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Storage and Hybrid Integration Project Design Engagement Memo 1.0

Engagement Topic: Storage and Hybrid Design Framework and Modules
Date: November 14, 2024

Feedback Requested:

- Specific comments on the Modules decision-making and the IESO's Design Considerations.
- Are there Design modules or considerations not included that are relevant to the IESO's design work?
- To allow participants to better express their costs based on different operating conditions, should the IESO consider Stage of Charge (SoC) ranges tied to bids and offers in some form, other options such as a price adder, or not consider this? An example of what this could look like for a market participant is that they submit the following 20 P/Q set:
    - 0-20% SoC will have 5 P/Q pairs branching full injection and withdrawal range;
    - 21-60% SoC will have 5 P/Q pairs branching full injection and withdrawal range;
    - 61-80% SoC will have 5 P/Q pairs branching full injection and withdrawal range;
    - 81-100% SoC will have 5 P/Q pairs branching full injection and withdrawal range.
- Market participants could be required to submit a day ahead SoC estimate. Due to day-ahead market (DAM) bid submission window closing 14 hours prior to real time (RT), what considerations should the IESO have for DAM in relation to market participant SoC estimation? How can the IESO support an estimate that will accurately reflect the full SoC value that could be present at the start of the next day?

- Are there any missing parameters that could help the IESO more accurately reflect storage's operating characteristics in the market optimization tools and produce more optimal outcomes in the market? Any other reasons that you will need to notify the control room of necessary changes in the mandatory window?

Purpose

The purpose of this document is to obtain feedback and provide detail on the IESO's market design work with respect to updating the storage resource and co-located hybrid participation model. This memo will articulate how the IESO will undertake and organize the project's market design work to enhance storage and co-located hybrid participation and support reliability by providing accurate market schedules. The project is also seeking feedback on any gaps or design improvements. After collecting feedback from stakeholders, the IESO may adjust aspects of the market design or considerations where practical.

The specific implementation of the design 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 at a future date. Any material changes to the design as a result of implementation discovery will be discussed with stakeholders.

Background

The Enabling Resources Program (ERP) will further integrate storage, hybrids, and distributed energy resources (referred to as "ERP Resources") into IESO Administered Markets (IAM), tools and processes. By leveraging the ERP Resources effectively, the program seeks to ensure a reliable and sustainable electricity system for Ontario's future.

A foundational storage participation model was implemented in 2021 (through the Storage Design Project[1]) and a foundational co-located hybrid model was implemented in 2023 (through

[1] Operating through the Energy Storage Advisory Group, the IESO launched an engagement to seek feedback on the development of a design for how storage will participate in the IAMs here: https://www.ieso.ca/en/Sector-Participants/Engagement-Initiatives/Engagements/Energy-Storage-Advisory-Group

the Hybrid Integration Project[2]). Today, the ERP is focused on implementing an enhanced resource model for storage, and the co-located hybrid participation model and DER participation (DERs will be discussed through its own dedicated engagement separate from storage and hybrids). The enhanced storage model is intended to improve upon the foundational storage model in terms of market efficiency, operational efficiency, better safeguards to support reliability, and supporting resource participation in other grid services. This document serves to describe the market design on storage and hybrids conducted to date.

ERP Definitions

For the purposes of participating in the IESO's wholesale markets, the ERP has defined storage and hybrid ERP Resources as follows:

Storage	Hybrids
A resource used for the sole purpose of withdrawing electricity from the electricity system, storing that electricity, and re-injecting it, or a portion thereof, into the electricity system.	Combined resources consisting of electricity storage and generation resources located behind a single connection point that participates in the IESO markets as a single resource or separate resources[3].

Approach to Design

Modules and Design Elements

This market design work is specific to updating the storage resource and co-located hybrid participation models. This work is typically done by considering impacts of design from being 'built to bill'/'cradle to grave' approach, specifically considering impacts to various IESO processes, systems, tools, rules and manuals. Design content is therefore split into each of these components, referred to as design modules which can be made up of more granular design elements.

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[2] https://ieso.ca/en/Sector-Participants/Engagement-Initiatives/Engagements/Hybrid-Integration-Project

[3] Please note that the IESO has explored a single resource (also referred to as "integrated") and separate resource (also referred to as "co-located") model for hybrids, and currently has only pursued a separate resource/co-located model.

Some of these modules and elements need predecessor decisions to begin their design work. The project is sequencing modules and design elements to address design decisions that will be needed in subsequent designs. For example, the core "Optimization" element within the "Grid and Market Operations" module, is the likely precursor design decisions to support other design modules and elements.

Enhanced Storage Participation Model

Existing Design Framework

The IESO laid the groundwork for an interim/foundational storage model through the Energy Storage Advisory Group in 2020. Storage resources currently operate under the storage models that are described in the published Design Document. In 2021, the IESO completed amendments to the Market Rules and associated Market Manuals to clarify participation of storage resources in the IESO-Administered Markets. The inclusion of storage in the Market Rules and Manuals provided the foundational participation model for electricity storage, unlocking participation in the wholesale markets and paving the way for electricity storage resources to successfully clear the IESO's capacity auction. This foundational design was predicated on not performing any major updates to IESO tools or systems, so it has been expected the existing design creates limitations in how storage resources can be used in various markets and services.

Enhanced Design Framework

Post Market Renewal Program (MRP) implementation, the IESO will have the opportunity to update systems and tools to better integrate storage resources into our systems. The key enhancements to the storage model provide the ability to better facilitate participation in various markets and services while also giving the IESO's Dispatch Scheduling and Optimization (DSO) algorithm, the ability to 'see' an electricity storage resource for what it truly is: a single energy limited resource that can withdraw, store and inject energy. This is an improvement on the current interim storage design, which models electricity storage as two-resources at the same connection point: a separate generation resource and a separate load resource with several manual workarounds for state-of-charge management and to ensure both resources are not dispatched simultaneously. Some of the key features and decisions necessary to support this model and expand participation are summarized in the table below. Usage of these framework decisions vary by if storage is dispatchable, self-scheduling, and by technology (these decisions are described in the modules below):

Table 1: Post Implementation Design Framework

Feature	Description
Resource Modelling	• Storage will be modelled in IESO's tools as a single bi-directional resource that can both inject (offer) or withdraw (bid) across a continuous offer curve.
State-of-Charge (SoC)	• State-of-charge will be modelled in IESO tools to support efficient/reliable use of storage (will ensure tools have view or forecasted state-of-charge so only feasible dispatch or scheduling instructions issued)[4].
Regulation Service	• Storage will be integrated into regulation service tools and systems, as well as determining ability and impacts to providing other grid services[5].
Uplifts	• Storage to be exempt[6] from uplifts on energy withdrawn as "fuel" for the sole purpose of being able to provide services back to the grid at a future point in time. E.g. energy from station service is not exempt.

