Figure 1: Project Scope

Scope of MPM Phase 1 Design

This design outlines how MPM will implement key decisions to support the transition to the SMSR and ensure robust safeguards against the exercise of market power.

Ex-Ante Validations of Non-Financial Dispatch Data: MPM will validate non-financial dispatch data submissions against their corresponding registration parameters in the ex-ante timeframe to prevent exercise of market power through operational parameters.

Ex-Ante Mitigation for Economic Withholding: The design incorporates SMSRs into MPM's mitigation functionality in the dispatch scheduling and optimization (DSO), enabling before-the-fact mitigation for this new resource type and addressing changes introduced by the updated bi-directional energy offer curve.

Settlement Mitigation of Make-Whole Payments: Settlement processes will utilize a mitigated offer curve that reflects the updated energy offer and operating reserve (OR) offer structure, ensuring accurate make-whole payment calculations.

Ex-Post Mitigation for Physical Withholding: After-the-fact physical withholding assessment may be triggered when submitted quantities are less than the applicable reference quantities and, if physical withholding is established, settlement charges will apply.

Batch #	Design Module	Design Element
1	Grid and Market Operations	Optimization (Energy & Operating Reserves)
2	Grid and Market Operations	Dispatch data and other inputs
	Grid and Market Operations	Operations Integration
	Connection and Registration	Market Registration
		Connection Assessment and Approval
	Settlements	Market Settlement
	Contracts	Contract Impacts
	Market Power Mitigation (MPM)	Ex-ante, ex-post, settlements mitigation
3	Hybrid	All modules

Figure 2: Design Modules and Elements for Phase 1

Design Principles

The guiding principles for MPM design of ERP Phase 1 includes mitigation of exercise of market power through:

- economic withholding, which can occur when one or more market participants (MPs) offer a portion of, or all of, their resource's available capacity at prices materially higher than short-run marginal costs;
- physical withholding, which can occur when one or more MPs refrain from offering energy or Operating Reserve otherwise available, or withholding operational capabilities through dispatch data submissions;
- settlement payments, which can occur when submitted offers result in excessive payments when potential for exercise of market power is present.

To mitigate these risks, the MPM framework will promote competition, fair pricing and a reliable system operation.

MPM Enabling Resource Participation Design

Ex-Ante Validation of Non-Financial Dispatch Data Parameters

A resource may submit dispatch data parameters that can deviate from its registered non-financial dispatch data parameters, potentially resulting in scheduling restrictions. To mitigate potential market power concerns associated with newly introduced dispatch data parameters, the IESO will validate these submissions against the resource's registered parameters within the predefined conduct thresholds.

If a submitted dispatch data parameter falls outside the acceptable range defined by the conduct threshold, the submission will be rejected. Once rejected, the resource may resubmit the dispatch data within the acceptable range to pass validation.

Refer to the ERP Dispatch Data and Other Inputs Design Document for details on new dispatch data parameters applicable to:

- Minimum State of Charge (MinSoC);
- Maximum State of Charge (MaxSoC);
- Cycle Efficiency.

No new non-financial reference levels (NFRLs) will be registered for the above noted dispatch data parameters. Validation will be performed using predefined thresholds against relevant registered parameters. The IESO will enshrine validation rules and applicable conduct thresholds within the Market Rules, allowing updates through an amendment process as necessary.

These new MPM validations will apply only to SMSRs eligible to register and submit the new dispatch data parameters. Table 1 **Error! Reference source not found.**below provides the list of newly introduced non-financial dispatch data parameters and respective conduct thresholds used for passing validation.

Table 1: MPM Validation Rules and Conduct Thresholds related to new Dispatch Data Parameters

Dispatch Data Parameters	Validation Rules and Conduct Thresholds
Minimum State of Charge	Submitted MinSoC is less than or equal to the registered MinSoC plus 30% of the registered MaxSoC[1]
Maximum State of Charge	Submitted MaxSoC is greater than or equal to 70% of the registered MaxSoC parameter

[1] The registered MinSoC and registered MaxSoC (not the absolute MinSoC and absolute MaxSoC) are used to validate dispatch data submissions. More information on the registered MinSoC and MaxSoC is available in the Dispatch Data and Other Inputs Design document.

Dispatch Data Parameters	Validation Rules and Conduct Thresholds
Cycle Efficiency	Submitted cycle efficiency is greater than or equal to 50% of the registered cycle efficiency parameter

Ex-Ante Mitigation for Economic Withholding

The ex-ante mitigation approach for economic withholding remains conceptually the same as the design currently implemented through Market Rules. Market power conditions must be met for a resource's offer to be considered for ex-ante mitigation testing. When these conditions are satisfied, the resource undergoes a conduct test. If the conduct test fails, a price impact test is performed. Failure of the price impact test results in replacing a portion of or the entirety of the offer with the applicable reference level value. Existing market power conditions, and the relevant conduct test thresholds and price impact test thresholds will continue to apply to SMSRs in the energy and OR markets.

This testing is performed independently in both the Day-Ahead Market (DAM) calculation engine and the pre-dispatch (PD) calculation engine. The real-time (RT) calculation engine does not perform ex-ante testing, instead, it carries forward any mitigation decisions from the PD process for the applicable hours.

The IESO will continue to evaluate system conditions for potential local and global market power conditions in both energy and OR markets. For the SMSR, these conditions apply to the resource and are not specific to its operating mode (i.e., charging or discharging).

Ex-Ante Mitigation of Energy Offer

Ex-ante mitigation in the DAM and the PD calculation engines will be updated to incorporate new SMSRs. The charging portion of the bi-directional offer structure will not be subjected to ex-ante mitigation, unless an adjustment is needed to maintain monotonicity. This approach is consistent with the existing framework, as dispatchable load resources are not subjected to ex-ante mitigation for energy price impacts and are obligated to bid below the corresponding dispatchable generation resource offers. The adjustment of the charging portion is described in the Ex-Ante Energy Offer Mitigation Methodology section below.

SMSRs will be assessed for conditions related to Narrow Constrained Area (NCA), Dynamic Constrained Area (DCA), Broad Constrained Area (BCA) and Global Market Power (GMP) testing in the energy market. These resources are included in constrained area designations similar to other generation resources today.

The injection portion of the bi-directional offer curve of an SMSR will be subject to ex-ante mitigation. When applicable conditions are met, this portion will be tested against the energy offer reference level, which is created exclusively for injection megawatt-hours (MWhs). If the conduct test fails, the resource proceeds to the price impact test.

