Energy Storage Design Project Draft Design Document for Stakeholder Comment

Published for February 18 Energy Storage Advisory Group Meeting

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1. Introduction and Context

1.1. The context of energy storage integration

The Energy Storage Design Project has been commissioned by the Independent Electricity System Operator (IESO) 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 culmination of the IESO's problem definition work with **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.

- These general developments include:
- Falling technology costs,
- Growing energy storage participation in wholesale markets,
- An emerging minimum, de facto standard for energy storage integration in U.S. wholesale markets as a result of U.S. Federal Energy Regulatory Commission (FERC) Order 841, which focuses on ensuring electric storage resource (ESR) access to wholesale energy, ancillary services and capacity markets; and,
- A commitment by the IESO to address the energy storage barriers identified in its December 2018 report, "*Removing Obstacles for Storage Resources in Ontario*".

Recent public statements included in Table 1 demonstrate the mounting interest in energy storage integration.

The IESO's report, "*Removing Obstacles for Storage Resources in Ontario*" outlines a variety of energy storage barriers that fall under the jurisdiction of the IESO, the Ontario Energy Board, and the Ontario Ministry of Energy, Northern Development and Mines. The scope of this design document is limited to addressing the barriers within the IESO's jurisdiction and more specifically, energy storage facilities in the IESO-administered markets (IAMs).

To date, a number of energy storage projects have been participating in various facets of the 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 FERC Order 841, have required more fulsome integration of energy storage into all wholesale market products. The interim and long-term measures outlined in this design document are meant to serve a very similar scope and purpose.

Table 1 - Selected examples of public statements reflecting the growing trend of mainstream energy storage use in the electricity industry

"The cost projections developed in this work utilize the normalized cost reductions across the literature, and result in 21-67% capital cost reductions by 2030 and 31-80% cost reductions by 2050. The cost projections are also accompanied by assumed operations and maintenance costs, lifetimes, and round-trip efficiencies, and these performance metrics are benchmarked against other published values."

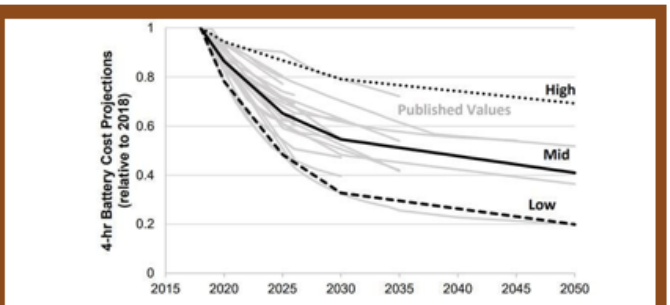


Figure 1. Battery cost projections for 4-hour lithium-ion systems, with values relative to 2018.

Cole, Wesley, and A. Will Frazier. 2019. Cost Projections for Utility-Scale Battery Storage. Golden, CO: U.S. Department of Energy, National Renewable Energy Laboratory. NREL/TP-6A20-73222.

"We find that better integration of electric storage resources into the RTO/ISO markets is necessary to enhance competition and, in turn, help to ensure that these markets produce just and reasonable rates."

U.S. Federal Energy Regulatory Commission Order 841 – Energy Storage Participation in Wholesale Markets

"Storage is another priority for us this year. We will be working with the Energy Storage Advisory group to help enable storage to compete in our markets. This is in line with efforts of our U.S. system operators who are required by FERC to fully enable storage to compete to provide all energy, capacity and ancillary services by the end of 2019."

Peter Gregg, CEO, IESO
Ontario Energy Network Luncheon
January 28, 2019

"Recommendation: The IESO should review and amend its Market Rules, where possible, to clarify the participation of storage resources in IESO-administered markets."

IESO Report, "Removing Obstacles for Storage Resources in Ontario"

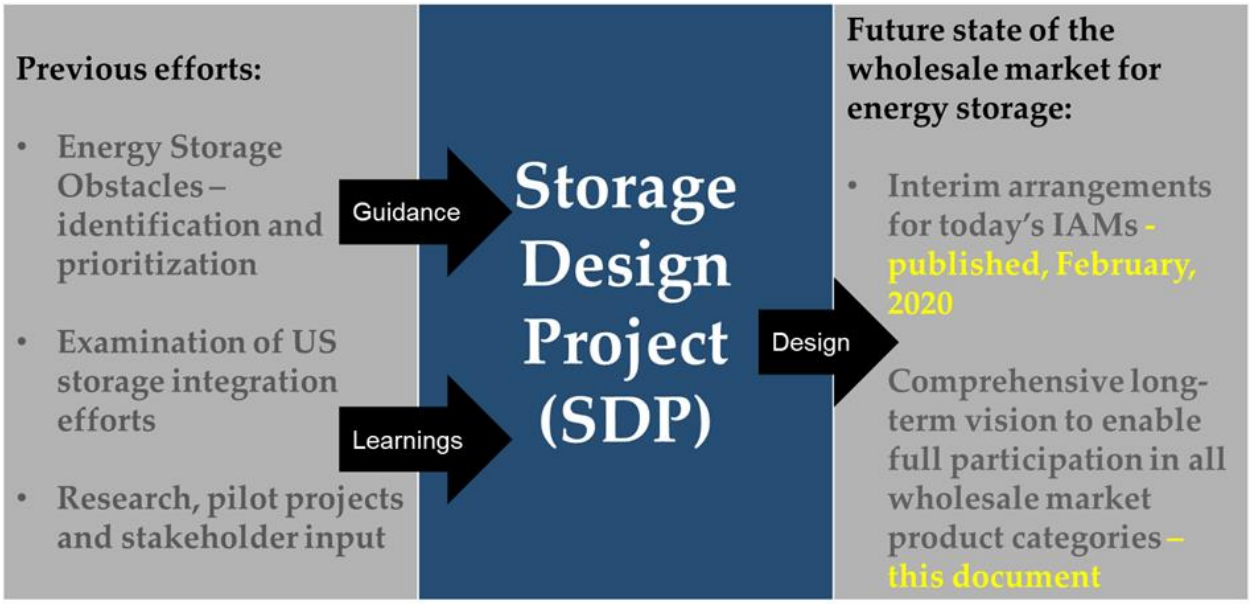
December 19, 2018

"Under Order 841, released earlier this year, U.S. system operators must establish participation models and market rules that recognize the physical and operational characteristics of electric storage resources. In the absence of similar requirements in Ontario, the IESO is committed to proactively tackling the barriers within its control to take advantage of resources that are often less expensive and easier to deploy and that provide a faster and more accurate response to market signals."

IESO Business Plan, 2019-2021
September 2018

1.2. Energy Storage Design Project Deliverables and Scope

Figure 1 - Project overview



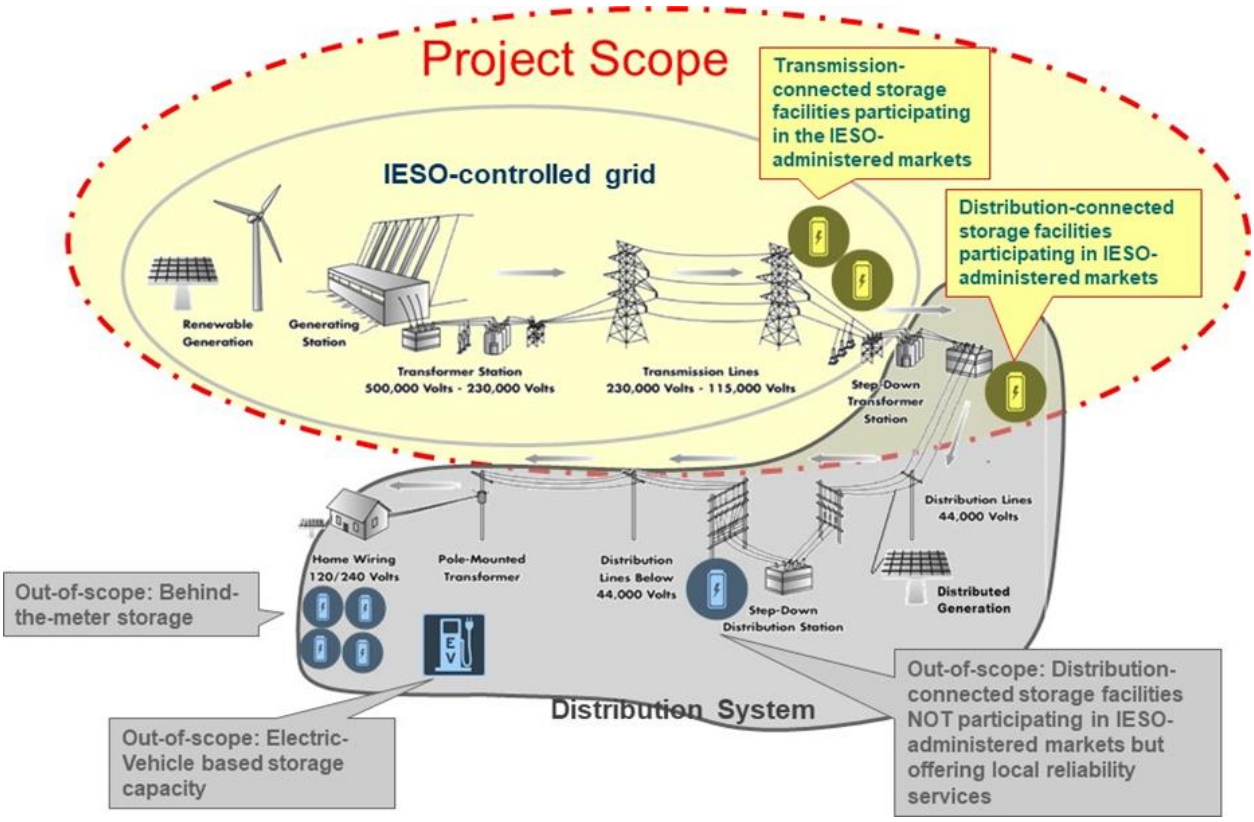
The Energy Storage Design Project is specifically tasked to address that portion of the December 2018 report, *Removing Obstacles for Storage Resources in Ontario*, pertaining to obstacles within the purview of the IESO. These include the following three general recommendations set out in the report:

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."

In terms of facilities involved, the Energy Storage Design Project is aimed at energy storage facilities that are registered to participate in the IAMs, including participating facilities that might be embedded within a distribution system

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



The IAMs and the IESO Market Rules do not encompass facilities that are not registered to participate, such as behind-the-meter energy storage. These other types of energy storage facilities are outside the jurisdiction of the IESO Market Rules generally, and this project in particular.

It is expected that various facets of bringing 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 distributed energy resources 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 as follows:

1. **Scope of this document**

   This design document is intended to:

   1. Answer key questions about how the IESO will treat storage in IAMs before and after the implementation of the Market Renewal Program
   2. Reflect different timeframes (with greater detail for interim measures and a higher-level design discussion for long-term changes)

   The design contained in this document directly addresses the recommendations contained in the IESO's December 2018 report, Removing Obstacles for Storage Resources in Ontario" which identified three general recommendation areas, which are directly under the IESO's control as follows:

   1. Review and amend the IESO Market Rules
   2. Develop guidance for storage resources providing multiple services to the IAMs
   3. Consider the market-efficiency impact of applying wholesale uplift charges

2. **Implementation Measures**

   Market Rules and Market manuals: As required, the Energy Storage Design Project will draft and invite stakeholder feedback on market rule/manual language required to implement interim measures (see interim measures for energy storage).
   Produce an inventory and description of future market rules/manual changes required to implement long-term design questions addressed in the project.

3. **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.

4. **Separate deliverable from this document**

   Schedule for market updates: Develop high-level schedule to roll out changes implied by this document, that reflect dependencies and timings of other initiatives.

1.4. Anticipated stages of development

This project anticipates the following three stages of storage development will occur over the next several years, subject to the IESO's compliance with regulatory budgeting and business planning processes that the IESO must adhere to. These stages will be referenced across the next two chapters of this document as follows.

Interim Period

See chapter 2

Stage 1: Interim framework to clarify storage participation in today's IAMs

Related project: Capacity auction

Long-term design changes:

See chapter 3

Stage 2: Changes to allow energy storage resources to provide regulation service, energy and operating reserve

Related project: SCADA EMS upgrade (nominally targeting Q1 2022), plus additional requisite system changes to effect the use of the energy storage for regulation service

Stage 3: Enduring participation model for energy storage resources enabling more efficient scheduling of energy and operating reserve

Related projects: future Dispatch Scheduling and Optimization (DSO) tool changes and replacement of settlement systems

1.5. 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 registered in the IESO wholesale market (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 internal energy storage integration projects and programs, some of which are summarized in Table 2.

Table 2 - Energy storage milestones in Ontario

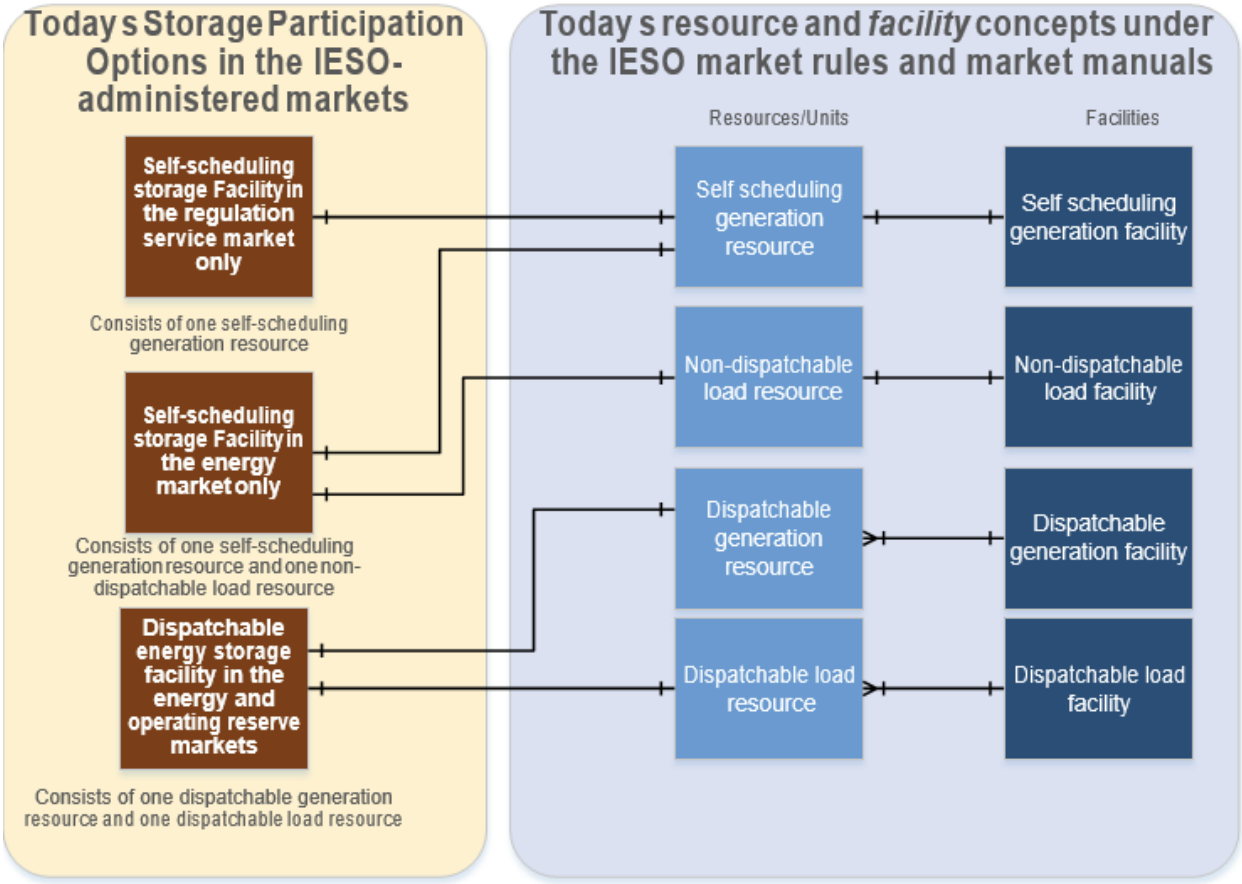
Timeframe	Event	Purpose
2013	Alternative Technologies for Regulation Program RFP	Seek technological diversity for future supply of regulation service
2014	Phase 1 Energy Storage Program RFP	Targeted procurement of energy storage capacity for ancillary services
2015	Phase 2 Energy Storage Program RFP	Targeted procurement of energy storage capacity
December 2017	Alternative Technologies for Regulation 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
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…"

Timeframe	Event	Purpose
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

During the course of these recent activities the IESO has made its own observations regarding potential obstacles to energy storage integration, and worked collaboratively with the energy storage stakeholder community to gain their perspectives on these issues as well. These consultations were conducted through the IESO Energy Storage Advisory Group (ESAG) and this culminated in the December, 2018 release of IESO's report, *Removing Obstacles for Storage Resources in Ontario*. As noted earlier, this report and its findings formed the impetus behind the Storage Design Project. In addition, the IESO's various energy storage pilot programs have necessitated the development of various approaches to energy storage integration using existing software platforms and process. The general framework used by these earlier efforts is summarized in section 1.6 and forms the basis of many of the design features to be used in the interim period described in chapter 2.

1.6. Restrictions on energy storage participation in today's IESO-administered markets

Figure 3 - Allowable storage participation arrangements in today's IAMs



Currently, the IAMs allow for three types of energy storage participation within the limitations of market rules and supporting software tools. These include:

1. Storage facilities participating in the regulation service market only

In today's IAMs, a generator facility must be dispatchable and participate in the real-time energy market to provide regulation service. These facilities are economically dispatched in the real-time energy market to a basepoint position that allows the generating facility enough range (sometimes colloquially referred to as "headroom") to provide the stipulated amount of regulation service capacity. This arrangement allows dispatchable generation facilities to participate in the real-time energy market and optimize their operations when providing regulation service. In addition, generation facilities providing regulation may also provide operating reserve during periods when they are not providing regulation service. However, the

limitations of current IESO tools necessitate a different treatment for energy storage facilities in today's market. Under this arrangement, the IESO registers energy storage facilities as self-scheduling generation facilities which sit entirely outside of the real-time energy and operating reserve markets. Such facilities receive and respond to a regulation signal directly from the IESO's automatic generation control (AGC). These facilities are effectively unseen by the IESO's Dispatch Scheduling and Optimization (DSO) engine – largely due to the incompatibility between the resource model of a self-scheduling generator and the reality of an energy storage facility injecting and withdrawing energy during the course of providing regulation service. As a result, they do not submit self-schedules into the day-ahead commitment process or the real-time energy market.