Rationale:

- Single resource modelling provides greater market participation for storage resources

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[4] Scheduling and dispatch also considers participant bid/offer curve or actions needed to support reliability. E.g. the participant will need to have adequate SOC and an economic offer (or be used if deemed necessary for reliability) to be dispatched

[5] This is only to support storage in IESO tool sets if eventually contracted and then scheduled. Necessary procurements/contracting is still required to facilitate participation in regulation service. This contracting will not be done as part of ERP. This project will not consider introducing a co-optimization change to IESO scheduling and dispatch.

[6] Does not apply to uplifts or charges that may be administered by but are outside of IESO's purview (e.g. transmission charges, distribution charges, etc.)

- Creating single resource model and SoC constraint can better optimize resources with storage specific information and parameters. This supports more reliable and better optimization decisions as well as reduces both the amount of manual effort required by control room operators and resource owners to accommodate short notice SoC changes.
- Increased regulation service need in the future; storage has technical capability to provide this service. Storage provides regulation in other jurisdictions and has been tested in IESO pilots.
- Storage is currently exempt from Global Adjustment for withdrawals that are injected back into the grid. Removing other uplifts on consumption used as fuel is intended to facilitate competition between storage and other technologies, while ensuring the ratepayer is not negatively impacted by unnecessarily higher costs.

Scope Considerations

Technology

- Primarily focus on supporting updates to battery storage.
- Will consider the applicability to other technology types that could be classified as storage, most notably pumped generation storage and other existing storage types.

Resource Considerations

- Electricity storage resources whose sole purpose of withdrawing electricity from the electricity system, storing that electricity, and re-injecting it, or a portion thereof, into the electricity system.
- These resources are single-site energy storage resources greater than 1 MW that are registered to participate in the IAMs (less than 10 MW for self scheduling), including participating resources that are embedded within a distribution network (not including aggregated DER participation models).
- Dispatchable Storage and self-scheduling storage will be within scope to align with other generation/resource types.

Modules Explored and Design Questions

Module 1: Capacity

Design Elements: Capacity Qualifications & Performance Obligations and Assessment

The design elements under this module clarify how capacity adequacy value of resources may be determined (capacity qualification), the performance obligations related to qualified capacity, and how performance may be assessed.

The IESO intends to:

- Continue to utilize the existing performance obligations for storage and unforced capacity (UCAP) methodologies unless deemed insufficient to address a single resource model.

Rationale: No change is needed as the existing UCAP methodologies are based on the underlying storage technology and not the participation model that a storage resource uses. Capacity can continue to be qualified on the injection capability with the single resource model.

Detailed Design Considerations for Capacity

- N/A

Module 2: Connection and Registration

Design Elements: Connection Assessment and Approval (CAA), Market Registration (Resource Registration, Prudential Security, Revenue Meter Registration, Telemetry)

The design elements under this module clarify how a market participant completes connection to the IESO grid and register for participation in the IAMs.

For Connection Assessment and Approval, the IESO intends to:

- Continue to utilize existing CAA/System Impact Assessment (SIA) practices and determine if generic connection requirements are needed to support regulation service of storage (or if it is nuanced and this should be determined through specific regulation service acquisition method).

Rationale: The CAA/SIA processes for storage that already exists are sufficient and are not impacted by the participation model that a storage resource uses.

For Market Registration – Resource Registration the IESO intends to:

- Determine what resource/facility/technology types should be classified under a storage model classification and transitioned to the new single resource model. The IESO will need to determine certain requirements or conditions to utilize a single resource model.
- Register those storage resources under a single resource model with dedicated resource and equipment attributes.
- Continue to register storage as either a dispatchable or self-scheduling resource based on existing eligibility requirements which are similar to those applicable to generation resources today.
- Determine which registration requirements will be necessary to support the integration of applicable storage resources into regulation service.

Rationale: Battery storage will utilize a single resource model, but some resource types, specifically pump generation storage share characteristics of storage and hydro, and determinations will need to be made if a single resource model is applicable to that resource type. To date, under the foundational design, storage resources have been registered using generator and load equipment and resource attributes that exist on the Online IESO automated registration system with further supplementation of storage specific data via email. Given that the enhanced storage design will result in a dedicated storage model with unique attributes, the existing registration process for storage and related registration tools will need to be updated. Incorporation of storage specific attributes into the registration process will be necessary to drive the IESO tools to properly account for state-of-charge.

Single resource registration for specific storage types is needed to support greater market participation. This will eliminate the need of two resource model for those specific storage types as well as the applicable rules that would have been relevant for the storage resource operating under the two-resource model. For clarity, market access for dispatchable storage and standalone dispatchable generators as well as self-scheduling generators and self-scheduling storage should align as a result. See below for this description of market access comparison.

Table 1: Comparison of Market Access for Registered Electricity Storage and Registered Generation

Market Access	Dispatchable Generator	Dispatchable Storage	Self-Scheduling Generator	Self-Scheduling Storage[7]
Capacity Market Auction – Submit Capacity offers	Yes	Yes	No	No
Day-Ahead-Market- submit energy and operating reserve offers	Yes	Yes	No	No
Day-Ahead Market – submit energy schedules	No	No	Yes	Yes
Day-Ahead-Market-can set the market clearing price	Yes	Yes	No	No
Real-time markets- submit energy and operating reserve offers	Yes	Yes	No	No
Real-time markets – submit energy self-schedules	No	No	Yes	Yes

[7] Note this table only summarizes the market access with respect to the injection capability of a self-scheduling storage. In MRP, a self-scheduling storage follows the behaviour of a self-scheduling generator when injecting and a Price Responsive Load when withdrawing. There is unique market access for Price Responsive Loads in the different market timeframes. The IESO proposes that similar treatment is carried forward with the enhanced storage model.

