Energy Storage Design Project

Long-Term Design Vision Document

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Executive Summary

For the past several years, the Independent Electricity System Operator (IESO) has sought to remove barriers to electricity storage participation in Ontario's wholesale electricity market. As noted in Chapter 1, the events leading to the publication of this Design Vision document have progressed from early-stage, proof-of-concept experimental programs with storage facilities, to a formalized problem definition exercise with the IESO's Energy Storage Advisory Group (ESAG),[1] to the initiation of the Storage Design Project (SDP), which has produced this document. These events have paralleled a broader industry trend in which storage facilities have fallen in cost, filled the prospective build queues in many wholesale markets, and secured a guaranteed right of access to U.S. wholesale markets.[2]

The SDP was tasked with addressing two major challenges:

1. Clarify how storage resources[3] can participate in today's IESO-Administered Markets (i.e. the interim period), and
2. Provide a vision for how storage resources will participate in the IESO-Administered Markets (IAMs) on an enduring basis once investment in IESO tool upgrades to fully integrate storage resources are made (i.e. the long-term period).

At the time of publication of this document, the SDP's work on the first task has progressed to formal amendment proposals to the IESO Market Rules and supporting market manuals in order to implement the Interim Design published by the SDP in February, 2020.

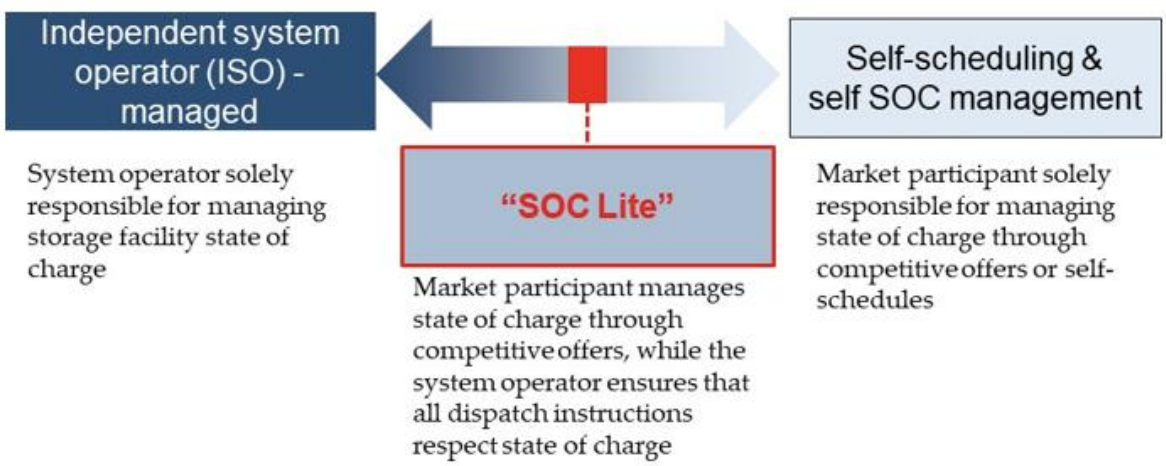
This Long-Term Design Vision document fulfills the second task assigned to the SDP. In the most general terms, the overarching objective of the Long-Term Design Vision is to provide electricity storage facilities with expanded access to the wholesale market.

At the heart of the Long-Term Design Vision, is a foundational design choice regarding what type of state of charge (SOC) management framework to use. Storage facilities have an inherently finite capacity to store electrical energy. When combined with the economics of an open, competitive electricity market there arises a crucial question regarding if, how, and to what extent the system operator should consider this finite storage capacity. Over the course of this

[1] See also, the December, 2018 IESO Report, "Removing Obstacles for Storage Resources in Ontario" which resulted from this exercise.
[2] With reference to, U.S. Federal Energy Regulatory Commission, Order No. 841, "*Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*" (Issued February 15, 2018)
[3] Note: While this set of goals was originally worded to refer to "energy storage resources", the SDP project has since refined this terminology to "electricity storage resources" comprising "electricity storage facilities."

project, the SDP extensively examined a spectrum of choices regarding this question. The choices ranged from options whereby the system operator actively manages storage facility operations (to optimize SOC), to options at the opposite ends of the spectrum where storage facilities would have responsibility for securing their schedules in the market and adhering to dispatch instructions. As detailed in Chapter 2 of this document, this design question was resolved by an intermediate option referred to as SOC Management Lite (short name: "SOC Lite"). SOC Lite strikes a critical balance between optimizing the electricity system as a whole, while affording storage market participants the freedom to optimize their individual assets.

Summary of SOC Management design spectrum and the SOC Lite design choice



Most other design decisions (with the exception of regulation service and uplift allocation) are driven by the decision to propose SOC Lite, which also brings a number of improvements relative to the Interim Design arrangements. These improvements are further detailed in Chapter 2 and generally include:

- **Recognizing the physical reality of storage facilities:** A new **single resource model** (see section 2.3) recognizes the ability of storage facilities to inject, store and withdraw energy within the IESO's dispatch scheduling and optimization (DSO) engine. This proposal would also enable storage facilities to submit **continuous offer curves** (see section 2.7) that span their injection and withdrawal operating ranges, bringing greater market efficiency to the electricity market's price-setting and scheduling processes (see sections 2.4, 2.5 and 2.6) and fewer manual workarounds compared to the present Interim Design.

- **Alleviating the 'revenue stacking' problem,[4] while achieving greater market efficiency and competition**: Under SOC Lite, storage facilities will be able to offer their full operating capabilities in **energy** and **operating reserve**, with the assurance that the IESO will not issue real-time dispatch instructions to them that exceed their operational capabilities (see sections 2.5 and 2.6). In addition, dispatchable facilities will have the capability to provide regulation service in conjunction with energy and operating reserve (see section 2.8).
- **Effective allocation of common uplift costs**: The Long-Term Design Vision will revise the manner in which these common system costs ("uplift") accrue to storage facilities in order to incent greater efficiency and avoid a distortion to the bottom line costs for Ontario consumers (see section 2.9).

[4] In the ESAG's December, 2018 report "Removing Obstacles for Storage Resources in Ontario" the present inability of storage facilities to 'stack' revenue from multiple sources, including the wholesale market, was a priority obstacle identified by stakeholders.

1. Introduction and Context

1.1. The context of energy storage integration

This design vision document is the last major deliverable of the Independent Electricity System Operator's (IESO) Storage Design Project (SDP) which has been underway since October, 2019. It is the culmination of an extensive, two-year stakeholder consultation effort that began prior to the commencement of the SDP and continued under the project itself.

The SDP was initiated to address a specific set of energy storage barriers identified in the December, 2018 IESO Report, "*Removing Obstacles for Storage Resources in Ontario*". The 2018 report was the result of the IESO's problem definition work with the Energy Storage Advisory Group (ESAG), its growing energy storage portfolio and accelerating changes to the energy storage industry's landscape, both in Ontario and elsewhere.

To date, a number of energy storage projects have been participating in various facets of the IESO-administered markets (IAMs), often under the auspices of specific, targeted procurements aimed at the provision of ancillary services such as regulation service and reactive support and voltage control. This parallels the experience of many U.S. wholesale markets where energy storage gained an early foothold in the regulation service market. More recently however, regulatory developments in the U.S., such as Federal Energy Regulatory Commission (FERC) Order 841, have required a more fulsome integration of energy storage participation in all categories of wholesale market products. Here in Ontario's electricity market, the SDP was tasked in addressing a similar set of energy storage integration issues in terms of two major challenges as follows:

1. Clarify how energy storage resources can participate in today's IESO-Administered Markets (i.e. the interim period), and
2. Provide a vision for how storage resources will participate in the IESO-Administered Markets on an enduring basis once investment in IESO tool upgrades to fully integrate storage resources are made (i.e. the long-term period)

This document addresses the second of these two major tasks.

Problem definition phase:

The IESO's December, 2018 report, "Removing Obstacles for Storage Resources in Ontario" outlined a variety of energy storage barriers that fall under the jurisdiction of the IESO, the Ontario Energy Board (OEB), and the Ontario Ministry of Energy, Northern Development and Mines. Over the course of 2019, the IESO worked with member organizations of ESAG to further refine a list of potential energy storage design topics that fell within the IESO's jurisdiction to resolve. The December 2018 report, included the following three general recommendations set out in the report:

1. "The IESO should review and amend its Market Rules, where possible, to clarify the participation of storage resources in IESO-administered markets"
2. "The IESO should lead further discussions to consider the potential impacts to market efficiency resulting from the application of uplift charges."
3. "The IESO should lead discussions with the storage community to better understand the breadth of wholesale market services that energy storage could provide and how to integrate this into the current IESO-administered markets."

These recommendations culminated in the initialization of the SDP in the fall of 2019. The project began with the refinement of a matrix of interim and long-term design issues that were targeted to be addressed by the document, "Energy Storage Design Project Draft Design Document for Stakeholder Comment, February 4, 2020" (the "Interim Design") and this Long-Term Design Vision document, respectively.

Interim Design – recent developments:

In February, 2020 the IESO SDP released an Interim Design document putting forward temporary measures for addressing the storage barriers within the IESO's jurisdiction and more specifically, energy storage facilities in the current IAMs. These interim measures are a significant step forward for electricity storage facility integration in the IESO-administered markets and transparency for storage investors. For the first time, the requirements for electricity storage facilities in every stage of market participation, from registration to operations, will be publicly codified in the IESO market rules.

As of the date of the publication of this document, the Interim Design proposals set out in the SDP Interim Design document have been developed into specific, proposed amendments to the IESO Market Rules and supporting market manuals. The reader is directed to the ESAG and market rule amendment web pages of the IESO website for further information regarding the latest status of these proposed amendments.

Long-Term Design Vision - time context:

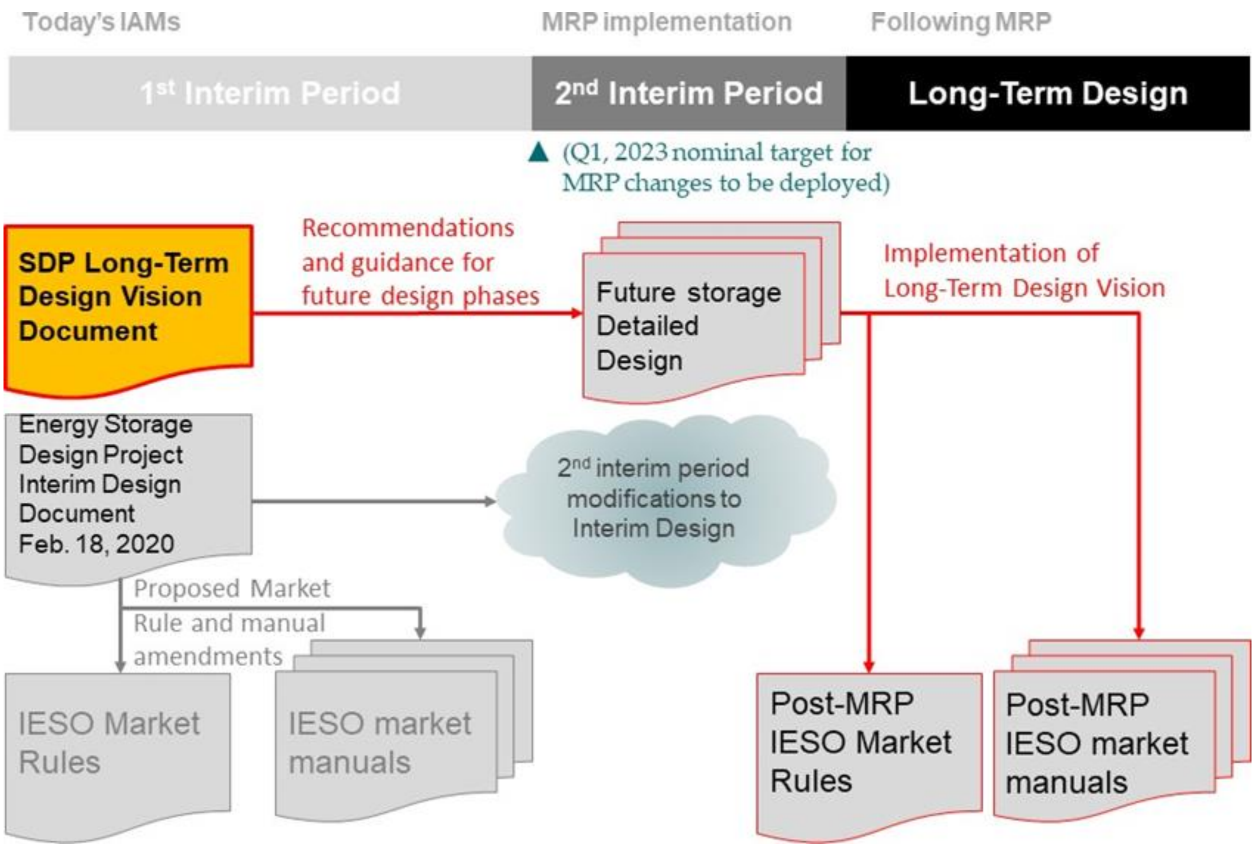
This document lays out the enduring vision after the Market Renewal Program (MRP) energy stream projects[5] are implemented, and will help inform future work on the future design. In the

[5] The energy stream projects refer to the Day-Ahead Market, single-schedule real-time market, and the enhanced pre-dispatch + unit commitment process – see Market Renewal pages on IESO website for details.

intervening time, it is expected that the Interim Design now being implemented will have to be further modified in order to integrate with the IAMs following the implementation of the MRP. Commentary on the MRP-related linkages to the various recommendations in this design proposal are provided throughout Chapter 2 of this document.

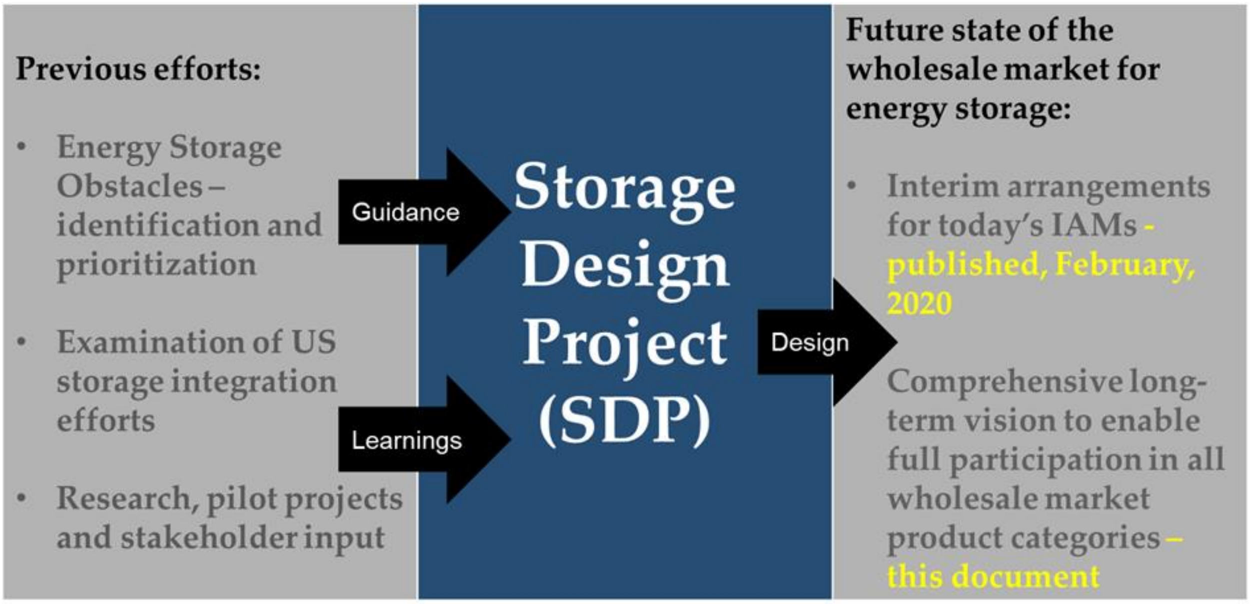
The long-term detailed design phase and any modifications to the Interim Design, that may be required after the implementation of MRP, lie outside the scope of this document and the current phase of the SDP project. However, a summary of these major milestones, as they are currently envisioned, is summarized in the Figure 1-1 that follows.

Figure 1-1 - Summary of anticipated stages towards the implementation of the Long-Term Design Vision



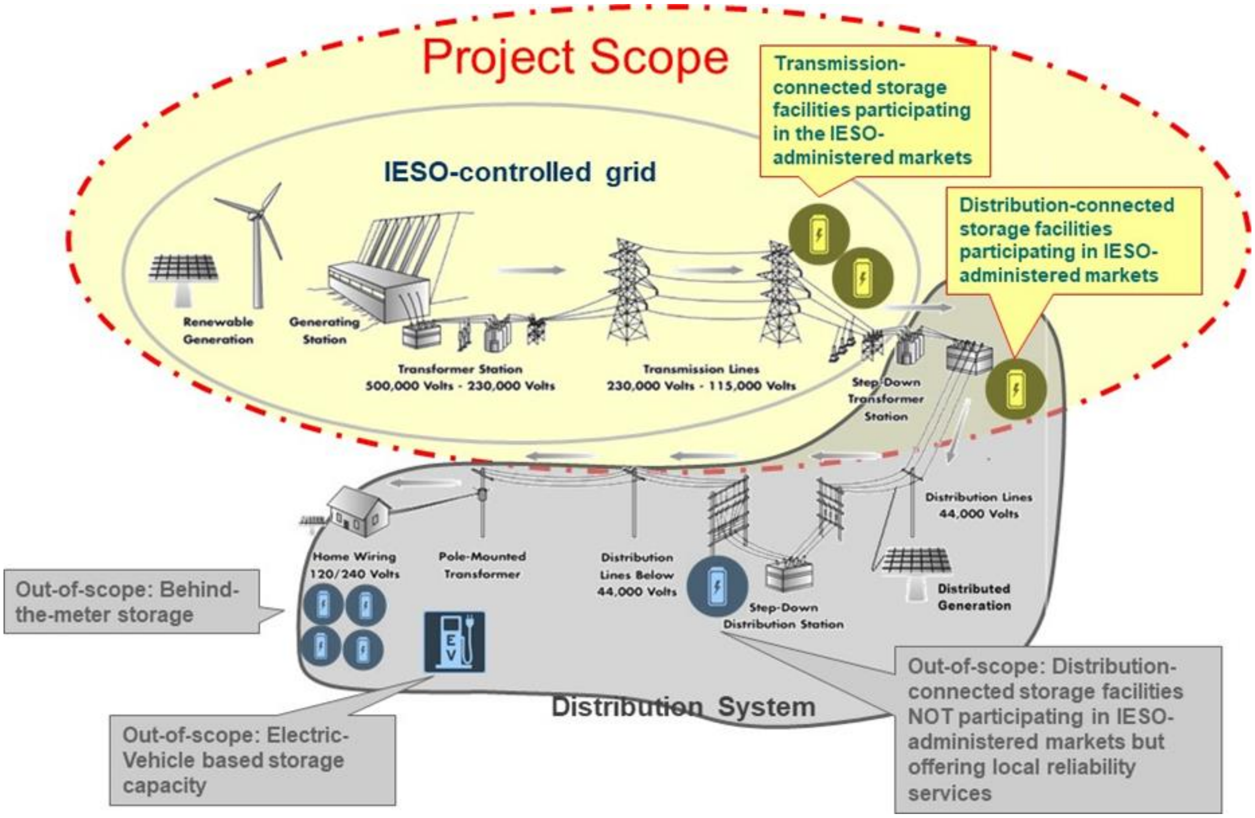
1.2. Energy Storage Design Project Scope

Figure 1-2 - Project overview



In terms of facilities involved, the SDP is aimed at energy storage facilities that are registered to participate in the IAMs, including participating facilities that are embedded within a distribution system. The overall scope of facilities involved is portrayed in the Figure 1-3.