Ex-Ante Energy Offer Mitigation Methodology

- If the market participant offers only charging laminations, no mitigation is required.
- If the participant offers only injection laminations, mitigation is required.
- If both charging and injection laminations are offered, mitigation applies to the injection portion, and adjustments may be required on the charging side as applicable.

Table 2 and Figure 3 below are examples of the ex-ante mitigation process for a normal mitigation scenario where the energy offer reference level is higher than the highest charging price. The ex-ante mitigation process applies to submitted bi-directional offers, which are mitigated during the day-ahead (DA) and pre-dispatch (PD) timeframes – only if the conduct test fails. The example below shows the interaction between the submitted bi-directional offer and reference level for a specific hour of the day.

Table 2: General Example of a Bi-directional Energy Offer and Reference Levels

SUBMITTED OFFER		REFERENCE LEVEL		MITIGATED OFFER	
MW	$	MW	$	MW	$
-200	-100			-200	-100
-100	-50			-100	-50
-70	100			-70	100
-30	150			-30	150
0	300	0	200	0	200
200	300	250	200	200	200

This SMSR fails the price impact test and the mitigated offer is produced as follows:

- prices from the discharge laminations of 0 MW to 200 MW are copied from the reference level; and
- prices from the charging laminations from -30 MW to -200 MW are copied over from the submitted offer.

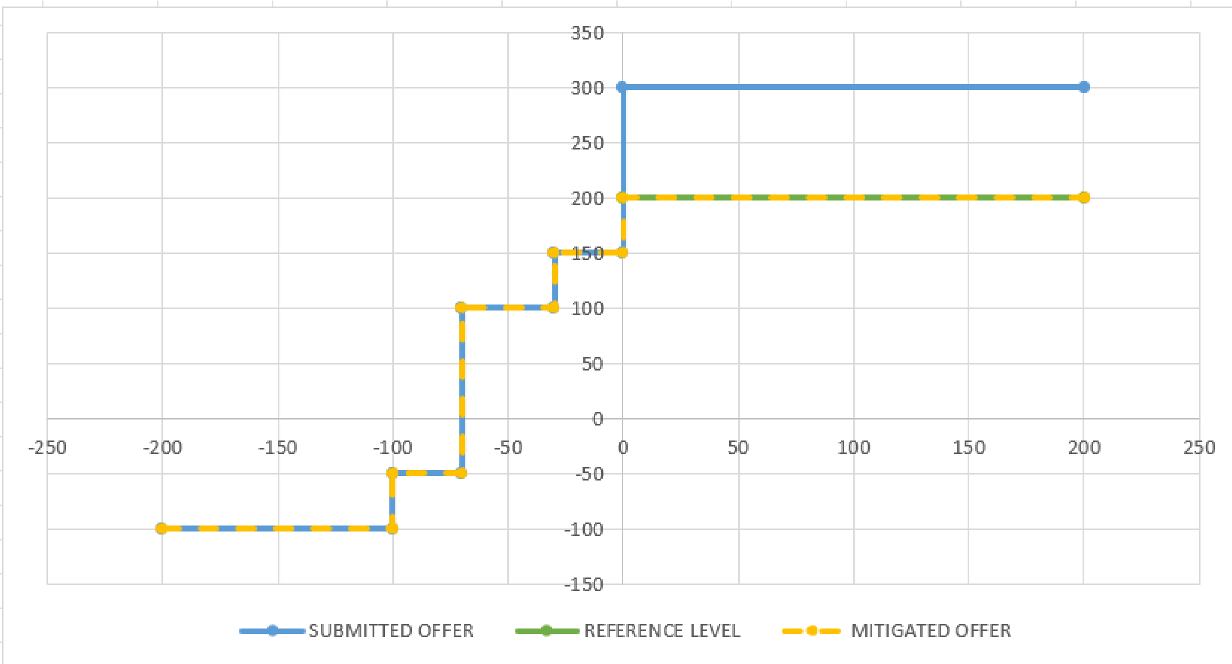

Figure 3: Example of Normal Mitigation Scenario of Bi-directional Offer

When creating the mitigated offer, the charging laminations of the energy offer curve may require a price offset to maintain a monotonically non-decreasing price curve. The table below illustrates an uncommon scenario involving a hypothetical bi-directional offer submission for both charging and discharging segments where an adjustment of the charging laminations is necessary. The reference level is set for the discharging portions, and the mitigation of those discharging segments result in a mitigated bi-directional offer. This situation is uncommon, as the energy offer reference level for an energy storage resource (ESR) is typically higher than the values shown in this example. The Energy Offer Reference Level Design for SMSR section below outlines the construction of the energy offer reference level and the parameters used in its calculation. This reference level reflects the full cost of energy injection, including but not limited to charging costs, operating and maintenance and opportunity costs. These collective components generally result in a value that exceeds the energy charging price. As a result, such circumstances are expected to be infrequent.

An example of when price adjustment of the charging laminations is required to maintain monotonicity is shown in Table 3 and Figure 4 below.

Table 3: Edge-Case Example of a Bi-directional Offer and Reference Levels

SUBMITTED OFFER		REFERENCE LEVEL		MITIGATED OFFER	
MW	$	MW	$	MW	$
-200	-100			-200	-100
-100	-50			-100	-50
-70	20			-70	9.98
-30	30			-30	9.99
0	50	0	10	0	10
50	50	250	10	200	10
100	100				
150	150				
200	200				

The discharge laminations of 0 MW to 200 MW are copied from the reference level. The prices of the charging lamination from -30 MW to -200 MW are transferred to the mitigated offer after applying the adjustment described in the subsequent paragraph below.