Real-time markets –can set market clearing price	Yes	Yes	No	No
Real-time markets-provide regulation service	Yes	Yes*	No	No*

*Through the design stage the IESO will make the determination of registration requirements for storage resources to provide regulation service. The IESO's aim is to support a storage resource to provide energy market services in addition to regulation service (like other regulation service providers), although, storage resources dedicated to only regulation service could allow for easier implementation and will also be subject to exclusion from the OR market if providing regulation.

Specific attributes are required for all IESO participation models, including storage. Below is a list of potential storage attributes that are being considered by the IESO for battery storage for energy, reserve and regulation. Further consideration will be needed if other types of storage have unique parameters. Some of these parameters are still separated between a generator and load based on the foundational IESO storage design and it will need to be determined if this paradigm should be maintained in these circumstances or certain parameters will need to be migrated to a single resource parameter that could inject or withdraw.

Table 2: Storage Resource Attributes for Enhanced Storage Model

Attribute	Units of Measure (if applicable)	Description	Source (Static/Telemetered)
Certified Duration of Service	Minutes	Usually expressed in minutes, the Certified Duration of Service of a resource is calculated from the registered Upper Energy Limit, Lower Energy Limit, and registered Upper Operating Limit. Certified quantities are determined during testing.	Static Registration Data
Cycle Efficiency (CycleEfficiency,g)	%	The percent of charging energy which is returned by	Static Registration Data

		the storage resource via discharging	
Economic Maximum Power Mode (ECO_Pmax,g)	MW	The maximum active power output for operation as indicated by the market participant	Telemetered value
Economic Maximum Charge Limit (ECO_SOC max,g)	MWh	The dynamic, current maximum energy limit that is indicated by the market participant subject to the following constraint ECO_SOCmax,g ≤ SOCMAXg	Telemetered value
Economic Minimum Power Mode (ECO_Pmin,g)	MW	The minimum active power output for operation as indicated by the market participant	Telemetered value
Economic Minimum Charge Limit (ECO_SOC min,g)	MWh	The dynamic, current minimum energy limit that is indicated by the market participant subject to the following constraint: ECO_SOCmin,g ≥ SOCMIN,g	Telemetered value
Upper Power Operating Limit (injecting) [Pmax,g]	MW	The maximum active power output (MW) for operation when injecting (also known as electricity storage capacity)	Static Registration Data
Lower Power Operating Limit (injecting) [Pmin,g]	MW	The minimum active power output (MW) for operation when injecting	Static Registration Data
Lower Power Operating Limit	MW	The minimum active power consumed (MW) when withdrawing (MW)	Static Registration Data

(withdrawing) [Pmin,l]			
Upper Power Operating Limit (withdrawing) [Pmax,l]	MW	The maximum active power consumed (MW) when withdrawing (MW)	Static Registration Data
Lower Energy Limit [SOCMIN,g]	MWh	The lowest energy amount (MWh) to which the electricity storage system can be consistently discharged without damage beyond expected degradation from normal use.	Static Registration Data
Upper Energy Limit (SOCMAX,g)	MWh	The maximum energy amount (MWh)to which the electricity storage system can be consistently charged without damage beyond expected degradation from normal use	Static Registration Data
Operating reserve Ramp Rate [Operating reserve RampRate,g]	MW per minute	From Market Rules, Appendix 7: The single operating reserve ramp rate in MW per minute associated with g∈OFFERS.	Dispatch Data
Ramp Rate Down for dispatchable generation resources [RampRate DOWN, gJ]	MW per minute	From Market Rules, Appendix 7: The energy ramping down rate in MW per minute associated with the jth block of GENERATIONRAM PDOWNBLOCKg for g∈OFFERS	Dispatch Data

Ramp Rate Down for dispatchable load resources [Ramp Rate DOWN, pJ]	MW per minute	From Market Rules, Appendix 7: The energy ramping down rate in MW per minute associated with the jth block of PURCHASERAMPDO WNBLO CKp for p∈BIDS	Dispatch Data
Ramp Rate Up for dispatchable generation resources [Ramp Rate UP, gJ]	MW per minute	From market rules, Appendix 7: The energy ramping up rate in MW per minute associated with the jth block of GENERATIONRAMP UPBLOCKg for g ∈ OFFERS.	Dispatch Data
Ramp Rate Up for dispatchable load resources [Ramp Rate UP, pJ]	MW per minute	From market rules, Appendix 7: The energy ramping up rate in MW per minute associated with the jth block of PURCHASERAMPUP BLOCKpp∈BIDS	Dispatch Data
Remaining Duration of Service	Minutes or as a % of SoC	The remaining expected time, based upon current state-of-charge and certified duration of service, until the resource achieves its upper energy limit or lower energy limit assuming the resource continues operating at the present active power level	Calculated from telemetered and registration data
State-of-charge (SoC)	%	The degree to which storage is charged relative to the maximum certified electricity storage capacity of the system	Estimated (DAM) Telemetered value and forecasted (PD and RT)

For Market Registration – Prudential Requirements the IESO intends to:

- Continue to apply prudential security requirements at the market participant level for all storage resources with requirements based upon the expected net amount owed by the market participant across all resources under that market participant, but considering changes required to exclude uplifts.

Rationale: This above prudential treatment preserves the existing prudential treatment for storage and is still applicable regardless of whether a single resource is being used or not.

For Market Registration – Revenue Meter Registration the IESO intends to:

- Continue to use a single bi-directional meter to meet revenue meter registration requirements for storage.
- No longer use two defined meter points to represent storage, but instead, adopt a single defined meter point for storage to coincide with the use of a single resource model to ensure alignment of locational marginal pricing (LMP).

Rationale: Existing storage revenue meter requirements are adequate regardless of whether storage is modelled with two separate resources or a single resource. One bi-directional revenue meter will be required to measure both injections and withdrawals from storage. A change in how the defined meter point is determined for storage will be required as the number of defined meter points typically need to match the number of resources to help facilitate accurate settlements. Each delivery point/metering point is assigned to a specific LMP and to avoid conflicting LMP's for the single resource this will need to be adapted.

For Market Registration – Telemetry the IESO intends to:

- Continue to enforce or augment telemetry requirements outlined in Appendix 4.24 and 4.25 of the Market Rules.

Rationale: During the Storage Design Project, telemetry points for the enduring design were anticipated and thus were already made as requirements for electricity storage market participants.