Figure 1-3 - Scope of the Energy Storage Design Project, which encompasses energy storage facilities registered in the IAMs



The IAMs and related IESO Market Rules do not encompass facilities that are not registered to participate, such as behind-the-meter facilities. Such types of energy storage facilities are outside the jurisdiction of the IESO Market Rules, and therefore, this project.

It is expected that various facets of bringing Distributed Energy Resources (DERs) and behind-the-meter resources into the IAMs will be addressed through a number of venues including the IESO Market Development Advisory Group. Further information may also be found on the IESO webpage for the Innovation and Sector Evolution White Paper Series, where the IESO is in the process of releasing a series of discussion papers regarding the potential future integration of DERs into the wholesale market.

1.3. Deliverables of the Energy Storage Design Project

This document is one of a number of key deliverables of the Energy Storage Design Project, which are listed herein:

This document is one of a number of key deliverables of the Energy Storage Design Project, which are listed herein:

1. **Interim Design (Published February, 2020)**

   SDP Interim Design document: The SDP Interim Design document provided guidance to the market rule and market manual amendments now underway to implement the IESOs interim energy storage integration framework

2. **Long-Term Design Vision (Scope of this document)**

   SDP Long-Term Design Vision Document: This document is intended to provide a high-level vision of how the IESO will treat storage in the IAMs on an enduring basis once investment in IESO tool upgrades to fully integrate storage resources are made.

3. **Interim Implementation measures (Draft amendment proposals published, June, 2020)**

   Draft Market Rules and market manuals: As of the date of publication of this document, the Storage Design Project has formally proposed amendments to the Market Rule/manual language required to implement interim measures (see Interim Design). The reader is directed to the IESO website for latest status of these amendments as they proceed through the formal change management process

4. **Interim Implementation measures**

   Inventory of IESO tool/process changes: An internal IESO effort to develop a comprehensive list of tools/processes that will require updating to enable design questions addressed in the project.

5. **Schedule for Market Enhancements**

   Schedule for deploying Design Vision: Provide clarity on next steps for storage integration beyond the scope of the SDP.

1.4. The IESO's history with energy storage so far

Energy storage in the Ontario electricity system is not new. The Sir Adam Beck Pump Generating Station has been an important, but entirely unique fixture of the Ontario electricity system since 1957, and has participated in the IAMs since market opening in 2002. Until recently, however, it has been the only energy storage facility in the IESO-administered markets (as both load and generation). In addition, this facility is integrated with the operations of the Beck 1 and Beck 2 hydroelectric generating stations, making its operational profile unique relative to many other "standalone" pump generating stations around the world. Approximately seven years ago, the IESO began to take the first steps towards understanding the capabilities and possibilities of a wider array of energy storage technologies.

Since 2013, the IESO has actively encouraged and solicited the participation of energy storage facilities in the IAMs through a variety of pilot projects and programs. In addition, it has contemplated various other energy storage integration projects and programs, some of which are summarized in Table 1-1.

Table 1-1 - Energy storage milestones in Ontario

Timeframe	Event	Purpose
2013	Alternative Technologies for Regulation (ATR) Program RFP	Seek technological diversity for future supply of regulation service
2014	Phase 1 Energy Storage Program RFP	Targeted procurement of energy storage capacity for ancillary services
2015	Phase 2 Energy Storage Program RFP[6]	Targeted procurement of energy storage capacity
December 2017	ATR Phase 3 program	IESO commences the next phase of the ATR program to test fast regulation and synthetic inertia experiments at the two ATR facilities

[6] Note: This procurement was initiated under the former Ontario Power Authority prior to being merged with the IESO.

Timeframe	Event	Purpose
April 2018	IESO Energy Storage Advisory Group (ESAG) founded	Terms of reference includes a focus on "…evolving policy, rules, processes and tools to better enable the integration of storage resources…"
December 2018	Release of IESO's report, Removing Obstacles for Storage Resources in Ontario	Recommendations to remove all obstacles to full energy storage participation in all wholesale market products
October 2019	Overview of Energy Storage Design Project presented to Energy Storage Advisory Group	The formal initiation of this Energy Storage Design Project
February 2020	Storage Design Project, Interim Design document published	Articulation of the Interim framework for energy storage integration
May 2020	SOC Management Lite design framework recommendation posted for comment	Overview of the proposed approach to state of charge management in the SDP enduring design

1.5. Long-Term improvements over the current SDP Interim Design arrangements

Today, energy storage facilities are subject to a number of unintended restrictions on their participation in the IAMs, which are core to the barriers identified in Removing Obstacles for Storage Resources in Ontario. The reasons behind this largely centre around the fact that today's Market Rules pre-date the presence of non pump-generation storage (PGS) facilities in wholesale markets. This current situation requires separate, and sometimes mutually exclusive, participation arrangements for energy, operating reserve and regulation service.

The matrix in Table 1-2 depicts the combinations of wholesale market products that an energy storage participant can participate in during the interim period that is now being implemented. In many cases, for an energy storage facility, registration to participate in a given wholesale market service product is mutually-exclusive to providing another service (e.g. regulation service precludes participation in the energy and operating reserve markets). In other cases, participation, although allowed, may be less than optimal for both the facility operator and the market as a whole.

The Interim Design now affords electricity storage facilities with a formalized and transparent framework to participate in various wholesale market products. This alone is a significant improvement in the accessibility of the wholesale market. In many cases however, a "loss of market efficiency" may occur because the IESO's dispatch scheduling and optimization tool is unable to respect the state of charge limitations of the energy storage facility. As a result, during the interim period, electricity storage participants will be required to make advance assessments of their storage facilities' operations during each upcoming dispatch hour to ensure they will have adequate state of charge for their operations for the entire hour.

Table 1-2 - Feasible market participation combinations in various wholesale market product categories during the interim period

	Energy	Operating reserve	Regulation service	Reactive support and voltage control	Capacity auction
Energy	Yes – but with market efficiency loss	Yes – but with restrictions and market efficiency loss	No	Yes – but with market efficiency loss	Yes – but with market efficiency loss
Operating reserve	Yes – but with restrictions and market efficiency loss	Yes – but with restrictions and market efficiency loss	No	Yes – but with restrictions and market efficiency loss	Yes – but with restrictions and market efficiency loss
Regulation service	No	No	Yes	Yes – but with market efficiency loss	No
Reactive support and voltage control	Yes – but with market efficiency loss	Yes – but with restrictions and market efficiency loss	Yes – but with market efficiency loss	Yes	Yes
Capacity auction	Yes – but with market efficiency loss	Yes – but with restrictions and market efficiency loss	No	Yes	Yes

The design vision put forward in Chapter 2 of this document is intended to improve upon the SDP Interim Design, in terms of market access, revenue stacking for storage facilities, market efficiency, operational efficiency and better safeguards to protect reliability. As outlined in Chapter 2, a combination of a new storage facility model, a new state of charge management approach, and other supporting design features are envisioned to realize improvements, relative to the current Interim Design, in each of these areas. In particular, the Long-Term Design Vision is expected to result in improvements that will facilitate:

- More efficient scheduling of energy in the Day-Ahead Market (DAM), and real-time markets for SOC-limited storage resources;
- Automatic safeguards to ensure real-time dispatch of energy is SOC-feasible;
- Allowing dispatchable energy storage facilities to offer their full operating range for operating reserve;
- Automatic safeguards to ensure a SOC-limited storage resource can be scheduled for operating reserve;
- Allowing dispatchable storage facilities to provide regulation service along with other wholesale products; and,
- Open new possibilities for potential future regulation products.

A summary of these improvements, in terms of how they enable participation of a dispatchable storage facility across each combination of wholesale market product category, is summarized in Table 1-3.

Table 1-3 - Feasible market participation combinations in various wholesale market product categories during the interim period after the Long-Term Design Vision is implemented

	Energy	Operating reserve	Regulation service	Reactive support and voltage control	Capacity auction
Energy	Yes	Yes	Yes	Yes	Yes
Operating reserve	Yes	Yes	Yes	Yes	Yes
Regulation service	Yes	Yes	Yes	Yes	Yes
Reactive support and voltage control	Yes	Yes	Yes	Yes	Yes
Capacity auction	Yes	Yes	Yes	Yes	Yes

1.6. Design principles

While the Storage Design Project is separate from the IESO Market Renewal Program, it generally adheres to the same market design principles employed by the Market Renewal Program[7] – specifically:

1. **Efficiency** - lower out-of-market payments and focus on delivering efficient outcomes to reduce system costs
2. **Competition** - provide open, fair, non-discriminatory competitive opportunities for participants to help meet evolving system needs
3. **Implementability** - work together with our stakeholders to evolve the market in a feasible and practical manner
4. **Certainty** - establish stable, enduring market-based mechanisms that send clear, efficient price signals
5. **Transparency** - accurate, timely and relevant information is available and accessible to market participants to enable their effective participation in the market"[8]

In **Chapter 2,** each of the major recommendations put forward as part of the Long-Term Design Vision is assessed against each of these design principles.

[7] See also: IESO, "*Market Renewal Mission and Principles*" on the IESO website at: http://www.ieso.ca/en/Market-Renewal/Background/Overview-of-Market-Renewal
[8] Ibid.

2. Long-Term Design Vision

2.1. Design elements and questions addressed in this chapter

This Long-Term Design Vision document elaborates on the most crucial questions for long-term energy storage integration that were identified by the IESO Energy Storage Advisory Group and summarized in Table 3-1 below. This list of design issues does not constitute a comprehensive list of all detailed design topics – many of which will have to be addressed at later stages of a future integration project. Rather this set of issues is intended to frame the overall design vision to guide future design work, based upon the stakeholder input over the past two years.

Throughout this chapter, a number of second-order design questions are identified - to be addressed in a future detailed design phase.

The vision for long-term energy storage integration put forward here will supplant most of the various interim energy storage design features being put into place at the time of this document's publication.

Many of the long-term design issues parallel those of the interim period, as described in the SDP Interim Design document. The crucial difference is in the approach envisioned to take place over the long-term. In the Interim Design it was contemplated that energy storage would integrate with the current load and generation resource models, the current electricity market, and utilize numerous imperfect workarounds in order to minimize the need for near-term tool changes. In this Long-Term Design Vision, essentially the opposite is true in each of these approaches. The Long-Term Design Vision will use a new resource model that recognizes the physical characteristics of an electricity storage facility, integrate with the new markets as implemented by the IESO Market Renewal Program (MRP), and take advantage of the new Market Management System (MMS) platform that is being implemented as part of that effort.

For these reasons, this document will revisit many of the same design issues that were initially addressed in the Interim Design, albeit with a new approach. The end state goal of the Storage Design Project: to provide electricity storage facilities with expanded access to the wholesale market.

Table 2-1 - Energy Storage Long-Term Design Issues

Design element	Design questions
1. Market and facility registration	1.1 How should an energy storage facility be registered into the IAMs?
2. Ability of Electricity Storage Resources (ESRs) to set market- clearing price in the energy and operating reserve markets	2.1 Should ESRs be able to set the market-clearing price?
3. Day-Ahead Market (DAM) and day-ahead commitment process (DACP): bidding and scheduling of ESRs	3.1 Who should optimize SOC of ESRs in the DAM: the ESR, system operator, or give ESRs the choice?
4. State of charge (SOC) management in real-time (RT) energy market	4.1 Who should optimize SOC of energy storage resources (ESRs) in the RT energy market: the ESR, the system operator; or give ESRs the choice?
5. RT energy and operating reserve markets: bidding and scheduling of ESRs	5.1 What offer curve shape (e.g. continuous through zero, discontinuous, convex) should ESRs be allowed to use to offer into the energy and operating reserve markets?
6. Regulation service	6.1 What are the rules for what proportion of an ESR's total capacity gets used for regulation, energy and operating reserve – both at different times and simultaneously?
7. Settlement and charges	7.1 How will uplift charges stipulated by the IESO Market Rules be applied to energy storage resources?[9]

[9] Note: this table was established in the earlier stages of the SDP project using the broad terms "energy storage facilities" and "energy storage resources". More recently, the proposed codification of the Interim Design in the IESO Market Rules has adopted the use of "electricity storage resources" and "electricity storage facilities."

2.2. Overview

For the most part, the SDP Long-Term Design is envisioned to replace the interim measures put forward by the SDP Interim Design document. As of the date of publication of this document, the interim measures are being proposed for formal introduction into the IESO Market Rules and market manuals. Once implemented, the interim measures are expected to be further modified to operate in the IESO-administered markets after MRP is implemented and will remain in place in their modified form until such time as they are supplanted by the Long-Term Design.

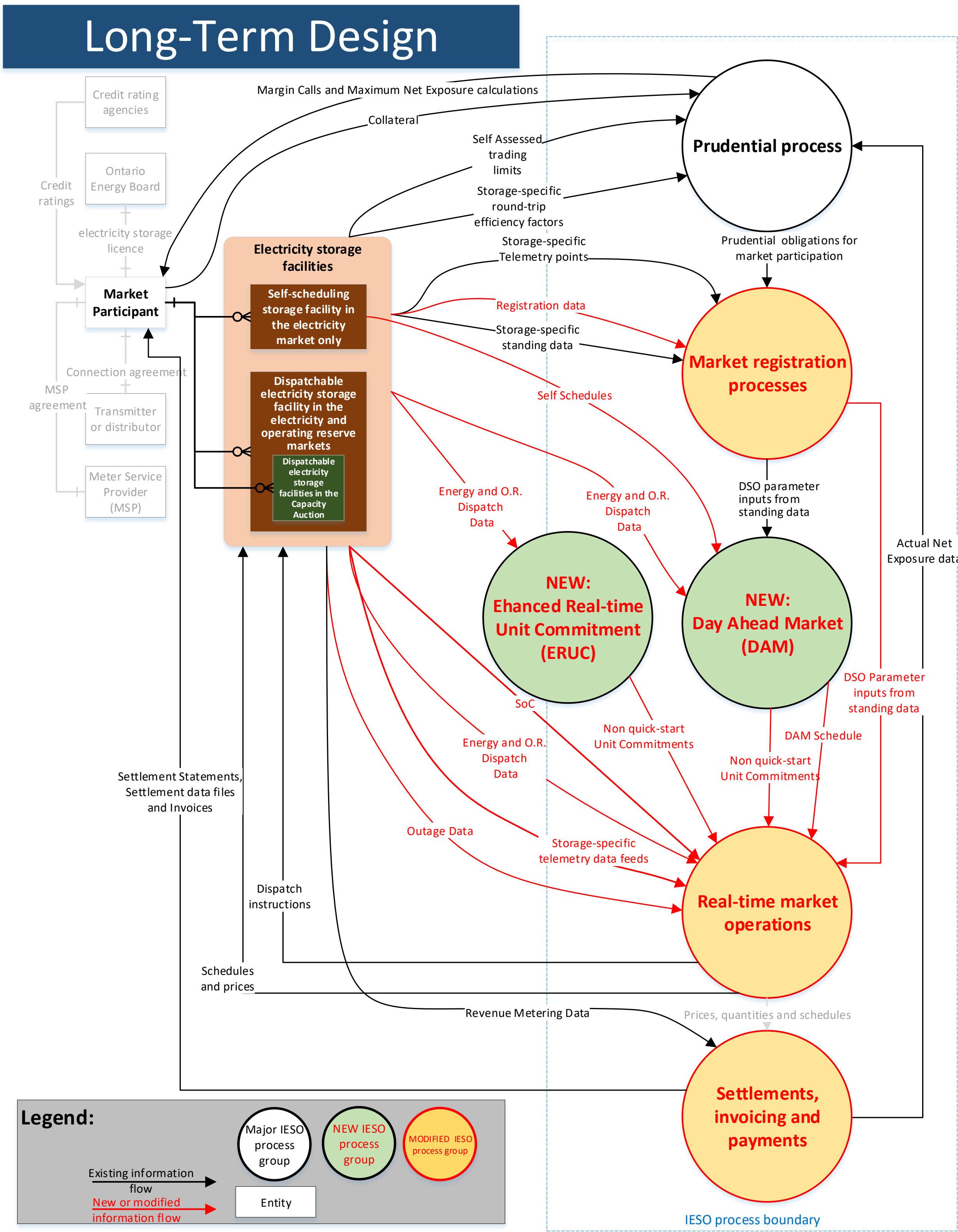
The Long-Term Design Vision is intended to integrate with new and modified IESO process groups that have been proposed by the IESO Market Renewal Program including, but not confined to:

1. a new Day-Ahead Market;
2. an enhanced pre-dispatch and unit commitment process;
3. modified processes for market participant authorization and facility registration;
4. a modified real-time market evolving to a "single-schedule market";
5. a modified settlements process to accommodate "two-settlement" mechanisms spanning both the day-ahead and real-time markets; and,
6. a new ex ante market power mitigation framework spanning both the day-ahead and real- time markets.

The reader is directed to the Market Renewal pages of the IESO website for further information regarding these proposed additions and modifications that will occur prior to the implementation of this design vision. Throughout this chapter, each design issue is described in the context of these changes. In addition, various detailed design issues to be addressed at later project stages are also briefly identified, though this may not be an exhaustive or definitive list of the detailed design issues that may arise as the enduring vision is implemented.

A summary of the major IESO process groups and information flows addressed by the SDP Long-Term Design Vision is illustrated in Figure 2-1 on the next page.

Figure 2-1 - Summary of design features contemplated during the long-term period



The desired end state of these long-term design measures is to provide expanded market access for energy storage facilities. Essentially, a dispatchable electricity storage facility should be able to seek the necessary authorizations to participate in the same wholesale market trading products, as the comparable, dispatchable generator. Conversely, a self-scheduling storage facility should have comparable access to wholesale trading as a self-scheduling generator. A comparison of these targeted access rights is summarized in Table 2-2.

Table 2-2 - Comparison of market access for registered electricity storage facilities and registered generation facilities

Market Access	Dispatchable Generator	Dispatchable Storage facility	Self Scheduling Generator	Self-Scheduling Storage facility
Capacity Market Auction – submit capacity offers[10]	Yes	Yes	No	No
Day-Ahead Market – submit energy and operating reserve offers	Yes	Yes	No	No
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
Real-time markets – can set the market clearing price	Yes	Yes	No	No

[10] Subject to the rules of the Capacity Market – not in scope of SDP project.

Market Access	**Dispatchable Generator**	**Dispatchable Storage facility**	**Self Scheduling Generator**	**Self-Scheduling Storage facility**
Real-time markets – provide regulation service[11]	Yes	Yes	No	No
Real-time markets – provide reactive support and voltage control service[12]	Yes	Yes	Yes	Yes

The remainder of this chapter will discuss the prominent features of this design vision to facilitate enhanced market access for storage facilities, in terms of each of the long-term design issues outlined in Table 2-1.