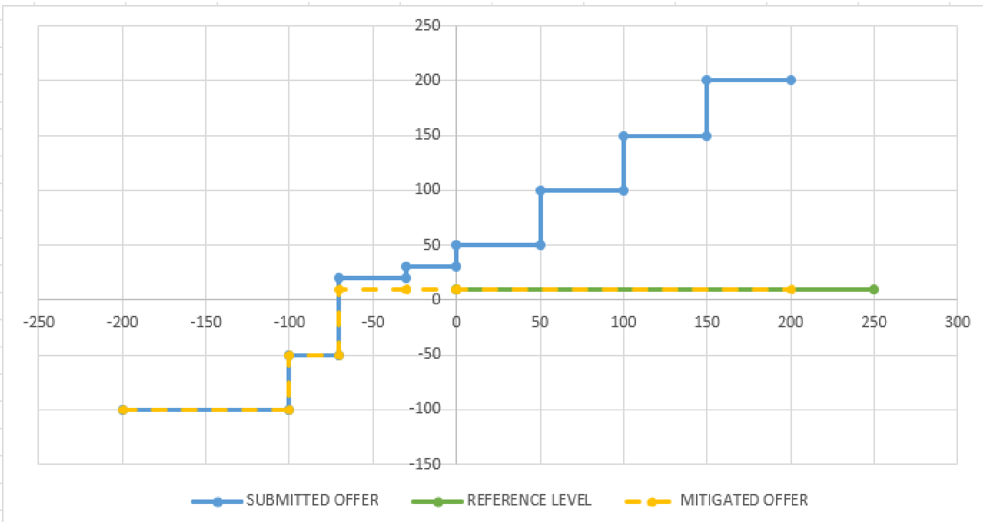

Figure 4: Mitigated Offer for an Edge-Case Example of Bi-directional Offer and Reference Levels

The graph above shows the submitted curve between -70 MW to 0 MW with a higher charging price than the first discharge lamination of the reference level curve. The price of charging lamination of -30 MW to 0 MW is reduced by 0.01 $/MWh, which is lower than the price of the first discharge lamination. The price is further reduced by 0.01 $/MWh for the charging lamination of -70 MW to -30.1 MW. This ensures that the mitigated offer respects monotonicity. When performing the conduct test for an SMSR, testing applies only to the positive megawatts-hours of the submitted bi-directional offer curve.

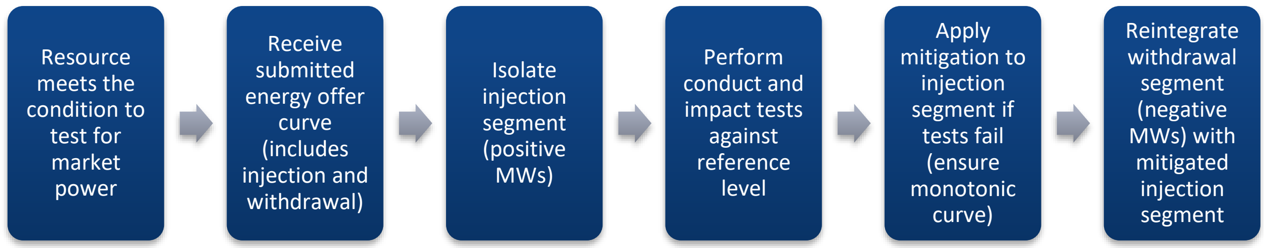

Figure 5: Ex-ante Energy Offers Mitigation Process for SMSR

Ex-Ante Mitigation of Operating Reserve Offer

The IESO will continue to test for both local market power and global market power OR conditions across all three classes of OR offers. SMSRs are subject to these assessments and will be included as candidates for testing. When testing a specific class of OR, MPM evaluates all offers from any class capable of meeting the OR requirement.

SMSRs will be tested for the global market power condition for OR if the locational marginal price (LMP) of a class of OR exceeds $15/MW. If a resource is included in a reserve area with minimum constraint, it will also be tested for local market power for OR. The existing exemptions for resources located in reserve areas with a binding maximum constraint remain unchanged post-ERP.

The conduct test will be performed using the methodology currently implemented. The only difference is in the range of the OR offer and the corresponding reference level, which now span from zero MW up to the sum of the maximum charge and discharge capability of the resource. Details on the OR reference level design for the SMSR are provided in the Financial Reference Levels**Error! Reference source not found.** section. More information on the operating reserve offer is available in the Operating Reserve Offer section of the Dispatch Data and Other Inputs Design document.

Application of Price Impact Test

For SMSRs that fail the conduct test, the price impact test is performed. The current methodology of the price impact test for energy and OR will continue to be applied to SMSRs.

For energy, resources that submitted offers outside the conduct thresholds will be subjected to the price impact test. If the price impact exceeds the applicable threshold, the submitted offer will be replaced with a mitigated offer as described above in the Ex-Ante Energy Offer Mitigation Methodology section.

For OR, resources that submitted offers outside the conduct thresholds will be subjected to the price impact test. If the price impact exceeds the applicable threshold, the submitted offer will be replaced with the corresponding reference level.

When the price impact test fails, the mitigated bi-directional offer for energy and/or mitigated OR offers, as applicable, will be used by the DA and PD calculation engines to produce schedules and prices.

Settlement Mitigation of Make-Whole Payments

The IESO will continue to apply settlement mitigation for make-whole payments related to local and global market power conditions arising from either the energy market or the OR markets, incorporating the new SMSR into its assessments. Updates to make-whole payment are detailed in the ERP Wholesale Settlement Design for Single Model Storage Resources document.

For settlement mitigation, the market power conditions, the conduct and the make-whole payment impact test methodologies will remain unchanged from the current design. Settlement mitigation will continue to independently perform the conduct test, consistent with the ex-ante mitigation design described earlier in this document. Consistent with current settlement mitigation design, settlement mitigation will test SMSRs for reliability conditions when present.

If the conduct test is failed, the price impact test will be performed consistent with current design. The conduct test and the make-whole payment impact test will use the most restrictive condition threshold applicable to any dispatch hour.

Settlement Mitigation Applicability

Settlement Mitigation is not performed for every type of bi-directional offer made by the SMSR. The three points below indicate if settlement mitigation is performed under various bi-directional offer submissions.

- If the MP offers only charging laminations, no settlement mitigation is required;
- If the MP offers only injection laminations, settlement mitigation is required;
- If both charging and injection laminations are offered, settlement mitigation applies to the injection portion, and adjustments may be required on the charging side as applicable; and
- For OR offers, settlement mitigation applies to the OR capability from charging and injection.

Ex-Post Mitigation for Physical Withholding

The IESO may continue to test energy and OR offers for physical withholding using reference quantities. Reference quantities are IESO's estimates of MWh or MW that a resource is expected to offer. Market power can be exercised when MWs or MWhs are withheld from being offered in the market, resulting in increased LMPs. Physical withholding tests will remain an ex-post process, applied to both DA and RT offers.