2. Storage facilities participating in the energy market only

Under this arrangement, the IESO registers such facilities as self-scheduling generation facilities, which are only required to submit self-schedules, as opposed to bid and offers. Unlike a dispatchable facility these facilities are not dispatched by the IESO on a five- minute basis. Self-scheduling energy storage facilities submit self-schedules into both the day-ahead commitment process and the real-time energy market in the same manner as a self-scheduling generator. This arrangement is very similar to the participation arrangements of a self-scheduling generator, though the IESO's Dispatch Scheduling and Optimization (DSO) currently has no awareness of the state-of-charge of self-scheduling energy storage facilities. This creates a degree of uncertainty as to the extent to which self-scheduling storage facilities might adhere to their own self-schedules in a given dispatch interval.

3. Storage facilities participating as dispatchable facilities in the energy and operating reserve markets

Currently, a storage facility participating as a dispatchable facility in the energy and operating reserve markets must be modeled as two separate dispatchable resources – specifically, as a dispatchable load resource and a dispatchable generation resource. The intent of this arrangement is to provide a dispatchable energy storage facility with access to the real-time energy and operating reserve markets in a manner similar to a dispatchable generator or a dispatchable load. As noted above however, this arrangement does not currently overcome the limitation of not being able to participate in regulation service as a dispatchable facility. Dispatchable energy storage facilities must necessarily be subject to certain operating restrictions to account for the fact that the IESO's core Dispatch Scheduling and Optimization (DSO) engine:

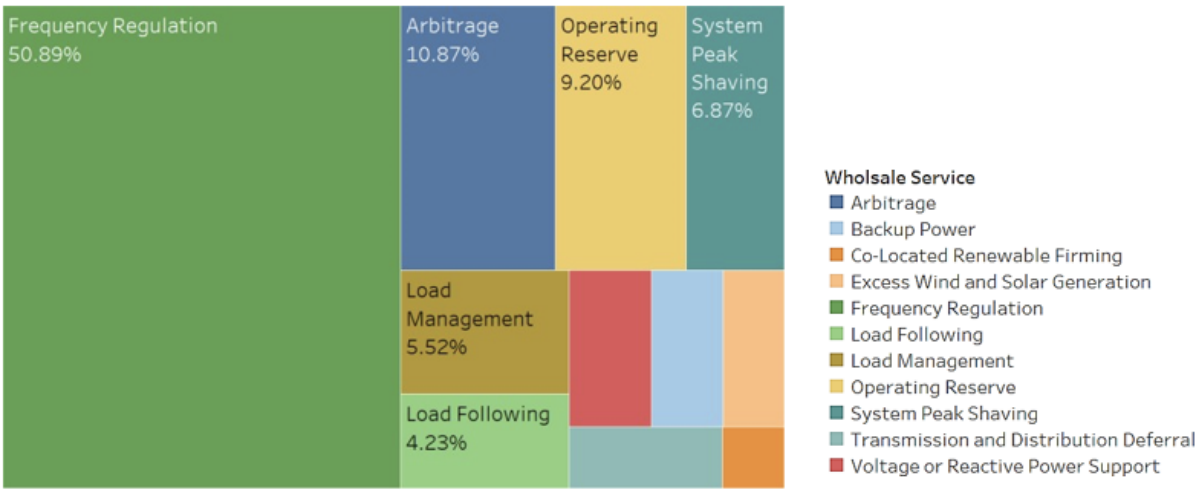
a. Lacks the ability to recognize that these two resources in fact constitute a single energy storage facility;

b. Cannot model the storage facility as a single facility or resource. The storage facility comprised by the two resources may in fact be subject to further limitations regarding its capacity to store energy.

These restrictions will be discussed in further detail in the next chapter.

As noted earlier, regulation service was one of the first wholesale market segments to see growth in energy storage participation in both U.S. and Ontario wholesale markets. Over time, energy storage has gained a foothold in other segments of wholesale markets, but often with imperfect efficiency or an inability to seamlessly provide products in multiple categories. This is a core problem that FERC Order 841 is intended to address. While the IESO is not under FERC jurisdiction, this is an issue of common interest to system operators and prospective energy storage market participants.

Figure 4 - Energy storage participation in U.S. wholesale markets, 2018[1]



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 current state of affairs 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.

[1] Source: United States Energy Information Administration, *Electric Power Annual 2018*

The matrix below (Table 3) depicts the combinations of wholesale market products that an energy storage resource can participate in today. 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 – see also, "Storage facilities participating in the regulation service market only" in this section above). In other cases, participation although allowed, may be less than optimal for both the facility operator and the market as a whole.

In many cases a "loss of efficiency" may occur because the IESO's core 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 energy storage market participants will be required to make advance assessments of their facilities' operations during each upcoming dispatch hour to ensure they will have adequate state of charge for their operations for the entire hour. This is particularly true for any participation options intersecting with energy and operating reserve, and will be further detailed in the various design features set out in chapter 2.

Table 3 - Cross-reference of allowable wholesale market product combinations available to energy storage facilities in today's IAMs

	Real-time energy	Operating reserve	Regulation service	Reactive support and voltage control	Demand response
Real-time energy	Yes – but with efficiency loss	Yes – but with restrictions and efficiency loss	No	Yes – but with efficiency loss	No
Operating reserve	Yes – but with restrictions and efficiency loss	Yes – but with restrictions and efficiency loss	No	Yes – but with restrictions and efficiency loss	No
Regulation service	No	No	Yes – but with efficiency loss	Yes – but with efficiency loss	No
Reactive support and voltage control	Yes – but with efficiency losses	Yes – but with restrictions and efficiency loss	Yes – but with efficiency loss	Yes	No
Demand response	No	No	No	No	Yes – rules for storage to be clarified in capacity auction design

1.7. Design elements and their relationship to energy storage barriers identified in ESAG's December 2018 report

Over the past two years, as part of efforts to examine potential options for energy storage integration, the IESO and ESAG stakeholders have identified a number of design elements. These design elements each map to one or more recommendation areas from the IESO's report regarding the removal of energy storage obstacles. Table 4 illustrates the key relationships between each design element within the scope of this project, and the barriers outlined in the December 2018, report, *Removing Obstacles for Storage Resources in Ontario*, as well as projects that will be affected by these changes.

Table 4 - Design elements, barriers and affected projects

IESO report – energy storage barriers identified	Design element	Downstream project dependencies
1. Inability of the IESO dispatch scheduling optimization (DSO) engine to model energy storage functionality 2. Absence of mechanisms to enable energy storage facilities to offer multiple, non- overlapping services	1. State-of-charge (SoC) management in RT energy market	Input to DSO updates, SCADA EMS upgrade project, capacity auction, and replacement of settlement systems (RSS)

IESO report – energy storage barriers identified	Design element	Downstream project dependencies
	2. Day-ahead market (DAM) and day-ahead commitment process (DACP): bidding and scheduling of ESRs	Input to DSO updates, SCADA EMS upgrade project, capacity auction and RSS
	3. Real-time energy and operating reserve markets: bidding and scheduling of ESRs	Input to DSO updates, capacity auction and RSS
3. Inability of energy storage to participate in the IESO operating reserve (OR) market	4. Ability of ESR to set market clearing price in the energy and operating reserve markets	Input to DSO updates
4. Inability to optimize regulation service in the IAMs from energy	5. Regulation service	Input to DSO updates, SCADA EMS upgrade project, capacity auction and RSS
5. Market-Efficiency Impact of Applying Wholesale Uplift Charges	6. Settlement and charges	Input to RSS
6. Absence of mechanisms to enable energy storage facilities to offer multiple, non- overlapping services	7. Prudential security	None
7. Absence of mechanisms to enable energy storage facilities to offer multiple, non- overlapping services	8. Prudential security	None

The IESO report contained two other recommendations which are being addressed as follows:

1. **Clarification of performance requirements for inverter-based technologies**

   These matters are currently the subject of proposed market rule amendments to appendix 4.2. and 4.3 of chapter 4 of the IESO Market Rules, as of the date of this design document.

2. **Lack of clarity with respect to storage in the interconnection process**

   This is being addressed as part of the IESO's general efforts to streamline and clarify its interconnection process outside the scope of the Energy Storage Design Project.

1.8. Design principles

While the Energy 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[2] – 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"[3]

[2] 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
[3] Ibid.

This design document takes into account several design considerations discussed with the ESAG including:

1. **Realizing increased reliability, efficiency and competition.** Through this project we will seek design solutions that contribute to reliability, efficiency, and competition at the bulk level. By extension, this includes adherence to all applicable regulatory requirements, including the reliability standards set out by North American Electricity Reliability Corporation.

   Related Market Renewal design principles: Efficiency, competition, and transparency

2. **Building on the practical experiences of other jurisdictions** that are integrating energy storage resources into wholesale markets – most notably the recent developments surrounding FERC Order 841 discussed earlier in this section.

   Related Market Renewal design principles: Certainty

3. **Maximizing the likelihood of timely implementation by**:

   a. Accounting for the capabilities of the software tools that will be selected outside the scope of this project
   b. Reducing design complexity wherever possible
   c. Avoiding design by exception, i.e., ensuring that the design has an overall framework that can be applied to the widest possible range of storage technologies

   Related Market Renewal design principles: Implementability and certainty

1.9. Interim design features subject to further review

As of the date of this draft design document, the IESO is considering the implementation details for some of the interim design features described in section 2 of this document. Of particular importance, is the prospective implementation of design feature SoC 2 – addressing potential changes to SoC-limited bids and offers:

The IESO is currently considering two technical options as to how this design feature will be implemented by the IESO and used by energy storage market participants: These two alternatives as follows:

1. **Option 1 under consideration by IESO:** Allowing energy storage faculties to signal state-of-charge limitations during the mandatory window (the two-hour period preceding each real-time dispatch hour) via the IESO's outage management process and the control room operations window (CROW) system.
2. **Option 2 under consideration by IESO:** Allowing energy storage faculties to signal state-of-charge limitations during the mandatory window via changes to bids and offers, from the resources comprising that storage facility, by a stipulated cut-off time prior to the end of the mandatory window.

In either case, these options will achieve the desired objective of allowing dispatchable energy storage facilities to proactively notify the IESO of state-of-charge limitations during real-time market operations, thereby avoiding situations where they must refuse infeasible dispatch instructions.

2. Interim Measures for Energy Storage

2.1. Design elements and questions addressed in this chapter

This chapter addresses the interim measures for various design elements and questions that are most pressing during the interim period and until a permanent state-of-charge management framework is developed. Long-term design questions are addressed in the next chapter of this document (See long-term implementation chapter 3).

Table 5 - Interim design elements and related design questions

Design element	Design questions
1. State of charge (SoC) management in Real-Time energy market	1.1 Who should optimize SoC of energy storage resources (ESRs) in the real-time energy market: the ESR, the system operator; or give ESRs the choice?
2. Day-ahead market (DAM)[4] and day-ahead commitment process (DACP): bidding and scheduling of ESRs	2.2 How should ESRs participate in the DACP pre-Market Renewal Program?
3. Real-time energy and operating reserve markets: bidding and scheduling of ESRs	3.2 What guidelines or restrictions should be placed on ESRs providing operating reserve?
4. Ability of ESRs to set market-clearing price in the energy and operating reserve markets	4.2 Should ESRs > 10 MW be allowed to self-schedule? Note: this issue may be affected by the SoC management option (Design element # 1)
7. Prudential security	7.1 What prudential security requirements will apply to ESRs?

[4] Note: The day-ahead market aspect of this design feature is not part of the interim design measures and will be addressed as part of the longer-interim design – please see chapter 3 for further details.

Design element	Design questions
8. Market and facility registration	8.1 How should an energy storage facility be registered into the IAMs?

2.2. Overview of interim design features

This chapter addresses energy storage design elements that are relevant to:

1. Dispatchable energy storage facilities participating in the capacity auction
2. Storage facilities participating as self-scheduling generation facilities in the energy market only
3. Storage facilities participating as self-scheduling generation facilities in the regulation service market only
4. Storage facilities participating as dispatchable facilities in the energy and operating reserve markets

The interim period starts when the IESO baseline documentation is updated to reflect the interim design features set out in this chapter, and is expected to last until the interim design is succeeded by the applicable successor design features set out in chapter 3. During this time span it is anticipated that:

- Dispatchable energy storage facilities will be admitted into the capacity auction
- Energy storage facilities may participate in the real-time energy market as dispatchable facilities
- Energy storage facilities may participate in the real-time energy market as self-scheduling facilities if they are between 1 megawatt (MW) and 10 MW in size.
- Energy storage facilities may participate in the real-time operating reserve market as dispatchable facilities.
- Energy storage facilities may participate in the regulation service market as self-scheduling facilities

The sum total of these development efforts would realize the following, feasible market participation options over the course of this interim period.

Table 6 - Feasible market participation options over the interim period

	Real-time energy	Operating reserve	Regulation service	Reactive support and voltage control	Capacity auction
Real-time energy	Yes – but with efficiency loss	Yes – but with restrictions and efficiency loss	Yes – but with efficiency loss	Yes – but with efficiency loss	Yes – but with efficiency loss
Operating reserve	Yes – but with restrictions and efficiency loss	Yes – but with restrictions and efficiency loss	Yes – but with restrictions and efficiency loss	Yes – but with restrictions and efficiency loss	Yes – but with restrictions and efficiency loss
Regulation service	Yes – but with efficiency loss	Yes – but with restrictions and efficiency loss	Yes	Yes – but with efficiency loss	Yes, subject to capacity auction obligations
Reactive support and voltage control	Yes – but with efficiency loss	Yes – but with restrictions and efficiency loss	Yes – but with efficiency loss	Yes	Yes
Capacity auction	Yes – but with efficiency loss	Yes – but with restrictions and efficiency loss	Yes, subject to capacity auction obligations	Yes	Yes

During the interim period, the design features contemplated in this chapter will affect the flow of information to and from the following major IESO process groupings:

1. Prudential security
2. Market registration, and particularly the facility registration sub-process
3. The day-ahead commitment process (DACP)
4. Real-time market operations

The major IESO process and attendant data flows affected by the design features contemplated in this chapter are summarized in two diagrams on the following pages.

1. Figure 5 is a current state, high-level data flow diagram of the major IESO process groups affected by the interim design features.
2. Figure 6 depicts the interim design features themselves, and the new, storage-specific information flows to be introduced during the interim period.

Figure 5 - Summary of major IESO process groups and information flows affected by the design features contemplated during the interim period

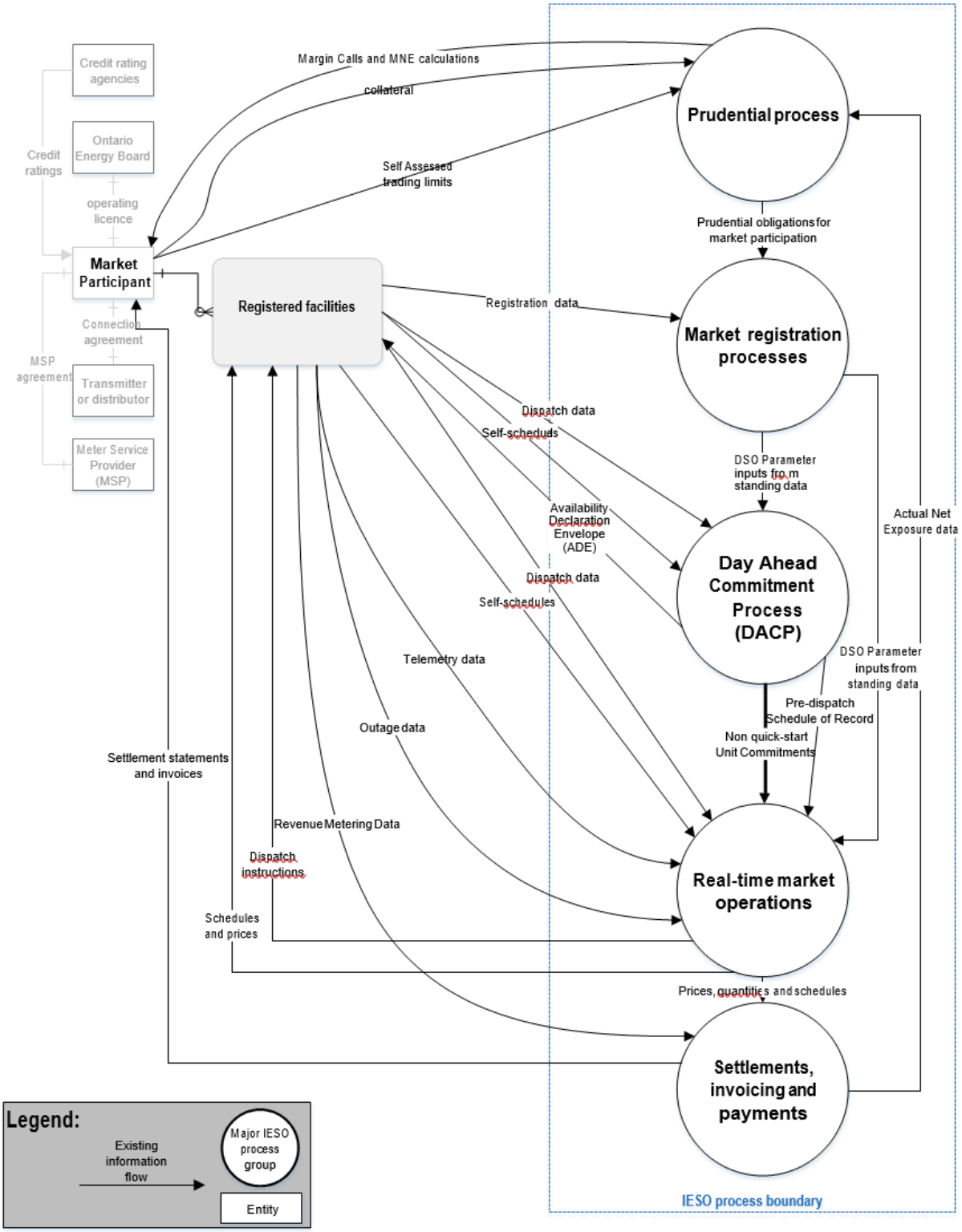
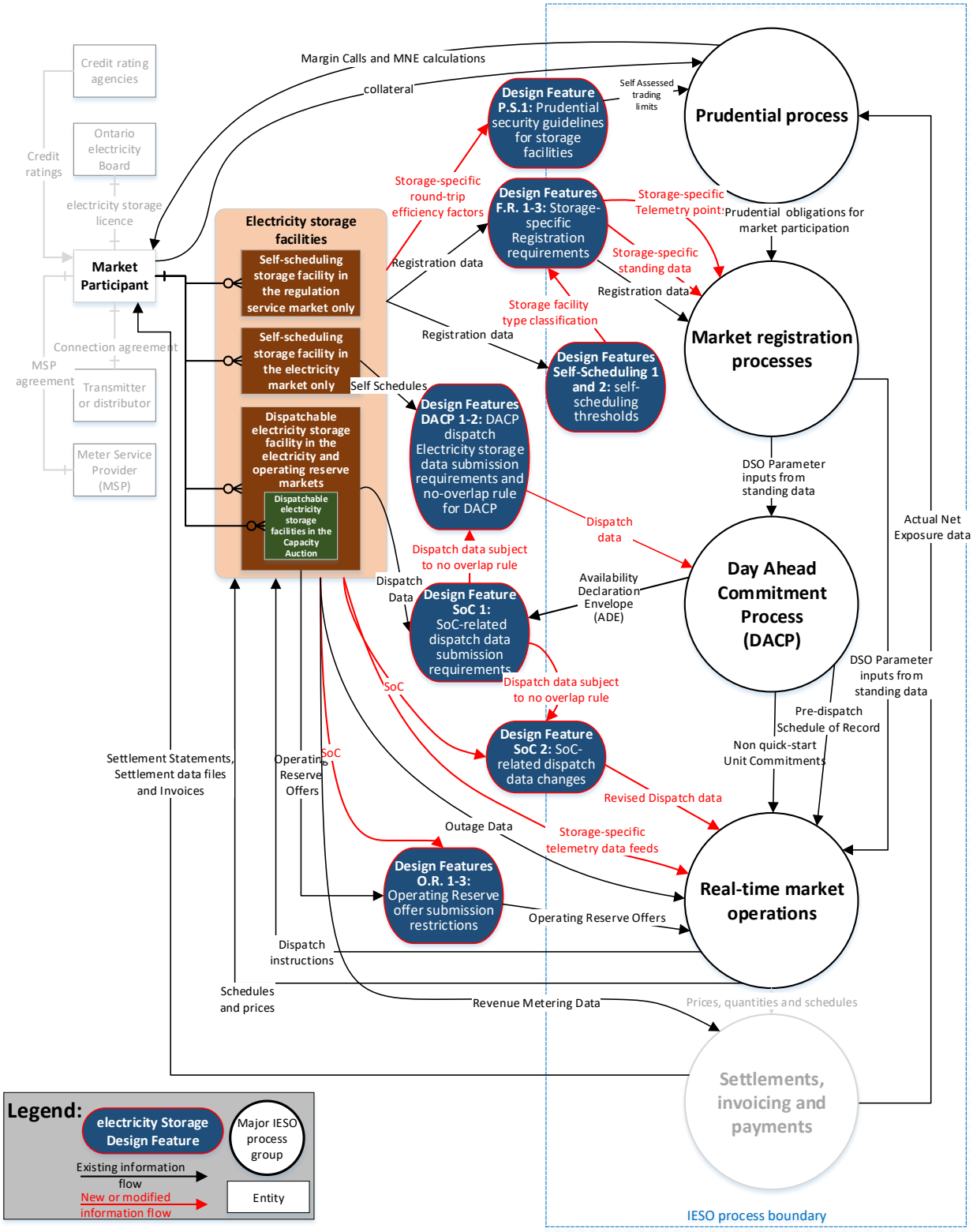