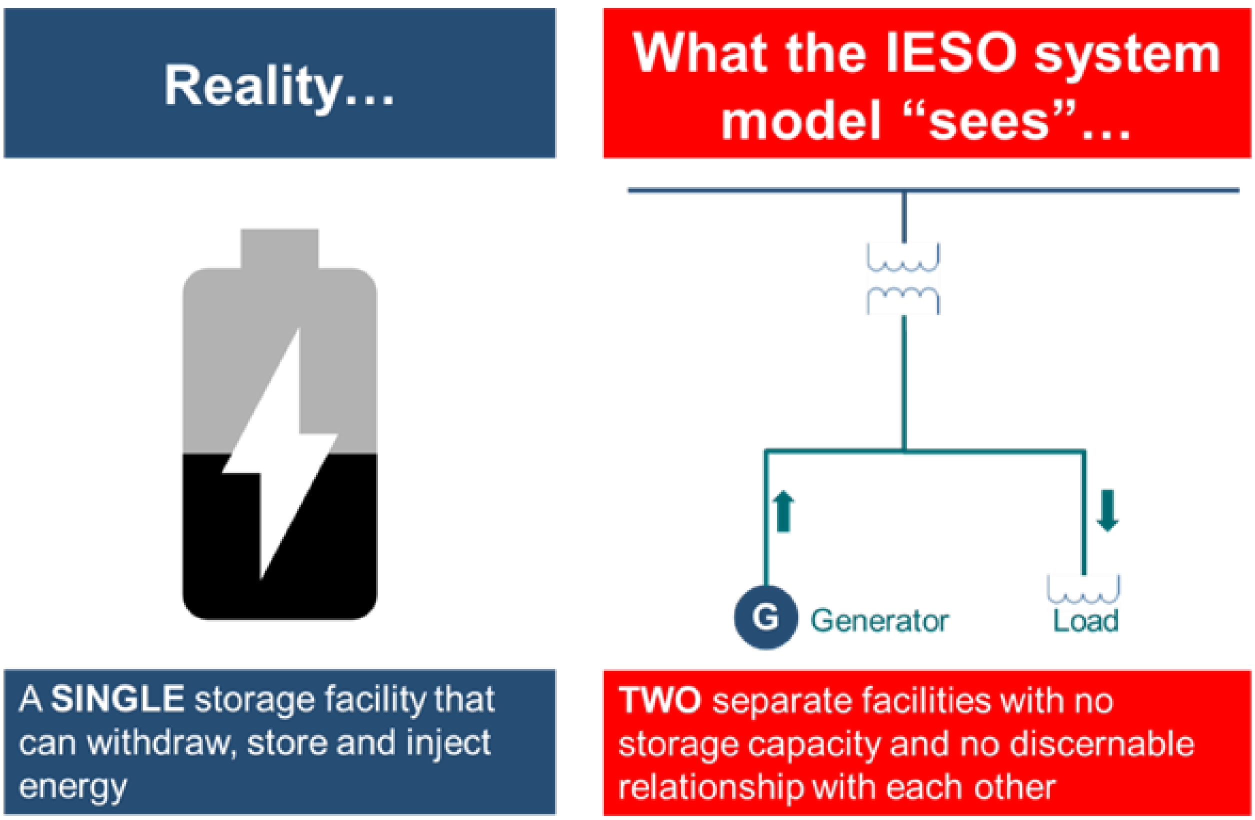
[11] Currently a contracted service, subject to IESO's procurement policy for ancillary services – not in scope of SDP project.
[12] Ibid.

2.3. Market and facility registration

Design element	Design question
1. Market and facility registration	1.1 How should an energy storage facility be registered into the IAMs?

2.3.1. Design issue overview

Figure 2-2 - Current DSO construct of a dispatchable electricity storage facility



At the heart of the Long-Term Design Vision for energy storage integration, is giving the IESO's Dispatch Scheduling and Optimization (DSO) algorithm, the ability to 'see' an electricity storage facility for what it truly is: a facility that can withdraw, store and inject energy. In the absence of this construct, the current SDP Interim Design relies upon a 'two-resource model' whereby an electricity storage facility is modeled as a separate generation and load resource (see Figure 2-2).[13] This in turn has necessitated a myriad of manual workarounds for both the IESO and

[13] IESO Market Manual 1.5 section 3 describes a "resource" as follows: A "Resource" is a unique IESO representation of a part of or the entire Physical Facility. Each Resource is associated with a *connection point*. If a

market participants which were specified in the SDP Interim Design document and are now in the process of being codified in the IESO Market Rules. The new facility registration model proposed here, will pave the way for a significant improvement to several aspects of the current SDP Interim Design. It will do so by enabling:

- the "SOC Lite" state of charge management construct, described further on in this document, which will make use of state of charge information to better optimize and safely dispatch energy storage facilities;
- a more reliable method of managing facility operations for both the IESO and the market participant, by recognizing the full range of electricity storage capabilities (i.e. charging, discharging and energy storage) at the resource level; and
- greater market efficiency by ensuring the state of charge limitations of each electricity storage resource comprising an electricity storage facility accounted for by the DSO.

To accomplish this, this Long-Term Design Vision document is recommending a facility registration framework based upon a single resource model that supports the aforementioned benefits.

2.3.2. Design vision recommendations

1. Registration of self-scheduling electricity storage facilities should be based upon a single resource model that can withdraw, store and inject energy.
2. Registration of dispatchable electricity storage facilities should be based upon a single resource model that can withdraw, store and inject energy.
3. The maximum size threshold for self-scheduling electricity storage facilities should be equivalent to the threshold for self-scheduling generation facilities.
4. Dispatchable electricity storage facilities may be authorized to participate in the same wholesale market products as dispatchable generation facilities.
5. Self-scheduling electricity storage facilities may be authorized to participate in the same wholesale market products as self-scheduling generation facilities.
6. The minimum size threshold for dispatchable energy storage facilities should be the same level that applies to dispatchable generation facilities.
7. All electricity storage facilities should be required to register certain static registration parameters, as introduced in the SDP Interim Design, to support the SOC management and prudential security processes.

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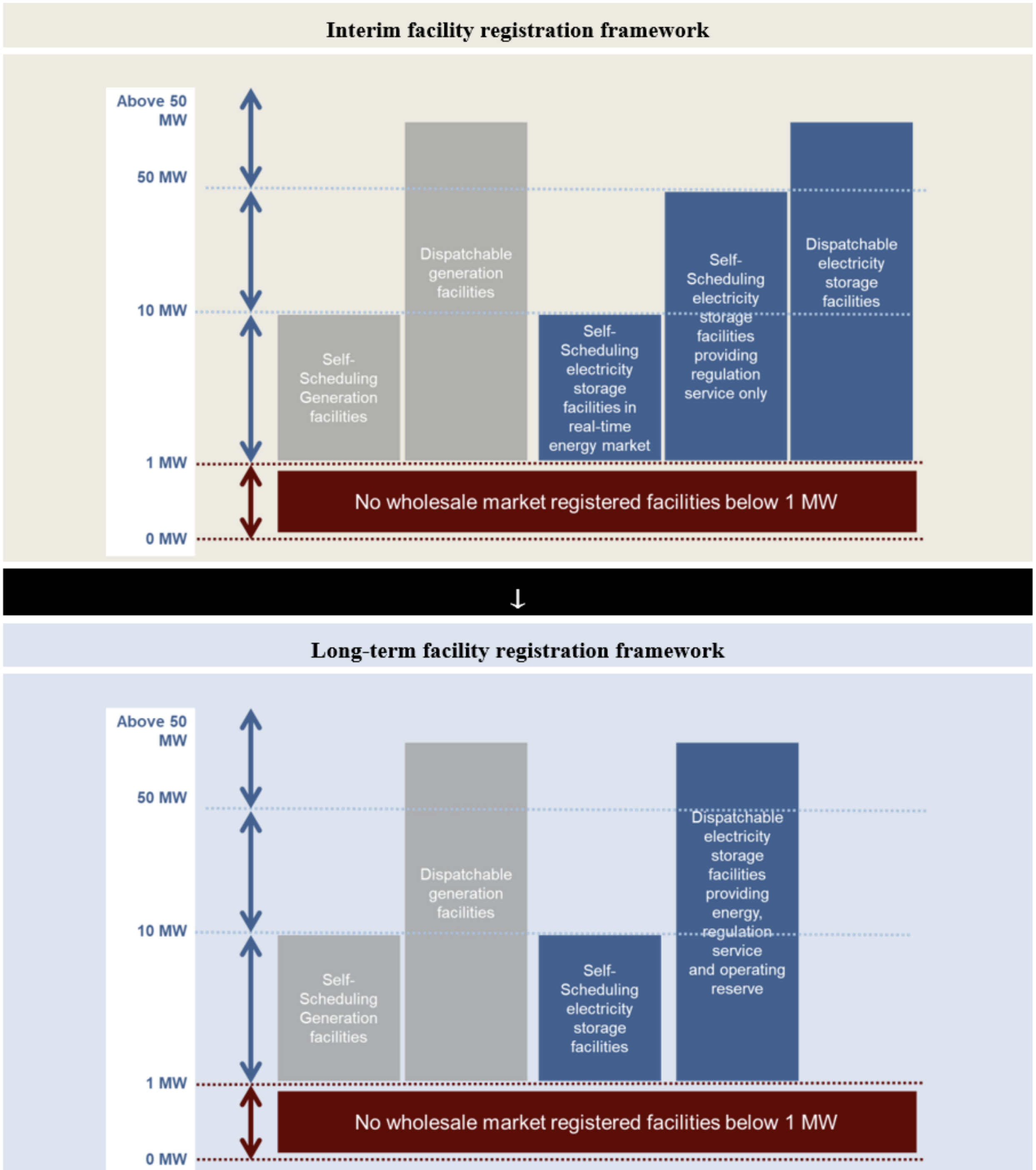
facility has more than one connection point, the facility will be represented by more than one Resource. The submission of *bids, offers* and/or *schedules* is done at the Resource level."

8. An electricity storage participant must be registered for each electricity storage facility. This is a core requirement that carries over from the interim arrangement

Overall, the long-term facility registration construct will reduce the number of electricity storage types from three to two,[14] and these resulting facility types will observe the same size thresholds as the equivalent class of generation facility (i.e. equivalency between dispatchable and self-scheduling facility classes). Having this parity between the generator and storage classes of registered facilities underlies a key objective of the SDP - which is to improve market access. This parity between generation facility types and storage facility types is illustrated in the Figure 2-3.

[14] Specifically, the current Interim Design presently encompasses i. dispatchable storage facilities ii. self-scheduling storage facilities; and iii. self-scheduling storage facilities providing regulation service only.

Figure 2-3 - Facility size thresholds: interim facility registration framework vs long-term facility registration framework



In addition, the new facility construct will use a single storage resource model to represent dispatchable and self-scheduling storage facilities. All electricity storage resources will be represented in the DSO as resources that can withdraw, store and inject energy. The static parameters of these withdrawal, storage, and injection rates and quantities will be a key component of the electricity storage facility registration process.

The differences between the resource model for self-scheduling and dispatchable facilities is also less pronounced in the enduring design than in the Interim Design. Both models will now use the single resource model - with the main differences being the electricity market trading privileges (i.e. dispatchable, self-scheduling, operating reserve, regulation, etc.) assigned to each facility. In today's IAMs, a dispatchable facility may be comprised of one or more resources.

Dispatchable electricity storage facilities will also have the flexibility to sub-divide the facility into multiple storage resources, in a manner similar to a dispatchable generation facility. These similarities and differences are summarized in Figure 2-4 and 2-5.

Figure 2-4 - Overview of changes to the self-scheduling facility construct from the Interim Design to the enduring design

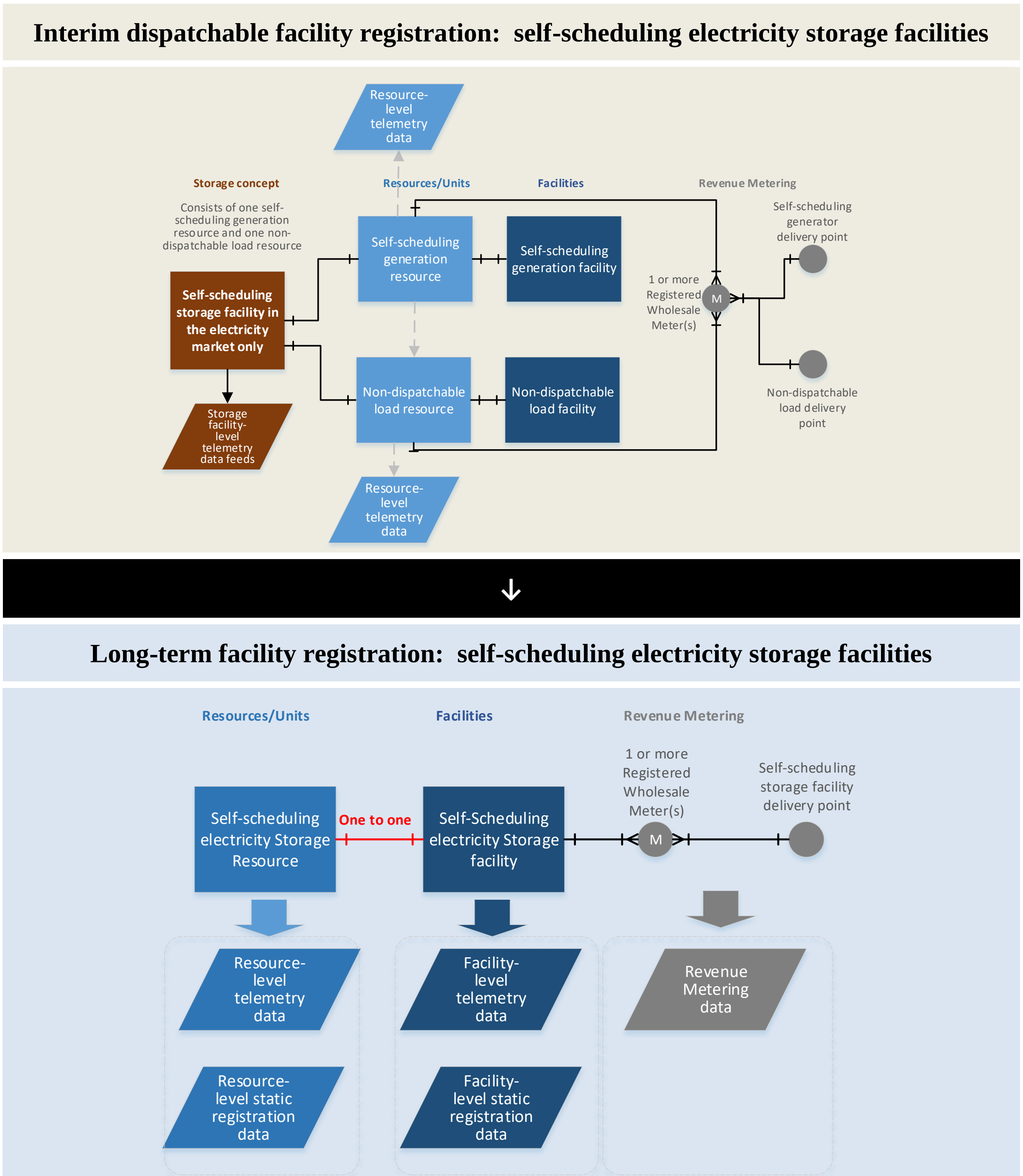
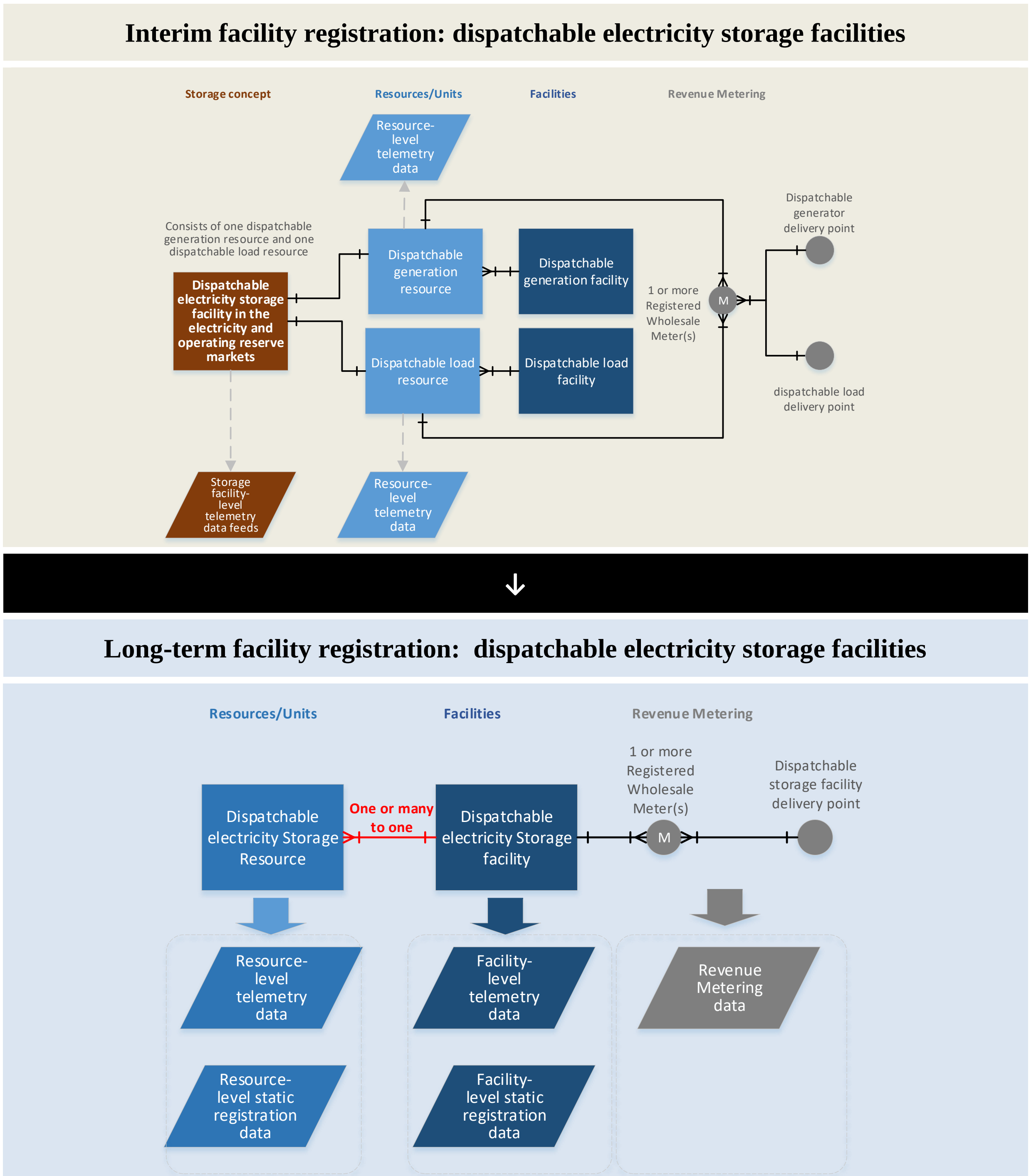


Figure 2-5 - Overview to changes to the dispatchable facility construct from the Interim Design to the enduring design



In all cases, electricity storage facilities will provide dynamic SOC data to support the real-time state of charge management construct described in this document. In addition, the necessary static data for each facility and resource will also be recorded in order to support this model and validate dispatch data submissions. These static and dynamic data series are summarized in Appendix 'A' of this document, and will be registered for each storage facility.

2.3.3. MRP context

The enduring storage facility registration model is intended to support electricity storage operations in the new MRP Day-Ahead Market, pre-dispatch and single-schedule real-time markets. While the usage of the facility model may vary slightly between these three stages of market integration (see also section 2.6, "State of charge management in the real-time energy market"), the underlying facility model will be identical. Overall, there should be no secondary change impacts on these MRP design features beyond the implementation of the new electricity storage facility model.