For SMSRs, the IESO will establish reference quantities (RQs) in collaboration with MPs. Market control entities will continue to play a role in the physical withholding process, and all SMSRs must register a market control entity for physical withholding. Testing will be performed at both the individual resource level and the associated market control entity level. The IESO will update the associated market control entity level conduct test to include hourly evaluations for SMSRs.

Physical withholding applies only to individual resources with a capacity greater than 10 MW. For market control entities, the aggregate capability of associated resources must also exceed 10 MW. For SMSRs:

- discharge capability is represented by the Maximum Generator Resource Active Power Capability; and
- charging capability is represented by the Maximum Negative Generator Resource Active Power Capability.

To determine capacity criteria for SMSRs, the IESO will use the Maximum Generator Resource Active Power Capability for both energy and OR qualification in physical withholding testing. For OR qualification, the IESO will also consider additional OR supply capability during charging mode provided through the maximum negative generator resource active power capability. The IESO will not assess the energy charging range for physical withholding. OR supply capability during charging and discharging mode will be assessed for physical withholding.

RQs for the SMSRs differ from those for the DMSRs, with the differences detailed in the Reference Quantities section. The conditions for testing energy and OR for physical withholding remain unchanged, as does the conduct and price impact test approach. Physical withholding conduct tests will be performed for each dispatch hour of a dispatch day. These conduct tests will be independently performed for energy and each applicable class of OR. The settlement charge calculations related to physical withholding will also remain consistent with pre-ERP design.

Financial Reference Levels

Before a resource is permitted to participate in the energy and the OR markets, the IESO must establish appropriate reference levels. These reference levels for financial dispatch data parameters are determined for both energy and OR, based on the resource's registration eligibility.

For SMSRs, financial reference levels must include:

- energy offer reference level ($/MWh); and
- OR offer reference level for each class of OR the resource is eligible to provide ($/MW).

SMSRs can maintain multiple financial reference level datasets to reflect different cost configurations within seasonal (summer and winter) profiles. For example, there may be a more expensive cost profile for a given operating configuration and a less expensive cost profile for another mode of operation. To determine which reference level applies for a given hour, the IESO performs a total hourly cost calculation, which sums the energy costs across profiles. For SMSRs, this calculation uses energy injection reference levels only. The selected reference level is reported and passed to the DSO for ex-ante mitigation purposes and is also provided downstream for settlement mitigation.

The SMSR OR offer will retain the current offer structure design. MPs may submit up to five PQ pairs with positive MW quantities, and these quantities can reflect an expanded OR capability enabled by both charging and discharging operations.

The financial reference levels (FRLs) of SMSRs include three main updates:

- charging cost, which captures the expense associated with energy consumption for storage resources;
- opportunity cost, representing the foregone revenue when a resource provides energy in the current timeframe instead of pursuing alternative market opportunities; and
- OR offer FRLs include auxiliary energy consumption calculations.

Energy Offer Reference Level Design for SMSR

The energy offer reference level will be created exclusively for the injection portion of the bi-directional offer curve. No reference levels will be determined for charging (negative MW range). Consequently, the MW range for the energy offer reference level will span from 0 MW to the Maximum Generator Resource Active Power Capability. To maintain a total of 20 price-quantity (PQ) pairs across both injection and charging operating ranges, the energy offer reference level will have a maximum of 18 price laminations, reserving space for charging laminations if mitigation occurs.

This section presents newly introduced formulas for the charging cost and opportunity costs components, which under ERP, will be specifically applicable to the SMSR. The charging cost component represents the commodity cost of charging the battery. It differs from the opportunity cost, which represents the revenue forgone by using an hour of energy now instead of preserving it for future periods when market prices are higher. The concepts remain the same, but the approach was refined and the IESO's estimate of these values was enhanced. The

Cycle Efficiency parameter (formerly called round-trip efficiency) is also being updated to incorporate the new dispatch data introduced through ERP.

Equation 1 below presents the formula for the Energy Offer Reference Level ($/MWh) for the SMSR, with all subcomponents in $/MWh.

Note that the new formulas and parameters presented in this document demonstrate the FRL design for SMSRs. The final formulas will be reflected in the appropriate Market Manuals during implementation of this design.

$$\begin{aligned}\boldsymbol{SMSR\ Energy\ Offer\ Reference\ Level} \\ = Max\Bigg(&\left(\frac{Charging\ Commodity\ Cost}{Cycle\ Efficiency}\right) + \frac{Charging\ Uplifts}{Cycle\ Efficiency} \\ &+ \frac{Transmission\ and\ Distribution\ Charges}{Cycle\ Efficiency} + Global\ Adjustment \\ &+ Station\ Service\ Cost + Major\ Maintenance \\ &+ Scheduled\ Maintenance\ Electrical\ and\ Mechanical \\ &+ Unscheduled\ Maintenance\ Costs, (Battery\ Storage\ Opportunity\ Cost)\Bigg)\end{aligned}$$

Equation 1

Charging Commodity Cost

Cycle Efficiency

Cycle Efficiency used in the new SMSR energy offer reference level will be sourced from participant-submitted daily dispatch data. The cycle efficiency will not include internal service load (ISL), which represents any auxiliary loads and station service loads of the battery. Costs related to ISLs are captured in the design through the station service cost parameter of the energy offer reference level or the auxiliary energy consumption component of the OR offer reference level. If the MP does not have a separately metered station service, the IESO will consult with the MP on how to appropriately determine the eligible station service cost.

Using the new market participant-submitted cycle efficiency parameter for financial reference level calculations eliminates the need for MPM to separately collect cycle efficiency information during reference level consultations, reducing duplicate effort. It also better reflects short-term efficiency conditions, as reduced recent injections lead to lower cycle efficiency and higher losses that are captured as higher costs.

Adoption of Principle of Pumped Hydro FRL

The SMSR FRL design will adopt elements from the pumped hydroelectric energy offer FRL formula, specifically the dynamically calculated charging cost component, which takes a historical seven-day rolling average LMP from charging operations. Instead of Pumping Efficiency, the Cycle Efficiency dispatch data will be utilized to calculate the charging cost. The current pumped hydro FRL formula is shown below in Equation 2.

$$\boldsymbol{Pumped\ Hydro\ Energy\ Offer\ FRL} = Max\left(\left(\frac{Pumping\ Power\ Cost}{Pumping\ Efficieny}\right) + Fixed\ Energy\ Regulatory\ Charge + Hydroelectric\ Fuel\ Costs + CAD\ Energy\ Offer\ O\&M\ Costs\ per\ breakpoint + USD\ Energy\ Offer\ O\&M\ Costs\ per\ breakpoint, (Intraday\ Opportunity\ Cost + Storage\ Horizon\ Opportunity\ Cost + Forebay\ Refill\ Opportunity\ Cost)\right)$$

Equation 2

Charging Cost Calculation for SMSR

The Charging Commodity Cost is a new parameter introduced for the SMSR. It is conceptually similar to the Pumping Power Cost used in the pumped hydroelectric energy-offer FRL formula. The Charging Commodity Cost represents the seven-day rolling average charging cost for the same resource. The sum of the real-time LMPs multiplied by the power scheduled for each hour is divided by the total power scheduled over the seven-day period. This is a dynamically calculated component that updates the Charging Commodity Cost daily.