Figure 6 - Summary of design features contemplated during the interim period



As noted in Figure 6, the interim period will employ a number of interim design measures, which are summarized in Table 7 and elaborated on throughout this chapter.

Table 7 - Interim period design measures

Design feature	Affected IESO processes	Expected lifespan of design feature	Successor design feature (if applicable)
Self-scheduling 1 – maintain current capacity limit of 10 MW for self-scheduling energy storage resources in the real-time energy market	Facility registration	Indefinitely[5]	n/a
Design feature self-scheduling 2 – raise current capacity limit for self-scheduling energy storage resources providing regulation service only	Facility registration	Interim period until EMS upgrade project and related tool changes are complete	Dispatchable energy storage facility model, for the duration of the interim period, followed by the enduring dispatchable energy storage facility model
Facility registration F.R. 1 – registration of self-scheduling energy storage facilities providing regulation service only	Facility registration	Interim period	Enduring dispatchable energy storage facility model
Facility registration F.R. 2 – registration of self-scheduling energy storage facilities up to 10 MW in the real-time energy market	Facility registration	Interim period	Enduring self-scheduling energy storage facility model

[5] i.e., beyond the interim period and the implementation of the Market Renewal Program.

Design feature	Affected IESO processes	Expected lifespan of design feature	Successor design feature (if applicable)
Design feature F.R. 3 – registration of dispatchable energy storage facilities	Facility registration	Interim period	Enduring dispatchable energy storage facility model
Design feature P.S. 1 – prudential support obligation for market participants with energy storage facilities	Prudential security	Indefinitely	n/a
Design feature DACP 1 – DACP data submission requirements for each class of interim energy storage participation	DACP	Interim period	Day-ahead market
Design feature DACP 2 – no overlap rule for bids and offers into the DACP for energy storage facilities	DACP	Interim period	Day-ahead market
Design feature SoC 1 – restriction against overlapping or equal bid/offer prices	DACP Real-time market operations	Interim period	Enduring state-of-charge management framework
Design feature SoC 2 – addressing potential changes to SoC-limited bids and offers	Real-time market operations	Interim period	Enduring state-of-charge management framework
Design feature Operating Reserve O.R.1 – no simultaneous offers of operating reserve from the two resources	Real-time market operations	Interim period	Enduring state-of-charge management framework

Design feature	Affected IESO processes	Expected lifespan of design feature	Successor design feature (if applicable)
comprising a dispatchable energy storage facility			
Design feature O.R. 2 – operating reserve requirements specific to a dispatchable load resource comprising a dispatchable energy storage facility	Real-time market operations	Interim period	Enduring state-of-charge management framework
Design feature O.R. 3 – operating reserve requirements specific to a dispatchable generator resource comprising a dispatchable energy storage facility	Real-time market operations	Interim period	Enduring state-of-charge management framework

The remainder of this chapter describes the various interim measures that will be put into place during this time period in order to realize the participation possibilities for energy storage facilities that were outlined above.

2.3. Ability of ESRs to set market-clearing price (MCP) in the energy and operating reserve markets

Design element	Design question
Ability of energy storage facility to set market-clearing price in the energy and operating reserve markets	Should energy storage facilities > 10 MW be allowed to self-schedule?

2.3.1. Design issue overview

Today, some energy storage facilities in the IAMs (participating through various pilot programs) must be registered as a self-scheduling resource in order to provide regulation service. In addition, some storage facilities choose to be self-scheduling, provided that they are below the threshold size of 10 MW. This limit mirrors the same demarcation point for self-scheduling generators as set out the IESO Market Rules.

If an energy storage facility is self-scheduling, then it is free to utilize its SoC while not subject to IESO dispatch. While it cannot set the market-clearing price, it can indirectly affect price by self-scheduling. Consequently, self-scheduling resources are price-takers.

As energy storage facilities grow in size and number, the size threshold for their inclusion in the market as fully-dispatchable facilities will become a vital consideration – particularly in the interim period until a more robust real-time SoC construct is put in place.

2.3.2. Applicability of these design features

The design features outlined in this section are applicable to:

- **Self-scheduling energy storage resources** in the real-time energy market
- **Self-scheduling energy storage resources** providing regulation service

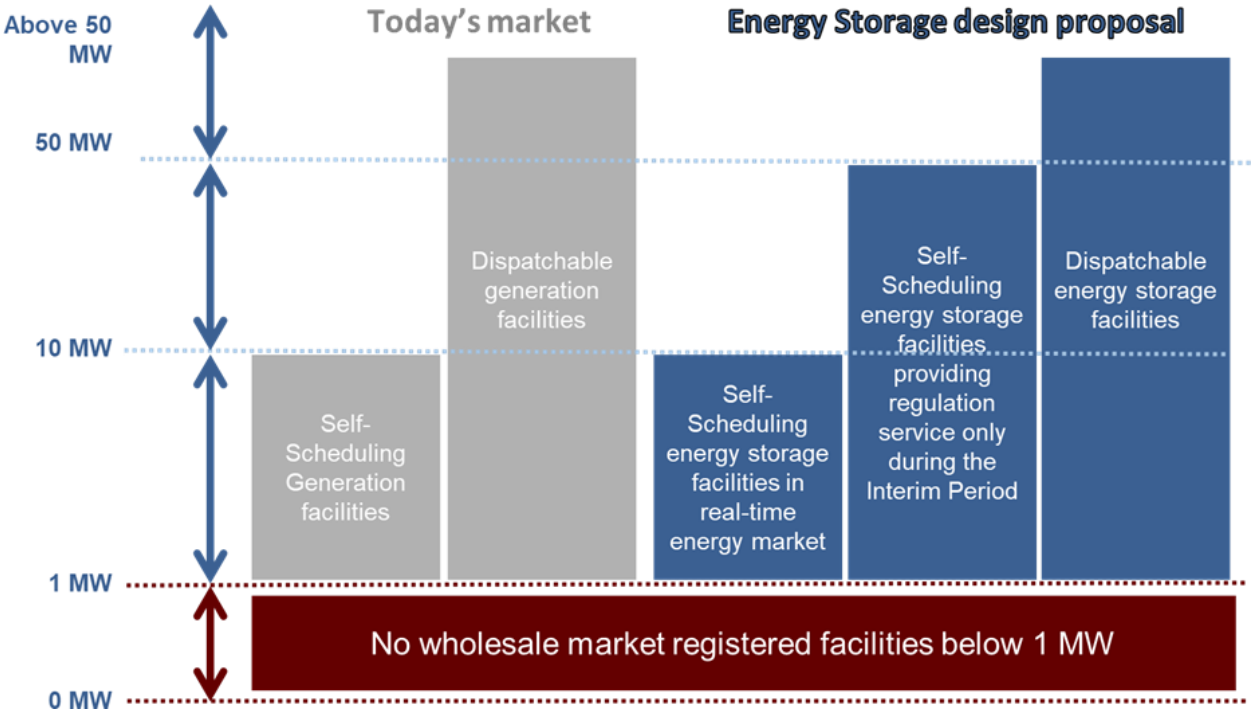
2.3.3. Design features in summary

The remainder of this section will discuss the following design features in detail.

Design feature self-scheduling 1 – maintain current maximum facility capacity limit of 10 MW for self-scheduling energy storage resources in the real-time energy market. This design feature will maintain the current maximum size of 10 MW for a self-scheduling energy storage facility participating in the real-time energy market.

Design feature self-scheduling 2 – raise current capacity limit for self-scheduling energy storage resources providing regulation service only. Under this design feature, an energy storage facility may exceed 10 MW in size AND be a registered as a self-scheduling facility, if it is solely providing regulation service during the Interim Period.

Figure 7 - Overview of energy storage size threshold limits during the Interim Period



2.3.4. Design feature self-scheduling 1 – maintain current maximum facility capacity limit of 10 MW for self-scheduling energy storage resources in the real-time energy market

The current limit of 10 MW as the maximum threshold size for self-scheduling generation facilities is a longstanding provision of the IESO Market Rules (specifically, chapter 4, section 7.3.2, and chapter 7, section 2.2.9). In addition, the 10 MW threshold is also important to a number of other aspects of market participation. For example, 10 MW is also used in the following contexts:

- The threshold for an embedded generation facility where a connection assessment becomes mandatory (see connection assessment pages of the IESO website
- Part of the compliance deadband limit officially stated by the IESO in its interpretation bulletin (see IMO_MKRI_0001, *Compliance with Dispatch Instructions Issued to Dispatchable Facilities, June 29, 2009* - available on the interpretations bulletins webpage
- The threshold value at which forced outages must be reflected in bids/offer in the mandatory window and/or reported through the outage management process (see IESO Market Manual 4.2, appendix A)

The significance of the 10 MW threshold in these areas makes it a natural demarcation point beyond which a facility in the IAMs must become dispatchable.

Given the above situation, and in the absence of any evidence that energy storage technology uniquely affects the level of significance of the 10 MW threshold, this design feature proposes that the 10 MW limit for self-scheduling energy storage facilities remain unchanged. This feature should remain in effect indefinitely, or until such time as this limit may be universally changed for all types of self-scheduling facilities.

2.3.5. Design feature self-scheduling 1 rationale

The recommended design approach for this Interim Design feature addresses the storage design project principles discussed in section 1.8 as follows:

1. Yielding benefit to ratepayers, the electricity system and the IAMs

This design feature generally enables energy storage participation in the real-time energy market as a self-scheduling energy storage facility. By doing so, it will bring better market depth and liquidity for real-time energy trading from energy storage resources. This may be particularly valuable during the interim period, should energy storage resources become a fast-growing segment of the wholesale market before the IESO can put a permanent state-of-charge framework in place.

The self-scheduling 1 design feature more specifically provides equality of access to the wholesale market between today's self-scheduling generators and self-scheduling energy storage facilities.

2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

The self-scheduling 1 design feature generally provides a means of wholesale market access for small-scale energy storage facilities down to 1 MW. In U.S. markets under FERC jurisdiction, the participation threshold for small-scale energy storage facilities is being dropped to 100 kW though it remains to be seen what the uptake in this market segment will be. This is a matter that the IESO will continue to monitor as these jurisdictions proceed to implement this rule during the interim period. In the meantime, self-scheduling energy storage facilities will be subject to the same minimum 1 MW and maximum 10 MW thresholds that self-scheduling generation facilities are subject to in the IAMs.

3. Maximize the chances of timely implementation

The self-scheduling 1 design feature does not require a tool change in order to be implemented. This rule can be deployed immediately following the necessary changes to IESO Market Rules and market manuals through the IESO's baseline management process.

2.3.6. Design feature self-scheduling 2 – raise current capacity limit for self-scheduling energy storage resources providing regulation service only above 10 MW

As noted earlier, there is a unique barrier affecting energy storage facilities providing regulation service in the current market. Currently such facilities must be registered as a resource having the characteristics as a self-scheduling generation facility, but with the unique feature of being able to provide regulation service in the withdrawal and injection operating resources. Modeling such facilities in the IESO's automatic generation control (AGC) tool in this manner immediately negates them from also participating in the wholesale energy market.

During the interim period, and until such time as the IESO's AGC tool is upgraded via the EMS upgrade project, the IESO should have the ability to utilize the capabilities of energy storage facilities exceeding 10 MW in capacity. The restrictions facing energy storage facilities in this category are truly unique relative to other forms of generation. For this reason, it is proposed that self-scheduling energy storage resources providing regulation service only may exceed the 10 MW threshold, up to an IESO-stipulated maximum that shall not exceed 50 MW, for the shorter of:

- The time period in which they may be a party to an ancillary services agreement with the IESO to provide regulation service to the IAMs; or
- That portion of the interim period, until such time as the IESO's AGC tool is upgraded via the SCADA EMS Upgrade project

The IESO shall set this threshold as a matter of any specific regulation service procurement objectives that it might pursue during the interim period, taking account the need to balance the benefits of increased competition from energy storage, versus the reliability and efficiency risks of using regulation from resources that cannot be fully modeled in the dispatch scheduling and optimization (DSO) engine.

2.3.7. Design feature self-scheduling 2 rationale

The recommended design approach for this interim design feature addresses the storage design project principles discussed in section 1.8 as follows.

1. Realizing increased reliability, efficiency and competition

Design feature self-scheduling 2 generally enables energy storage participation in the regulation service market as a self-scheduling energy storage facility. By doing so, it will bring better market depth and liquidity to regulation service procurements from energy storage facilities. This

may be particularly valuable during the interim period, should energy storage resources become a fast-growing segment of the wholesale market before the IESO can put a permanent state-of-charge framework in place.

The self-scheduling 2 design feature is specifically driven by a limitation of the software tools currently employed by the IESO which will be replaced over the course of the interim period.

2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

As noted in chapter 1 of this design document, regulation service is one of the first wholesale market segments that has seen active energy storage participation in various markets around the world. This design feature ensures that the IESO can take advantage of this trend during the interim period.

3. Maximize the chances of timely implementation

The self-scheduling 2 design feature does not require a tool change in order to implemented. This rule can be deployed immediately following the necessary changes to IESO Market Rules and market manuals through the IESO's baseline management process.

2.4. Market and facility registration

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

2.4.1. Design issue overview

In the absence of a formal definition of energy storage facilities in the market rules and market manuals, there is uncertainty in the allowable models for storage facilities. The concept of dispatchable energy storage facilities shall apply to those participating in the capacity auction and those participating as/or merchant energy storage facilities that may not be in the capacity auction or otherwise unsuccessful in the capacity auction.

This section clarifies how the IESO will address the question of registering energy storage facilities in the IAMs to provide ancillary services during the interim period. This section does not provide guidance to behind-the-meter energy storage, or distribution-connected storage facilities not participating in the wholesale market.

2.4.2. Applicability of these design features

This section provides an overview of the facility registration requirements for the following types of energy storage facilities that are expected to be supported during the interim period.

1. **Design feature F.R. 1 –** If a storage facility provides regulation during the interim period it shall be registered as a self-scheduling generator only, without a load resource.
2. **Design feature F.R. 2 –** Self-scheduling storage facilities under 10 MW in size participating in the energy market may be registered as a self-scheduling generator and a non-dispatchable load.
3. **Design feature F.R. 3** – Dispatchable energy storage facilities participating in the energy market during the interim period may be registered as a dispatchable load and a dispatchable generator.

Each energy storage facility shall be subject to one of the above registration arrangements. A storage facility participating in the capacity auction may register in the capacity auction as a dispatchable energy storage facility, which is comprised of a dispatchable load and a dispatchable generator resource. This latter type of storage facility is further detailed in the capacity auction design construct. However, its registration features are identical to the description of dispatchable energy storage facilities participating in the energy market provided in this section.

2.4.3. Design features in summary

The remainder of this section will discuss the following design features in detail

Design feature F.R. 1 – registration of self-scheduling energy storage facilities providing regulation service only

This design feature is currently in use in today's IAMs as part of the IESO's various regulation service pilot programs. The method for registering such facilities would be formalized by clarifying changes to the various market rules and market manuals governing how such facilities should be registered on a going-forward basis.