2.3.4. Applicability of these design features and linkages

These design vision proposals would apply to the two major types of electricity storage facilities that would remain in the Long-Term Design once implemented:

1. **Dispatchable electricity storage facilities:** This model will replace the current two-resource model implemented for dispatchable electricity storage facilities in the Interim Design period and also replace the notion of self-scheduling electricity storage facilities providing regulation services only. Under the new long-term framework, a single resource model will replace the two-resource model. Like dispatchable generation facilities, additional authorization is required for specific wholesale products such as the provision of operating reserve and regulation service.
2. **Self-scheduling electricity storage facilities:** This model will replace the current two- resource model implemented for self-scheduling storage facilities, providing energy only, as implemented in the Interim Design. Once implemented, self-scheduling electricity storage facilities may acquire the same wholesale trading privileges that are available to self-scheduling generating facilities.

2.3.5. Rationale and alternatives considered

This section discusses how these design vision elements of the SDP Long-Term Design Vision serves each of the market design principles whose definitions are provided in section 1.6.

- **"Efficiency", "Competition":** As noted under the state of charge management section, enabling SOC Lite (see also, sections 2.5 and 2.6) will enable both greater market efficiency and more competition in every major wholesale trading product. This single resource model design choice, and the SOC Lite construct it enables, allows storage facilities to more easily participate in these product categories. In addition, the single resource model allows storage facilities to offer their full operating ranges for both energy and operating reserve to a level beyond what is currently supported under the SDP Interim Design.
- **"Implementability":** Given that the IESO is putting forward SOC Lite as the state of charge management framework for this design vision, a single resource model of an electricity storage facility is essential to its implementation. Storage facilities comprised of storage resources are able to submit continuous offer curves for each resource covering their entire range of consumption, storage and injection of energy. The resulting schedules can be further constrained due to the SOC limits of the resources to which those offer curves are associated. This will enhance both the efficiency of the optimization process and overall competition by bringing more capacity of competitively-offered energy and operating reserve to the market.
- **"Certainty":** During the stakeholder engagement phase of the SDP project, the notion of a single resource model emerged as a key area of consensus with widespread support from most members of the ESAG. It is foundational to any of the SOC management models discussed below in which the system operator makes use of the state of charge data in the DSO process. Even under the Self-SOC Management approach, the single resource model helps reduce the possibility of infeasible dispatch, by recognizing each storage resource as a single resource.
- **"Transparency":** Implementing a single resource facility registration model is foundational to the transparency benefits of the SOC Lite state of charge management approach, including continuous offer curves over the facility's entire operating range, providing resource-level state of charge telemetry to the DSO engine and by generally having a resource model that is intended to represent an actual energy storage facility.

2.3.6. Future design considerations

The testing and validation of static registration parameters, as set out in **Appendix 'A'** will be an important matter to be detailed and clarified at the detailed design phase. As a point of future detailed design, electricity storage facilities may be required to register various parametric "reference levels" to support the new ex ante market power mitigation framework proposed by the Market Renewal Program. Specifying those parameters will be a matter for the detailed design phase, and this effort may benefit from the examination of other jurisdictions that are implementing similar market power mitigation measures for storage facilities.

In addition, the associations between electricity storage participants and electricity storage facilities as part of the Authorization and Participation process will also have to be clarified at the detailed design phase. Some of the most important issues that will need to be addressed are whether or not:

1. the prudential security for physical trading by electricity storage facilities in the IESO administered markets may be based upon the framework established for electricity storage market participants in the interim period and subject to any modifications as a result of the Market Renewal Program.
2. electricity storage participants choosing to engage in virtual transactions will be subject to the same prudential security framework as any other market participants authorized to conduct virtual transactions.
3. the authorization to participate in the IESO administered markets process established in the interim period is still applicable.
4. an entity registered as an electricity storage participant may register for any other types of market participant roles for which they meet the registration requirements, and as permissible by law, including, but not necessarily confined to:

    1. Generator
    2. Variable generator
    3. Regulation service provider
    4. Energy trader
    5. Wholesale customer
    6. Distributor
    7. Transmitter
    8. Transmission rights
    9. Metering service provider
    10. Virtual transaction energy trader; and
    11. Day Ahead Market price responsive load

2.4. Ability of ESRs to set market-clearing price in the energy and operating reserve markets

Design element	Design questions
2. Ability of ESRs to set market-clearing price in the energy and operating reserve markets	2.1 Should ESRs be able to set the market-clearing price?

2.4.1. Design issue overview

Should electricity storage facilities be able to set the market-clearing price? During the extensive rulemaking process undertaken by the United States Federal Energy Regulatory Commission for facilitating energy storage access to U.S. wholesale markets (FERC Order 841) this design issue was of crucial importance. With answering ‘yes’ to this question comes immediate implications for electricity storage facility registration, offer curves, and the manner in which electricity storage facilities are accounted for in the dispatch, scheduling and optimization (DSO) algorithm. In the end, FERC indeed answered this in the affirmative in FERC Order 841 and it has been central to the design of energy storage integration frameworks in U.S. markets.

As part of the IESO Storage Design Project (SDP) Interim Design, this issue was also addressed. Like FERC, the SDP project has sought a similar goal of providing electricity storage facilities with access to wholesale market trading products. By developing a two-resource model for dispatchable electricity storage facilities in the interim period, it will be immediately possible for such facilities to set the market clearing price for energy and operating reserve. By virtue of providing competitive offers into the electricity market, it logically flows that these resources should be included in price formation. As noted below, this same recommendation carries over to the Long-Term Design Vision and the future IESO administered markets once modified by the Market Renewal Program – though the form of implementation will necessarily differ slightly, in order to fit the single resource storage model.

2.4.2. Design Vision recommendations

1. A dispatchable electricity storage resource may set the price in any day-ahead trading product for which it is authorized to participate in.
2. A dispatchable electricity storage resource may set the price in the pre-dispatch process for any trading product for which it is authorized to participate in.
3. A dispatchable electricity storage resource may set the price in any real-time trading product for which it is authorized to participate in.

2.4.3. MRP context

All dispatchable facilities will be able to set the real-time electricity price within MRP. The Market Renewal Program will be adding a new Day-Ahead Market and modifying the pre-dispatch + enhanced real-time unit commitment process to complement modifications to the real-time markets. All of these measures will expand and enhance the participation options for dispatchable facilities and it is expected that these measures should extend to electricity storage facilities, with the exception of unit commitments, which are confined to eligible 'non-quick start (NQS)' resources.

2.4.4. Applicability of these design features and linkages

Under present practice, only dispatchable facilities may set the market clearing price in the IESO administered markets. As a result, this set of design recommendations will only apply to dispatchable electricity storage facilities, for the wholesale trading products for which they are authorized to trade.

Self-scheduling facilities (storage or generation facilities) may not set market clearing prices and it is expected that this arrangement will extend to the future IESO-administered markets after the MRP modifications have been implemented.

2.4.5. Rationale and alternatives considered

This section discusses how these elements of the SDP Long-Term Design Vision serves each of the MRP market design principles whose definitions are provided in section 2.6 ("Design Principles").

- **"Efficiency", "Competition" and "Implementability":** Quite simply, the inclusion of energy storage facilities only fully yields the benefits of greater market efficiency and competition if their capacity is brought to bear on the price setting process. The rationale for this recommendation is intertwined with the selection of the state of charge management methodology that spans the day-ahead and real-time markets. If the SDP had selected a SOC management methodology that doesn't necessitate the submission of competitive offers into the electricity market that would, by extension, preclude those resources from being considered during the price formulation process. While some variants of ISO (independent system operator)-managed and self-managed SOC management frameworks would have potentially not required competitive offers. However, such an approach would be incongruent with the key objective of an open electricity market. In the case of this design vision, the selection of SOC Lite as the foundational state of charge management framework obliges all participating dispatchable storage facilities to participate in the price setting process. A further discussion of this rationale may be found in section 2.6.
- **"Certainty" and "Transparency":** Certainty and transparency are the central arguments to allowing dispatchable electricity storage facilities to set the market clearing price. To do otherwise, would result in an informational distortion to the demand and supply curves used for setting prices in the electricity market, reducing certainty for all market participants. At best this would result in a distorted market clearing price - sending an inefficient signal to other resources in the market regarding the supply/demand balance. At worst, the arrangement would create an informational asymmetry that could be exploited by larger energy storage facilities to manipulate the market clearing price (by virtue of shifting demand and supply curve segments not represented in the price formation process via offers).

2.4.6. Future design considerations

There are at least two aspects of publishing and reporting market information that may have to be considered in the detailed design phase in order to ensure that electricity storage facilities contribute to an efficient market. More specifically, the level of information disclosure to and from the electricity market should not create information asymmetry between electricity storage facilities and other types of facilities. The two main areas of consideration will likely be as follows:

1. The design details regarding publishing and reporting market information should consider, to the greatest extent possible, how to avoid the creation of information asymmetry between electricity storage facilities and other types of facilities in the IESO-administered markets. For greater certainty, this principle should extend to both access to market information by electricity storage participants, and the reporting on the operations of electricity storage facilities to the rest of the market.
2. The execution of a fair framework for publishing and reporting market information for electricity storage facilities and the rest of the market will, by necessity, encompass an examination of the publishing and reporting framework arising from the final implementation of Market Renewal Program.

2.5. Day-ahead market (DAM): bidding and scheduling of ESRs

Design element	**Design questions**
3. Day-ahead market (DAM): bidding and scheduling of ESRs	3.1 Who should optimize SOC of ESRs in the DAM: the ESR, system operator, or give ESRs the choice?

2.5.1. Design issue overview

Over the course of the SDP, the IESO and stakeholders examined a number of potential options for state of charge management in both the day-ahead and real-time markets. Of particular assistance to this effort was a taxonomy of the options put forward by Electric Power Research Institute (EPRI). The EPRI examination of SOC management models has been articulated in two EPRI reports[15] and was also summarized in a presentation to the IESO Energy Storage Advisory Group (ESAG) on March 26th.

The EPRI conceptual model presented a spectrum of choices ranging from options where the system operator has almost complete control over the storage facility usage, to options where all aspects of state of charge management reside with the facility asset owner/market participant. At the heart of these options is a crucial design trade-off: optimization from the standpoint of the system as a whole vs optimization purely from the standpoint of the storage asset owner. Like many aspects of electricity market design, a viable solution must be able to serve both interests. It is here where this design vision ultimately centred around the "SOC Lite" option – which is generally an intermediate option between the extreme ends of the EPRI SOC-management spectrum. Effectively, SOC Lite provides the system operator with the opportunity to make the best possible use of a SOC-limited facility for the benefit of the system as a whole, while affording the maximum flexibility to the storage asset owner to signal the value of that facility's services to a competitive market.

SOC Lite's reliance upon competitive offers from storage facilities to signal value is consistent with the notion of an open electricity market where control over facilities and how they are offered resides with the facility's registered market participant. While Self SOC Management also meets this bar, there are inherent reliability, and market efficiency drawbacks in the Self

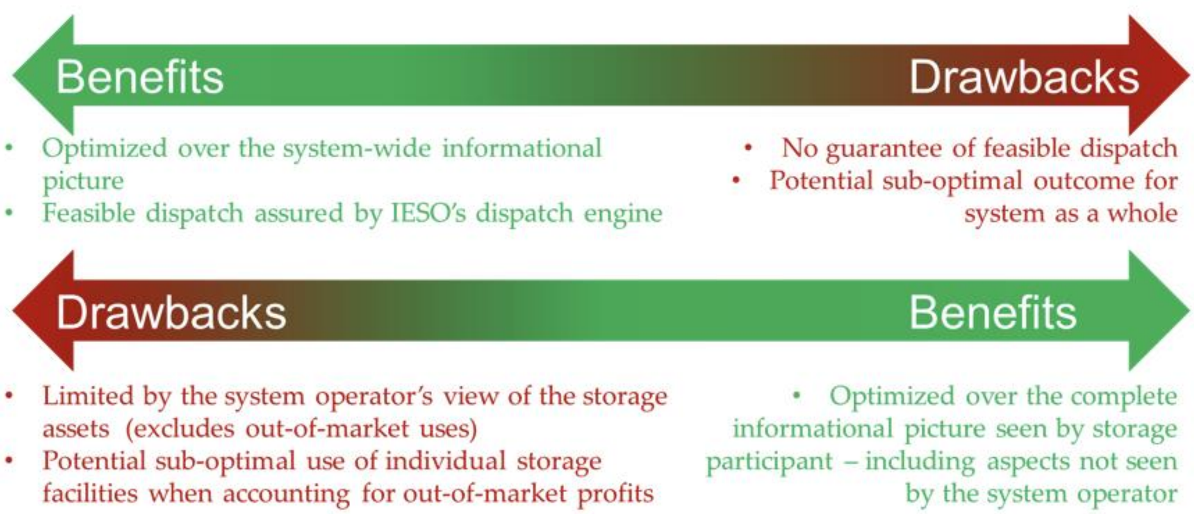
[15] 1) Public report: EPRI, "*Independent System Operator and Regional Transmission Organization Energy Storage Market Modeling Working Group White Paper: Current State of the Art in Modeling Energy Storage in Electricity Markets and Alternative Designs for Improved Economic Efficiency",* document ID: 3002012327, Mar 29, 2018.
2) Proprietary report: EPRI, "*Integrating Electric Storage Resources into Electricity Market Operations: Evaluation of Day-ahead and Real-time State of Charge Management Options"* document ID: 3002016228, June 8, 2020 – see also, IESO ESAG webpages for EPRI public presentation summarizing the findings of this public report.

SOC Management option, which withholds SOC data from consideration by the dispatch algorithm that is seeking to optimize the entire electricity market.

Nothing in the SOC Lite design choice would relieve a storage facility from its obligation to manage offers and follow dispatch instructions – as with any other type of facility in the market. In the real-time market, SOC Lite transfers much of the responsibility for formulating SOC-feasible dispatch, in real-time, to the system operator, with little or no loss of 'flexibility' to the market participant.

Figure 2-6 - Summary of design philosophies and trade-offs behind the various EPRI conceptual models of state of charge management models

	Strong ISO Intervention in storage operations			Little or no ISO intervention in storage operations
	EPRI "ISO-SOC-Management"	EPRI "SOC-Management-Lite"	EPRI "Self-SOC Management"	EPRI "Self-Schedule" option
Philosophy	The system operator has more information than any individual market participant and should therefore manage all aspects of optimizing and scheduling energy storage	Let energy storage facilities react to immediate price changes – and ensure any SOC constraints are accounted for within the DSO Allow market participants to submit modified bid/offer data reflective of storage resource capabilities and/or other data to reflect SOC limitations	Let energy storage facilities react to immediate price changes – and ensure any SOC constraints are indirectly accounted for within the DSO via bid/offer changes. Allow market participants to submit modified bid/offer data in order to signal SOC limits. *{analogous to current treatment of dispatchable storage in IESO Interim Design)*	Let energy storage facilities react to immediate price changes whenever and wherever possible – and don't worry if SOC constraints can be directly seen by the DSO *{analogous to current treatment of self-scheduling storage in IESO Interim Design)*



In the context of the Day-Ahead Market, this issue also needs to ensure that the principal difference in economic outcomes between the Day-Ahead Market and the real-time market is the management of day-ahead risk.

2.5.2. Design Vision recommendations

1. The Day-Ahead Market Calculation Engine should use the same electricity storage resource model as the real-time market.
2. An electricity storage resource may participate in buying and selling the same wholesale market products, for which it is authorized, in both the DAM and real-time markets.
3. The DAM should optimize an electricity storage facility over the same 24-hour time horizon as other resources in the DAM utilizing offers from dispatchable electricity storage facilities and self-schedules submitted by self-scheduling electricity storage facilities.
4. The DAM calculation engine should optimize energy schedules for dispatchable electricity storage facilities, based on their offer data and accounting for their calculated state of charge values. SOC values for electricity storage facilities shall be initialized in the first hour of the optimization window using a static or dynamic value submitted by each applicable electricity storage participant.
5. Dispatchable electricity storage facilities may be authorized to sell operating reserve (O.R.) in the DAM on the same criteria as other types of dispatchable facilities. The IESO and its stakeholders should determine if it is necessary to require the DAM calculation engine to account for a state of charge value when determining O.R. schedules. Such determination may include a review of the performance of other electricity markets and an examination of the real-time market's ability to address DAM-to-real-time operating reserve shortfalls after the commencement of DAM operations

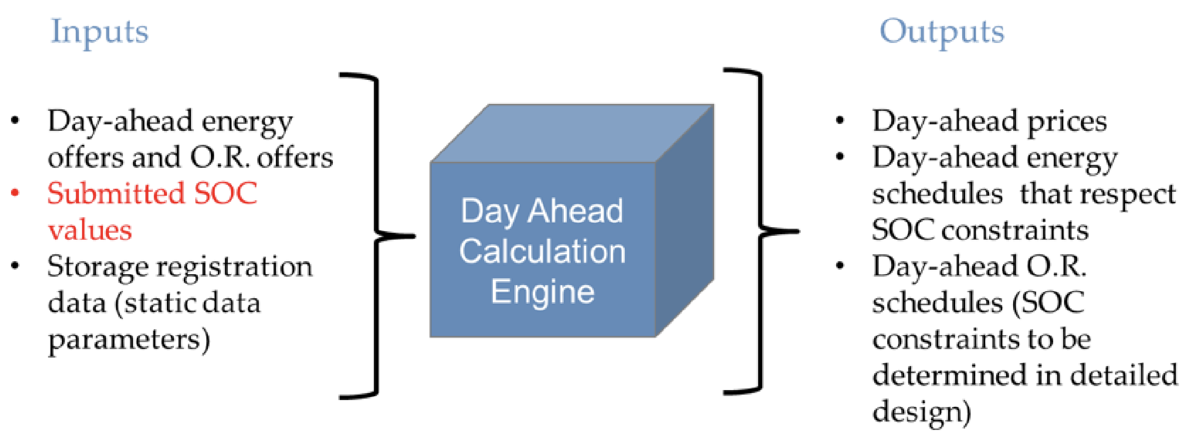
Overall, the Day-Ahead instance of the Dispatch Scheduling and Optimization (DSO) – also referred to as the Day Ahead Calculation Engine or DACE engine - will optimize energy storage facilities for energy in the same manner as other facilities participating in the Day-Ahead Market, with the important exception of accounting for state of charge for storage facilities. In addition, this includes any requirements to secure a day-ahead Availability Declaration Envelope (ADE) by virtue of submitting offers into the DAM.[16]

[16] At the time of publication of this document, the MRP DAM High-level Design document calls for such a measure to be implemented as part of the DAM. An ADE requirement, like today's Day Ahead Commitment Process, requires a facility to provide day-ahead offers for an amount of capacity equal to or greater than any quantity of energy they may wish to offer into the real-time market for the corresponding hours the next day.

A combination of registered attributes for energy storage facilities (see also, **Appendix 'A'**), and an initial, SOC value will allow storage facilities to receive a day-ahead schedule that respects the facilities' SOC limitations.

In the most general terms, the Day Ahead Calculation Engine will use storage facilities' static parameters, and submitted SOC, to determine day-ahead schedules that respect SOC calculated relative to the initial, submitted value from hour 1 of the optimization.

Figure 2-7 - Overview of storage-related inputs and outputs to the Day Ahead Calculation Engine (day-ahead DSO process)



As currently envisioned by MRP, the Day-Ahead Market will run each pre-dispatch day at 6:00 a.m. to 10:00 a.m. This necessitates an assumed starting value for SOC for electricity storage facility energy schedules that don't begin until 12:00 a.m. the next day.