Detailed Design Considerations for Connection and Registration

- Consider developing a transition plan to re-register storage registered under the foundational model into the new enhanced model with minimal disruption to IESO and market participation operations.
- Consider the option of maintaining the two-resource model for certain storage based on specific criteria.
- Determine if what the IESO classifies as storage requires any review of OEB licensing requirements to support resource/facility type in the IESO registration processes.
- Determine if any further documentation could be required to facilitate storage resource registration and integration into regulation service.
- Assess resource requirements to provide regulation service and other necessary changes to allow them to provide additional services and considering their registration type (previously storage was enabled to provide regulation service in a pilot based on the self-scheduling resource type classification). This also needs to consider the impact to the resource being unable to provide OR if the resource is also providing regulation service (storage resources in other jurisdictions typically saturate OR markets.
- Define specific facility and resource registration attributes for storage. Attributes should be universal/agnostic, whenever possible, to apply to any storage resource that will be participating in the IAMs (e.g., batteries, compressed air, fly wheels, etc.).
- Fully outline storage participant prudential security requirements in post-MRP market rules and manuals.
- Incorporate static parameters as part of the registration process for the enhanced storage model to support the prudential security process.
- Confirm that Global Adjustment will continue to be calculated on the load amount under the enhanced model, which can have impacts to settlement and prudential calculations.
- Update resource level information requirements required for the prudential process and Prudential Manager tool that is being introduced alongside MRP, given that there will be a shift from a two-resource model to a single resource model for storage.
- Clarify new parameters needed to support prudential security (if any).
- Consider implications and a transition plan for facilities that are already participating under the foundational model.

Module 3: Grid and Market Operations

Design Elements: Dispatch Data and Other Inputs, Optimization, Regulation Service Operation

The design elements under this module clarify how the storage facility participates in energy, OR markets, and regulation service. This includes what the IESO needs to dispatch resources, consider them in the optimization across all timeframes, as well as considerations for regulation service participation (both providing the service, and impacts to other service offerings).

For Dispatch Data and Other Inputs the IESO intends to:

- Model dispatchable storage with a single resource that submits bids and offers through a continuous offer curve, spanning the entire charge-discharge operating range of a storage facility.
- Model SoC for dispatchable storage within the day-ahead, pre-dispatch and real-time market calculation engines. Consider the interplay of different markets and services in regard to its utilization in the various market calculation engines.
- Model self-scheduling storage with a single resource that submits self-schedules through a continuous offer curve for DAM and its generation self-schedules for other time frames (note: self-scheduling storage will operate like how they operate post MRP implementation, where they will share characteristics of a self-scheduling generator and price responsive load). Consider modelling SoC in the day-ahead time frame but omit it from PD and RT scheduling or dispatch.
- Allow storage facilities to have the ability to submit outage de-rates to withdrawal, injection or storage capabilities.
- Consider bid and offer parameters that are unique to storage and will allow the IESO to better optimize their usage. Specifically, the IESO can explore linking specific SoC ranges to different bid and offers sets for each storage resource.

Rationale: Continuous offer curves and modelling of SoC are the key design constructs for the enhanced storage participation model. A single resource model with a continuous offer curve simplifies the way dispatchable storage participate in the wholesale markets, eliminating the potential for conflicting dispatch instructions (for the withdrawal and injection capabilities of storage) and reducing the need for after the fact assessment and compliance activities (required today to ensure storage is bidding appropriately). A continuous offer curve also allows for SoC management and enables the IESO’s tools to consider the full operating range of storage when developing schedules in real-time and looking ahead.

For self-scheduling storage, they will be required to participate in the interim period under MRP as a self-scheduling generator and price responsive load (PRL). Characteristics of both will follow through into a similar enhanced self-scheduling storage model for day-ahead and real-time:

- Day-ahead: utilize a single bid/offer curve. Allows storage to mimic self-scheduler and PRL. Self-Scheduling generators must submit dispatch data into the day-ahead market for the amount of energy they reasonably expect to provide in each dispatch hour of the real-time market, and price responsive loads that intend to consume energy in the real-time market for a given dispatch hour of a dispatch day must submit dispatch data into the day-ahead market for those hours. Self-scheduling storage will be exempt from ADE requirements.
- In real-time: only offers will be considered for their hourly schedules and will consume as a non-dispatchable load in real time.

Modelling SoC within the IESO's calculation engines can improve efficiency and increase reliability for the use of storage facilities. Modelling SoC enables the IESO's optimization algorithms to schedule storage injections and withdrawals in the periods when they best align with system needs and conditions, accounting for the energy limited nature of storage resources. There is a clear need for dispatchable storage to have SoC across all timeframes, but for self-scheduling it may only be necessary for the day-ahead market due to financial commitments respecting operational constraints of the storage, while in real time the storage will monitor its own SoC, as they generally control their own schedule.

Storage resources may need to express prices and quantities based on differing SoC levels to help facilitate their participation, have additional price adders considering certain static operation states, or other methods. Considering that storage is energy limited (they are expected to typically operate for a maximum of a few hours, typically 4), usage at different SoC levels or depth of operation (the amount of usage from a single dispatch) could impact degradation of the facility, and the requirement to manage IESO market constructs (like the DAM and the mandatory window, where final bids/offers are submitted 2 hours prior to real time) where static price/quantity pair sets may be insufficient to address different scenarios.

For Optimization the IESO intends to:

- Determine how storage will be considered in the optimization, considering new attributes, across all engines. This includes an emphasis on how the pre-dispatch and real-time engines will support each other to ensure the most efficient use of storage resources and proper functioning of the market.
- Consider the impact of providing multiple grid services (including non-co-optimized services) with the optimization of storage resources.

Rationale: Scheduling and dispatching storage is generally a matter of maximizing the gain from trade. In some circumstances the IESO also determines when certain resources will benefit the grid the most. Doing so without complete foresight of how future hours will materialize requires that the IESO make determinations of what time periods specific resources should be dispatched or held for future hours where they could be a more cost-effective option to meet system needs and support maximizing the gain from trade. This is specifically an issue for storage considering it is energy limited. Through the optimization the IESO will develop a set of conditions of when to utilize storage considering its energy limitation. These conditions can severely impact, or drive make whole payments and the settlement module of the design.

The consideration of storage with its unique parameters provides an automated process to schedule and dispatch storage. This better equips storage to manage their resource potentially limits manual actions that are currently required by storage in the existing market. This also improves their opportunity to be scheduled and dispatched within their operational constraints as well as facilitating arbitrage opportunities.