The Charging Commodity Cost solely represents the energy commodity component associated with charging the storage resource, as defined in Equation 3. Non-commodity charging uplifts are excluded from this term and are instead modeled through additional parameters that are consistent with the formulation in Equation 2. This includes transmission and distribution charges, as well as other applicable regulatory and tariff-based charges which are each represented by a distinct parameter. All non-commodity charging parameters are adjusted by dividing by the charging efficiency to reflect losses incurred during energy charging.

This will establish the charging cost price floor in the SMSR energy offer reference level and is applicable to both the DA and RT reference level calculations. The reference level takes the maximum of the incurred short-run marginal cost and the opportunity cost. The charging commodity cost captures the costs of the scheduled charging while the opportunity cost approach complements it by looking for the highest LMP forecasts, which will generally cover the magnitude of any atypical charging costs. It removes redundancy of calculations and promotes simplicity.

$$Charging\ Commodity\ Cost\ \left(\frac{\$}{MWh}\right) = \frac{\sum_{n}^{r=1}\left(\sum_{2016}^{i=1}\left(Charging\ Withdrawal\ Costs\ \left(\frac{\$}{MWh}\right) \times Scheduled\ Power\ (MWh)\right)_{i}^{resource\ r}\right)}{\sum_{n}^{r=1}\left(\sum_{2016}^{i=1} Scheduled\ Power\ (MWh)_{i}^{resource\ r}\right)}$$

Equation 3

Let i be the number of intervals in the rolling seven-day period (2016 intervals)

Let n be the number of SMSRs

If no charging has been conducted during the previous seven-day period, the IESO uses the last non-zero value for the Charging Commodity Cost calculated for the SMSR.

Opportunity Cost

Opportunity Cost Calculations

The Opportunity Cost component will ensure that the MPs are able to reflect the forgone future revenues when an SMSR could have used its limited energy in an hour with a higher price or LMP. Opportunity costs are integral to energy storage resources, which are always considered energy limited since they have limited storage capacity. Most batteries in the Ontario market have a four-hour storage capacity. Battery procurements with other durations of storage may require future refinement for Opportunity Costs.

A new opportunity cost parameter will be introduced for the new modeling specific to battery storage resources, specifically the Battery Storage Opportunity Cost (BSOC).

The Day-Ahead BSOC will be the maximum of Approaches 1 and 2 (discussed below), referred to below in Equation 4, which use historical price forecasting. The OnPeak Historical Price in Approach 1 accounts for seasonality and utilizes the resource's historical prices from the same period of the prior 3 years to forecast opportunity costs. The Historical RT Storage Duration LMP in Approach 2 captures short-term trends and utilizes recent prices to forecast opportunity costs. Day-ahead opportunity costs are applied to the energy offer reference levels calculated for the DAM. Day-ahead reference levels are published prior to 6 AM EPT before the opening of the DA dispatch data submission window. DAM FRL Values Report contains reference levels to be used by the DA calculation engine and may inform MP in submitting their DA offer. Therefore, the resource-specific LMPs for the next dispatch day are not available to determine opportunity costs for DA since they are produced after the reference levels are calculated.

$$DayAhead\ Battery\ Storage\ Opportunity\ Cost\ = MAX(OnPeak\ Historical\ Price,\ Historical\ RT\ Storage\ Duration\ LMP)$$

Equation 4

The Realtime BSOC will be the maximum of the four approaches. The Realtime BSOC uses the day-ahead BSOC calculation from Approaches 1 (OnPeak Historical Price) and 2 (Historical RT Storage Duration LMP) and introduces forward-looking LMPs produced by the DSO from Approaches 3 and 4 as shown below in Equation 5. Approaches 3 (Highest DayAhead LMP) and 4 (Highest PD Advisory LMP) are called the Highest DayAhead LMP and Highest PD Advisory LMP. As these forward-looking LMPs are only available after the calculation engine runs, Approaches 3 and 4 can only be applied to RT reference levels. The information available to support RT opportunity cost calculations is more current, allowing for more frequent and accurate updates to opportunity cost estimates as the market approaches RT.

$$Realtime\ Battery\ Storage\ Opportunity\ Cost\ =\ MAX(OnPeak\ Historical\ Price,\ Historical\ RT\ Storage\ Duration\ LMP,\quad Highest\ DayAhead\ LMP,\ Highest\ PD\ Advisory\ LMP)$$

Equation 5

All opportunity cost approaches will be dynamically calculated by the IESO and the IESO will take the maximum opportunity cost value calculated from each approach. Each approach will have different forecast methodology to account for multiple ways that prices may trend.

Approach 1: OnPeak Historical Price

Approach 1 will forecast opportunity costs for a week (seven days) and will use the average hourly on peak prices for the same week in the previous three years. This approach is available for resources that have at least one year of history. On peak hours refer to the 7 AM to 11 PM EST timeframe on business days.

The average on peak prices for the same week of the previous three years will be further averaged to obtain an opportunity cost value that captures the seasonal price trends from previous years as shown below in Equations 12-15.

Let:

- $P_{y,h}$= on-peak hourly price in year y and hour h of the same week
- On Peak= number of on-peak hours in that week

$$Year\ 1\ OC_1 = \frac{1}{\text{OnPeak}} \sum_{h \in \text{OnPeak}} P_{1,h}$$

Equation 6

$$Year\ 2\ OC_2 = \frac{1}{\text{OnPeak}} \sum_{h \in \text{OnPeak}} P_{2,h}$$

Equation 7

$$Year\ 3\ OC_3 = \frac{1}{OnPeak} \sum_{h \in OnPeak} P_{3,h}$$

Equation 8

$$OnPeak\ Historical\ Price = \frac{Year\ 1\ OC_1 + Year\ 2\ OC_2 + Year\ 3\ OC_3}{3}$$

Equation 9

Example:

Assume $OnPeak\ Historical\ Price$ is being calculated for March 10, 2026. The on peak prices for the week starts March 10, 2026, to March 16, 2026, inclusive.