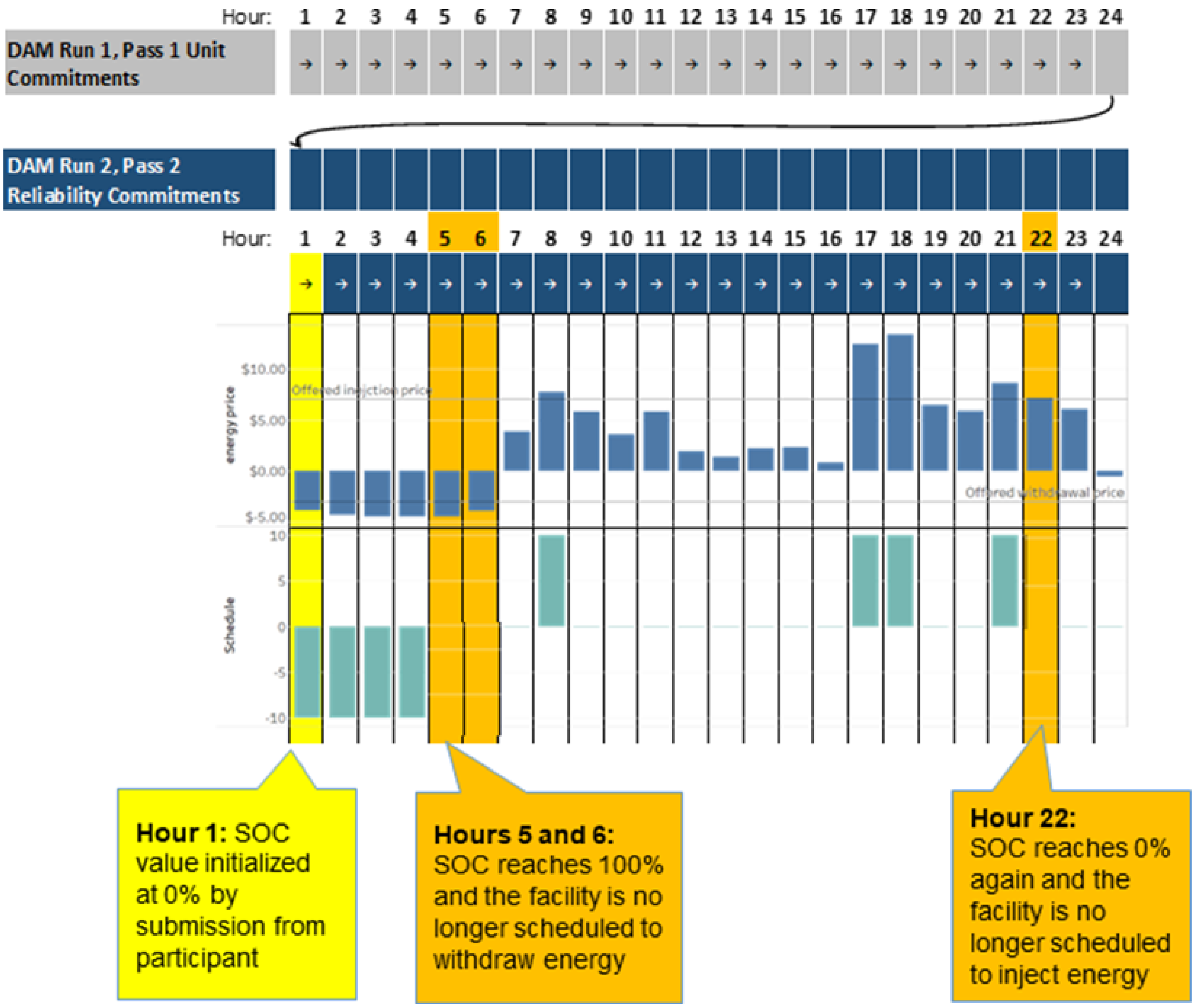
As an example, consider a facility with a four-hour maximum duration of service (i.e. the facility can withdraw or inject at full power mode for a maximum of 4 hours) which economically clears the DAM with its offered withdrawal price for the first six hours (see Figure 2-8). Given that the Day-Ahead Calculation Engine is aware of:

- the storage facility's maximum and minimum SOC values;
- the assumed starting SOC value, as submitted by the market participant (0% in this example); and,
- the facility's maximum rates of energy withdrawal and injection

The Day-Ahead Calculation Engine is able to account for the fact that the facility cannot withdraw any more energy after the first 4 hours. As a result, the DAM schedules the maximum energy withdrawal for the first 4 hours and then drops the schedule to zero for the next two hours, even though the withdrawal price is economic relative to the DAM price.

This example is illustrated in the figure that follows. In the same example, it is also shown where the SOC constraint in the DAM becomes relevant again later in the day as the facility's energy storage buffer is exhausted. In hour 22, the facility is no longer scheduled to inject energy even though its offered injection price clears in the DAM.

Figure 2-8 - example of an electricity storage facility with a 4-hour duration of service where the SOC constraint applies in hours 5, 6 and 22 of the DAM optimization run



2.5.3. MRP context

MRP will institute a new Day-Ahead Market (DAM) to replace today's Day-Ahead Commitment Process (DACP) with various objectives including:

- Facilitate day-ahead physical and virtual trading of energy.
- Secure physical unit commitments from non-quick start resources.
- Maintain a day-ahead Availability Declaration Envelope for generators.
- Support ex ante market power mitigation.

By extension, accommodating energy storage in the DAM will supplant existing design features of the SDP Interim Design currently requiring electricity storage facilities to submit dispatch data into the DACP. At the time of drafting this document, the DAM detailed design document was still pending and several aspects of electricity storage deployment in the DAM will need to be addressed as part of a later, detailed design effort following the initial deployment of the DAM.

2.5.4. Applicability of these design features and linkages

The application of the SOC Lite state of charge management framework will apply to dispatchable electricity storage facilities participating in the Day-Ahead Market. By necessity, such facilities will need to participate in the DAM in order to receive an Availability Declaration Envelope for the following dispatch day. Self-scheduling storage facilities will continue to maintain responsibility to submit their own self-schedules and adhere to them outside of the SOC constraint used to support SOC Lite.

2.5.5. Rationale and alternatives considered

This section provides further description of how these elements of the SDP Long-Term Design Vision serves each of the market design principles whose definition are provided in section 2.6 ("Design Principles").

As noted above, the SDP project and its stakeholders reviewed and considered the full range of SOC management arrangements presented by the Electric Power Research Institute and found that SOC Lite measured up most favourably to the following MRP design principles:

- **"Efficiency":** As noted above, in the DAM SOC Lite allows energy-limited storage facilities to be optimized over the 24-hour DAM optimization timeframe, based upon competitive offers, while ensuring that the resulting energy schedules adhere to projected SOC levels. In addition, this design choice allows storage facilities to more easily offer their full operating ranges for both energy and operating reserve to a level beyond what is currently supported under the SDP Interim Design.

- **"Competition":** Overall, the inclusion of energy storage in the DAM process enhances competition in the DAM and real-time markets. It is perhaps here more than anywhere else where the SOC Lite proposal serves the central purpose of the SDP design vision by providing electricity storage facilities with opportunities to participate in the wholesale market on a footing similar to the comparable class of generator. The dispatch data submission modifications envisioned in this vision document (see also section 2.7, “Real-time energy and operating reserve markets: bidding and scheduling of ESRs”) will enable the full range of an energy storage facility’s operating capabilities to be offered into both the DAM and real-time markets for both energy and operating reserve.
- **"Implementability":** Another benefit of SOC Lite, is that it is likely highly compatible with the Market Management System platform selected by the IESO to support the deployment of the Market Renewal Program. Over the course of the SDP’s ESAG consultations over the past two-years, stakeholders have stressed the importance of an expedient energy storage integration solution that provides access to wholesale market trading products. Generally, SOC Lite provides the possibility of minimizing system modifications, and by extension, accelerating the deployment of this design vision following the implementation of the MRP market changes. In the day-ahead timeframe, one crucial remaining detailed design issue that may affect implementation timelines, is whether or not day-ahead SOC constraints should also be modeled for operating reserve schedules (see also section 2.5.6, “Future design considerations”).
- **"Certainty":** As noted in the section that follows, SOC Lite provides assurance to both the system operator and the electricity storage participant that real-time schedules will be feasible from a SOC management standpoint. This is perhaps less important in the Day-Ahead Market timeframe, where physical market participants may still buy or sell their way out of a day-ahead position in the real-time market. Nonetheless, the inclusion of bids and offers from storage facilities in the DAM still provides a higher degree of certainty for all market participants that DAM prices signal the market’s collective best guess regarding conditions for the next dispatch day. Conversely, excluding energy storage facilities from the DAM would provide a guaranteed difference in how the DAM and real-time markets reflect supply/demand balance – and by extension, less certainty.
- **"Transparency”:** SOC Lite requires the submission of a starting SOC data value, for each storage facility, to the Dispatch Scheduling and Optimization engine that clears the DAM. Given that the electricity storage participant’s DAM schedule will be affected by this initial value submitted into the DAM, they have a clear incentive to signal their best estimate of the starting SOC value for the next dispatch day and they have the remaining

hours of the current dispatch day to manoeuver their facility so that the actual SOC value matches their DAM submitted value by the first hour of the dispatch day. This creates a similar opportunity that dispatchable generators have to ensure that DAM schedules match their anticipated physical production schedule for the next day.

2.5.6. Future design considerations

As noted in the recommendations section above, a key question for optimization of electricity storage facilities in the DAM, is whether or not day-ahead operating reserve schedules should also optimize for SOC. Over the course of the SDP project it was noted that some jurisdictions in North America are not planning to implement this constraint for O.R. schedules. In addition, the MRP DAM High-Level Design document makes two important statements regarding the nature of an O.R. schedule in the DAM:

"Having more resources available to set DAM prices will better reflect the value of producing or consuming the next unit of energy or operating reserve."

"The IESO has determined that resources that can be scheduled to produce an incremental unit of energy or operating reserve on an hourly basis in the DAM will be eligible to set DAM prices, even if they are unable to set prices in real-time."

IESO, "Day-Ahead Market High-Level Design"

The practical reality is that DAM schedules will always depart from real-time schedules for matters outside the control of the IESO or market participants (e.g. weather, equipment failure, unanticipated demand swings, etc.). However, when it comes to O.R. schedules, there is also a known difference between the DAM and real-time markets: the real-time DSO will always ensure that a storage facility has at least one hour remaining duration of service in order to be scheduled to provide O.R. (given the market rule requirement that a facility activated for O.R. must be able to support that activation for at least one hour). Does this difference make for a less efficient or less reliable market? This difference between day-ahead and real-time optimization approaches may very well be acceptable, so long as this difference is known to all participants in the market.

This is where a DAM schedule for energy or operating reserve is different from a unit commitment schedule: a market participant has the option of buying or selling their way out of a DAM schedule for energy or operating reserve as an alternative to matching a DAM schedule to physical operations in real-time. Like other commodity markets, the underlying motive for this may be either speculative profit seeking, or a conservative risk hedging approach.

For these reasons, it has been proposed that this portion of the Long-Term Design Vision be left to the latter detailed design phase, so that a final decision on this matter can be supported by real-world observations of DAM-to-real-time performance in Ontario, and other jurisdictions where energy storage participates in a DAM. More specifically, to what extent do real-time schedules adhere to DAM schedules, and where there are differences, how well is that gap closed without creating artificial arbitrage opportunities? In a well-functioning, competitive market, supply shortfalls and surpluses between DAM and real-time should be quickly corrected for by market participants, given the profit motive to do so.

The outcome of this decision may affect computational performance of the DAM DSO engine and overall project implementation timelines. These factors may also have to weigh into the final decision regarding the modeling of SOC constraints for day-ahead operating reserve schedules.

2.6. State of charge (SOC) management in the real-time energy market

Design element	**Design questions**
4. State of charge (SOC) management in RT energy market	4.1 Who should optimize SOC of energy storage resources (ESRs) in the RT energy market: the ESR, the system operator; or give ESRs the choice?

2.6.1. Design issue overview

In the SDP Interim Design, a host of temporary measures were put in place to address the central challenge to energy storage integration in the IESO-administered markets: the present inability of the Dispatch Scheduling and Optimization engine to account for state of charge. The Interim Design measures largely involved manual workarounds on the part of the IESO and market participants to address those limitations and included:

- changes to dispatch data during the Mandatory Window (in the final two hours before each dispatch hour);
- restrictions against overlapping or equal bid/offer prices;
- self-assessment of state of charge prior to submitting operating reserve offers; and
- prevention of load and generation resources comprising a storage facility from providing operating reserve offers at the same time.

Together, these measures provide a limited degree of access to the wholesale markets with a number of restrictions, manual overhead costs, and losses of efficiency. It is also the core goal of the SDP to improve upon these arrangements by providing better market access. For example, the inability to use no more than half of a storage facility's operating range to provide operating reserve at any given time limits the potential contribution of these resources to the market. In addition, dispatchable storage facilities are currently unable to provide regulation service. All of these issues were acknowledged in the SDP Interim Design as matters to be addressed as part of the Long-Term Design Vision.

The selection of the SOC Lite framework resolves the problems identified with the Interim Design and obsolesces most of the SOC-related design features that it implemented. In addition to reducing manual overhead for both the IESO and market participants, SOC Lite paves the way for realizing a number of the original goals of the SDP project. The benefits of SOC Lite include:

- Assurance to the system operator and market participants that all dispatch schedules for energy and operating reserve will account for state of charge, by taking a telemetry snapshot.
- More efficient use of state of charge in the near-term, 12-interval look-ahead of the Multi-Interval Optimization (MIO) sequence.
- Automatic inclusion of state of charge in the dispatch algorithm, obviating any need for last minute, SOC-related changes to dispatch data during the Mandatory Window.
- Optimization of all dispatchable storage facilities over a continuous offer curve for each resource.
- Ability to offer the full operating range of the storage facility (see also section 2.7, "Real-time energy and operating reserve markets: bidding and scheduling of ESRs").
- Allowance for dispatchable storage facilities to provide regulation service in conjunction with energy and operating reserve (see also section 2.8, "Regulation service").

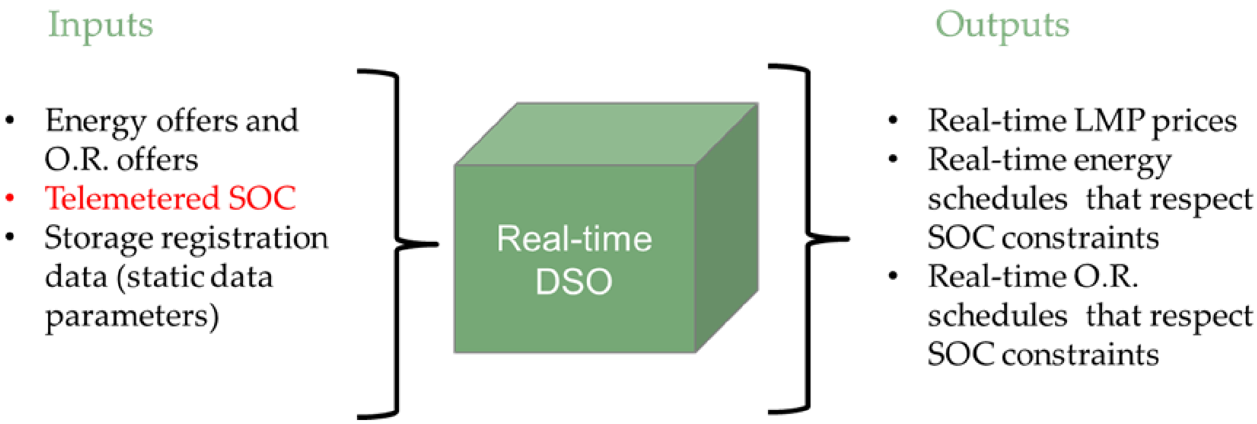
As noted below, the SOC Lite framework is foundational to many of the other design choices proposed (e.g. facility resource model, continuous offer curve, price-setting, etc.) in this Long-Term Design Vision for long-term energy storage integration.

2.6.2. Design Vision recommendations

1. Interim Design measures for managing SOC-related constraints via changes to energy and operating reserve offers during the 2-hour period prior to each dispatch hour ("the Mandatory Window") should be replaced by the introduction of this Long-Term Design.
2. The real-time constrained energy dispatch sequence should account for SOC when formulating dispatch schedules for the real-time market.
3. The real-time constrained energy dispatch sequence should use a data snapshot of real-time state of charge of an electricity storage facility to determine its estimated state at
4. the time of dispatch and ensure that the facility's energy and operating reserve dispatch schedules respect the facility's Lower Energy Limit and Upper Energy Limit along with maximum power limits for injections and withdrawals.
5. The real-time constrained energy dispatch sequence should use a data snapshot of real-time state of charge of an electricity storage facility to determine its estimated state at the time of dispatch and ensure that the facility's operating reserve schedule is backed by the facility's capability to sustain an activation of that operating reserve schedule for at least one hour.

In real-time, under the SOC Lite framework, the DSO will use dispatch data in the form of continuous offer curves and self-schedules as well as a telemetry snapshot of each electricity storage facility. Like the DAM DSO engine, storage-specific, parametric registration data is also used in conjunction with the other input data elements to ensure feasible dispatch. Both energy and operating reserve schedule outputs from this process will respect the SOC limitations of each storage facility. All other aspects of the real-time DSO engine (such as the formation of real-time locational prices for example) operate in the usual manner after the introduction of the SOC-specific constraints. A summary of critical, storage-related inputs and outputs from the real-time DSO is summarized in the diagram that follows.

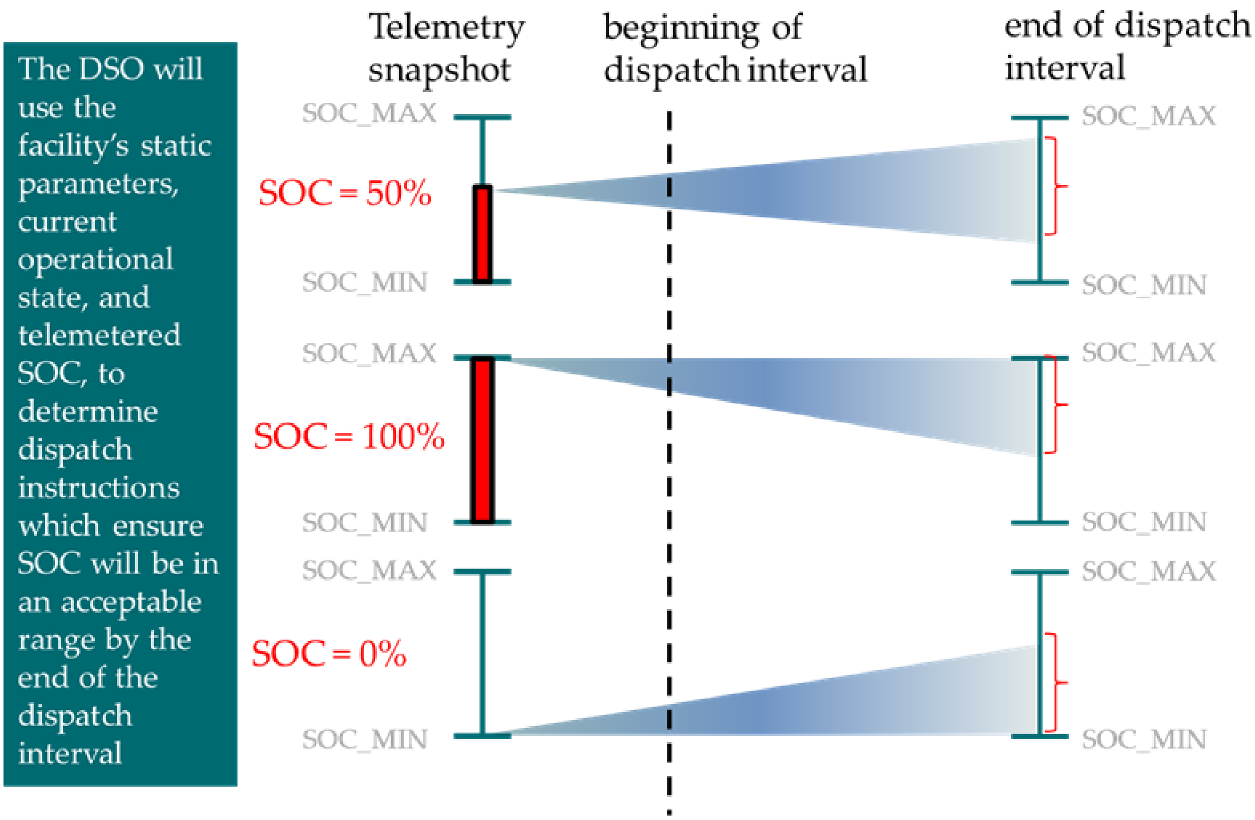
Figure 2-9 - Overview to storage-related inputs and outputs to the real-time DSO for dispatchable storage facilities



Real-time energy state of charge constraints:

Under SOC Lite, real-time dispatch relies upon taking a snapshot of each storage facility’s SOC value and assessing the potential states the facility will be in by the time the dispatch instruction is issued, several minutes after the snapshot is taken. Various examples of this process are illustrated in Figure 2-10.