For Regulation Service Operation the IESO intends to:

- Determine methods to integrate a single resource storage model into regulation service tools and systems, as well as considering if it could provide the service through both injections and withdrawals.
- Determine impacts to providing in the energy market (note that regulation service providers are omitted from offering/providing OR from the same resource when scheduled for regulation) and that optimization process when the storage could also be scheduled to provide regulation service.

- Determine how to consider the energy limited nature of storage resource to maintain a consistent minimum availability of regulation service through the hours that storage is expected to provide the service.

Rationale: Storage is energy limited and will have challenges to maintain steady generation output over multiple hours. The IESO will need to consider utilization of both generation and withdrawal capabilities and scenarios that could be most applicable to storage being a regulation service provider.

Detailed Design Considerations for Grid and Market Operations

- Determine how the market participant of storage should submit a starting SoC value to initialize the day-ahead optimization process. The Storage Design Project suggested a variety of potential design options for how to facilitate this, including daily data submissions, and registered default values. Design will explore how other electricity markets have successfully incorporated state-of-charge constructs into their respective day-ahead markets.
- Consider if the proposed state-of-charge management construct will make the concept of the maximum daily energy limit (DEL) obsolete for electricity storage.
- Consider if the Availability Declaration Envelope (ADE) concept can be removed for storage, given that most storage technology is fast-responding and can respond to market signals and can therefore provide value in helping alleviate real time reliability issues. Imposing an ADE may otherwise limit the operational capability and real-time flexibility from storage technology.
- Consider if a storage resource must only provide regulation service for ease of implementation. Storage resource would be omitted from OR participation based on existing market rules.
- Consider if a storage resource can utilize regulation from both the injection and withdrawal capability of the resource. There could be a nuanced approach needed to set basepoints for both sides of the resource.
- Consider degradation and limits to operation on the ability to provide regulation service.

Module 4: Settlements

Design Elements: Market Settlement, Uplift Charges

The design elements under this module clarify market settlement to ensure that participants with storage facilities understand how their participation will be reflected on their settlement statements and invoices.

For Market Settlement IESO intends to:

- Replace the current two resource settlement process for storage facilities with a single resource settlement across the entire charging/discharging profile of a storage facility. A single delivery point will be required due to adopting a single resource model.
- Consider impacts to make whole payments as a result of new parameters, dispatch data and optimization.
- Consider the inclusion of regulation service into storage settlements.

Rationale: The enhanced storage model will require modification to the IESO's market settlement process for storage, requiring settlement of a single resource across a storage facility's entire charging/discharging profile. The settlement process will also need to reflect the IESO's "two-settlement" mechanisms spanning both the day-ahead and Real-Time Markets post-MRP.

For Uplift Charges the IESO intends to:

- Exempt storage from uplift charges on energy withdrawn as 'fuel' for the sole purpose of being able to provide services back to the grid at a future point in time.
- Continue to charge uplifts on withdrawals for any other purpose (e.g. commercial use of energy, station service, cooling fans, office lighting, etc.)

Rationale: Energy storage primarily withdraws for the purpose of providing electricity services to the grid. When uplift costs are charged on energy withdrawn for the purpose of providing grid services, storage are likely to offer energy injections with the intention of recovering those costs. This outcome can lead to higher costs for end-use consumers while providing no additional benefit.

A jurisdictional scan undertaken for the Storage Design Project showed that storage resources in neighbouring markets are also generally exempted from uplifts:

- **Midcontinent Independent System Operator (MISO)**: Storage is not assessed for uplift charges based on the principle MWs bought to charge will be sold back to the market when discharging.
- **ISO New England (ISO-NE)**: Uplift exemptions currently applied to Pumped Generation Storage (PGS) are extended to Storage.
- **New York System Independent System Operator (NY-ISO)**: Similar to Pumped Generation Storage (PGS), storage is modelled as a negative generator (as opposed to load) and avoids paying uplifts in equal treatment with generators.

Detailed Design Considerations for Settlements

- Consider the impact that switching storage to a single resource may have on IESO settlement charge types.
- Determine the exact tool upgrades, processes, and charge type modifications required to enable the settlement of storage as a single resource.
- Determine how to separate the values for energy withdrawn as 'fuel' and energy withdrawn for other purposes. Solutions could potentially be achieved through; (i) additional metering to segment station service and other commercial loads, or (ii) determining a financial offset to the uplift value of energy withdrawn to ensure only the fuel portion is exempted.
- Account for situations where withdrawals and injections tied to that withdrawal (the 'fuel' for the injection) could branch into different settlement periods.
- Assess the impact of differentiating the two types of consumption on IESO's Commercial Reconciliation System (CRS).

Design Decisions – Market Power Mitigation

Design Elements: Ex-ante (economic withholding) Market Power Mitigation and Ex-post (physical withholding) Market Power Mitigation

The design elements under this module clarify how a storage market participant will be subjected to market power mitigation. This module looks at market mitigation under the (i) ex-ante (i.e., economic withholding) and (ii) ex-post (i.e., physical withholding) time frames. Market Power Mitigation (MPM) refers to actions necessary to prevent market participants from taking advantage of their market power in a local market.

For Ex-ante Market Power Mitigation, the IESO intends to:

- Subject dispatchable storage facilities to the post-MRP MPM ex-ante framework.
- Apply ex-ante resource specific reference levels and quantities for storage facilities to enhanced models.
- Ensure the ex-ante MPM requirements and procedures that have been developed for storage under the foundational model are carried forward to work for storage under the enhanced framework or are augmented as necessary, i.e support a single offer curve, and SoC as necessary.
    - Determine need to update ex-ante MPM requirements to consider continuous bid/offer curve that could be tied to different SoC bands (if implemented)
    - Facilitate any new ex-ante parameters or dispatch data developed by the enhanced model to MPM as required.
- Determine if there is a need to update ex-ante MPM requirements to consider the withdrawal side of the storage resource.

Rationale: The ex-ante Market Power Mitigation process will need to continue to work under the enhanced storage model. The current ex-ante framework for storage facilities being developed within MRP will need a complete assessment to determine impacts as a result of transitioning to the enhanced model. All ex-ante MPM requirements for storage were designed for the two-resource model, as well as consider only the generation resource, and no SoC impacts.