Design feature F.R. 2 – registration of self-scheduling energy storage facilities up to 10 MW in the real-time energy market (not providing regulation service)

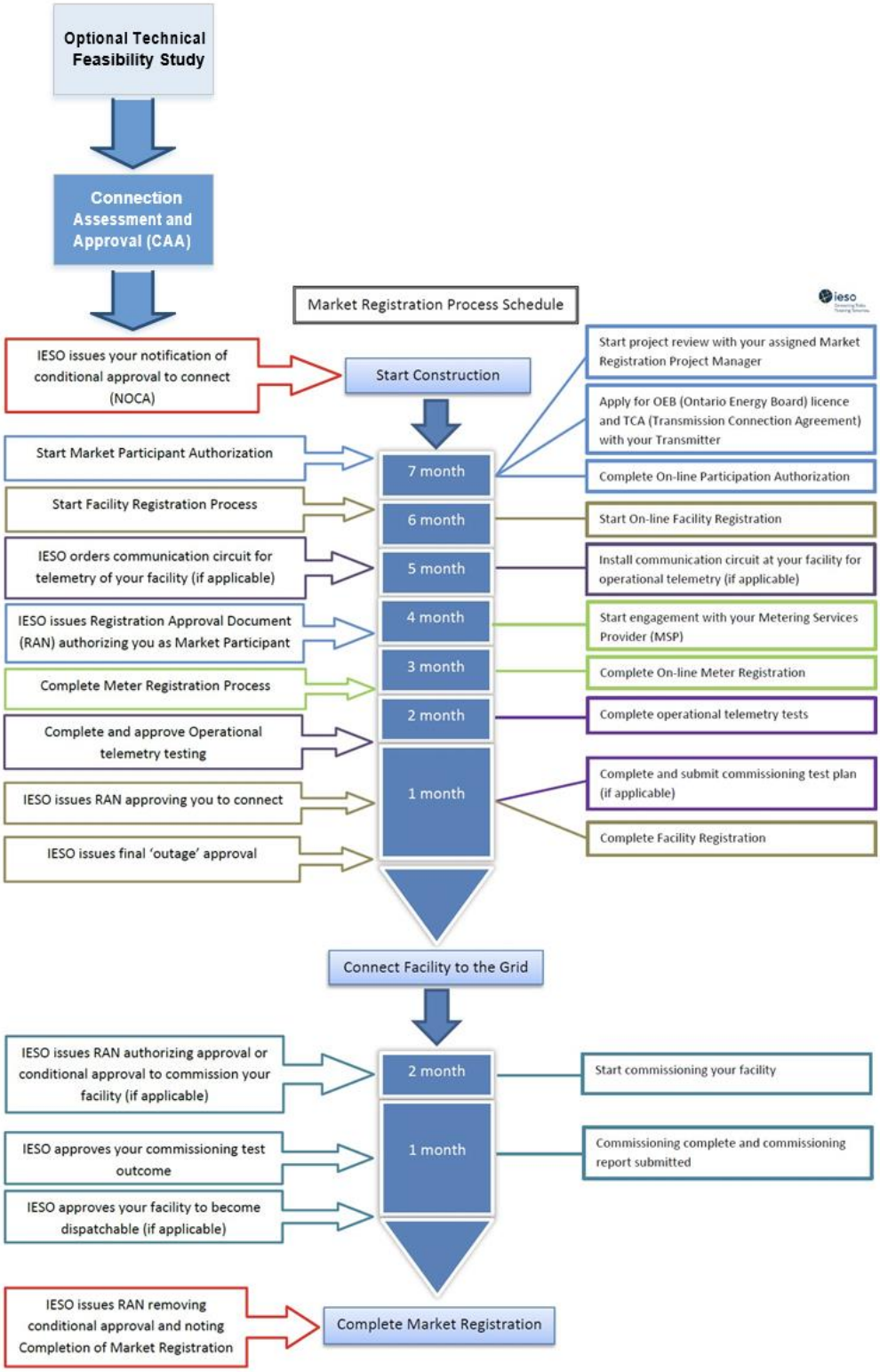
This design feature is currently in use in today's IAMs as part of the IESO's various energy storage pilot programs. The method for registering such facilities would be formalized by clarifying changes to the various market rules and market manuals governing how such facilities should be registered on a going-forward basis.

Design feature F.R. 3 – registration of dispatchable energy storage facilities

This design feature is currently in use in today's IAMs for a sub-set of energy storage facilities participating in the Phase 1 energy storage program. The method for registering such facilities would be formalized by clarifying changes to the various market rules and market manuals governing how such facilities should be registered on a going-forward basis.

NOTE: in the tables that follow, yellow-shaded cells highlight sections with new registration requirements specific to energy storage facilities.

Figure 8 - Major steps in current registration process



2.4.4. Upstream processes to facility registration

Facility registration is a sub-process to the overall market registration process and is preceded by:

- An optional technical feasibility study step, which is only performed at the request of the connection applicant to help determine the feasibility of a significant, potential project (see IESO website: http://www.ieso.ca/Sector-Participants/Connection-Assessments/Technical-Feasibility-Study)
- The connection assessment and approval (CAA) process (see IESO website: http://www.ieso.ca/Sector-Participants/Connection-Assessments/Obtaining-A-Connection-Assessment) which is further sub-divided into the following categories as listed in IESO Market Manual 2.10:

    (a) "the connection of a new or modified generation facility or the connection of a new or modified embedded generation facility greater than 10 MW;
    (b) the connection of a new or modified transmission facility;
    (c) the connection of a new or modified load facility or an one-time addition of load greater than 10 MW;
    (d) a new or existing load facility (transmission-connected load facility or embedded-load facility) providing demand response capacity greater than 10 MW at the IESO-controlled grid connection point;
    (e) the modification of protection systems; and
    (f) the connection of a new or modified ancillary services facility"

These two upstream processes are further detailed on the IESO website. The CAA process is further sub-divided into the preparation of a system impact assessment (SIA) or an expedited SIA (ESIA).

To date, energy storage facilities have largely used the CAA process in the context of the provision of ancillary services. In some cases, the resulting system impact assessment (SIA) has culminated in the consideration of the proposed storage facility as both a dispatchable generator and dispatchable load resource. In other cases involving the exclusive provision of regulation service from an energy storage facility, the resulting SIA has considered the facility in the context of a self-scheduling generator. Past examples of these SIAs for energy storage facilities may be found on the IESO website at the following location:

http://www.ieso.ca/en/Sector-Participants/Connection-Assessments/Application-Status

No material changes to these upstream processes are contemplated by this Energy Storage Design Project during the interim period. However, they may be affected by:

- Proposed amendments to appendix 4.2 and 4.3 of the IESO Market Rules that were pending as of the date of publication of this document (see proceedings of the August 13, 2019 Technical Panel meeting, *Item 5: Updates to performance requirements for generation, load and electricity storage.* These rules would affect the performance standards for the underlying generation and load resources that might comprise an energy storage facility.
- Additional clarifications that the IESO may make to its website and related connection assessment guides regarding the applicability of the CAA process to energy storage facilities.

In the sections that follow is a description of how storage-specific requirements will be addressed during the interim period during registration process. In some cases, these requirements may necessitate amendments to the IESO Market Rules and associated market manuals in order to clarify the ongoing application of these measures during the interim period.

2.4.5. Design feature F.R. 1 – registration of self-scheduling energy storage facilities providing regulation service only

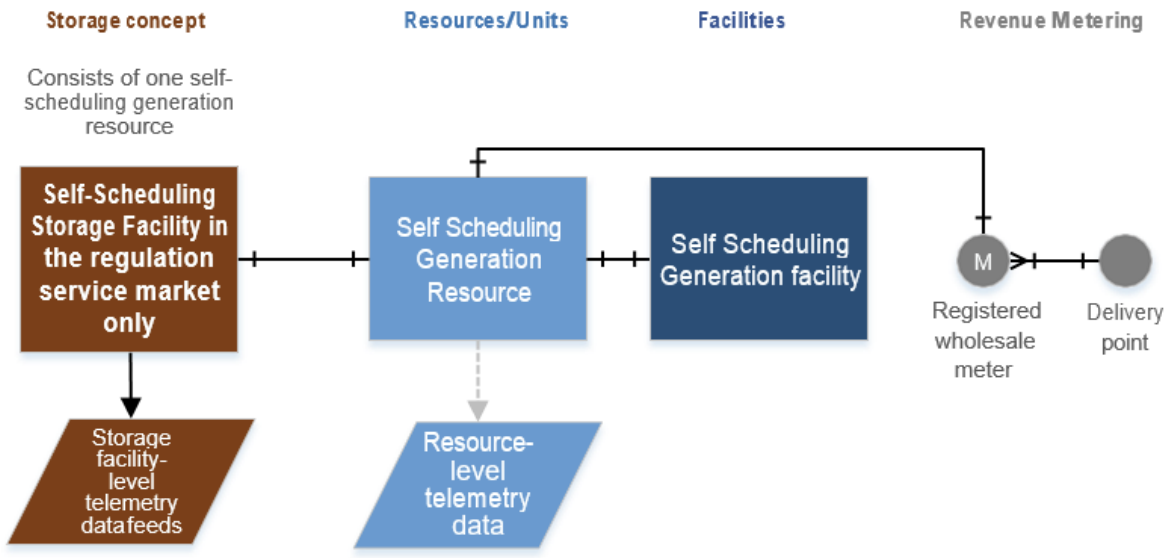
During the interim period, self-scheduling energy storage facilities providing regulation service only will closely resemble the registration profile of a self-scheduling generation facility, with the crucial exception that such facilities will not participate directly in the real-time energy market.

Such facilities will include:

- A self-scheduling generation resource mapped to a self-scheduling generation facility
- At least one registered wholesale meter (RWM) meeting all requirements of chapter 6 of the IESO market rules and related appendices
- All monitoring equipment to meet the requirement prescribed by the market rules and applicable market manuals for a facility providing ancillary services

A summary of these critical relationships is provided in Figure 9.

Figure 9 - Design feature F.R. 1's critical facility registration relationships for a self-scheduling storage facility



Allowable participation in wholesale market products for self scheduling energy storage facilities providing regulation service.

Real-time energy	Operating reserve	Regulation service	Reactive support and voltage control[6]	Capacity auction
No	No	Yes	Yes	No

NOTE: in the tables that follow, yellow-shaded cells highlight sections with new registration requirements specific to energy storage facilities.

[6] Note: it is possible for a facility to reach an agreement with the IESO to receive compensation for reactive power losses – see IESO Market Rules, chapter 7, section 9.4.4.

Table 8 - Summary of storage-specific measures for design feature F.R. 1 (self-scheduling energy storage facilities providing regulation service only)

Market registration process	**Sub-process**	**Storage-specific impact under design feature F.R. 1** (self-scheduling energy storage facilities providing regulation service only)
Market participant authorization	Authorization	All existing market participant registration requirements (see IESO Market Rules, chapter 2, appendices to chapter 2, and IESO market manuals 1.1 to 1.3) **AND:** OEB electricity storage licence required: *"An electricity storage licence enables the licensee to generate electricity or provide ancillary services for sale through the IESO-administered markets or directly to another person; purchase electricity or ancillary services in the IESO-administered markets or directly from a generator; and sell electricity or ancillary services through the IESO-administered markets or directly to another person, other than a consumer"*[7]
Market participant authorization	Issuance of registration authorization notice (RAN) regarding market participant status	No change
Telemetry set-up	IESO determination of communication circuit set-up	No change

[7] Ontario Energy Board website, "Electricity storage licence", accessed on November 22, 2019

Market registration process	**Sub-process**	**Storage-specific impact under design feature F.R. 1** (self-scheduling energy storage facilities providing regulation service only)
Telemetry set-up	Determine telemetry data points	Telemetry points for a self-scheduling generator registered to provide an ancillary service will include: Market Rules, appendix 4.15 – *IESO Monitoring Requirements: Generators* The IESO will not permit telemetry to be optional for those facilities with nameplate rating of less than 10 MW **AND** Storage-specific telemetry required – associated with the storage facility as a whole not the individual, underlying resources (see appendix A and note below): • Economic maximum power mode (ECO_$P_{max,g}$) • Economic minimum power mode (ECO_$P_{min,g}$) • Economic minimum state of charge (ECO_$SOC_{min,g}$) • Economic maximum state of charge (ECO_$SOC_{max,g}$) • State-of-charge (SoC) • Regulation basepoint (basepoint)
Telemetry set-up	Telemetry set-up	No change

Market registration process	**Sub-process**	**Storage-specific impact under design feature F.R. 1** (self-scheduling energy storage facilities providing regulation service only)
Telemetry set-up	Operational telemetry testing	No charge
Facility registration	Capture facility-specific standing data	May be subject to certain requirements proposed under current market rule amendments to Market Rules appendix 4.2 – generation facility requirements **AND** Subject to Market Rules appendix 4.8 – *network impact information: ancillary services providers* and appendix 4.15 – *IESO Monitoring Requirements: Generators* **AND** Subject to storage-specific standing data required (see appendix A **and note below**): • Certified Duration of Service (derived from $SOCMAX_g$ and $P_{max,g}$) • Cycle Efficiency ($CycleEfficiency_g$) • Full Power Operating Mode ($P_{max,g}$) • Low Power Operating Mode ($P_{min,g}$) • Lower Energy Limit ($SOCMIN_g$) • Upper Energy Limit ($SOCMAX_g$)
Meter registration	Register metering service provider (MSP) for facility	No change
Meter registration	Revenue meter set-up and registration	No change

Market registration process	**Sub-process**	**Storage-specific impact under design feature F.R. 1** (self-scheduling energy storage facilities providing regulation service only)
Commissioning	Commissioning testing	Commissioning testing may be subject to certain requirements proposed under amendments to Market Rules appendix 4.2 – *Generation facility requirements*
Commissioning	Certification testing for regulation service	No change
Commissioning	Dispatchability Testing	Not applicable
Commissioning	Issuance of registration authorization notice (RAN) regarding entry into commissioning process	No change

Notes regarding telemetry data points

The following telemetry data points are for future use by the IESO and would not be immediately used within the interim state of charge management framework described earlier in this chapter:

- Economic Maximum Power Mode ($ECO\_P_{max,g}$)
- Economic Minimum Power Mode ($ECO\_P_{min,g}$)
- Economic Minimum State of Charge ($ECO\_SOC_{min,g}$)
- Economic Maximum State of Charge ($ECO\_SOC_{max,g}$)

These data values are further defined in Appendix A of this document.

2.4.6. Design feature F.R. 1 rationale

The recommended design approach for this interim design feature addresses the Energy Storage Design Project principles discussed in section 1.8 as follows:

1. Realizing increased reliability, efficiency and competition

Design feature F.R. 1 generally enables energy storage participation in the regulation service market as a self-scheduling energy storage facility. By doing so, it will bring better market depth and liquidity to regulation service procurements from energy storage facilities. This may be particularly valuable during the interim period, should energy storage resources become a fast-growing segment of the wholesale market before the IESO can put a permanent state-of-charge framework in place.

2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

As noted in chapter 1 of this design document, regulation service is one of the first wholesale market segments that has seen active energy storage participation in various markets around the world. This design feature ensures that the IESO can take advantage of this trend during the interim period.

3. Maximize the chances of timely implementation

Design feature F.R. 1 is already in use in the IAMs for four energy storage facilities participating in regulation service under various energy storage pilot programs. By formalizing these registration requirements, in the IESO market rules and market manuals, this will allow other energy storage facilities to prepare to participate in future regulation service procurements that may occur during the interim period.

2.4.7. Design feature F.R. 2 – registration of self-scheduling energy storage facilities up to 10 MW in the real-time energy market (not providing regulation service)

During the interim period, self-scheduling energy storage facilities up to 10 MW in capacity in the real-time energy market only will closely resemble the registration profile of a self-scheduling generation facility, associated with a non-dispatchable load facility.

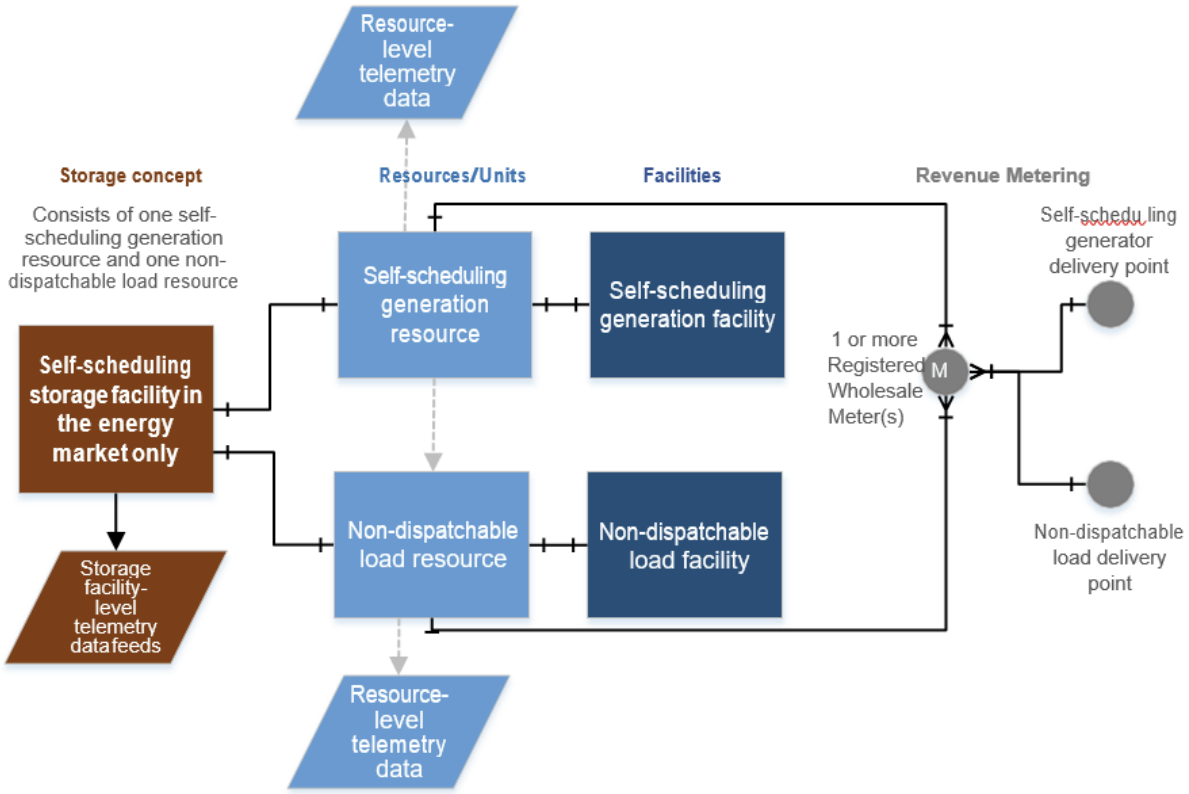
Such facilities will include:

- A self-scheduling generation resource mapped to a self-scheduling generation facility which will be associated with all energy injections by the facility

- A non-dispatchable load facility also associated with the self-scheduling energy storage facility which will be associated with all energy withdrawals by the facility
- At least one registered wholesale meter (RWM) meeting all requirements of chapter 6 of the IESO Market Rules and related appendices, where the injection channel from that RWM is registered to the self-scheduling generator resource delivery point and where the withdrawal channel from that RWM mapped to the non-dispatchable load resource delivery point. It is also allowable to register a separate RWM for each resource.