Figure 2-10 - SOC Lite assessment of feasible dispatch range by the time each dispatch instruction is issued



This constraint provides both the IESO and the market participant assurance that the facility can meet the dispatch schedules for energy.

Real-time operating reserve state of charge constraints:

Presently, the SDP Interim Storage Design requires electricity storage participants who are authorized to provide operating reserve in the IESO-administered markets to observe several important restrictions:

- The electricity storage participant may not offer operating reserve from the load and generation resource comprising an electricity storage facility at the same time.
- When offering operating reserve from the load or generation resource, an electricity storage participant may only offer energy from the corresponding resource for the corresponding hours.
- The electricity storage participant must ensure that the facility has an adequate remaining duration of service at the time the operating reserve offer is submitted prior to the dispatch hour.

The sum total of these measures imparts an additional work task burden both upon the market participant to apply these measures, and the IESO to enforce them. In addition, there is a less than efficient outcome for the rest of the market as a significant portion of an energy storage facility's total capability must be withheld from the market at times when the facility is attempting to provide operating reserve.

With SOC Lite, all of these operational issues are taken care of automatically by the DSO in real-time and electricity storage participants are free to offer the full capability of their facilities (i.e. over both their withdrawal and injection range) for both energy and operating reserve, at the same time. To do this, the DSO engine uses the telemetry snapshot of the storage facility's SOC level (as described above) and determines if the facility has a minimum stored energy capacity available to meet an activation of the offered amount of operating reserve for at least one hour.

Enabling storage resources to offer the full range of their capabilities into the real-time energy and operating reserve markets, while reducing the manual operational burden for both the IESO and market participants is a significant benefit that should be realized from the SOC Lite design vision.

Multi-Interval Optimization (MIO):

In today's real-time market constrained dispatch sequence, the MIO process continuously optimizes gains from trade over the coming hour (i.e. beyond the immediate, 5-minute dispatch interval). To ensure both the consistent treatment of electricity storage facilities and their effective use, it is recommended that electricity storage facilities and their real-time SOC constraint considerations be included in MIO.

MIO is, in fact, a two-step process of:

1. combined optimization of a selected set of "advisory" intervals over the 12- interval study horizon; and,
2. solving the constraints for each individual interval in the study period

MIO executes every five minutes and the first interval in the study period constitutes the dispatch interval. It is from the results of this first interval in the MIO study period that the IESO's dispatch instructions are derived.

In the example contained in the figure below, successively more expensive generators A, B, and C are more efficiently utilized when considering the next five intervals, as opposed to just the current dispatch interval (i.e. the "myopic" dispatch approach).

In the example below, generator 'B' is ramped up sooner so as to avoid the use of the most expensive generator 'C' in the higher- demand intervals at the end of the study horizon. The result: an optimal outcome for the rolling, 1-hour study period, as opposed to each individual dispatch interval.

Figure 2-11 - Differences in outcomes in a three-generator example in a myopic dispatch approach (left) and a MIO approach (right)[17]

Interval	1	2	3	4	5
Generator A	50	100	100	100	100
Generator B	0	0	35	70	100
Generator C	0	0	15	15	0
Demand in MW	+50	+50	+50	+35	+15
Cost/Interval	$2,000	$4,000	$8,750	$10,500	$9,000
Total Cost	$34,250				

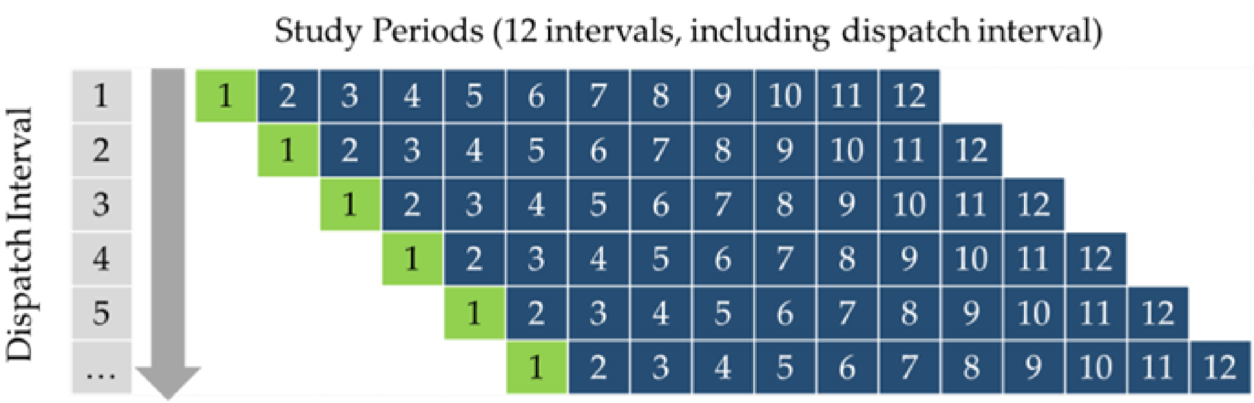
Single Interval Optimization

Interval	1	2	3	4	5
Generator A	50	85	100	100	100
Generator B	0	15	50	85	100
Generator C	0	0	0	0	0
Demand in MW	+50	+50	+50	+35	+15
Cost/Interval	$2,000	$4,150	$6,500	$8,250	$9,000
Total Cost	$29,900				

Multi-Interval Optimization

In order to work properly, MIO must consider the same scope of inputs and constraints as would be used in single-interval ("myopic") dispatch. Under SOC Lite this also holds true. Specifically, the first interval of each 12-interval MIO study period is initialized with telemetered SOC and the state estimation[18] for the first interval. This helps set the necessary parameters for the remaining intervals in the study period, in a manner similar to the DAM optimization engine, except that in this case the sequence is initialized by actual/telemetered SOC, as opposed to a submitted value from the market participant.

Figure 2-12 - MIO study periods with interval 1 initialized with telemetered SOC data



[17] Source: IESO Quick Take: *Multi-Interval Optimization (MIO).* Generator values are in MW. Each generator unit production cost is relatively higher in sequence from Generator 'A' to Generator 'C'.
[18] i.e. the estimated state that the electricity system and all facilities will be in by the time the dispatch instruction is calculated and issued to the market participant.

2.6.3. MRP context

For the most part, electricity storage facilities should work seamlessly with the new "single-schedule" market presently being developed by the IESO Market Renewal Program. The storage-specific measures outlined in this section largely define the main design issues, which will allow storage facilities to submit competitive offers for energy and operating reserve in the real-time market. As noted below, one of the main remaining areas of detailed design will involve the specific treatment of storage facilities in the ex ante market power mitigation framework that will be a component of MRP's single-schedule market implementation.

2.6.4. Applicability of these design features and linkages

The application of the SOC Lite framework is foundational to virtually all other aspects of this SPD Long-Term Design Vision, perhaps with the exception of the allocation of uplift settlement amounts to storage facilities. Adopting SOC Lite in the real-time market results in a number of consequential design choices to support this model and realize its benefits, including:

- The application of SOC Lite in the Day-Ahead Market to provide consistency between the DAM and real-time optimization processes;
- The ability of electricity storage facilities to set the market clearing price;
- The ability of dispatchable electricity storage facilities to provide regulation service; and
- The single resource model for energy storage facilities, which in turn supports the provision of continuous offer curves from energy storage facilities.

2.6.5. Rationale and alternatives considered

These elements of the SDP Long-Term Design Vision serve each of the market design principles whose definition are provided in section 2.6 ("Design Principles") as follows:

- **"Efficiency":** As noted above, real-time SOC Lite allows energy-limited storage facilities to be optimized over the rolling, 12-interval look-ahead period of the Multi-Interval Optimization (MIO) process. In addition, this design choice allows storage facilities to more easily offer their full operating ranges for both energy and operating reserve to a level beyond what is currently supported under the SDP Interim Design.
- **"Competition":** It is perhaps here more than anywhere else where the SOC Lite proposal serves the central purpose of the SDP design vision by providing electricity storage facilities with opportunities to participate in the wholesale market on a footing similar to the equivalent class of generator. The dispatch data submission modifications envisioned in this vision document (see also section 2.7, "Real-time energy and operating reserve markets: bidding and scheduling of ESRs") will enable the full range of an energy

storage facility's operating capabilities to be offered into both the DAM and real-time markets for both energy and operating reserve. In addition, these changes are a component part to enabling dispatchable energy storage facilities to have the same capabilities to provide regulation service as dispatchable generators (see also section 2.8, "Regulation Service").

- **"Implementability":** Over the course of the SDP's ESAG consultations over the past two years, stakeholders have stressed the importance of an expedient energy storage integration solution that provides access to wholesale market trading products. Another benefit of SOC Lite, is that it is likely highly compatible with the Market Management System platform selected by the IESO to support the deployment of the Market Renewal Program. Generally, SOC Lite provides the possibility of a minimizing system modifications, and by extension, accelerating the deployment of this design vision following the implementation of the MRP changes.
- **"Certainty":** SOC Lite provides assurance to both the system operator and the electricity storage participant that real-time scheduling decisions are being based upon the latest data on the operating state of the electricity storage facility. This provides certainty that the resulting dispatch instructions respect the bounds of the facility's storage capabilities. This, in turn, provides broader certainty to the rest of the market that near-term optimization decisions being made by the MIO optimization sequence will not be abrogated by unexpected or unseen SOC limitations of storage facilities.
- **"Transparency":** SOC Lite requires the use of telemetered SOC data from every electricity storage facility by the Dispatch Scheduling and Optimization engine that clears the electricity market. As a result, SOC data can be used by the DSO to account for the state of every energy storage facility in the market during price formation and dispatch. This includes the latest changes to SOC levels within the dispatch hour itself – something that cannot be accounted for in the Interim SOC management framework currently being put into place today.

2.6.6. Future design considerations

Derates for energy storage facilities:

Like generators, energy storage facilities may be subject to partial derates for periods of time due to scheduled maintenance and other, unexpected conditions. These interim changes to capability will need to be signalled to the DSO as they occur, in order for SOC-related constraints to work properly under those circumstances. Given that storage facilities could be derated for injection, withdrawal and storage capabilities, the detailed design will need to determine how that information will be signalled to the DSO.

Form of data inputs:

The precise form of the SOC-related dispatch constraints will be dependent upon the form of the inbound dispatch data - which will need to be addressed at the detailed design phase. Once those details are determined (e.g. the method by which injections and withdrawals are distinguished within a continuous offer curve), the mathematical form of SOC-related constraints will be codified in the description of the real-time DSO in the Appendices[19] to the IESO Market Rules.

Ex ante market power mitigation:

The MRP Detailed Design document, "Market Power Mitigation" has indicated that dispatchable electricity storage facilities shall generally be subject to the same ex ante market power mitigation framework that will apply to other types of dispatchable facilities, once the MRP energy stream is deployed. However, the precise details as to how this will be deployed, including the setting of storage-related parameters raises a number of second-order questions that will need to be addressed in the detailed design phase.

Modifications to storage offers due to SOC limits:

Presently, storage facilities, along with other types of facilities are expected to modify bids and offers during the Mandatory Window two hours prior to each dispatch hour. Under the Interim Design, this extends to SOC limitations. It will need to be determined if there is any necessity for dispatchable storage facilities to modify their offers, due to SOC constraints, when the SOC Lite framework will automatically account for any binding constraints at the time of dispatch.

[19] Currently, the mathematical form of the DSO may be found in the Appendices to Chapter 7 of the IESO Market Rules

2.7. Real-time energy and operating reserve markets: bidding and scheduling of ESRs

Design element	Design questions
5. RT energy and operating reserve markets: bidding and scheduling of ESRs	5.1 What offer curve shape (e.g., continuous through zero, discontinuous, convex) should ESRs be allowed to use to offer into the energy and operating reserve markets?

2.7.1. Design issue overview

This issue, regarding dispatch data submission from electricity storage facilities, was originally posed in the context of the real-time energy market. However, as this Long-Term Design Vision will commence after the IESO Market Renewal Program is implemented, it is also important to consider how this issue will apply to both the real-time, single-schedule market and the Day-Ahead Market. To the greatest extent possible, the SDP has sought to put forward a design proposal for energy storage offers with minimal differences between both markets which:

- supports the implementation of the SOC Lite charge management framework, as described in this design vision document;
- is consistent with the storage facility resource model described in this design vision document;
- can be applied to the widest possible array of electricity storage technologies;
- fully exploits the flexibility and capabilities of fast-ramping energy storage technologies; and
- allows electricity storage market participants the same opportunity to signal marginal costs of their services to the electricity market as the comparable class generation facility.

As will be described in this section, this set of design vision recommendations also supplants the bid/offer construct implemented as part of the SDP Interim Design for dispatchable storage facilities. In the original SDP Interim Design, such facilities made use of a two-resource model which necessitated the submission of both bids and offers, along with a host of manual workarounds on the part of the market participant in order to ensure the IESO’s DSO was able to formulate SOC-feasible dispatch instructions. These measures would be replaced by the introduction of SOC Lite and the new dispatch data submission framework discussed in this section.

2.7.2. Design Vision recommendations

1. **Static Data Inputs– Day Ahead and real-time: All** electricity storage facilities will need to register static facility characteristics, as set out in Appendix 'A' that set boundaries on dynamic data inputs that may be provided by the electricity storage participant.
2. **Dynamic Data Inputs – Day Ahead:** All electricity storage facilities may submit an initial state of charge value to initialize the optimization process for energy and/or operating reserve in the Day-Ahead Market. In the future detailed design, it shall be determined if the initial SOC value can also be established via a registered default value.
3. **Day-Ahead Market Energy Offers:** A dispatchable electricity storage facility may submit a day-ahead energy offer encompassing the injection and withdrawal range of each electricity storage resource comprising the associated electricity storage facility.
4. **Day-Ahead Market Operating Reserve Offers:** A dispatchable electricity storage facility may submit a day-ahead operating reserve offer encompassing the injection and withdrawal range of each electricity storage resource comprising the associated electricity storage facility, where that facility has been registered and authorized to provide operating reserve in the Day-Ahead Market.
5. **Real-Time Market Energy Offers:** A dispatchable electricity storage facility may submit a real-time energy offer encompassing the injection and withdrawal range of each electricity storage resource comprising the associated electricity storage facility.
6. **Real-Time Market Operating Reserve Offers:** A dispatchable electricity storage facility may submit a real-time operating reserve offer encompassing the injection and withdrawal range of each electricity storage resource comprising the associated electricity storage facility, where that facility has been registered and authorized to provide operating reserve in the real-time market.
7. **Dynamic Data Inputs – Real-Time:** Each dispatchable and self-scheduling electricity storage facility shall provide to the IESO, a real-time, telemetered value of its actual state of charge along with other telemetered values prescribed by the Market Rules.

Static data inputs generally:

As noted in the facility registration recommendations, electricity storage facilities will need to register sufficient, storage-specific static data parameters (see also, Appendix 'A') to support the SOC Lite framework. This includes data that will put boundaries on the submission of MW quantities in dispatch data such as upper and lower power operating limits that need to be provided to the DSO to ensure dispatch is within facility capabilities.

None of this should alter the fundamental competition dynamic between electricity storage facilities and other types of resources in the electricity market. This framework only differs from a generation facility by virtue of the fact that a storage facility may have different maximum and minimum power levels for injecting and withdrawing energy from the electricity system. Like a generator, these values may be further, temporarily derated due to temporary operating circumstances that may occur from time to time after registration.

SOC data:

As noted above, the only major difference in dispatch data submissions between the Day-Ahead Market and real-time market is the manner in which the facility's state of charge data is conveyed to the DSO. In the Day-Ahead Market, SOC will be a submitted value provided by the market participant for each electricity storage facility. The precise form of this data submission is a matter of detailed design.

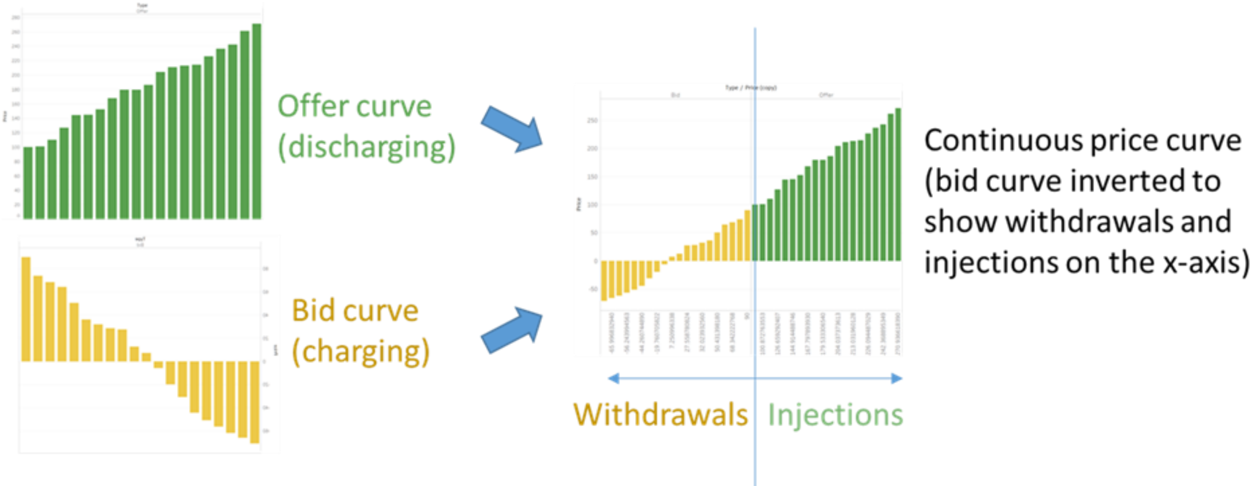
As noted in the recommendations regarding state of charge management in the real-time electricity market, SOC is provided to the DSO via telemetry feeds for real-time and pre-dispatch runs of the dispatch algorithm.

Offer curves to match the single resource energy storage model:

By developing a single resource model to support the SOC Lite framework, it necessarily follows that each dispatchable electricity storage resource will submit a continuous offer curve to represent the value of both energy withdrawals and energy injections.