For Ex-post Market Power Mitigation, the IESO intends to:

- Subject dispatchable storage facilities to the post-MRP MPM ex-post framework.
- Apply ex-post resource specific reference levels and quantities for storage facilities to enhanced models.
- Ensure the ex-post MPM requirements and procedures that have been developed for storage under the foundational model are carried forward to work for storage under the enhanced framework or are augmented as necessary, i.e. considers single offer curve and SoC.
    - Determine need to update ex-post MPM requirements to consider continuous bid/offer curve that could be tied to different SoC bands (if implemented).
    - Facilitate any new ex-post parameters or dispatch data developed by the enhanced model to MPM as required.

- Determine if there is a need to update ex-post MPM requirements for consider the withdrawal side of the storage resource.

Rationale: The ex-post Market Power Mitigation process will need to continue to work under the enhanced storage model. The current ex-post framework for storage facilities being developed within MRP will need a complete assessment to determine impacts as a result of transitioning to the enhanced model. All ex-post MPM requirements for storage were designed for the two-resource model, as well as consider only the generation resource, and no SoC impacts.

Besides integrating the necessary parameters, and new dispatch data submitted by participant under the enhanced model, there may need to be additional considerations of how to track physical withholding of storage resources with the consideration of SoC, specifically in the DAM where participants may choose to bypass DAM without any financial commitments by setting a zero SoC value and not having any mitigation on the bidding side of the resource's bid/offer curve.

Detailed Design Considerations for Market Power Mitigation

- Consider how Market Mitigation Tool(s) for the purpose of ex-ante mitigation may need to be modified due to the transition to the single resource model.
- Consider if there are scenarios which mitigation (e.g., offer mitigation) could result in unintended consequences. For example, the market participant intended to generate but the DSO mitigates it to consume instead due to need to generate in future hours.
- Consider how Market Mitigation Tool(s) for the purpose of ex-post mitigation may need to be modified due to the transition to the single resource model.
- Determine physical withholding requirements for storage by also considering the integration of SoC.
- Design Workshop Considerations (new detailed design questions, vendor impact, etc.)
- Consider the need to adopt different ex-post reference levels for storage when injecting and withdrawing.
- Consider whether if a battery re-charges and incurs higher operating costs if that would trigger MPM.
- Consider the impact on mitigation if regulation services are being scheduled.

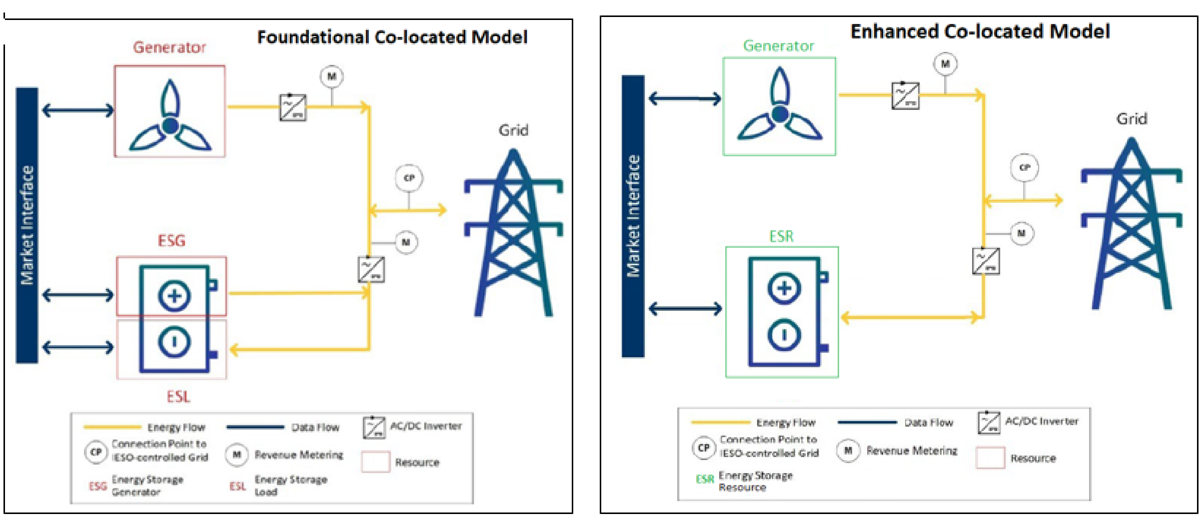
Co-located Hybrid Participation Model

The enhanced co-located hybrid model is closely tied to the enhanced storage model and builds upon the IESO's existing foundational co-located model. The primary change for the enhanced hybrid model is to leverage the enhanced storage model for the storage resource within the hybrid facility. Therefore, benefits of the enhanced storage model are applicable to the enhanced co-located hybrid model, in addition with the possibility to provide further automation considerations that could be needed for hybrid models.

Existing Design Framework

As with the foundational co-located model, the generator and storage resources that participate under the hybrid participation model are modelled separately, participate in wholesale markets separately and are settled separately. The resources merely share some of the same equipment which can reduce build costs for developers. Figure 1 below demonstrates a conceptual diagram of the IESO's foundational and enhanced co-located model used to model a generator-battery storage hybrid.

Figure 1: Diagram showing Differences between Foundational and Enhanced Co-located Models for Hybrids



Innovations, Research and Development

Post Implementation Design Framework

The majority of the enhanced co-located model design is based on the enhanced storage model and existing generator models. For co-located resources participating under a hybrid model it is possible for the combined Installed Capacity of the storage and generator resources to be greater than the capability of their interconnection. In such cases, the IESO will consider more sophisticated solutions then the current design such as requiring the co-located resources to ensure their combined offers do not exceed their interconnection limit (solutions can range from more simplistic set limits of bid/offers or more complicated optimization processes).

Table 4 below highlights some of the key features of the enhanced co-located hybrids:

Table 4: Key Features of Enhanced Co-located Hybrid Model

Feature	Description

Following Enhanced Storage Design – Resource Modelling, SoC, etc.	• Co-located resources under the hybrid model will be modelled as two distinct resources:
	  o Storage resource with a single continuous offer curve (i.e., based on the enhanced storage model above.
	  o Generator resource leveraging the appropriate existing resource model (e.g., the variable generator model for a solar or a wind facility.)
	• State-of-charge of the storage resource will be modelled in the IESO tools.
	• Storage to be exempt from uplifts on energy withdrawn as "fuel" for the sole purpose of being able to provide services back to the grid at a future point in time.
	• The generation resource will continue to leverage the appropriate existing resource model (e.g. the variable generation model for a solar or wind facility).
	• (TBD) If regulation service is enabled when utilizing a hybrid participation model, it will be through either storage resource or other generator type that has already been enabled in IESO tool sets. This will also consider connection point limitations that are relevant to the hybrid participation model.