A summary of these critical relationships is provided in Figure 10.

Figure 10 - Design feature F.R. 2's critical facility registration relationships for a self-scheduling storage facility



Allowable participation for self-scheduling energy storage facilities in wholesale market products:

Real-time energy	Operating reserve	Regulation service	Reactive support and voltage control	Capacity auction
Yes	No	No	Yes	No

Exceptions and changes required to the current market registration process:

Given the above arrangements, Table 8 describes those areas of the market registration process whereby a self-scheduling energy storage facility in the real-time energy market will depart from the usual arrangements for such resources:

Table 9 - Summary of storage-specific measures for design feature F.R. 2 (self-scheduling energy storage facilities in the energy market)

Market registration process	Sub-process	Storage-specific impact under design feature F.R. 1 (self-scheduling energy storage facilities providing regulation service only)
Market participant authorization	Authorization	All existing market participant registration requirements (see IESO Market Rules, chapter 2, appendices to chapter 2, and IESO market manuals 1.1 to 1.3) **AND:** OEB electricity storage licence required: *"An electricity storage licence enables the licensee to generate electricity or provide ancillary services for sale through the IESO-administered markets or directly to another person; purchase electricity or ancillary services in the IESO-administered markets or directly from a generator; and sell electricity or ancillary services through the IESO-*

Market registration process	**Sub-process**	**Storage-specific impact under design feature F.R. 1 (self-scheduling energy storage facilities providing regulation service only)**
		administered markets or directly to another person, other than a consumer'[8]
Market participant authorization	Issuance of registration authorization notice (RAN) regarding market participant status	No change
Telemetry set-up	IESO determination of communication circuit set-up	No change
Telemetry set-up	Determine telemetry data points	Telemetry points for a self-scheduling generator registered to provide an ancillary service will include: Market Rules, appendix 4.15 – *IESO Monitoring Requirements: Generators* The IESO will not permit telemetry to be optional for those facilities with nameplate rating of less than 10 MW **AND** Storage-specific telemetry required – associated with the storage facility as a whole not the individual, underlying resources (see appendix A and note below): • Economic maximum power mode ($ECO\_P_{max,g}$)

[8] Ontario Energy Board website, "Electricity storage licence", accessed on November 22, 2019

Market registration process	**Sub-process**	**Storage-specific impact under design feature F.R. 1 (self-scheduling energy storage facilities providing regulation service only)**
		• Economic minimum power mode (ECO_$P_{min,g}$) • Economic minimum state of charge (ECO_$SOC_{min,g}$) • Economic maximum state of charge (ECO_$SOC_{max,g}$) • State-of-charge (SoC)
Telemetry set-up	Telemetry set-up	No change
Telemetry set-up	Operational telemetry testing	No charge
Facility registration	Capture facility-specific standing data	May be subject to certain requirements proposed under current market rule amendments to Market Rules appendix 4.2 – *generation facility requirements and appendix 4.3 – requirements of connected wholesale customers and distributors connected to the IESO-controlled grid* **AND** Subject to Market Rules appendix 4.8 – *network impact information: ancillary services providers and appendix 4.15 – IESO Monitoring Requirements: Generators* **AND** Subject to storage-specific standing data required (see **appendix A and note below**): • Certified Duration of Service (derived from SOCMAXg and Pmax,g)

Market registration process	**Sub-process**	**Storage-specific impact under design feature F.R. 1 (self-scheduling energy storage facilities providing regulation service only)**
		• Cycle Efficiency ($CycleEfficiency_g$) • Full Power Operating Mode ($P_{max,g}$) • Low Power Operating Mode ($P_{min,g}$) • Lower Energy Limit ($SOCMIN_g$) • Upper Energy Limit ($SOCMAX_g$)
Meter registration	Register metering service provider (MSP) for facility	No change
Meter registration	Revenue meter set-up and registration	No change
Commissioning	Commissioning testing	Commissioning to demonstrate adherence to Market Rules appendix 4.2 – *Generation Facility Requirements and Appendix 4.3 – Requirements of Connected Wholesale Customers and Distributors Connected to the IESO-Controlled Grid*
Commissioning	Certification testing for regulation service	No change
Commissioning	Dispatchability Testing	Not applicable
Commissioning	Issuance of registration authorization notice (RAN) regarding entry into commissioning process	No change

Notes regarding telemetry data points

The following telemetry data points are for future use by the IESO and would not be immediately used within the interim state of charge management framework described earlier in this chapter:

- Economic Maximum Power Mode (ECO_$P_{max,g}$)
- Economic Minimum Power Mode (ECO_$P_{min,g}$)
- Economic Minimum State of Charge (ECO_$SOC_{min,g}$)
- Economic Maximum State of Charge (ECO_$SOC_{max,g}$)

These data values are further defined in **Appendix 'A'** of this document.

2.4.8. Design feature F.R. 2 rationale

The recommended design approach for this interim design feature addresses the Energy Storage Design Project principles discussed in section 1.8 as follows.

1. Realizing increased reliability, efficiency and competition

This design feature generally enables energy storage participation in the real-time energy market as a self-scheduling energy storage facility. By doing so, it will bring better market depth and liquidity for real-time energy trading from energy storage resources. This may be particularly valuable during the interim period, should energy storage resources become a fast-growing segment of the wholesale market, before the IESO can put a permanent state-of-charge framework in place.

2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

The F.R. 2 design feature generally provides a means of wholesale market access for small-scale energy storage facilities down to 1 MW. In U.S. markets under FERC jurisdiction, the participation threshold for small-scale energy storage facilities is being dropped to 100 kW though it remains to be seen what the uptake in this market segment will be. This is a matter that the IESO will continue to monitor as these jurisdictions proceed to implement this rule during the interim period. In the meantime, self-scheduling energy storage facilities will be subject to the same minimum 1 MW and maximum 10 MW thresholds that self-scheduling generation facilities are subject to in the IAMs.

3. Maximize the chances of timely implementation

Design feature F.R. 2 is already in use in the IAMs for energy storage facilities participating in the real-time energy market under various energy storage pilot programs. By formalizing these registration requirements in the IESO Market Rules and market manuals, this will allow other energy storage facilities to more efficiently discover and prepare for the IESO facility registration process.

2.4.9. Design feature F.R. 3 – registration of dispatchable energy storage facilities

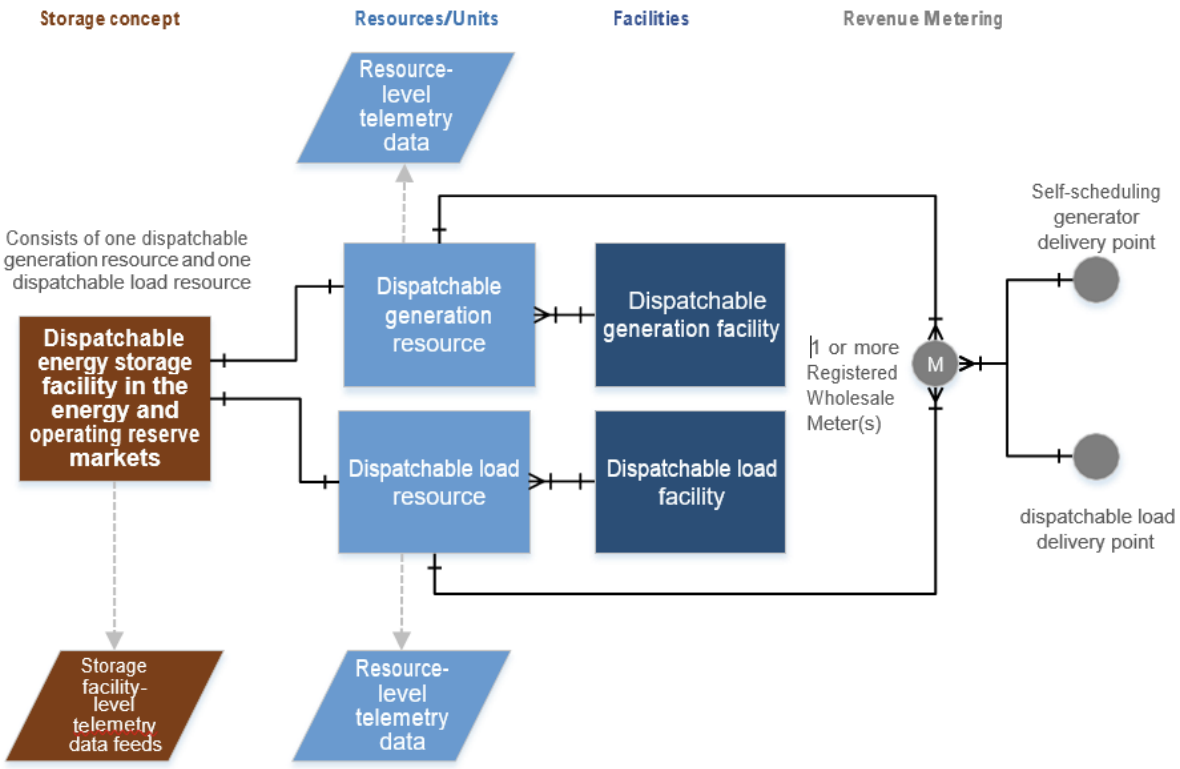
During the interim period, dispatchable energy storage facilities in the real-time energy market will closely resemble the registration profile of a dispatchable generation resource, associated with a dispatchable load facility. These two resources are used to model the discharge and charging capabilities, respectively, of the underlying dispatchable energy storage facility.

Such facilities will include:

- The sub-set of dispatchable energy storage facilities participating in the capacity auction
- A dispatchable generation resource mapped to a dispatchable generation facility which will be associated with all energy injections by the storage facility
- A dispatchable load resource mapped to a dispatchable load facility which will be associated with all energy withdrawals by the storage facility
- At least one registered wholesale meter (RWM) meeting all requirements of chapter 6 of the IESO Market Rules and related appendices, where the injection channel from that RWM is registered to the dispatchable generation resource delivery point and where the withdrawal channel from that RWM mapped to the dispatchable load resource delivery point. It is also allowable to register a separate RWM for each resource.

A summary of these critical relationships is provided in Figure 11.

Figure 11 - Design feature F.R. 3's critical facility registration relationships for a dispatchable energy storage facility



Allowable participation for dispatchable energy storage facilities in wholesale market products

Real-time energy	Operating reserve	Regulation service	Reactive support and voltage control	Capacity auction
Yes	Yes	No	Yes	Yes – if the facility meets the requirements of a dispatchable energy storage facility participating in the capacity auction (see capacity auction design for further details)

Exceptions and changes required to the current market registration process

Given the above arrangements, Table 10 describes those areas of the market registration process where a dispatchable energy storage facility will depart from the usual arrangements for the underlying resource components.

Table 10 - Summary of storage-specific measures for design feature F.R. 3 (dispatchable energy storage facilities)

Market registration process	**Sub-process**	**Storage-specific impact under design feature F.R. 3 (dispatchable energy storage facilities)**
Market participant authorization	Authorization	All existing market participant registration requirements (see IESO Market Rules, chapter 2, appendices to chapter 2, and IESO market manuals 1.1 to 1.3) **AND** OEB electricity storage licence required: *"An electricity storage licence enables the licensee to generate electricity or provide ancillary services for sale through the IESO-administered markets or directly to another person; purchase electricity or ancillary services in the IESO-administered markets or directly from a generator; and sell electricity or ancillary services through the IESO-administered markets or directly to another person, other than a consumer"*[9]
Market participant authorization		
Market participant authorization	Issuance of registration authorization notice (RAN) regarding market participant status	No change

[9] Ontario Energy Board website, "Electricity storage license", accessed on November 22, 2019

Market registration process	**Sub-process**	**Storage-specific impact under design feature F.R. 3 (dispatchable energy storage facilities)**
Telemetry set-up	IESO determination of communication circuit set-up	No change
Telemetry set-up	Determine telemetry data points	All applicable telemetry points dispatchable generation facility and a dispatchable load facility including: Market Rules, appendix 4.17 – *IESO monitoring requirements: connected wholesale customers and distributors* **AND** Market Rules, appendix 4.15 – *IESO Monitoring Requirements: Generators* **AND** Storage-specific telemetry required – associated with the storage facility as a whole not the individual, underlying resources (see appendix A and note below): • Economic Maximum Power Mode ($ECO\_P_{max,g}$) • Economic Minimum Power Mode ($ECO\_P_{min,g}$) • Economic Minimum State of Charge ($ECO\_SOC_{min,g}$) • Economic Maximum State of Charge ($ECO\_SOC_{max,g}$) • State of Charge (SoC)

Market registration process	**Sub-process**	**Storage-specific impact under design feature F.R. 3 (dispatchable energy storage facilities)**
Telemetry set-up	Telemetry set-up	No change
Telemetry set-up	Operational telemetry testing	No change
Facility registration	Capture facility-specific standing data	May be subject to certain requirements proposed under current market rule amendments to market rules Appendix 4.2 – *generation facility requirements and appendix 4.3 – requirements of connected wholesale customers and distributors connected to the IESO-controlled grid* **AND** IESO Market Rules, appendix 4.15 – *IESO Monitoring Requirements: Generators* **AND** IESO Market Rules, Appendix 4.17 – *IESO Monitoring Requirements: Connected Wholesale Customers and Distributors* **AND** Subject to storage-specific standing data required (see appendix A and note below): • Certified Duration of Service (derived from SOCMAXg and $P_{max,g}$) • Cycle Efficiency ($CycleEfficiency_g$) • Full Power Operating Mode ($P_{max,g}$) • Low Power Operating Mode ($P_{min,g}$) • Lower Energy Limit ($SOCMIN_g$) • Upper Energy Limit ($SOCMAX_g$)

Market registration process	**Sub-process**	**Storage-specific impact under design feature F.R. 3 (dispatchable energy storage facilities)**
Meter registration	Register metering service provider (MSP) for facility	No change
Meter registration	Revenue meter set-up and registration	No change
Commissioning	Commissioning testing	Commissioning testing to demonstrate adherence to Market Rules appendix 4.2 – *Generation Facility Requirements and appendix 4.3 – Requirements of Connected Wholesale Customers and Distributors Connected to the IESO-Controlled Grid* and any modifications as a result of proposed amendments to those provisions as of the date of this design document.
Commissioning	Certification testing for regulation service	Not applicable
Commissioning	Dispatchability Testing	No change
Commissioning	Issuance of registration authorization notice (RAN) regarding entry into commissioning process	No change

Notes regarding telemetry data points

The following telemetry data points are for future use by the IESO and would not be immediately used within the interim state of charge management framework described earlier in this chapter:

- Economic Maximum Power Mode (ECO_$P_{max,g}$)
- Economic Minimum Power Mode (ECO_$P_{min,g}$)
- Economic Minimum State of Charge (ECO_$SOC_{min,g}$)
- Economic Maximum State of Charge (ECO_$SOC_{max,g}$)

These data values are further defined in **Appendix 'A'** of this document.

2.4.10. Design feature F.R. 3 rationale

The recommended design approach for this interim design feature addresses the Energy Storage Design Project principles discussed in section 1.8 as follows.

1. Realizing increased reliability, efficiency and competition

This design feature generally enables energy storage participation in the real-time energy market and operating reserve market as a dispatchable energy storage facility. It also encompasses dispatchable energy storage facilities participating in IESO capacity auctions. By doing so, it will bring better market depth and liquidity for real-time energy trading from energy storage resources and IESO capacity procurement. This may be particularly valuable during the interim period, should energy storage resources become a fast-growing segment of the wholesale market before the IESO can put a permanent state-of-charge framework in place.

2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

The F.R. 3 design feature is generally consistent with some wholesale market jurisdictions that currently use a two-resource model for dispatchable energy storage facilities. More importantly however, the overall usage construct spanning design features SoC 1-2, DACP 1-3 and O.R. 1-3 will allow these facilities to more seamlessly transition to a single resource model under the enduring energy storage participation framework.

3. Maximize the chances of timely implementation

Design feature F.R. 3 is already in use in the IAMs for energy storage facilities participating in the real-time energy market under various energy storage pilot programs. By formalizing these registration requirements in the IESO Market Rules and market manuals, this will allow other energy storage facilities to more efficiently discover and prepare for the IESO facility registration process.

2.4.11. Summary of registration requirements for each storage facility sub-type

Table 11 - Registration requirements for sub-type of storage facility

Energy storage facility sub-type	Energy storage facility level telemetry requirements	Component resource/ unit sub-type	* Performance requirements	* Facility registration standing data requirements	* Resource level monitoring requirements	* Facility monitoring performance standards
Self-Scheduling energy storage facilities providing regulation service only	See Design feature F.R. 1 – registration of self-scheduling energy storage facilities providing regulation service only	Self-scheduling generator	Appendix 4.2	Appendix 4.5 A Appendix 4.6 Appendix 4.8 and as set out in F.R.1.	Appendix 4.15 and as set out in F.R.1.	Appendix 4.19
Self-scheduling energy storage facilities in the real-time energy market	See Design feature F.R. 2 – registration of self scheduling energy storage facilities up to 10 MW in the real-time energy market	Self-scheduling generator Non-dispatchable load	Appendix 4.2 Appendix 4.3	Appendix 4.5A Appendix 4.6 and as set out in F.R.2 Appendix 4.5A Appendix 4.7 and as set out in F.R.2	Appendix 4.15 and as set out in F.R.2 Appendix 4.17 and as set out in F.R.2	Appendix 4.19 Appendix 4.22
Dispatchable energy storage facilities	See Design feature F.R.3 - registration of dispatchable energy storage facilities	Dispatchable generator Dispatchable load	Appendix 4.2 Appendix 4.3	Appendix 4.5A Appendix 4.6 Appendix 4.5 A Appendix 4.7 and as set out in F.R.3	Appendix 4.15 and as set out in F.R.3 Appendix 4.17 and as set out in F.R.3	Appendix 4.19 Appendix 4.22

* Market Rules cross-reference: All appendix numbers refer to appendices of chapter 4 in the IESO Market Rules

2.5. Prudential security

Design element	Design question
Prudential security	What prudential security requirements will apply to ESRs?

2.5.1. Design issue overview

It is possible for an energy storage facility without an ancillary services contract, or fixed payment contract with the IESO to be a net market debtor in a given settlement period. However remote the risk may be, it is nonetheless a credit risk that may have to be evaluated by the IESO for prudential security purposes. This framework will need to provide a reasonable degree of financial security for other market participants.