For operating reserve offers, the value of operating reserve over both the withdrawals and injection range of a storage facility's operating capability can be efficiently signalled to the market. Unlike the Interim Design, there would no longer be a need to restrict a storage facility to providing operating reserve only from the injection or withdrawal side of the facility at any given moment of time (see also section 2.6, "State of charge (SOC) management in the real-time energy market").

Figure 2-13 - Example of how bids and offers of the interim, 2-resource model transition to a single continuous offer curve to support the single resource model in the enduring design



2.7.3. MRP context

Overall, the addition of the Day-Ahead Market creates an additional dimension to the dispatch data submission process. With the recommended addition of electricity storage resources participating in the DAM comes this set of recommendations to minimize the dispatch data differences between the DAM and the real-time market wherever possible. The only necessary exception to this general rule is with the additional requirement that energy storage facilities will need to submit a starting SOC value in order to properly initialize the DAM optimization engine each day (see also section 2.5, “Day-ahead market (DAM): bidding and scheduling of ESRs”).

2.7.4. Applicability of these design features and linkages

All electricity storage facilities (and their constituent resources) will be required to establish static, parametric facility data as part of the facility registration process (see also section 2.3, “Market and facility registration”), some of which, may be used to set limits on the submission of dispatch data into the DAM and real-time markets.

The submission requirements for SOC data in the DAM and real-time will be applicable to all dispatchable electricity storage facilities.

2.7.5. Rationale and alternatives considered

These elements of the SDP Long-Term Design Vision serve each of the market design principles whose definition are provided in section 2.6 ("Design Principles") as follows:

- **"Efficiency":** Introducing a continuous offer curve for dispatchable energy storage facilities ensures that the value of energy injections and withdrawals for the full operating range are constantly signalled to the market. As noted earlier this will result in market efficiency gains, relative to the present SDP Interim Design, in the following circumstances:
    - in the MIO process and, particularly, any time a storage facility becomes charge- limited within a dispatch hour (see also section 2.6, “State of charge (SOC) management in the real-time energy market”); and
    - in the provision of operating reserve, whereby operating reserve can be offered from the facility’s entire withdrawal-to-injection operating range.
- **"Competition”:** These measures generally support the inclusion of electricity storage facilities in the DAM, pre-dispatch and real-time markets on a footing similar to the comparable class of generator.
- **"Implementability":** This proposal is a necessary design feature of SOC Lite in both the DAM and real-time markets. The single resource model is essential to the successful implementation of the SOC Lite framework, and by extension, such facilities must be represented by a single, continuous offer curve.
- **"Certainty" and "Transparency”:** The submission of SOC data is a required element of the SOC Lite framework. Providing SOC data directly into the DSO provides greater certainty to both the system operator and the market participant that the resulting day-ahead and real-time dispatch schedules can be feasibly met by SOC-limited storage facilities.

2.7.6. Future design considerations

More than any other set of proposals in this Design Vision document, these particular propositions sit at the heart of the main operational interface between the IESO and storage market participants. As a result, there will inevitably be a number of detailed design considerations associated with the various data inputs proposed here. Some of the key areas of these recommendations that will have to be finalized at the detailed design phase are as follows:

Energy offer curve attributes in the DAM and real-time markets:

Currently, the real-time market in Ontario allows dispatchable generators to submit an energy offer comprised of a monotonically-increasing set of price-quantity ('p-q') pairs. The maximum number of p-q pairs that may be contained in an offer is 20, and this may be accompanied by up to five different ramp rates applying to a specified output range. In all cases, the offered energy and ramp rates must fall within the bounds of registered static data attributes for the facility or the latest derated value. While it is generally expected that an energy offer from an electricity storage facility will follow a similar set of principles, the precise form remains to be determined. The number and form of p-q pairs and allowable ramp rates will have to be considered as part of the detailed design.

In addition, the electricity storage participant will need to be able to specify which portions of the offer curve apply to energy withdrawals and injections. In some jurisdictions, this is accomplished by using negative values in the offer curve to represent offered quantities of energy withdrawals in the same curve as offered energy injections, which are represented as positive values. Regardless of the form of data submission chosen, the linearization of the offered withdrawal-to-injections will likely be necessary in order to ensure that the curve remains a continuous, monotonically-increasing set of p-q pairs that is usable within the price formation process of the DSO.

Operating reserve offer curve attributes in the DAM and real-time markets:

For operating reserve, a similar set of detailed design considerations, as with the energy offer curves, will present itself. In today's real-time market, an operating reserve offer must be accompanied by a corresponding energy offer or bid and it may contain up to five monotonically-increasing p-q pairs. Also, as noted earlier, there are currently additional restrictions placed on electricity storage facilities under the SDP Interim Design requirements that will need to be removed. Ultimately, an electricity storage facility should have the same flexibility as a generation facility to provide operating reserve, and SOC Lite will allow for the removal of the present restrictions on operating reserve offers from storage facilities. Together, these considerations should guide the final design of operating reserve offer curves for electricity storage facilities.

Day-Ahead SOC submissions:

This design vision contemplates that an electricity storage facility should be able to submit a starting SOC value to initialize the day-ahead optimization process. There are a variety of potential design options as to how to facilitate this, including daily data submissions, and registered default values. So long as the core optimization objective for the DAM is adhered to, the precise form of the DAM SOC submission is a matter to be resolved at the detailed design phase.

Self-schedules:

Presently, self schedules for self-scheduling generation facilities include a requirement to provide a production floor price at which the facility will stop injecting energy. In the detailed design phase, it will need to be determined if such a provision is required for electricity storage facilities. In addition, there is also the question of whether or not a complementary ceiling price for energy withdrawals should also be signaled to the market. Another option, which is currently being implemented in some U.S. jurisdictions is to simply assume that electricity storage self schedules are fixed during the day-ahead optimization process and/or the real-time process, thus obviating the need for break prices for withdrawals or injections. Regardless of the method chosen however, self-scheduling storage facilities should continue to have the same flexibility to self-schedule as self-scheduling generators.

Day Ahead physical bilateral contracts:

The current Day-Ahead Market detailed design contemplates the extension of physical bilateral contracts (PBCs) to the DAM. Presently, PBCs may be used in the real-time market to allow two market participants to remove a bilateral energy sale from being settled by the IESO. At issue is whether or not an electricity storage participant may submit day-ahead physical bilateral contact data in the same manner as other market participants authorized to participate in the DAM.

An energy storage facility can change from injections to withdrawals, or vice versa, within a given dispatch hour. Logistically this may complicate the designation of who the buying market participant and the selling market participant is for a given bilateral transaction. While this is not an insurmountable problem, an agreed upon set of ground rules for designating the buyer and seller in such transactions will have to be determined in the detailed design phase in order to make settlement of the PBCs feasible.

2.8. Regulation service

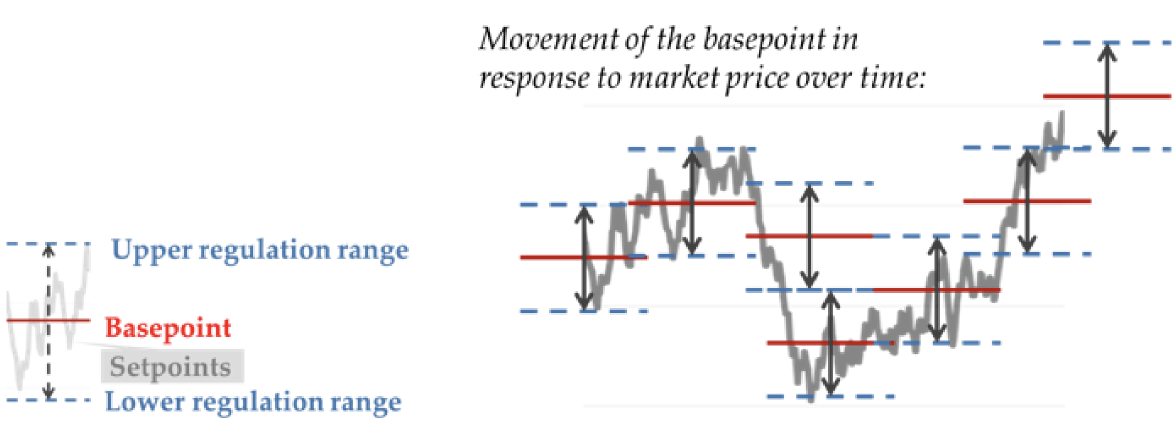
Design element	Design questions
6. Regulation service	6.1 What are the rules for what proportion of an ESR's total capacity gets used for regulation, energy and operating reserve – both at different times and simultaneously?

2.8.1. Design issue overview

"Regulation" is a type of ancillary service, which is currently procured by the IESO, on behalf of the electricity market under the authority of the IESO Market Rules. Chapter 11 of the IESO Market Rules defines regulation service as, "…the service required to control power system frequency and maintain the balance between load and generation." In its technical implementation, regulation service involves a facility responding directly to a 'setpoint' signal from the IESO's Automatic Generation Control (AGC) system, which moves active power levels on a second-to-second basis in response to frequency changes and power system imbalance.

These setpoint movements occur within a contracted range of the "basepoint," which usually resides in the middle of that regulation range. Today, the Dispatch Scheduling and Optimization (DSO) engine moves the basepoint of a generator up and down its feasible operating range, and according to market economics in response to prices. An example of this arrangement is illustrated in the figure below.

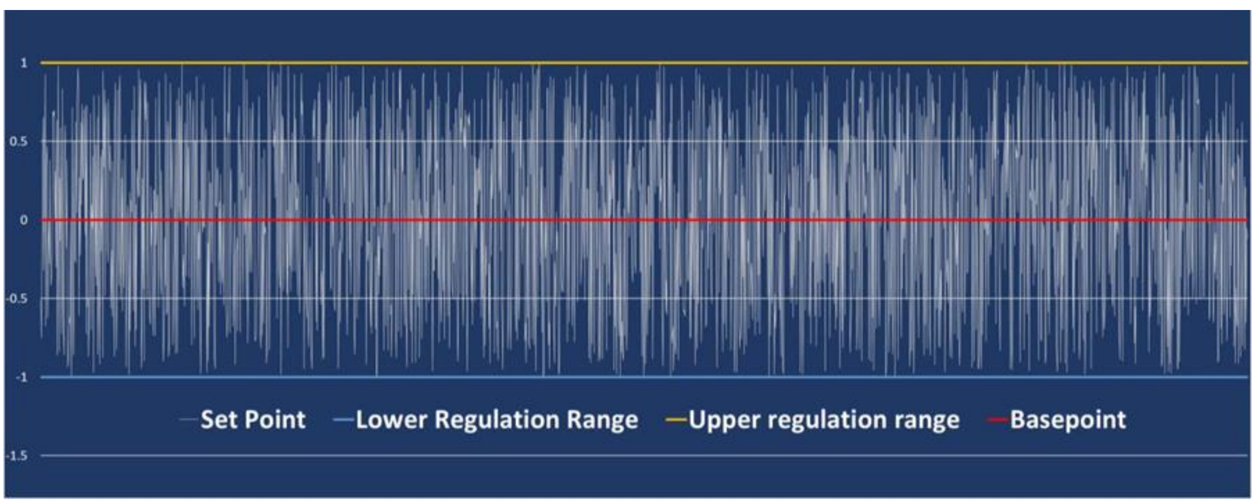
Figure 2-14 - Illustration of the setpoint and basepoint movements of a standard regulation signal for a generation facility



The AGC system then sends out regulation “setpoint” signals, that respect the upper and lower bounds of the regulation range provided by the facility. Dispatchable generation facilities may be assigned to regulation duty, in accordance with the applicable contractual obligations, for the entire dispatch day, or portions of the day. This process differs somewhat from wholesale markets in some other jurisdictions, where regulation, operating reserve and energy schedules are automatically optimized across the three product categories on an interval-to-interval basis (sometimes referred to as, ‘tri-optimization’).)

Today, energy storage facilities have been providing regulation service in Ontario through various pilot project initiatives. These present arrangements are affected by the fact that the DSO tool and the AGC tool essentially has no view of the storage facility due to the lack of a single resource storage model and the current inability to model state of charge. As a result, there is no economic movement of the basepoint, and the facility needs to be modeled as a self-scheduling generator in order to receive the AGC signal. A setpoint is sent from the AGC tool to the storage facility, usually holding the basepoint at a constant zero line (see Figure 2-15 for an illustrated example). This arrangement is currently captured in the SDP Interim Design.

Figure 2-15 - Typical regulation signal for a storage facility, centred around a zero basepoint under today’s Interim Design arrangements

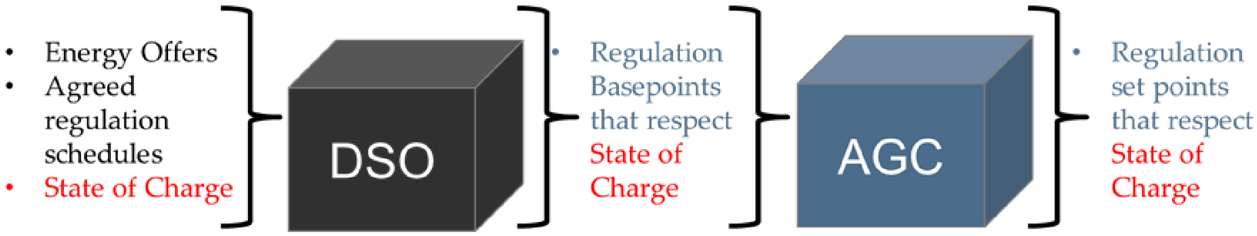


2.8.2. Design Vision recommendations

1. Dispatchable electricity storage facilities should be fully enabled to compete to efficiently provide multiple services including regulation, energy and operating reserve on the same basis as a dispatchable generation facility. This capability would be expected to be in place once:
   - this Long-Term Design Vision is implemented,
   - the IESO's SCADA EMS Upgrade project[20] is completed; and
   - any supporting tool changes are implemented to make use of the upgraded AGC tool capabilities from the IESO's SCADA EMS Upgrade project

Once the Long-Term Design Vision recommendations are implemented, regulation arrangements in Ontario should be able to take advantage of the market efficiency gains that SOC Lite presents. The overall objective is to ensure that regulation service from storage is deployed in a manner similar to generators. The main difference is that the DSO algorithm would now send unit basepoints for regulation service that respect state of charge. This overall information flow is illustrated in the figure that follows.

Figure 2-16 - Overview of principal information flows to create regulation signals that respect storage facility state of charge limits



It should be noted that in addition to implementing SOC Lite, these measures are also dependent upon two other efforts. First, the IESO's SCADA EMS Upgrade Project (underway at the time of publication of this document) includes a number of changes to incorporate storage facilities into the AGC tool. Secondly, additional tool changes are also required to enable this functionality. The timing of these additional changes has not yet been determined.

[20] The EMS/SCADA Upgrade Project is described in the IESO's 2019-2021 business plan as follows: *"This project will review our energy management and data acquisition requirements to establish a platform that provides the control room and back office staff with the tools necessary to monitor and manage power system reliability."* It also encompasses modifications to the AGC system as described in this section

2.8.3. MRP context

This particular design issue is largely divested from the pending MRP market changes, though it is expected to operate in the context of the new, single-schedule market once it is implemented. It is however, tied to the broader question of how the regulation service market might evolve over a longer time horizon – particularly in aspects of procurement policy for future regulation products and optimization of regulation service. As noted above, these matters are beyond the scope of the current SDP project.

2.8.4. Applicability of these design features and linkages

As noted earlier, under the Long-Term Design Vision, regulation service may only be provided by electricity storage facilities that are dispatchable. In addition, the capabilities recommended in this section are dependent upon other project streams including the completion of the SCADA EMS Upgrade Project and other tool changes required to fully enable the functionality of including storage in the AGC tool.

2.8.5. Rationale and alternatives considered

This section provides further description of how these elements of the SDP Long-Term Design Vision serves each of the market design principles whose definition are provided in section 1.7 ("Design Principles"):

- **"Efficiency":** Efficiency is one of the strongest arguments for implementing the regulation service recommendation of the Long-Term Design Vision. It has been an issue of considerable interest to many stakeholders in the ESAG group over the past two years. Specifically, the same storage asset will be able to move freely between providing regulation service, energy and operating reserve under arrangements that contribute to making the optimal choice between each of these products. Furthermore, sub-dividing the regulation service product category into segments that exploit both conventional and fast-ramping technologies holds the promise of a more efficient allocation of regulation service expenditures which are of common use to the entire electricity system. However, this is a matter of future design considerations as to how best to implement this. Experience in U.S. markets has shown that regulation products which exploit faster-ramping facilities have both economic value and staying power, as they've attracted more storage facilities into this segment of the market

- **"Competition":** Allowing storage facilities to move between regulation, energy and operating reserve levels the playing field between storage facilities participating in these products and conventional generators. Furthermore, the prospect of multiple, new facility types providing new regulation service products brings new competitive pressures on the Ontario regulation market which is currently mainly served by conventional facilities and a single type of regulation service product.
- **"Implementability":** As noted earlier, the full range benefits of these particular recommendations can only be realized by the implementation of the single resource model, AGC tool upgrades and other related tool changes. In addition, the final implementation of any new, potential regulation service products would be a matter of future policy implementation beyond the scope of these recommendations.
- **"Certainty" and "Transparency":** Currently, energy storage facilities providing regulation service in Ontario, receive a signal from the AGC system, in isolation of the competitive electricity market. As noted earlier, conventional generation facilities are subject to economic dispatch of their basepoints while under AGC control, to ensure that such facilities are responsive to the overall supply/demand balance while on regulation duty. If storage facilities are to have the opportunity to play a more prominent role in providing regulation service, then it logically follows that they should be integrated into the electricity market in a similar manner. These recommendations should achieve that purpose and lead to both greater certainties in real-time energy market price formation and more transparency for all participants in the regulation market.

2.8.6. Future design considerations

The most crucial future design considerations lie outside the scope of these recommendations, and centre around how best to use the proposed functionality put forward in this section.

Paving the way for future, potential regulation products:

Since 2011, U.S. Federal Energy Regulatory Commission (FERC) Order 755 has helped accelerate the growth of energy storage providing frequency regulation service in some U.S. wholesale markets. That earlier order addressed a perceived discriminatory approach to pricing regulation service, whereby existing market mechanisms didn't recognize the capabilities of fast-ramping resources. At the time, the FERC ordered system operators, "…to compensate frequency regulation resources based on the actual service provided, including a capacity payment that includes the marginal unit's opportunity costs and a payment for performance that reflects the quantity of frequency regulation service provided by a resource when the resource is accurately following the dispatch signal."

That order has continued to affect the trajectory of storage growth in U.S. ancillary services markets ever since. In addition, Order 755 has prompted some U.S. wholesale markets to further sub-divide regulation service into product categories that more specifically reward these faster-ramping capabilities.

This SDP Design Vision could **enable** a number potential regulation service products, of varying degrees of quality and capability in the future – these products are depicted in Figure 2-17.

However, the **implementation** of these products fall outside the scope of the SDP and could encompass other types of resources besides energy storage. Some examples of these potential products include:

- **Fast regulation service:** Such regulation service exploits the capabilities of fast-ramping facilities such as electricity storage facilities, by responding to unfiltered changes to imbalances in supply/demand and system frequency. By responding quickly to these changes, fast regulation service can displace a disproportionately larger quantity of conventional regulation service. For this reason, some U.S. markets sub-divide regulation markets into fast and conventional regulation service and typically price fast- regulation service above conventional regulation service.
- **SOC-limited regulation service:** This service would employ the full regulation range of an energy-limited resource, but the AGC tool would be cognizant of SOC level and reduce the quantity regulation service as SOC changes. Recognizing SOC limitations could be a means of defining an intermediate quality grade of regulation service that is priced accordingly.
- **Mode-limited regulation service:** Under these arrangements, a storage facility could be held in the charging or discharging range, depending on SOC levels. This would allow a storage facility to provide continuous regulation service for an indefinite period of time. The advantage of such a service is that it would boost the facility's value in terms of regulation capacity factor. However, the main disadvantage is that such a service would only utilize a portion of the facility's operating range at any given moment in time.