- Y1 OC = 53.25 $/MWh
- Y2 OC = 42.28 $/MWh
- Y3 OC = 86.63 $/MWh

On Peak Historical Price = (53.25+42.28+86.63) /3 = 60.72 $/MWh

The average price is then escalated using an electricity price index to generate a representative benchmark price that can be applied across multiple days within the opportunity window as shown below in Equation 10. The electricity price escalation is created using an average of three years price escalation for the resource for the week leading up to the dispatch day but ends the day prior to the dispatch day as shown below in Equation 11.

$$Approach\ 1\ Opportunity\ Cost = OnPeak\ Historical\ Price \times MAX(1 + Approach\ 1\ Electricity\ Escalation\ Factor, 1)$$

Equation 10

$$Approach\ 1\ Electricity\ Escalation\ Factor = \frac{1}{2}\left(\left(\frac{Year\ 3\ OC_3 - Year\ 2\ OC_2}{Year\ 2\ OC_2}\right) + \left(\frac{Year\ 2\ OC_2 - Year\ 1\ OC_1}{Year\ 1\ OC_1}\right)\right)$$

Equation 11

Example:

Approach 1 Electricity Escalation Factor = 0.5 x ((86.63– 42.28)/42.28 + (42.28-53.25)/53.25)

= 0.5 x (1.05 + -0.21)

=0.42

On Peak Historical Price x MAX (1 + Approach 1 Electricity Escalation Factor, 1)

=60.72 $/MWh x MAX (1+0.42, 1)

=86.22 $/MWh

Approach 2: Historical Real-time Storage Duration LMP

Approach 2 calculates the opportunity cost by using the historical LMPs of the resource. The historical LMPs for a defined time period are forecasted for the storage duration starting at the dispatch day for which the opportunity cost is calculated. This approach should consider short-term and recent price trends, and expects that the opportunity cost may continue to trend in alignment with recent history. The opportunity cost calculation for Approach 2 will apply to both the DA energy offer reference level and the RT energy offer reference level. The DA calculation uses slightly different LMPs and SoC than the RT calculation because at the time of the RT calculation, the IESO has more up-to-date information.

An important consideration is how often a resource plans to cycle and how long it intends to hold its charge. These choices influence the opportunity cost since a longer holding period increases the resource's exposure to higher LMPs. An energy storage resource will generally choose to arbitrage when LMPs are elevated. As a result, extending the holding period typically leads to higher expected LMPs, which in turn increases the opportunity cost value.

Two inputs are required related to how long a resource can store its charge in this opportunity cost calculation, specifically the storage duration and the state of charge information.

Storage Duration

MPM collects the cycling frequency assumptions as part of the reference level consultations, which indicate how much the resources intend to cycle. This modeling assumption will have an impact on the BSOC. For example, if the resource has one hour of SoC in the battery, it can technically hold it beyond a 24-hour period. On the contrary, batteries are quick-start resources with multiple opportunities to charge and discharge in the day, acting like peaking resources. There is variability and different considerations factored into how long a resource would hold its charge. To ensure a consistent approach across all SMSRs, for the purpose of developing the BSOC, the assumption is that the resource will only store energy for a maximum period of 7 days x 24 hours = 168 hours.

State of Charge Hours

The SoC hours is another input, and its function in the calculation identifies how many hours of charge at full capacity is in the battery. This measure drives how many of the highest LMPs are selected in the storage duration calculation.

The number of hours in storage is equal to SoC MWh divided by the resource's MAPC MW where MAPC is the registered Maximum Generator Resource Active Power Capability. The calculation is rounded down to the nearest integer.

The State of Charge Hours Input (in hours) used in the calculation will be a calculated number of hours as shown below in Equation 12.

$$State\ of\ Charge\ Hours\ Input: ROUNDDOWN\ (\frac{SOC\ MWh}{MAPC})$$

Equation 12

Day-Ahead Opportunity Cost Information

This subsection details the data that is used in the calculation for Approach 2 to determine the DA opportunity cost. The exact timing and sourcing of data may be subject to change dependent on feasibility and implementation, but the details below show the conceptual intent of the calculation.

Day-Ahead SoC Hours (# hours in storage)

For the DA reference level calculations, the IESO will use the DA SoC MWh, as established with MPs during the one-on-one reference level consultation.

The DA State of Charge Hours Input (in hours) used in the calculation will determine the number of hours as shown below in Equation 13:

$$DA\ State\ of\ Charge\ Hours\ Input: ROUNDDOWN\ (\frac{DA\ SOC\ MWh}{MAPC})$$

Equation 13

Which LMPs to use for Day-Ahead (DA) BSOC Calculation

LMPs are used to determine the opportunity cost, and this calculation will leverage a historical approach of what LMPs have been created in the recent storage duration.

Historic Looking: Lookback RT LMP from approximately ~HE4 Int 12 of D0 to HE5 Int 1 of D-7 (converted to average hourly LMP), which is based on the number of hours of the storage duration.

Real-Time Opportunity Information

This subsection details the data that is used in the calculation for Approach 2 to determine the RT opportunity cost. The exact timing and sourcing of data may be subject to change depending on feasibility and implementation, but the details below show the conceptual intent of the calculation. This calculation will use the inputs below for both RT FRL calculations (at approximately 17:30 EPT and post 20:00 EST) for SMSRs.

Real-time SoC Hours (hours in storage):

For the RT reference level calculations, the IESO will use the RT SoC MWh, as established with MPs during the one-on-one reference level consultation. This SoC value will be used to populate the SoC MWh in Equation 14:

$$RT\ State\ of\ Charge\ Hours\ Input: ROUNDDOWN\ (\frac{SOC\ MWh}{MAPC})$$

Equation 14

Which LMPs to use for RT Calculation

LMPs are used to determine the opportunity cost, and this calculation will leverage a historical approach of what LMPs have been created in the recent storage duration.

Historic Looking: Lookback RT LMP from approximately ~HE16 Int 12 of D0 to HE17 Int 1 of D-7 (converted to average hourly LMP), which is based on the number of hours of duration.