2.5.2. Applicability of these design features

The design features outlined in this section are applicable to all sub-types of energy storage facilities in the IAMs, during both the interim period and over the longer-term.

2.5.3. Design features in summary

The remainder of this section will discuss the following design feature in detail.

Design feature P.S. 1 – prudential support obligation for market participants with energy storage facilities

Under this design feature, the IESO would clarify how it assesses the prudential risk for energy storage facilities, particularly insofar as the determination of the quantity of assumed/estimated energy use. This would account for the registered Cycle Efficiency of the energy storage facility, and the implied amount of energy withdrawn from the IESO-administered markets cannot be returned for injection, owing to that efficiency rating.

2.5.4. Design feature P.S. 1 – prudential support obligation for market participants with energy storage facilities

Energy storage facilities shall work within the same prudential security framework that is applicable to all market participants. This framework provides security for all market participants against the mutual risk of a default by any market participant in the IAMs. Under the IESO Market Rules, all market participants may be subject to a default levy in the event that a market participant defaults against the electricity market and there is insufficient prudential security to

cover that default. Every aspect of today's prudential security framework is intended to minimize that risk for all involved.

The main storage-specific feature of the prudential security framework, is the manner in which the IESO determines the market participant's prudential support obligation for a storage facility. Here, the IESO will use each facility's:

- Registered cycle efficiency value – i.e., the proportion of energy that is returned for injection into the electricity system after it is withdrawn and stored
- Registered maximum state of charge (SOCMAXg) – i.e., the highest certified state of charge to which the energy storage system can be consistently charged without damage beyond expected degradation from normal use
- Registered duration of service – expressed in minutes, the certified duration of service of the facility is calculated from the Certified Energy Storage Capacity (SOCMAXg) and Certified Power Storage Capacity (Pmax,g) of the facility. Certified quantities are determined during testing.

The amount of energy lost in the process of withdrawing, storing and injecting energy represents the potential financial exposure to the market for energy that will not be returned for sale.

An example of this methodology is provided in appendix C (prudential support obligation example).

Table 12 summarizes the various stages of the prudential process, and any storage specific considerations that will be applied during those stages.

Table 12 - Summary of storage-specific changes to the prudential security framework

Current framework	Application to an energy storage facility
Major process: establish a market participant's maximum net exposure **Overall construct:** "With the exception of a market participant who has elected the no-margin call option, the maximum net exposure for a market participant is equal to the sum of its trading limit and default protection amount (chapter 2, section 5.3.1 of the Market Rules)." – IESO Market Manual 5.4	No change
Major process: establish a market participant's maximum net exposure **Sub-process:** determination of default protection amount "For a metered market participant, its default protection amount shall be equal to the IESO's estimate of the metered market participant's net settlement amounts for that energy market billing period, excluding estimated settlement amounts associated with the energy forward market and estimated settlement amounts associated with a transmission right, assuming 21 days of participation in the real-time market and assuming all energy injected or withdrawn is transacted through the real-time market (i.e., ignoring the impact of physical bilateral contracts)." – IESO Market Manual 5.4	IESO will base 21 days of participation on the round- trip efficiency of the energy storage facility, using the registered values of "Cycle Efficiency", and $SOCMAX_g$ = Estimated number of charging cycles during the assessment period * (1 - "Cycle Efficiency")* $SOCMAX_g$ The above quantity will be valued at the applicable rate for valuing energy withdrawals. Subject to the maximum possible value of energy storage roundtrip losses for the assessment period: $SOCMAXg \times (1 - CycleEfficiency) \times$ [Minutes per Month] Certified Duration of Service × 2

Current framework	Application to an energy storage facility
(See Appendix C - Prudential Support Obligation Example)	Where: **Cycle Efficiency** is defined in Appendix 'A' **$SOCMAX_g$** is defined in Appendix 'A'
Major process: Establish a market participant's maximum net exposure **Sub-process:** Determination of the minimum trading limit "The minimum trading limit for a metered market participant shall be equal to the IESO's estimate of the metered market participant's net settlement amounts, excluding estimated settlement amounts associated with the energy forward market and estimated settlement amounts associated with a transmission right, assuming seven days of participation in the real-time market and assuming all energy injected or withdrawn is transacted through the real-time market (i.e., ignoring the impact of physical bilateral contracts). The IESO may use a greater number, up to and including 49 days of participation in the real- time market for the determination of a metered market participant's minimum trading limit if that metered market participant was subject to more than one margin call per energy market billing period, provided that any such margin call is not the result of a price spike."– IESO Market Manual 5.4 (See Appendix C - Prudential Support Obligation Example)	IESO will base the required trading period (between 7 and 49 days) on the round- trip efficiency of the energy storage facility, using the registered values of "Cycle Efficiency", and SOCMAXg = Estimated number of charging cycles during the assessment period * (1 - "Cycle Efficiency")* SOCMAXg The above quantity will be valued at the applicable rate for valuing energy withdrawals. Subject to the maximum possible value of energy storage roundtrip losses for the assessment period: SOCMAXg × (1 − CycleEfficiency) × [Minutes per Month] Certified Duration of Service × 2 Where: **Cycle Efficiency** is defined in Appendix 'A' **$SOCMAX_g$** is defined in Appendix 'A'

Current framework	Application to an energy storage facility
Major process: Establish a market participant's maximum net exposure **Sub-process:** Adjustments for physical bilateral contracts: "A metered market participant with a credit rating of BBB- or higher, subject to any adjustment under section 5.8.2, may request its minimum trading limit be calculated removing the energy quantities associated with the participant's physical bilateral contracts registered with the IESO provided it submits to the IESO the quantity and duration of the applicable physical bilateral contracts and it notifies the IESO immediately upon a change in the quantity or duration of the physical bilateral contracts including the termination of any of the contracts. If the above conditions are met (chapter 2, section 5.3.8A of the market rules), the IESO shall determine the metered market participant's minimum trading limit assuming all energy injected or withdrawn is transacted through the real-time market net of energy quantities associated with those physical bilateral contracts." – IESO Market Manual 5.4	No change
Major process: Establish a market participant's maximum net exposure **Sub-process:** Adjustments for credit rating "The reduction in the level of prudential support obligation relative to the market participant's maximum net exposure that can be applied by the	No change

<table>
<tr><th>Current framework</th><th>Application to an energy storage facility</th></tr>
<tr><td>IESO based on a market participant’s credit rating….”

– IESO Market Manual 5.4

(See chapter 2, section 5.8.1 and 5.8.1A of the Market Rules and IESO Market Manual 5.4, appendix C)</td><td></td></tr>
<tr><td>Major process: Establish a market participant’s maximum net exposure

Sub-process: Adjustments for good payment history

“The IESO shall determine the dollar amount of any allowable reduction in the prudential support obligation of an unrated market participant, other than a distributor, by an amount equal to the monetary value prescribed, by the table below:”

<table><tr><th>Good payment History Categories for Non-Distributors</th><th>Allowable Reduction in Prudential Support</th></tr><tr><td>≥6 years</td><td>Lesser of 50% of maximum net exposure or $12,000,000</td></tr><tr><td>≥5 years, <6 years</td><td>Lesser of 30% of maximum net exposure or $7,500,000</td></tr><tr><td>≥4, <5 years</td><td>Lesser of 25% of maximum net exposure or $6,000,000</td></tr><tr><td>≥3, <4 years</td><td>Lesser of 20% of maximum net exposure or $4,500,000</td></tr><tr><td>≥2, <3 years</td><td>Lesser of 15% of maximum net exposure or $3,000,000</td></tr><tr><td><2 years</td><td>0</td></tr></table>
– IESO Market Rules, chapter 2, section 5.8.4</td><td>No change</td></tr>
<tr><td>Major process: Daily monitoring of prudential support

Sub-process: Actual net exposure calculations</td><td>No change</td></tr>
</table>

Current framework	Application to an energy storage facility
"Monitoring of estimate actual net exposure against the trading limit is done on a daily basis. The estimate actual net exposure calculation begins with estimates of charges for both dispatchable and non-dispatchable market participants. The estimated actual net exposure calculation will also take into account an adjustment for both dispatchable and non- dispatchable market participants, for an estimated level of physical bilateral contracts based on previous participant activity." – IESO Market Manual 5.4, section 1.3.2	
Major process: Daily monitoring of prudential support **Sub-process:** No margin call option "Subject to IESO approval, a market participant may elect the no-margin call option, which would exempt a market participant from receiving a margin call, regardless of the level of its estimate actual net exposure (chapter 2, sections 5.6.4, 5.6.5 and 5.6.6 of the Market Rules). The IESO will set the maximum net exposure for a market participant that has elected this option, to be equal to 70 days of market activity and assuming all of the participant's energy injected or withdrawn is transacted through the real-time market, or 100% of the market participant's net settlement amount for non-metered market participants.…" – IESO Market Manual 5.4, section 1.33	No change

Current framework	Application to an energy storage facility
Major process: Daily monitoring of prudential support **Sub-process:** Margin calls "Where a market participant's estimate actual net exposure equals or exceeds its trading limit, as identified in Table 1-1, the IESO issues a margin call to the market participant (with the exception of market participants under the no margin call option). The market participant is required to satisfy this margin call through paying a portion of the amount payable by cash sufficient to reduce the market participant's estimate actual net exposure to no more than 75% of the market participant's trading limit (Chapter 2, section 5.6.1 and 5.6.2 of the market rules)." – IESO Market Manual 5.4, section 1.3.2	No change
Major process: Event of default (See IESO Market Manual 5.4, section 1.3.2)	No change
Major process: Exercise of rights and remedies to prudential support **Sub-processes:** • Exercise of rights • Remedies cumulative • Application of prudential support against actual exposure • Payment of expenses • Deficiency	No change

Current framework	Application to an energy storage facility
(See IESO Market Rules, chapter 2, appendix 2.3, section 3)	

2.5.5. Design feature P.S. 1 rationale

The recommended design approach for this interim design feature addresses the Energy Storage Design Project principles discussed in section 1.8 as follows.

1. Yielding benefit to ratepayers, the electricity system and the IAMs

This design feature generally enables energy storage participation in the IAMs by clarifying how today's prudential security construct applies to them. By doing so, it will bring better market depth and liquidity to various segments of the wholesale market from energy storage facilities.

This may be particularly valuable during the interim period, should energy storage resources become a fast-growing segment of the wholesale market.

As noted above, P.S. 1 strikes a balanced and prudent approach to ensure that all market participants are protected against the risk of a default levy from a defaulting energy storage market participant. This is achieved by accounting for realistic round-trip losses that may accrue to the invoice of an energy storage market participant over the course of the assessment period.

2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

Many U.S. wholesale markets have financial security as a requirement for participation. In the case of design feature P.S. 1, the IESO is clarifying how today's construct in Ontario applies to energy storage facilities.

3. Maximize the chances of timely implementation

The self-scheduling 2 design feature does not require a tool change in order to be implemented. This rule can be deployed immediately following the necessary changes to IESO Market Rules and market manuals through the IESO's baseline management process.

2.5.6. Design feature P.S. 1 – summary of inputs, outputs and processing

Table 13 - Design feature P.S. 1 inputs, outputs and processing

Major process area	Requisite inputs	Processing	Outputs
Major process: Establish a market participant's maximum net exposure **Sub-process:** Determination of default protection amount	Registered values for each energy storage facility: • Cycle Efficiency • $SOCMAX_g$ is defined in Appendix 'A'\ • Certified Duration of Service 2) Estimated number of charging cycles per assessment period	Calculation of default protection amount	**Default protection amount:** used in MNE main calculation
Major process: Establish a market participant's maximum net exposure **Sub-process:** Determination of the minimum trading limit	Registered values for each energy storage facility: • Cycle Efficiency • $SOCMAX_g$ is defined in Appendix 'A' • Certified Duration of Service 2) Estimated number of charging cycles per assessment period	Calculation of minimum trading limit	**Minimum trading limit:** used in MNE main calculation

2.6. Day-ahead market (DAM) and day-ahead commitment process (DACP) – bidding and scheduling of ESRs

Design element	Design question
Day-ahead market (DAM) and day-ahead commitment process (DACP): bidding and scheduling of ESRs	How should ESRs participate in the DACP pre-Market Renewal Program?

2.6.1. Design issue overview

During the intervening period before the IESO day-ahead market is implemented, the question remains whether or not energy storage facilities should be required to provide dispatch data to the day-ahead commitment process (DACP). Design features DACP-1 and DACP-2 will put self-scheduling and dispatchable energy storage facilities on the same footing as self-scheduling and dispatchable generators in the wholesale market that are classified as "quick start" facilities. Under these arrangements, energy storage facilities will be required to support identical forms of dispatch data into the DACP process as set out under section 2.6.7 below. In addition dispatchable energy storage facilities will need to adhere to the "no overlap rule" for bid/offer prices that is set out under design feature SoC 1 (see "Design feature SoC 1 – restriction against overlapping or equal bid/offer prices" for further details)

2.6.2. Applicability of these features

The design features outlined in this section are applicable to:

- Dispatchable energy storage facilities in the RT energy market – regardless of any capacity auction commitments they may have
- Dispatchable energy storage facilities participating in the capacity auction – which are also modeled as a dispatchable generator and dispatchable load resource
- Self-scheduling energy storage facilities under 10 MW in capacity in the RT energy market

Eventually, these measures will also be applicable to storage facilities providing regulation service once the IESO has the tools functionality to model them in the real-time energy market.

2.6.3. Design features in summary

The remainder of this section will discuss the following design features in detail.

Design feature DACP 1 – DACP data submission requirements for each class of interim energy storage participation

Under this design feature, all energy storage facilities will be required to submit dispatch data into the IESO day-ahead commitment (DACP) process, in the same manner as the corresponding self-scheduling or dispatchable generation/load facility, as the case may be. The only exception is for self-scheduling energy storage facilities providing regulation service, due to the limitations of the current IESO software.

Design feature DACP 2 – No overlap rule for bids and offers into the DACP for energy storage facilities

This design feature is predicated upon design feature Design feature SoC 1 – restriction against overlapping or equal bid/offer prices. Under this arrangement all bid prices provided by a dispatchable energy storage facility into the DACP must be less than all offer prices for the corresponding dispatch hour.

2.6.4. Current arrangements

Under today's IESO Market Rules, all dispatchable facilities and various other facility types are required to submit data into the DACP. This is a mandatory requirement in order to participate in the real-time market during the ensuing dispatch day (see Implications of DACP data submissions).

Data submission requirements

1. Dispatchable generation facilities must submit dispatch data (i.e., offer curves for energy and operating reserve) into the DACP
2. Self-scheduling generation facilities must submit their self-schedules into the DACP
3. Other types of resources and boundary entities are also required, or otherwise have to the option to submit data, into the DACP including:

    a. Non-Quick Start units;
    b. Pseudo unit
    c. Quick start
    d. Transitional scheduling generators (TSG)
    e. Intermittent generators

f. Dispatchable loads
g. Importers (optional)
h. Exporters (optional)
i. Hourly demand response (HDR) resources

In addition to the above arrangements, the dispatchable generation resource comprising a dispatchable energy storage facility participating in the capacity auction will be required to submit dispatch data (i.e., offer curves) into the DACP.

Although this data submission process does not affect the financial obligations of most types of facilities (other than day-ahead production cost guarantee-eligible facilities and imports) it plays a vital reliability role for the IESO-controlled grid. It is during the DACP that the IESO makes decisions regarding unit commitments for the following dispatch day. These actions may also be supplemented by additional, real-time unit commitments as events unfold during the ensuing dispatch day. In addition, it is through the DACP process where facilities secure their "availability declaration envelope" (ADE) for the next dispatch day (see also, section 2.6.5 below).

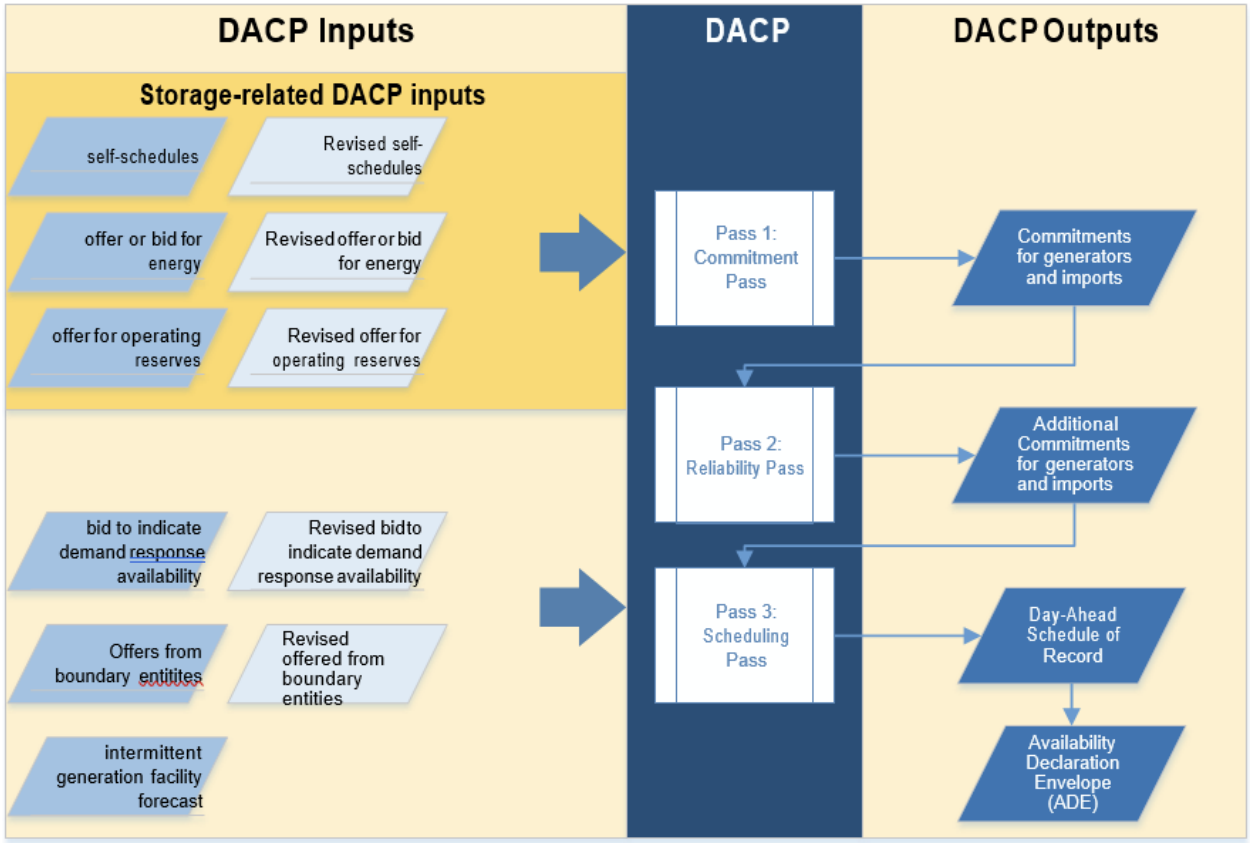
2.6.5. Implications of DACP data submissions

All data submissions into the real-time market are bound to a maximum quantity of energy set out in an availability declaration envelope (ADE) for each dispatch hour. The ADE for a given facility is established by virtue of the quantity of energy offered and bid by each resource constituting an energy storage facility, into the day-ahead commitment process (DACP). This ADE limit will apply to all applicable hours in the dispatch day (see IESO Market Rules, chapter 7, section 3.3A.2).