(Optional) Constraint Modeling/Consideration	• The ability to model or consider a constraint ion net injection/withdrawal from the generator and storage resource that is overbuilt to the connection point will be further explored.

Scope:

Technology

- Encompasses storage with another generator type. The generator type is agnostic and utilizes their own/existing resource model that they would operate under if it was sited individually.
- Will carry forward storage enhanced model changes applicable.

Resource/Facility Considerations

- Support the co-located model
- Resources will be dispatchable, operate independently, all behind the same shared interconnection point.
- These resources are single-site resources, each resource must be above 1 MW, that are registered to participate in the IAMs, including participating resources that are embedded within a distribution network (not including aggregated DER participation models).
- Please note:
    - the scope of the model only considers the generator + storage configuration. Other jurisdictions could have different definitions of a "hybrid" models, such as load + storage, multiple and different generator types, or other potential configurations. These other type of potential "hybrids" are not in scope of this project.
    - This project is not expected to impact the other generator resource models, but some assessment should be made during design or could be required as a result of some design decisions (i.e. modeling the connection point/constraint between resources).

Modules Explored and Design Questions

Module 1: Capacity

Design Elements: Capacity Qualification, Performance Obligation and Assessment

For procurement or capacity auctions that use UCAP methodologies for capacity qualification, capacity for co-located hybrids is qualified utilizing UCAP methodologies specific to the underlying generator and storage technology types of a given co-located hybrid.

For Capacity Qualification the IESO intends to:

- Continue to qualify capacity utilizing UCAP methodologies separately and specific to the underlying generator and storage technology types of a given co-located hybrid.
- Continue to limit the total ICAP for the resources comprising a co-located hybrid to be less than the capability of the combined facility's interconnection.

Rationale: This methodology was established for the foundational co-located model and since the enhanced co-located model still requires separate participation from the generator and storage resources under a co-located hybrid, the same methodology will continue to be used.

Module 2: Connection Process

Design Elements: Connection Assessment and Approval, Market Registration (Resource Registration, Facility information, Prudential Security, Revenue Meter Registration, Telemetry)

Any new or modified hybrids that connect to the IESO-controlled grid require a connection assessment, as specified by the Connection Assessment and Approval (CAA) process, market rules and market manuals. The design elements under this module clarifies how a market participant completes connection to the IESO grid and register for participation in the IAMs.

For Connection Assessment and Approval the IESO intends to:

- Continue to utilize existing CAA and SIA practices for co-located hybrids.

Rationale: The CAA and SIA process for co-located hybrids are not impacted by the introduction of the enhanced co-located participation model.

For Market Registration – Resource Registration the IESO intends to:

- Register co-located hybrids as two separate resources (or more depending on number of resources behind the connection point) with one utilizing the enhanced storage resource model;
    - Apply the static and dynamic model parameters developed for the enhanced storage model to the storage resource of the enhanced co-located hybrid model.
    - Continue to apply static and dynamic model parameters for the generator.
- Enable the separate resources of a co-located hybrid to be registered as dispatchable with the same individual size thresholds and access to wholesale market services of equivalent stand-alone resources.
- Allow only one RMP, one MMP and one operator across both the generator and storage resources under a co-located hybrid but will explore if more than one MMP can be enabled.
- Consider impacts from allowing storage to provide regulation service and any issues with allowing a storage under a co-located hybrid model from providing it.

Rationale: Since the underlying resources under a co-located hybrid will continue to participate in the wholesale markets as separate resources, they must continue be registered separately as well under the enhanced model.

For Market Registration - Prudential Security the IESO intends to:

- Continue to assess and apply prudential security requirements for the individual resources under a co-located hybrid.
- Continue to apply prudential security requirements at the market participant level, based upon the expected net amount owed by the market participant across all resources under that market participant

For Market Registration - Facility Information the IESO intends to:

- Continue to model the generator and storage of a co-located hybrid separately.
- Continue to determine additional modeling parameters that are required to model shared connection equipment (i.e. the constraint that could limit the total injection or withdrawal amount from both resources) between the generator and storage resources of a co-located hybrid during the market registration process.

Rationale: many of these decisions were established for the foundational co-located model after internal review from various business units and is not impacted by the participation model that a co-located hybrid uses as resources operate independently. The constraint between the resources could be a limiting factor and must be considered through various IESO processes.

For Market Registration - Revenue Meter Registration the IESO intends to:

- Continue to require one bi-directional revenue meter for the storage resource and one revenue meter for the generator resource of a co-located hybrid.

Rationale: Since the individual resources under a co-located hybrid are contracted and settled separately, they should also be metered separately. This should not change as a result of adopting the enhanced model.

Detailed Design Considerations for Connection Process

- Determine any challenges with existing metering configurations for co-located hybrids.
- Determine if existing processes can be improved by developing a market rule or market manual that outlines exactly or provides guidance of where the revenue meters for a co-located hybrid must be located.
- Determine if existing metering hardware requirements are suitable for DC-coupled resources. If they are not, consider working with Measurement Canada to develop requirements for metering DC systems.
- Consider how the updated registration tools and processes developed for the enhanced storage model could be leveraged efficiently to develop the registration tools and processes for the enhanced co-located design.
- Consider whether other hybrid configurations (such as DC-coupled) could be registered with minor changes using the market registration process and tools developed for co-located hybrids.
- Consider the impact and effort of transitioning existing hybrids registered under the foundational model to the enhanced model.

Module 3: Grid and Market Operations

Design Elements: Dispatch Data and Other Inputs, Optimization, Market Power Mitigation, Regulation Service Operation

The design elements under this module clarify how resources operating under a co-located hybrid participation model will participate in energy, OR markets, and regulation service. This includes what the IESO needs to dispatch resources, consider them in the optimization across all timeframes, as well as considerations for regulation service participation (both providing the service, and impacts to other service offerings).

For Dispatch and Other Inputs, the IESO intends to:

- Send separate dispatch instructions to the storage and generator resources under the enhanced co-located model.
- Utilize the continuous offer curve and the state-of-charge management designs for the dispatchable storage resource under the enhanced co-located model.
- Continue to utilize all existing designs for different standalone generator technologies for the generator resource under the enhanced co-located model.
- Require all storage charging as part of a hybrid participation model be done through the market and not "behind-the-meter".