Ranking and Averaging

Separately for the DA calculation and the RT calculation, the average hourly LMPs are collected, ranked and averaged to derive the final third approach output value. To derive the value, rank the top X highest LMPs and perform a simple average for the selected LMPs, where X represents the calculated SoC (hours).

Summary of Approach 2 Calculation Steps

Table 4: Summary of Calculation Steps for Approach 2

Topic	Calculation Steps	Example
Storage Duration	168 hours or 7 days	168 hours
DA State of Charge	ROUNDDOWN (DA SoC MWh ÷ MAPC)	SoC MWh= 300.0 MWh MAPC = 80.0 MW DA_SoC=ROUNDDOWN (300.0 ÷ 80.0) DA_SoC= 3 hours
RT State of Charge	ROUNDDOWN (RT SoC MWh ÷ MAPC)	SoC MWh= 300.0 MWh MAPC = 80.0 MW RT_SoC= ROUNDDOWN (300.0 ÷ 80.0) RT_SoC= 3 hours

Topic	Calculation Steps	Example
DA Historical LMP	Lookback RT LMP from ~HE4 Int 12 of D0 to HE5 Int 1 of D-7 (converted to average hourly LMP) which is based on the number of hours of the storage duration	Dispatch Day: March 14, 2026 LMP Lookback Start: March 6, 2026 HE5 Int 1 LMP Lookback End: March 13, 2026 HE4 Int 12
RT Historical LMP	Lookback RT LMP from ~HE16 Int 12 of D0 to HE17 Int 1 of D-7 (convert to average hourly LMP) which is based on the number of hours of duration	Dispatch Day: March 14, 2026 LMP Lookback Start: March 6, 2026 HE17 Int 1 LMP Lookback End: March 13, 2026 HE16 Int 12
Ranking	Rank and average the top X SoC hourly LMPs as the opportunity cost value where X represents the calculated state of charge (hours) in the earlier step	DA: (205.50 \$/MWh + 106.40 \$/MWh + 302.50 \$/MWh) ÷ 3 =204.80 \$/MWh RT: (315.20 \$/MWh + 205.50 \$/MWh + 106.40 \$/MWh) ÷ 3 = 209.03 \$/MWh

Approach 3: Highest Day-Ahead Market Prices for D+1

This approach is only utilized to calculate RT opportunity costs. The DSO produces resource-specific LMPs for the next dispatch day in the DA timeframe. These future prices are the best information produced by the calculation engines, since they use the most up-to-date information available at the time of the calculation.

This methodology will function in a manner consistent with the former intraday opportunity cost framework in DMSR. The highest DA LMP in the 24-hour period is the opportunity cost.

Example: The maximum DA LMP is $91.00/MWh and this will be the calculated result for Approach 3.

Table 5: Example of DA LMP Selection for Approach 3

Hour	DALMP ($/MWh)
1	5.45
2	10.73
3	15.54
4	17.10
5	20.89
6	30.99
7	15.00
8	91.00
9	20.48
10	45.57
11	49.87
12	75.04
13	10.37
14	3.48
15	0.09
16	1.78
17	56.25
18	20.04
19	21.35
20	15.99
21	-3.05
22	-0.10
23	-3.98
24	8.98

Approach 4: Highest Pre-dispatch Advisory Market Prices for D+1

This approach is only utilized to calculate RT opportunity costs. Similar to Approach 3, the opportunity cost calculations can use the PD advisory prices produced by the calculation engines. The first PD run for advisory hours out into the next day (D+1) will occur after 20:00 EST. After this time, the LMPs can be used for the opportunity cost calculation. The IESO will set the highest pre-dispatch advisory market prices for (D+1) as the Approach 4 opportunity cost value.

The IESO will implement a new RT reference level calculation that incorporates updated advisory prices to capture the most current opportunity costs. As the RT Market FRL Values report is published prior to 17:30 EPT, a new calculation and report will be published after the 20:00 EST PD run. The IESO will not update RT financial reference levels after this run. If MPs see that advisory prices are further increasing for subsequent PD runs, then the temporary reference level change requests can be submitted as necessary.

The use of a forward-looking approach means that the PD advisory prices should reflect short-term system conditions and changes that can impact LMPs. Currently, an MP may use the advisory prices to increase their charging cost if they foresee that the charging cost component is understated based on charging costs determined from the previous year. The MP is less likely to submit temporary reference level change requests in anticipation of LMP increases that are considered by the PD engine.

Example: At 20:00 EST PD engine run, the LMPs are produced for D+1. The maximum PD LMP is $100.05/MWh and this will be the calculated result for Approach 4.

Table 6: Example of PD LMP Selection for Approach 4

Hour	PD LMP ($/MWh)
1	61.02
2	20.35
3	4.05
4	17.64
5	12.06
6	5.01
7	60.31
8	51.87
9	35.54
10	21.67

Hour	PD LMP ($/MWh)
11	29.91
12	25.01
13	100.05
14	3.69
15	0.06
16	15.16
17	24.64
18	36.19
19	47.81
20	46.70
21	43.12
22	57.54
23	35.13
24	-5.06

OR Offer Reference Level Design for SMSR

For the SMSR, an MP submits its full range of OR capability covering both charging and discharging operations. However, the offer does not explicitly indicate which laminations correspond to charging or discharging. Each OR offer consists of up to five laminations, where each lamination represents a MW range paired with a price.

When the DSO schedules OR, it selects the required amount from the MP's offer based on system needs. The DSO determines the resource's operating mode using its visibility into the resource's SoC and scheduled energy dispatch. This allows the DSO to determine whether the resource can provide OR by reducing charging, increasing injection, or both. This design ensures that OR scheduling is consistent with the resource's RT capability and energy position. It also prevents infeasible commitments by aligning OR scheduling with the resource's actual operating mode and physical constraints.

The OR reference level is not designed to dynamically adjust based on the resource's operating mode (charging or discharging). Therefore, the OR reference level is represented using the discharging mode across the full range, as this reflects the higher cost of providing OR compared to charging. This approach ensures that the reference level is conservative and avoids underestimating costs when the resource is dispatched for OR while discharging.

The reason for this design choice is that MPs cannot associate their short-run marginal cost of providing OR with specific MW quantities across different operating modes. In other words, the cost structure for OR provision is not granular enough to differentiate between charging and discharging segments, making a single mode reference level necessary for simplicity and consistency.