DACP data submissions are also used by the IESO to assist the day-ahead unit commitment process as detailed in IESO Market Rules chapter 7, section 5.8 and appendix 7.5A. The decisions made in the DACP result in obligations on facilities that are eligible to receive the day-ahead production cost guarantee. In addition, the resulting schedule of record produced by the DACP is a signal to all market participants regarding anticipated supply/demand conditions.

These measures are all affected by the quality of input data into that process.

Figure 12 - Select inputs and outputs related to the DACP



2.6.6. Objectives of these design features

The objectives of these design features are to balance the considerations outlined above and specifically to ensure that:

- Energy storage remains a flexible resource which can quickly respond to prevailing real-time conditions
- Energy storage capacity is reasonably and realistically accounted for in the day-ahead timeframe when making day-ahead unit commitment decisions

These objectives are addressed by the two design features as follows:

1. Design Feature DACP 1

All sub-types of energy storage facilities shall submit their respective data into the DACP process with the exception of storage facilities providing regulation service only, until such time as the IESO tools are able to accommodate regulation schedules from such facilities.

2. Design Feature DACP 2:

This ensures there is no overlap between bids and offers submitted into the DACP by resources comprising a dispatchable energy storage facility. This design feature will employ the same rule for no overlapping of bids and offers as is employed in design feature SoC 1 – restriction against overlapping or equal bid/offer prices.

2.6.7. Design feature DACP 1 – DACP data submission requirements for each class of interim energy storage participation

Table 14 summarizes the DACP input requirements for energy storage facilities under this design feature.

Table 14 - DACP input requirements for energy storage facilities

Energy storage facility sub-type	DACP requirement
Dispatchable energy storage facilities participating in the capacity auction	Required to submit offers into DACP per capacity auction design
Energy storage facilities participating in the real-time energy market and operating reserve as dispatchable facilities	Required to submit bids and offers into DACP
Energy storage facilities participating in the real-time energy market as self-scheduling facilities	Required to submit self-schedules into the DACP for the underlying self-scheduling generator resource
Energy storage facilities providing regulation service market as self-scheduling facilities.	Not required to submit into the DACP – due to current software limitations, energy storage facilities providing regulation service are unable to concurrently participate in the energy market, however, once the IESO is able to model such facilities in the real-time energy market, this existing requirement will be applied, as is the case for all generation facilities

These data submissions for each storage facility and resource sub-type are further detailed in Table 15.

Table 15 - DACP data feature submissions for each type of storage facility and resource sub-type

		Resource Type				
Data description	**Unit of measure**	**Dispatchable energy storage facilities participating in the capacity auction**	**Dispatchable storage – dispatchable generator resource**	**Dispatchable storage – dispatchable load resource**	**Self-scheduling storage up to 50 MW – regulation service only**	**Self-scheduling storage up to 10 MW – energy market only**
Start-up costs	$					
Speed no-load costs	$					
Incremental energy bid	$/MWh		X	X		
Incremental energy offer	$/MWh	X	X	X		
Incremental energy quantity	MW	X	X	X		
Incremental OR offer	$/MWh	X	X	X		
Incremental OR quantity	MW	X	X	X		
Energy ramp up	MW/minute	X	X	X		
Energy ramp down	MW/minute	X	X	X		
OR ramp up	MW/minute	X	X	X		
Energy limit	MWh					
Schedules and forecasts	MWh					X
Dispatch price	$					X

2.6.8. Design feature DACP 1 rationale

The recommended design approach for this interim design feature addresses the Energy Storage Design Project principles discussed in section 1.8 as follows.

1. Realizing increased reliability, efficiency and competition

The DACP 1 design feature generally maintains continuity with the current information discovery framework that underlies the day-ahead commitment process – namely that all facilities should signal their intent for operations on the pre-dispatch day. There is a basic fairness premise behind this design feature. Namely, to ensure that energy storage facilities and generation facilities of the same Quick Start classification have the same obligation imparted upon them. Having this information affords the IESO and market participants with the maximum informational picture of the collective intent of the marketplace in the pre-dispatch schedule of record. To do otherwise would create an information asymmetry between energy storage market participants and the rest of the marketplace.

2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

The DACP is a unique feature to the IAMs, with most U.S. wholesale markets having a financially binding day-ahead market (DAM). However, having energy storage participate in the DACP will be a stepping stone to allowing these facilities to participate in the future DAM. DACP 1 will be supplanted by the DAM once it is implemented in Ontario.

3. Maximize the chances of timely implementation

The DACP 1 design feature does not require a software tool change in order to implemented. This requirement is already implied by the IESO Market Rules and will be explicitly clarified for energy storage facilities following the necessary changes to IESO Market Rules and market manuals through the IESO's baseline management process.

2.6.9. Design feature DACP 2 – No overlap rule for bids and offers into the DACP for energy storage facilities

This design feature will apply to:

- Dispatchable energy storage facilities in the real-time energy market – regardless of any Capacity Auction commitments they may have
- Dispatchable energy storage facilities participating in the capacity auction– which are also modeled as a dispatchable generator and dispatchable load resource; and

For these types of facilities, all dispatch data submissions into the DACP shall observe the same no-overlap rule described under Design feature SoC 1 – restriction against overlapping or equal bid/offer prices.

2.6.10. Design feature DACP 2 rationale

The recommended design approach for this interim design feature addresses the Energy Storage Design Project Principles discussed in section 1.8 as follows.

1. Realizing increased reliability, efficiency and competition

As noted in the description of the SoC 1 design feature, this measure specifically helps to ensure reliability by requiring energy storage bids and offers to adhere to the no overlap rule. This will help prevent the IESO's dispatch scheduling and optimization (DSO) algorithm from simultaneously dispatching the load and generation resources comprising a dispatchable energy storage facility. The no overlap rule is further detailed in the section covering design feature SoC 1 ("restriction against overlapping or equal bid/offer prices"). This same reliability principle holds true for the IESO's day-ahead commitment process and will be employed for all bid/offer submissions from dispatchable energy storage facilities into the DACP.

2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

The no overlap rule put forward in SoC 1 and used by DACP 1 effectively creates a continuous bid/offer curve for charging/discharging – similar to methods now being implemented in several

U.S. jurisdictions. Once the IESO develops a single resource model for energy storage facilities, dispatchable facilities using this design feature during the interim period should be able to more seamlessly transition to the long-term arrangements.

3. Maximize the chances of timely implementation

The DACP 2 design feature does not require a tool change in order to implemented. This method of bidding/offering can be deployed immediately following the necessary changes to IESO Market Rules and market manuals through the IESO's baseline management process.

2.6.11. Design features DACP 1 and DACP 2– inputs, outputs and processing summary

Figure 13 - Summary of design features DACP 1 and DACP 2

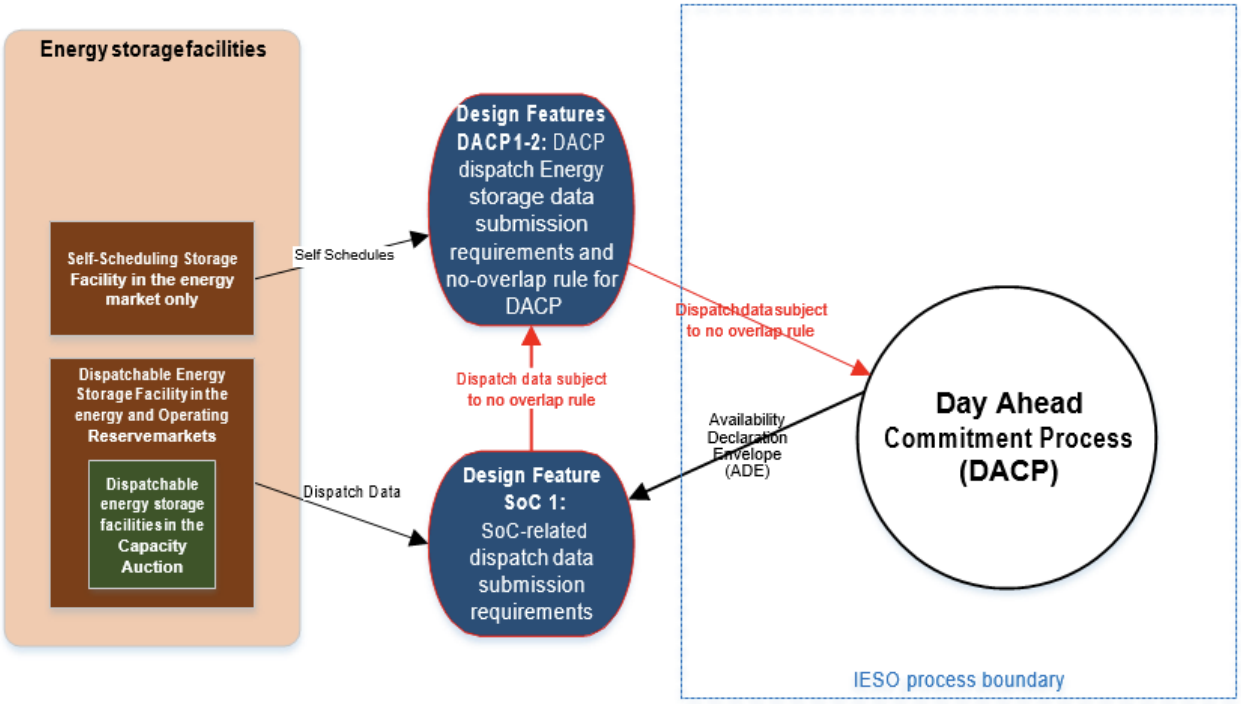


Table 16 - Summary of design features from DACP1 and DACP2

Design feature	Major process area	Requisite inputs	Processing	Outputs
DACP 1	Affects dispatch data inputs into DACP	Dispatch data adhering to no-overlap rule set out in Design Feature SoC 1	None – general requirement for DACP data submission	n/a
DACP 2	Affects dispatch data inputs into DACP	Dispatch data submissions into the DACP Bids from dispatchable load resources comprising a dispatchable energy storage facility Offers from dispatchable generation resources comprising a dispatchable energy storage facility Self-schedules from self- scheduling generation resources comprising a self-scheduling energy storage facility	Market participant ensures application of no overlap rule set out in Design feature SoC 1	DACP Dispatch data adhering to no-overlap rule set out in Design Feature SoC 1

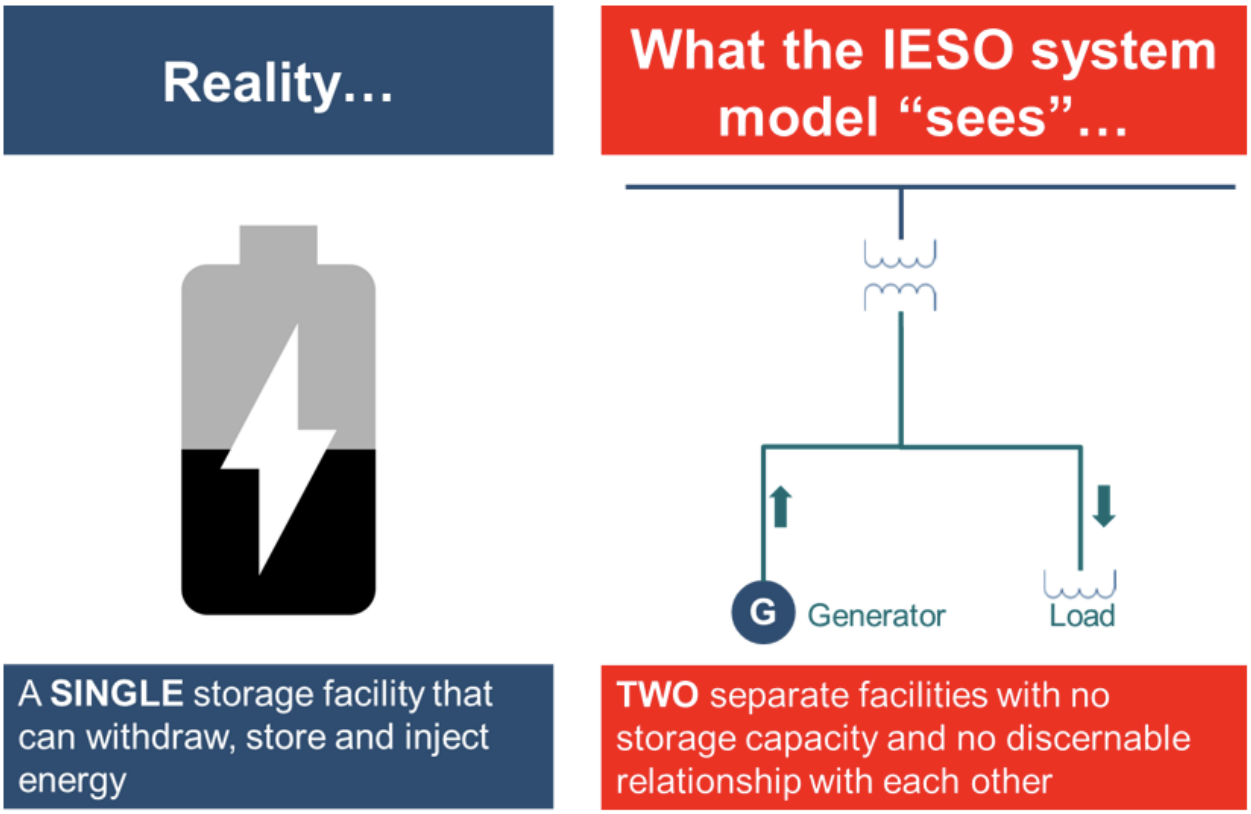
2.7. State of change (SOC) management in real-time energy market

Design element	Design question
State of charge (SoC) management in RT energy market	Who should optimize SoC of energy storage facilities in the real-time energy market: the energy storage facility, the system operator; or give ESRs the choice?

2.7.1. Design issue overview

This design element is driven by the fundamental construct of the IESO's dispatch scheduling and optimization (DSO) engine. The design of the DSO tool pre-dates the advent of wide-scale energy storage adoption. Under the current arrangements, the DSO cannot recognize the characteristics of a dispatchable energy storage facility that can withdraw, store and inject energy. Instead, a dispatchable storage facility must be modelled as a separate generator and load resource.

Figure 14 - Current DSO construct of a dispatchable energy storage facility



At issue, is how the finite state of charge of a dispatchable energy storage facility should be managed in the electricity market. The inability for the IESO's dispatch scheduling and optimization (DSO) tool to model energy storage facilities as a single resource:

- Creates a risk of conflicting dispatch by the DSO between the two facility components modelled (i.e., the generator and load resource)
- Results in the IESO core electricity market optimization function having no awareness of storage capacity or ability to optimize it

SThe solution space for this problem has two main branches: i. involving methods to be employed by the system operator (System Operator-managed SoC:); or, ii. the energy storage market participant (self-managed).

Electric Power Research Institute (EPRI) definitions:

- **System Operator-managed SoC**

  The system operator monitors the current SoC, anticipated SoC, and other related energy storage facility parameters (e.g., cycle efficiency) and makes scheduling decisions and schedules that explicitly lead to a desired and feasible SoC level at all times.

- **Self-managed SoC**

  The energy storage facility market participant provides cost/quantity offer curves that, to the best ability of the market participant, lead to desired and feasible SoC levels at all times without the need for explicit system operator intervention.

These two methods are not necessarily mutually-exclusive of one another.

With self-managed SoC, participants can implement their own strategy in the real-time market as events unfold, but there is a greater risk that energy in the energy storage facility will be near a SoC limit (e.g., 0% or 100%) and therefore the energy storage facility could not provide regulation service, meet a dispatch, or meet an operating reserve activation obligation.

System operator-managed SoC could allow the energy storage facility to be optimized using the full range of information that is available to the system operator, though this might negate strategic use of the facility's SoC by the participant.

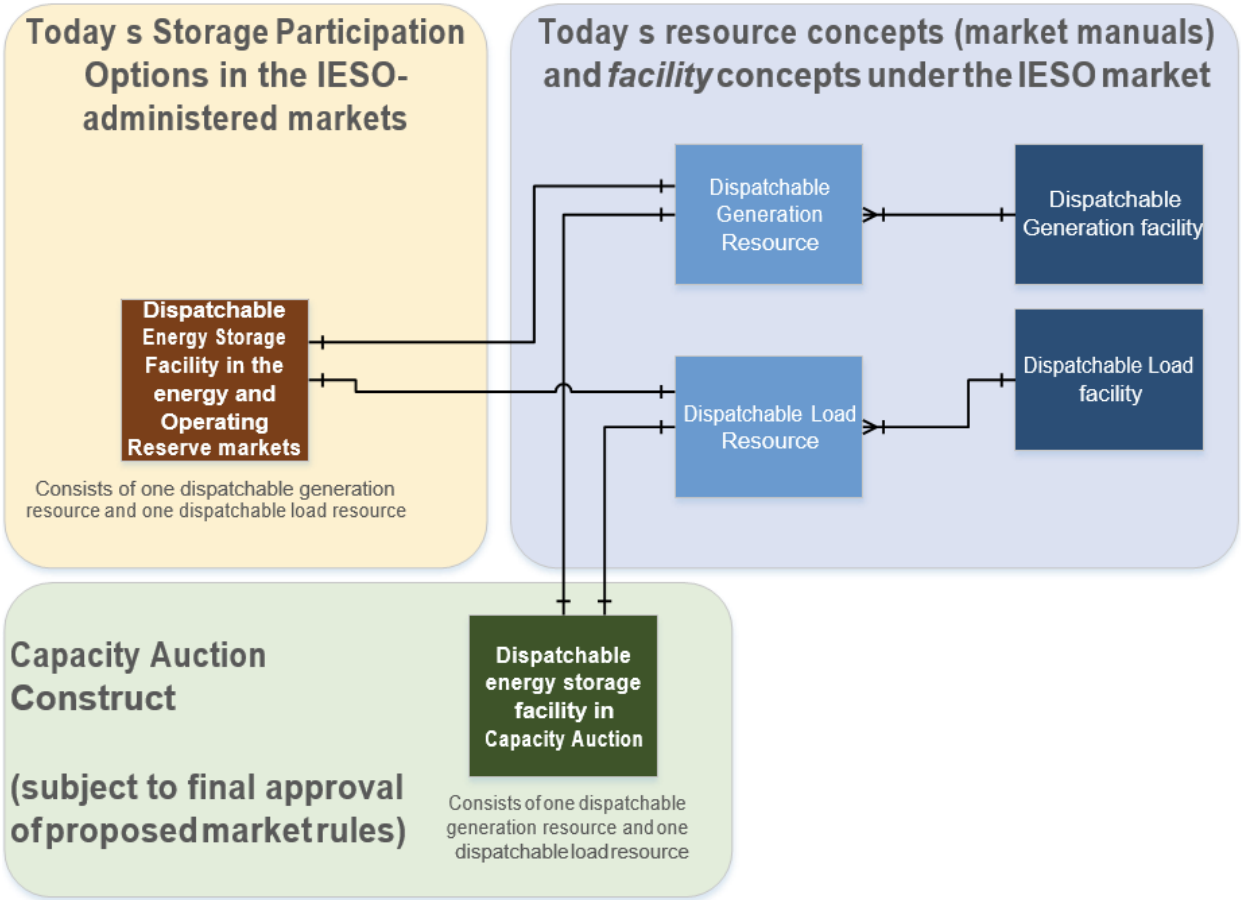
During the interim period, participants will be provided with a self-managed SoC framework until such time as the long-term measures are put into place (see chapter 3 for further details regarding long-term measures).