Figure 2-17 - Examples of potential, future regulation product categories that could be developed after the enduring design vision recommendations are implemented

2.9. Settlement and Charges

Design element	Design questions
7. Settlement and charges	7.1 How will uplift charges stipulated by the IESO Market Rules be applied to energy storage resources?

2.9.1. Design issue overview

The IESO operates Ontario's power system and its energy markets - ensuring that electricity is delivered to consumers when and where it is needed. In the final accounting, the total cost of electricity charged to consumers should equal the actual cost to dispatch that electricity. Due to the inherent complexities of the electricity system, not all costs are captured in the wholesale market price charged to consumers.

Market uplifts are used to settle the imbalance associated with reliability services that are not captured in the wholesale market price. Use of uplifts is common practice in other jurisdictions. Examples of uplifts include recovery of costs associated with ancillary services (e.g. operating reserve) and generator cost guarantees (e.g. real time cost guarantee program).

Most market uplifts are volumetric and apply to all market participants based on all Allocated Quantity of Energy Withdrawn (AQEW) from the wholesale market. Presently, this includes the AQEW of electricity storage participants. IESO market participants see each uplift as a separate line item on their IESO market settlement statements and invoices.

The question of uplifts was originally identified in the December, 2018 IESO Report, "Removing Obstacles for Storage Resources in Ontario" where it was recommended that the IESO examine the allocation of uplifts to energy storage facilities. For the purposes of these recommendations, "uplifts" shall refer to common charges under the jurisdiction of the IESO Market Rules. Other common charges to the electricity market are administered by the IESO, but are not under the authority of the IESO or the Market Rules. These include:

- Charges under government regulation (e.g. Global Adjustment, Rural and Remote Assistance); and
- Charges under the jurisdiction of the OEB (e.g. IESO Administration Fee).

The December, 2018 storage report also recommended that the Ontario Energy Board and the Government of Ontario conduct a similar investigation of settlement amounts under their respective jurisdictions. These charges are outside the scope of the SDP.

In 2019, Market Rules-governed uplift charges averaged approximately 1% of total wholesale market charges.[21] While generally a small proportion of total market costs, uplifts can vary significantly. For example, these charges can be higher if significant out-of-market-actions are required to maintain reliability.

2.9.2. Design Vision recommendations

2. The IESO proposes that electricity storage resources will be exempt from uplift charges on the energy withdrawn as ‘fuel’ for the sole purpose of being able to provide services back to the grid at a future point in time.[22]
3. Electricity storage resources will continue to be subject to uplift charges for all other withdrawals for any other purpose (e.g. commercial use of energy, station service, cooling fans, office lighting, etc.).

This design recommendation balances the need to consider a unique treatment for energy withdrawn as fuel while maintaining broadly consistent treatment of all other end-use withdrawals in the market. This design feature is expected to facilitate efficient competition between electricity storage and other technologies, while ensuring the ratepayer is not negatively impacted by unnecessarily higher costs.

2.9.3. MRP context

Uplifts are costs associated with maintaining the reliability of the grid that are not recovered through wholesale market prices. These costs to reliably serve load typically fall into one of three categories; (i) congestion management, (ii) commitment guarantees, and (iii) ancillary service recovery.

With the implementation of MRP, the current set of uplift charge types will be replaced with a new set of uplifts to reflect settlement under the new design. While the particular set of uplift charges will change, they will continue to be recovered from load on the basis that these uplift costs are to reliably serve load. Moreover, the principles underpinning the proposed ‘fuel’ exemption for electricity storage resources will not change with MRP.

2.9.4. Applicability of these design features and linkages

The uplift exemption on fuel will be applicable to both dispatchable and self-scheduling storage facilities.

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[21] Source: IESO monthly market update, December, 2019, weighted average rates for 2019

[22] This exemption applies only to those uplift charges under the purview of the IESO under the Market Rules.

2.9.5. Rationale and alternatives considered

Electricity storage resources are unique from both traditional load and generation resources. This was important to acknowledge as the IESO considered whether to treat the load component of electricity storage for the purpose of uplift more akin to a wholesale load or to investigate alternatives that better reflect its role as a service provider. The range of alternatives (to the status quo) included:

- A full exemption from uplift
- A partial exemption from uplifts on 'fuel'
- An uplift 'credit-on-injections' scheme

In order to help make an informed recommendation, the IESO considered a number of principles that explored market impacts of different uplift treatments. At its core, the IESO was conscious of the fact that any recommendation should not have a negative impact on ratepayers.

- **"Efficiency":** The IESO considered the efficiency impacts of uplift allocation. This analysis determined that applying uplift costs on all withdrawals made by electricity storage would ultimately result in higher costs for the end-use consumer.

  Uplift charges on suppliers must ultimately be at least passed through to consumers in the same market. Other end-use loads can pass this cost onto to some secondary market (i.e. the widget factory can pass the cost of electricity uplift from their sales of widgets). This is not the case with stand-alone storage. Storage exists in a closed loop where any levies applied by the market to electricity storage withdrawals must ultimately at least be recouped from the same market. The 'boomerang effect' of these pass-through costs from charging can ultimately lead to higher costs to end-use consumers. Alternatively, if this cost cannot be recovered, the resource must exit the market; neither of these scenarios result in ideal market outcomes.

  The IESO explored at a high-level various 'credit-on-injections' schemes (where the storage resource would pay all uplift on withdrawals but receive a credit on its injections. This is meant to address the so-called 'round trip' efficiency question, whereby the amount reinjected is lower than the amount withdrawn.

  Ultimately, the IESO determined that the partial exemption proposal was a more effective option. The 'reinjection' ratio is not simply a matter of physics; it can vary significantly due to the fact that market conditions may lead to very low energy utilization of ESR (on a monthly or annual basis). Often a storage resource's value to the market is through services like OR or increased quick start flexibility - rather than day-to-day energy flows. The low utilization means a credit-on-injection scheme can lead to instances of significant 'residual' uplift cost that would still need to be recovered from the market.

The IESO believes that market signals and resource competition already provide strong incentives for electricity storage (and other resources) to always seek ways to improve efficiency to undercut competitors and improve market outcomes without the need to force additional costs on resources via an uplift (dis)incentive.

- **"Competition":** Increased wholesale market competition from technologies such as ESRs is of benefit to the end-use consumer. The IESO considered the impact uplift costs would have on the supplier economics of storage and determined there is a risk that if they are unable to recover these uplift costs through the wholesale market, it could lead to resources exiting the market.
- The IESO also considered the issue from a fair competition perspective. Electricity storage is unique from generation in that its 'fuel' is electricity, and is unique from load in that its electricity consumption is for the express purpose of offering electricity back into the market at a later point. The uniqueness of this fuel component warranted a commensurate unique treatment separate from other types of withdrawals (including station service and end-use consumption). The 'fuel' exemption balances the need for a unique treatment while ensuring broad alignment with the treatment of other withdrawals of other resource types in the market. This approach is similar to other system operators in the U.S. who, generally have exempted storage from uplifts on withdrawals.
- **"Certainty and Transparency":** The fuel exemption helps ensure storage participation is driven by market price signals rather than after-the-fact uplift costs.
- **"Implementability":** There are multiple ways in which this can be achieved and the IESO will work with stakeholders to identify the most effective approach. There will be a need to ensure a means of separate treatment of fuel and other facility load required under this partial exemption.

2.9.6. Detailed Design considerations

The proposed 'fuel' uplift exemption will require separate accounting for energy withdrawn as fuel and all other facility load. Separate treatment for energy withdrawn for other purposes 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.

Appendix A - Glossary of storage-related terms

Notice regarding the table below:

This Appendix outlines storage-related terminology in regards to static and dynamic data series. As noted in the "Source" column below, some of these data series are dynamically sent between the IESO and electricity storage facilities, while others are established as part of the facility registration process. They are provided in this Appendix as a list of prospective data series that may be relevant to the implementation of the Design Vision put forth in this document and has some modifications relative to a similar Appendix appearing in the SDP Interim Design document. The inclusion and final form of the data series listed in this table is subject to final confirmation and/or modification at a future detailed design stage.

Table A -1 - Glossary of storage-related items

Term	Symbol or acronym (if applicable)	Units of measure (if applicable)	Description	Source
Basepoint	-	MW	The economic dispatch value (in MW), as determined by the System Operator or the market participant, that the Energy Storage facility operates at while providing Regulation Service.	IESO Dispatch Scheduling and Optimization tool – or – telemetered value from facility.
Certified Duration of Service	-	minutes	Usually expressed in minutes, the Certified Duration of Service of the facility is calculated from the registered Upper Energy Limit, Lower Energy Limit and registered Upper Power Operating Limit of the facility.	Registration Data

Term	Symbol or acronym (if applicable)	Units of measure (if applicable)	Description	Source
			Certified quantities are determined during testing. Certified Duration of Service = pper Energy limit − Lower Energy limitUppe $\frac{SOCMAX_g - SOCMIN_g}{P_{max,g}}$	
Cycle Efficiency	$CycleEfficiency_g$	%	The percent of charging energy which is returned by the storage facility via discharging.	Registration Data
Economic Maximum Power Mode	$ECO\_P_{max,g}$	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: $ECO\_SOC_{max,g} \leq SOCMAX_g$	Telemetered value
Economic Minimum Power Mode	$ECO\_P_{min,g}$	MW	The minimum active power output for operation as indicated by the market participant	Telemetered value

Term	Symbol or acronym (if applicable)	Units of measure (if applicable)	Description	Source
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: $ECO\_SOCmin,g \geq SOCMIN,g$	Telemetered value
Upper Power Operating Limit (injecting)	$P_{max,g}$	MW	The maximum active power output (MW) for operation when injecting (also known as electricity storage capacity)	Registration Data
Lower Power Operating Limit (injecting)	$P_{min,g}$	MW	The minimum active power output (MW) for operation when injecting	Registration Data
Lower Power Operating Limit (withdrawing)	$P_{min,l}$	MW	The minimum active power consumed (MW) when withdrawing (MW)	Registration Data
Upper Power Operating Limit (withdrawing)	$P_{max,l}$	MW	The maximum active power consumed (MW) when withdrawing (MW)	Registration Data
Lower Energy Limit	$SOCMIN,_{g}$	MWh	The lowest energy amount (MWh)to which the energy	Registration Data

Term	Symbol or acronym (if applicable)	Units of measure (if applicable)	Description	Source
			storage system can be consistently discharged without damage beyond expected degradation from normal use.	
Operating Reserve Ramp Rate	$OperatingReserveRampRate_g$	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 GENERATIONRAMPDOWNBLOCKg for g∈OFFERS	Dispatch Data
Ramp Rate Down for dispatchable load resources	RampRate 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	Dispatch Data

Term	Symbol or acronym (if applicable)	Units of measure (if applicable)	Description	Source
			PURCHASERAMPDO WNBLO CKp for p∈BIDS	
Ramp Rate Up for dispatchable generation resources	RampRate UP gJ		**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	RampRate 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 a facility hits its upper energy limit or lower energy limit assuming the facility continues operating at	Derived from telemetered and registration data

Term	Symbol or acronym (if applicable)	Units of measure (if applicable)	Description	Source
			the present active power level	
Setpoint	-	MW	The required active power injection or withdrawal determined by the system operator at a given moment in time while an energy storage facility is providing regulation service	IESO AGC tool
State of charge	SoC	As a percentage %	The degree to which storage is charged relative to the maximum certified energy storage capacity of the system	Telemetered value
Upper Energy Limit	$SOCMAX_g$	MWh	The maximum energy amount (MWh)to which the energy storage system can be consistently charged without damage beyond expected degradation from normal use	Registration data

Appendix B - Summary of SPD Design Vision Recommendations

Notice regarding the table below:

This Appendix lists all of the main recommendations from Chapter 2 that comprise the SDP Long-Term Design Vision.

Table B-1 - Summary of SDP Design Vision Recommendations

Design element	Design questions	Enduring design vision recommendations
1. Market and facility registration	1.1 How should an energy storage facility be registered into the IAMs?	1. Registration of self-scheduling electricity storage facilities should be based upon a single resource model that can withdraw, store and inject energy. 2. Registration of dispatchable electricity storage facilities should be based upon a single resource model that can withdraw, store and inject energy. 3. The maximum size threshold for self-scheduling electricity storage facilities should be equivalent to the threshold for self-scheduling generation facilities. 4. Dispatchable electricity storage facilities may be authorized to participate in the same wholesale market products as dispatchable generation facilities. 5. Self-scheduling electricity storage facilities may be authorized to participate in the same wholesale market products as self-scheduling generation facilities. 6. The minimum size threshold for dispatchable energy storage facilities should be the same level that applies to dispatchable generation facilities. 7. All electricity storage facilities should be required to register certain static registration parameters, as introduced in the SDP Interim Design, to support the SOC management and prudential security processes 8. An electricity storage participant must be registered for each electricity storage facility. This is a core requirement that carries over from the interim arrangement.

Design element	Design questions	Enduring design vision recommendations
2. Ability of ESRs to set market-clearing price in the energy and operating reserve markets	2.1 Should ESRs be able to set the market-clearing price?	1. A dispatchable electricity storage resource may set the price in any day-ahead trading product for which it is authorized to participate in. 2. A dispatchable electricity storage resource may set the price in the pre-dispatch process for any trading product for which it is authorized to participate in. 3. A dispatchable electricity storage resource may set the price in any real-time trading product for which it is authorized to participate in.
3. Day-ahead market (DAM) and day-ahead commitment process (DACP): bidding and scheduling of ESRs	3.1 Who should optimize SoC of ESRs in the DAM: the ESR, system operator, or give ESRs the choice?	1. The Day-Ahead Market Calculation Engine should use the same electricity storage resource model as the real-time market. 2. An electricity storage resource may participate in buying and selling the same wholesale market products, for which it is authorized, in both the DAM and real-time markets. 3. The DAM should optimize an electricity storage facility over the same 24-hour time horizon as other resources in the DAM utilizing offers from dispatchable electricity storage facilities and self-schedules submitted by self- scheduling electricity storage facilities. 4. The DAM calculation engine should optimize **energy schedules** for dispatchable electricity storage facilities, based on their offer data and accounting for their calculated state of charge values. SOC values for electricity storage facilities shall be initialized in the first hour of the optimization window using a static or dynamic value submitted by each applicable electricity storage participant. 5. Dispatchable electricity storage facilities may be authorized to sell **operating reserve** in the DAM on the same criteria as other types of dispatchable facilities. The IESO and its stakeholders should determine if it is

Design element	Design questions	Enduring design vision recommendations
		necessary to require the DAM calculation engine to account for a state of charge value when determining 6. O.R. schedules. Such determination may include a review of the performance of other electricity markets and an examination of the real-time market's ability to address DAM-to-real-time operating reserve shortfalls after the commencement of DAM operations.
4. State of charge (SoC) management in RT energy market	4.1 Who should optimize SoC of energy storage resources (ESRs) in the RT energy market: the ESR, the system operator; or give ESRs the choice?	1. Interim Design measures for managing SOC-related constraints via changes to energy and operating reserve offers during the 2-hour period prior to each dispatch hour ("the Mandatory Window") should be replaced by the introduction of this Long-Term Design. 2. The real-time multi-interval optimization (MIO) sequence should account for SOC when formulating dispatch schedules for the real-time market. 3. The real-time constrained energy dispatch sequence should use a data snapshot of real-time state of charge of an electricity storage facility to determine its estimated state at the time of dispatch and ensure that the facility's energy and operating reserve dispatch schedules respect the facility's Lower Energy Limit and Upper Energy Limit along with maximum power limits for injections and withdrawals. 4. The real-time constrained energy dispatch sequence shall use a data snapshot of real-time state of charge of an electricity storage facility to determine its estimated state at the time of dispatch and ensure that the facility's operating reserve schedule is backed by the facility's capability to sustain an activation of that operating 5. reserve schedule for at least one hour.
5. RT energy and operating	5.1 What offer curve shape	1. **Static Data Inputs– Day Ahead and real-time:** All electricity storage facilities will need to register static

Design element	Design questions	Enduring design vision recommendations
reserve markets: bidding and scheduling of ESRs	(e.g., continuous through zero, discontinuous, convex) should ESRs be allowed to use to offer into the energy and operating reserve markets?	facility characteristics, as set out in Appendix ‘A’ that set boundaries on dynamic data inputs that may be provided by the electricity storage participant. 2. **Dynamic Data Inputs – Day Ahead:** All electricity storage facilities may submit an initial state of charge value to initialize the optimization process for energy and/or operating reserve in the Day-Ahead Market. In the future detailed design, it shall be determined if the initial SOC value can also be established via a registered default value. 3. **Day-Ahead Market Energy Offers:** A dispatchable electricity storage facility may submit a day-ahead energy offer encompassing the injection and withdrawal range of each electricity storage resource comprising the associated electricity storage facility. 4. **Day-Ahead Market Operating Reserve Offers:** A dispatchable electricity storage facility may submit a day-ahead operating reserve offer encompassing the injection and withdrawal range of each electricity storage resource comprising the associated electricity storage facility, where that facility has been registered and authorized to provide operating reserve in the Day-Ahead Market. 5. **Real Time Market Energy Offers:** A dispatchable electricity storage facility may submit a real-time energy offer encompassing the injection and withdrawal range of each electricity storage resource comprising the associated electricity storage facility. 6. **Real Time Market Operating Reserve Offers:** A dispatchable electricity storage facility may submit a real-time operating reserve offer encompassing the injection and withdrawal range of each electricity storage resource comprising the associated electricity storage facility, where that facility has been registered

Design element	Design questions	Enduring design vision recommendations
		and authorized to provide operating reserve in the real-time market. 7. **Dynamic Data Inputs – Real-time:** Each dispatchable and self-scheduling electricity storage facility shall provide to the IESO, a real-time, telemetered value of its actual state of charge along with other telemetered values prescribed by the Market Rules.
6. Regulation service	6.1 What are the rules for what proportion of an ESR's total capacity gets used for regulation, energy and operating reserve	1. Dispatchable electricity storage facilities should be fully enabled to compete to efficiently provide multiple services including regulation, energy and operating reserve on the same basis as a dispatchable generation facility. This capability would be expected to be in place once: 1. this Long-Term Design Vision is implemented, 2. the IESO's SCADA EMS Upgrade project[23] is completed; and 3. any supporting tool changes are implemented to make use of the upgraded AGC tool capabilities from the IESO's SCADA EMS Upgrade project.
7. Settlement and charges	7.1 How will uplift charges stipulated by the IESO Market Rules be applied to energy storage resources?	1. The IESO proposes that electricity storage resources will be exempt from uplift charges on the energy withdrawn as 'fuel' for the sole purpose of being able to provide services back to the grid at a future point in time.[24] Electricity storage resources will continue to be subject to uplift charges for all other withdrawals for any other

[23] The EMS/SCADA Upgrade Project is described in the IESO's 2019-2021 business plan as follows: *"This project will review our energy management and data acquisition requirements to establish a platform that provides the control room and back office staff with the tools necessary to monitor and manage power system reliability."* It also encompasses modifications to the AGC system as described in this section.

[24] This exemption applies only to those uplift charges under the purview of the IESO under the Market Rules.

Design element	Design questions	Enduring design vision recommendations
		purpose (e.g. commercial use of energy, station service, cooling fans, office lighting, etc.).

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