Auxiliary Energy Consumption for Provision of OR

Auxiliary energy consumption is energy consumed by auxiliary services necessary for the electricity storage resource to respond to dispatch instructions. The OR reference level formula as shown below in Equation 15 and Equation 16 is updated for SMSRs to reflect a more dynamic electricity purchase price.

$$Operating\ Reserve\ Incremental\ Cost\ \left(\frac{\$}{MW}\right) = Auxiliary\ Energy\ Consumption\ \left(\frac{\$}{MW}\right)$$

Equation 15

$$Auxiliary\ Energy\ Consumption\ \left(\frac{\$}{MW}\right) = \frac{Auxiliary\ Power\ Consumed\ During\ 7\ Day\ Operation\ (MWh) \times 1\ hour}{7\ Day\ MWh\ Scheduled\ on\ Operating\ Reserve\ (MWh)} \times Average\ Electricity\ Purchase\ Price\ \left(\frac{\$}{MWh}\right)$$

Equation 16

The purchase price will be calculated dynamically as the seven-day rolling average RT LMP as shown below in **Error! Reference source not found.**. The Average Electricity Purchase Price equation will be an IESO dynamically calculated parameter of the average hourly LMPs for the past week.

$$Average\ Electricity\ Purchase\ Price\ \left(\frac{\$}{MWh}\right) = \frac{1}{168}\sum_{h=1}^{168} RTLMP_h$$

Equation 17

The Auxiliary Power Consumed during Operations (MWh) is updated to the Auxiliary Power Consumed During seven Day Operation (MWh) and will remain as a fixed component of Equation 16 above. As with today, MPM will work with MPs to establish this registered component.

The MW Offered on Operating Reserve (MWh) will be updated to the new seven Day MWh Scheduled on OR (MWh) as shown below in Equation 18. This will be a new dynamic component calculated by the IESO using a rolling seven-day summation of scheduled OR of a given class.

$$7\ Day\ MWh\ Scheduled\ on\ Operating\ Reserve\ \left(\frac{\$}{MWh}\right) = \frac{1}{168}\sum_{h=1}^{168} ORSchedule_h$$

Equation 18

Temporary Reference Level Change Request Updates

Temporary reference level change requests enable an MP to increase the applicable parameter from its established reference levels. This functionality enables MPs to incorporate the actual short-run costs of operation, not included in the registered reference levels, resulting from unexpected events that increase production costs in the DA or RT timeframes.

These temporary reference level change requests provide MPs with an immediate mechanism to update reference level values temporarily for a specific period, using pre-approved supporting information with the MPM team.

The IESO will explore enhancements to the submission process for temporary reference level change requests within Online IESO including extending the applicability period and reducing redundancy. These improvements are intended to enhance the user experience and improve submission efficiency. Any proposed improvements will be subject to further feasibility assessment.

Reference Quantities

RQs for an SMSR are established for both the energy market and each class of OR, and they apply to the DA and RT markets. The first version of DA RQs is published before the DA submission window opens at 06:00 EPT, ensuring MPs have visibility before submitting offers. RT RQs and a second version of DA RQs are published 14 days after the dispatch day.

Two distinct approaches are required because of structural differences between the existing DMSRs and the SMSR. For the DMSRs, the current design remains unchanged where the IESO creates separate RQs for the generating resource and the load resource.

For SMSRs, MPs are expected to provide outage and derate information to reflect the high and low operating limits of the resource. Outages can be submitted for:

- positive MW range (representing discharging capability); and
- negative MW range (representing charging capability).

RQs are adjusted to account for these outages and derates, ensuring that energy and OR capabilities reflect the resource’s actual availability. As MPs can submit independent derate values for positive and negative ranges, the resource may have different capabilities for charging and discharging, which will be factored into reference quantity RQ calculations.

RQs do not factor in SoC information as the DA and RT calculation engines will manage the resource's SoC based on market schedules, and schedule energy and OR according to feasibility.

Energy Offer Reference Quantities

The energy offer RQ for an SMSR represents the resource's maximum potential injection capability only, adjusted for any outages or derates for each hour of the dispatch day. There will be no energy offer RQ established for the charging capability.

The maximum potential injection output is defined as the registered MAPC, less any submitted outages or derates. This ensures that RQs reflect the resource's actual available capacity rather than its theoretical maximum. SMSRs may request monthly energy RQ modifiers to be applied as applicable.

Special Rule for Overnight Hours

For dispatch hours between 23:00 and 07:00 EST, the energy offer RQ will be set to zero since MPs have indicated their preference to charge within this period. An energy RQ of zero means, under the physical withholding framework, that the resource will not fail the conduct test regardless of the injection offers it submits for the DA or RT timeframe during this specific time period (i.e., HE 24 to HE 7). For clarity, zero MW energy RQ impacts only the injection range, therefore, the resource can submit MW quantities on the charging energy offers without risk of being flagged for physical withholding.

Operating Reserve Reference Quantities

For any class of OR, the OR offer RQ represents the resource's outage-adjusted capability for each dispatch hour to provide OR from both charging and discharging operations. This ensures that the calculation reflects the actual availability of the resource rather than its theoretical maximum capability.

Under the DMSRs, the OR RQ was set to zero for the individual dispatchable generation or dispatchable load resources as the reserve capability was not aggregated across modes. This separation in modeling and scheduling created complexity in how resources submitted OR offers, so the RQ design allowed for some flexibility. With the updated single resource modeling, this limitation will no longer apply. Reserve capability can now be aggregated across both modes under a single resource, eliminating the need for constant zero MW OR offer RQs and simplifying reserve offer structures.

For the SMSR, the formula for calculating the OR reference quantity is:

$$\boldsymbol{OR\ Offer\ Reference\ Quantity\ =}$$

$$(Maximum\ Generator\ Resource\ Active\ Power\ Capability\ -\ Injection\ Outages) + ABS(Maximum\ Negative\ Generator\ Active\ Power\ Capability) - ABS\ (Withdrawal\ Outages)$$

This formula accounts for both charging and discharging capabilities, adjusted for outages, and uses the absolute value of the charging range to ensure positive MW representation. SMSRs may request monthly OR RQ modifiers to be applied as applicable.

Special Rule for Overnight Hours

For dispatch hours between 23:00 and 07:00 EST, the OR offer RQ applies only to the charging capability. During this period the injection capability (as represented by the Maximum Generator Active Power Capability) and Injection Outages will be set to zero. This design provides MPs with greater flexibility to charge during overnight periods while still meeting reserve requirements.