Rationale: The design decisions/intentions, including continuous offer curves and state-of-charge management, will be carried through for the enhanced storage models operating under a co-located model.

For Optimization, the IESO intends to:

- Carry forward the enhanced storage model and optimization decisions to optimize the enhanced storage of the co-located hybrid participation model.
- Determine if any unique requirements for the enhanced co-located hybrids will need to be considered in the optimization across all engines.

Rationale: The design considerations discussed for the enhanced storage model, including continuous offer curves and state-of-charge management, will be carried through for the storage resource in the enhanced co-located model.

For Regulation Service Operation the IESO intends to:

- Determine if resources that are behind a single constraint in an enhanced co-located hybrid model should also be enabled to provide regulation service.

Rationale: additional challenges could be for co-located hybrids because of the constraint, and it may hinder a resources ability from providing a necessary service to meet reliability needs.

Detailed Design Considerations for Grid and Market Operations

- Account for all the enhanced storage model design considerations for regulation service to be carried though to model the storage resource under an enhanced co-located hybrid.
- Determine the feasibility of adding linked constraints to model resource limitations and dependencies between the separate storage and generator resources under an enhanced co-located hybrid.
- Determine impacts to optimization from including multiple resources providing multiple services and/or these resources participating in multiple markets.
- All detailed considerations from the enhanced storage model are present as the enhanced storage model will be part of the co-located hybrid. In addition, there would need to be considerations for other resource types who may be currently enabled to provide regulation service but are behind a single connection point with other resources.

Module 4: Settlements

Design Elements: Market Settlement, Uplift Charges

The design elements under this module clarify market settlement to ensure that each of the participants operating under an enhanced co-located participation model understand how their participation will be reflected on their settlement statements and invoices.

For Market Settlement, the IESO intends to:

- Continue to settle the resources within an enhanced co-located hybrid separately.
- Utilize the settlement design for the enhanced storage model for settlement of the storage resource under the enhanced co-located model.

Rationale: Since the generator and storage resources under a co-located hybrid participate separately and have separate revenue meters, those resources will continue to be settled separately under the enhanced co-located model.

For Uplift Charges, the IESO intends to:

- Exempt the storage resource in a co-located hybrid from uplift charges on energy withdrawn as 'fuel' for the sole purpose of being able to provide services back to the grid at a future point in time.
- Continue to charge uplifts on the enhanced storage resource or other resource types for withdrawals related to any other purpose besides to reinject that energy back to the grid.

Rationale: The enhanced storage resource part of the enhanced co-located model will also exempt uplift charges on the energy withdrawn by the storage resource as 'fuel' for the sole purpose of being able to provide services back to the grid at a future point in time.

Detailed Design Considerations for Settlements

- Account for similar market settlements and uplift considerations identified in the storage section of this document.

Module 5 Market Power Mitigation

Design Elements: Ex-ante (economic withholding) Market Power Mitigation, Ex-post (physical withholding) Market Power Mitigation

The design elements under this module clarify how a market participant using the enhanced co-located hybrid model will be subjected to market power mitigation. This module looks at market mitigation under the (i) ex-ante (i.e., economic withholding) and (ii) ex-post (i.e., physical withholding) time frames.

For Ex-ante Market Power Mitigation, the IESO intends to:

- Subject the individual dispatchable generator and storage resources separately under a co-located hybrid to the post-MRP ex-ante MPM framework.
- Continue to utilize resource specific ex-ante reference levels and quantities for the separate generator and storage resources under a co-located hybrid to support MPM,

utilize enhanced storage MPM requirements as applicable to appropriate storage resources utilizing a co-located hybrid participation model.

Rationale: This methodology was established for the foundational co-located model after internal review from various business units. Since the enhanced co-located model still requires separate participation from the generator and storage resources under a co-located hybrid, the same methodology will continue to be used by the enhanced co-located model with any necessary augmentation because of the enhanced storage design. Modelling of a MAQ or the constraint between requires could add additional scope to changes regarding MPM as it could require additional procedures to account of the constraint.

For Ex-post Market Power Mitigation, the IESO intends to:

- Subject the individual dispatchable generator and storage resources under a co-located hybrid to the post-MRP ex-post framework
- Continue to utilize resource specific ex-post reference levels and quantities for the separate generator and storage resources under a co-located hybrid to support MPM, while utilizing enhanced storage MPM requirements for storage resources participating under a co-located hybrid model.
- Determine if there are additional procedures or tool enhancements required as part of the MPM process that will delineate instances of respecting the Maximum Allowable Quantity (this is the max injection or withdrawal limit to the grid of the constraint supporting all resources) versus withholding energy (also considering the need for this if modelling the constraint of the combined facility is implemented).

Rationale: This methodology was established for the foundational co-located model after internal review from various business units. Since the enhanced co-located model still requires separate participation from the generator and storage resources under a co-located hybrid, the same methodology will continue to be used by the enhanced co-located model with any necessary augmentation because of the enhanced storage design. Modelling of a MAQ or the constraint between requires could add additional scope to changes regarding MPM as it could require additional procedures to account of the constraint.

Detailed Design Considerations for Market Power Mitigation

- Develop the precise details as to how the post-MRP MPM framework will apply to storage facilities in the ex-ante timeframe including the setting of storage-related reference parameters and if any additional changes need to be considered to factor in hybrids.
- Design Workshop Considerations (new detailed design questions, vendor impact, etc.)
- Determine timing of MPM implementation to ensure requirements of MPM are met and potential need for data collection period to set requirements.
- Develop the precise details as to how the post-MRP MPM framework will apply to storage facilities in the ex-post timeframe including the setting of storage-related reference parameters and if any additional changes need to be considered to factor in hybrids.
- Determine timing of MPM implementation to ensure requirements of MPM are met and potential need for data collection period to set requirements.

Next steps

The IESO encourages feedback from impacted market participants and other participants from across the energy sector on the questions asked in this memo as well as from topics discussed during the engagement session. Feedback received by the IESO will be reviewed with updates to the design memo considered to publish a final version on the ERP Project engagement webpage. Please refer to the storage and hybrid engagement page for a feedback form.

The IESO will begin work on the optimization design element which will support decision making across numerous modules and elements. A future engagement will take place on this topic, as well as any other topics that the IESO will need to collect feedback on to continue forward with the design work.