2.7.2. Applicability of these features

The design measures outlined in this section are applicable to:

- **Dispatchable energy storage facilities** in the real-time energy market – regardless of any capacity auction commitments they may have
- **Dispatchable energy storage facilities participating in the capacity auction** – which are also modeled as a dispatchable generator and dispatchable load resource

Figure 15 - Interim resource model for a dispatchable energy storage facility and a dispatchable energy storage facility participating in the capacity auction



2.7.3. Design features in summary

The remainder of this section will discuss the following design features in detail.

Design feature SoC 1 – restriction against overlapping or equal bid/offer prices

Under this feature, every bid price from a dispatchable energy storage facility in a given dispatch hour must be less than all offer prices for that facility in the same dispatch hour. This design feature will reduce the risk of receiving conflicting dispatch instructions for the generator and load resources comprising the energy storage faculty, and eliminate the possibility of overlapping CMSC payments.

Design feature SoC 2 – addressing potential changes to SoC-limited bids and offers

This design feature allows energy storage facilities to signal state-of-charge limitations to the IESO during the two-hour mandatory window period that precedes each dispatch hour. The framework will proactively reduce or prevent situations where such facilities must refuse dispatch instructions after they are issued by the IESO.

2.7.4. Objectives of the interim SoC management framework

The objectives of the interim framework set out in this chapter are to:

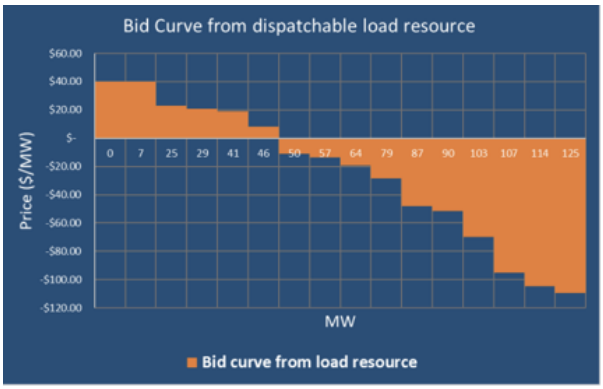
1. Prevent simultaneous dispatch of the energy storage facility's underlying dispatchable generation resource and dispatchable load resource
2. Allow the market participant to prevent situations in which either the dispatchable generation resource and dispatchable load resource comprising a dispatchable storage facility receives an infeasible dispatch instruction due to a state-of-charge limitation.

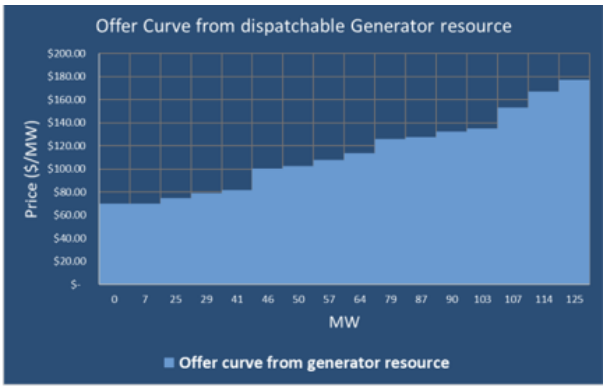
This interim framework is expected to be in place until such time as the IESO implements an enduring state-of-charge management framework in the dispatch scheduling and optimization (DSO) software tool.

2.7.5. Design feature SoC 1 – restriction against overlapping or equal bid/offer prices

Under today's Market Rules, construct (chapter 7, section 3.5), a dispatchable load facility and a dispatchable generation facility each submit a separate bid and offer curve, respectively. Each curve may be comprised of up to 20 and not less than two price points (p-q pairs) indicating the price and quantity of each segment of the bid/offer curve. In the case of an offer curve, each price must be monotonically increasing along the curve, and in the case of a bid curve, each price must be monotonically decreasing along the curve. Two hypothetical examples are illustrated below.

Hypothetical examples of bid and offer curves





Under the proposed design, these two curves should not overlap with each other if the two resources belong to the same dispatchable energy storage facility or to the same dispatchable energy storage facility participating in the capacity auction. "Overlap" constitutes any situation where a bid price for any segment of the bid curve for the dispatchable load resource is greater than or equal to the price of any segment of the offer curve for the corresponding dispatchable generation resource belonging to the same energy storage facility.

This restriction will be temporarily in place until such time as the IESO's DSO engine can explicitly recognize a relationship between the two underlying resources, and/or model the two resources as a single integrated facility.

This design feature is applicable to all dispatchable energy storage facilities – including those participating in the Capacity auction. The mathematical expression of this constraint using the notation set out in appendix 7.5 of the Market Rules, is as follows:

$$\text{PurchaseBidPrice}_{p,j} < \text{GenerationOfferPrice}_{g,J}$$

Where:

p and g are nodes comprising the same energy storage facility

$j \in \{J \mid 1 \leq j \leq 20\}$

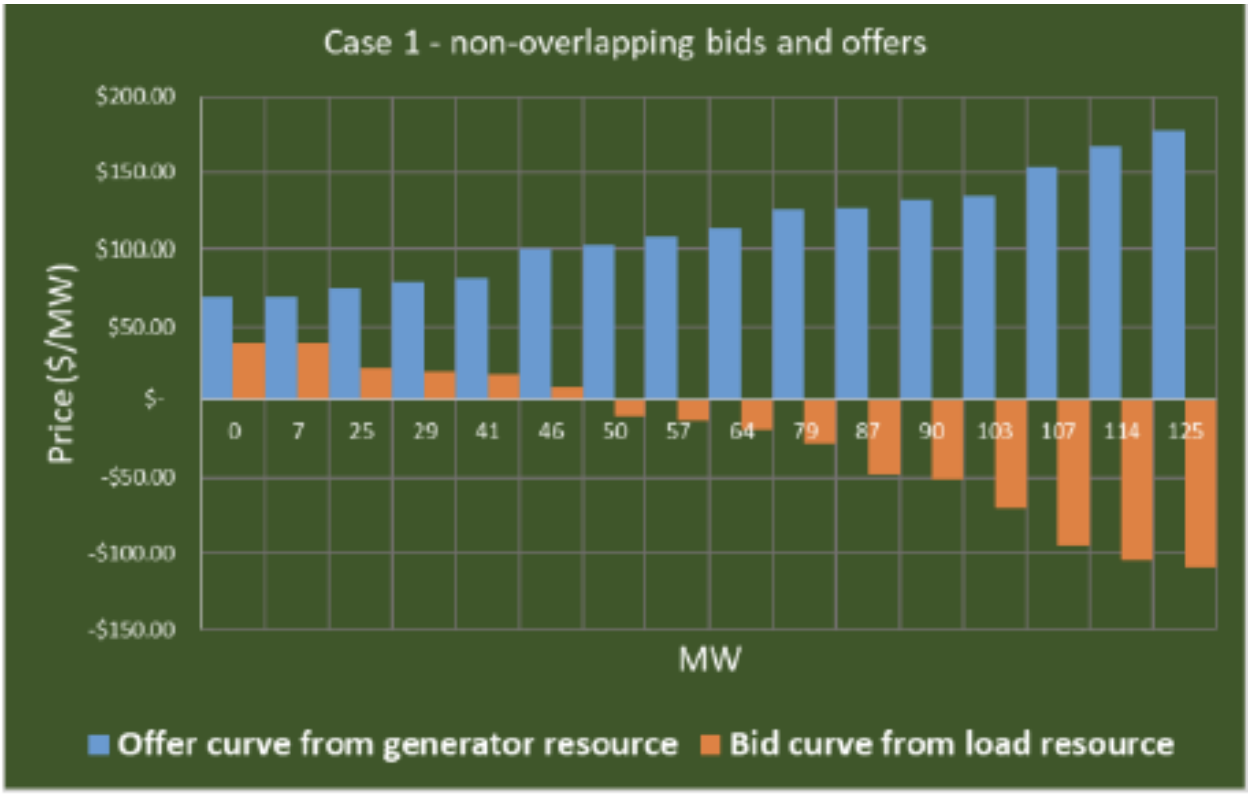
$\{j, p \mid j \in \text{PURCHASEBIDBLOCKS}_p, \text{where } p \in \text{BIDS}\}$

$\{j, g \mid j \in \text{GENERATIONOFFERBLOCKS}_g, \text{where } g \in \text{OFFERS}\}$

Where the sets, "PURCHASEBIDBLOCKS", "GENERATIONOFFERBLOCKS", "BIDS" and "OFFERS" are as defined in Appendix 7.5 of the market rules.

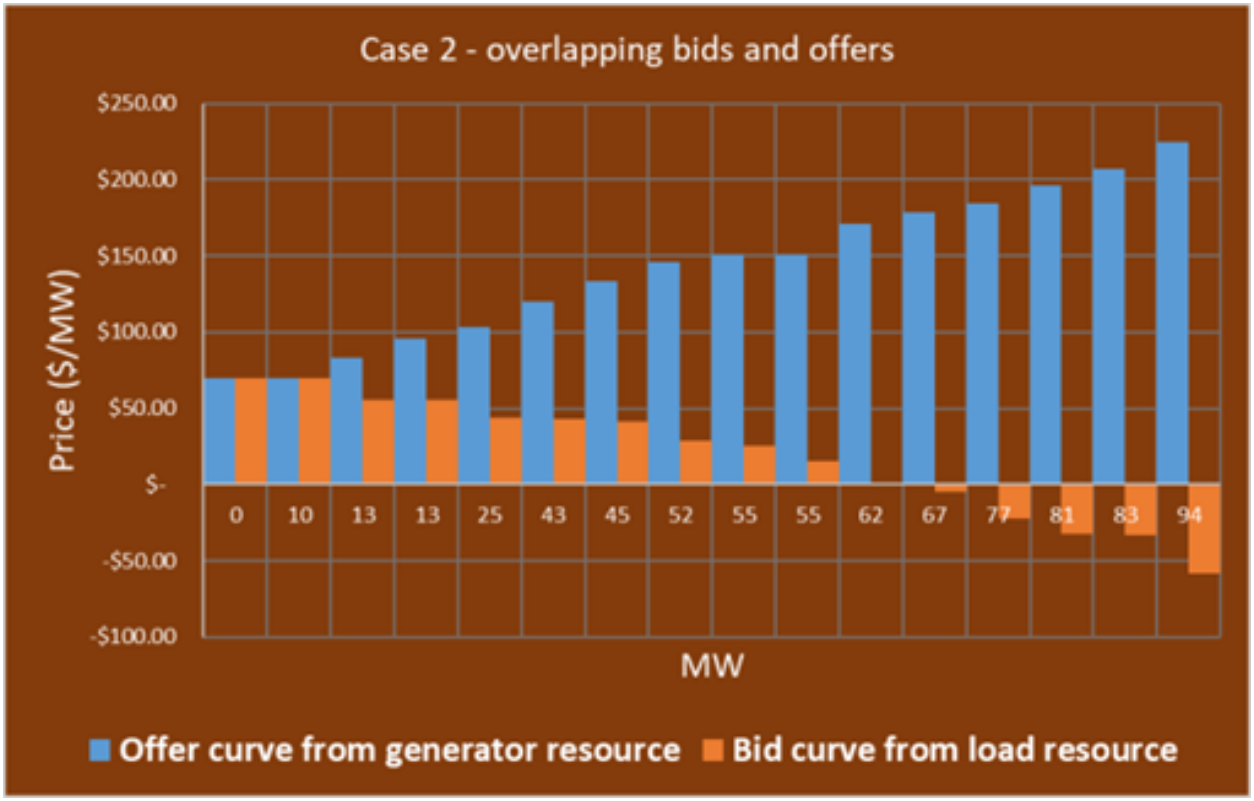
Given the above restrictions, no single bid price in the bid curve of a dispatchable load resource within an energy storage facility may be equal to or greater than any offer price of a dispatchable generation resources comprising that same energy storage facility. Three examples of acceptable and unacceptable bid/offer price ranges under the no-overlap rule are illustrated below.

Example 1 – Acceptable bid/offer combination where the bid curve and offer curve for a storage facility do not overlap



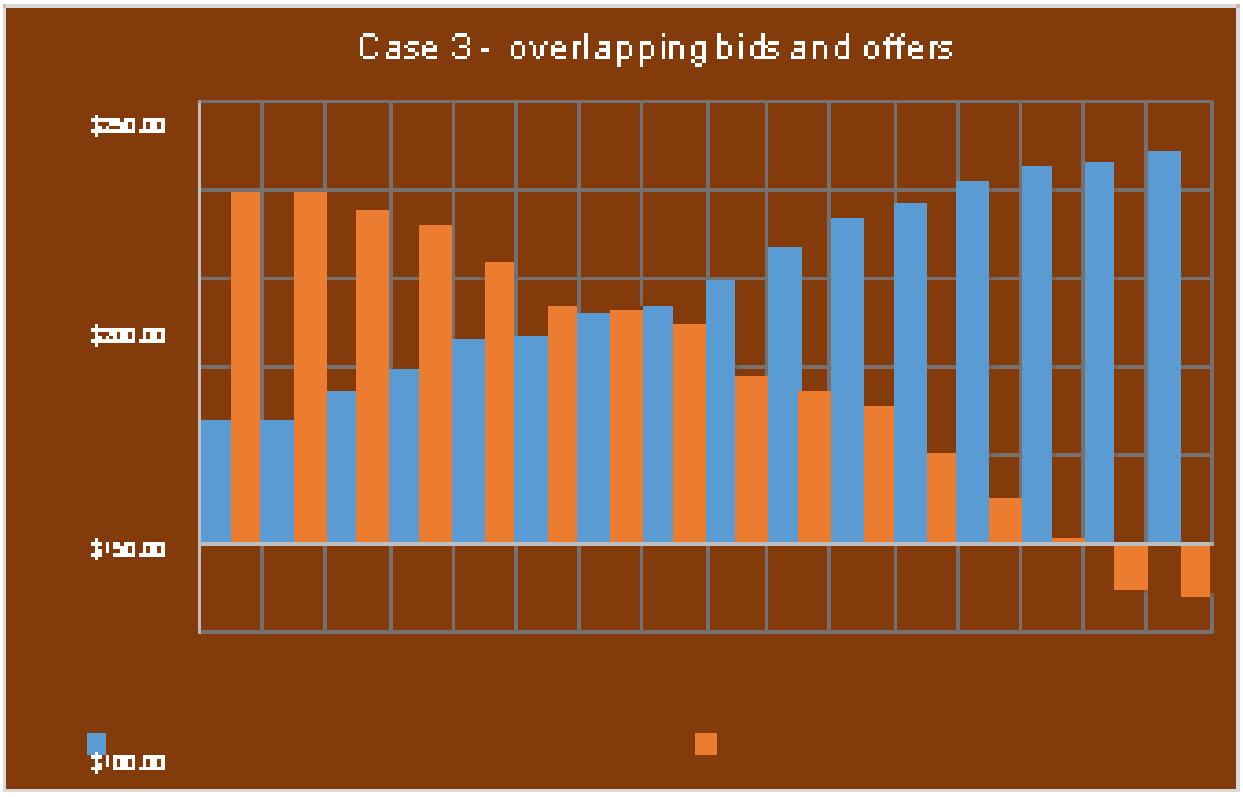
In the example above, all bid prices contained in the bid curve for the constituent dispatchable load resource belonging to the storage facility are less that all offer prices contained in the offer curve for the constituent dispatchable generation resource. This constitutes an acceptable, non-overlap situation which helps minimize the prospect of both underlying resources being dispatched by the IESO's DSO engine. Note that there must be a gap between the highest bid price and the lowest offer prices as is the case in the example above.

Example 2 – Unacceptable bid/offer combination where a portion of the bid curve price is equal to a portion of the curve price



In the example above, the first bid prices contained in the bid curve for the constituent dispatchable load resource belonging to the storage facility are equal to the first portion of offer prices contained in the offer curve for the constituent dispatchable generation resource. This constitutes an unacceptable, "overlap" situation as this raises the possibility of simultaneous dispatch of both resources at the price intersection point.

Example 3 – Unacceptable bid/offer combination where a portion of the bid curve price is greater than a portion of the offer curve price



In the example above, the first portion of bid prices contained in the bid curve for the constituent dispatchable load resource belonging to the storage facility are greater than the first portion of the offer prices contained in the offer curve for the constituent dispatchable generation resource. This constitutes an unacceptable, "overlap" situation as this raises heightened risk of simultaneous dispatch of the underlying resources.

Downstream dependencies

The no overlap rule of design feature SoC 1 shall be used for the submission of dispatch data into both the real-time market and the day-ahead commitment process (see Design feature DACP 2 – No overlap rule for bids and offers into the DACP for energy storage facilities).

2.7.6. Design feature SoC 1 rationale

The recommended design approach for this interim design feature addresses the Energy Storage Design Project principles discussed in section 1.8 as follows:

1. Realizing increased reliability, efficiency and competition

Design feature SoC 1 generally enables energy storage participation in the real-time energy market as a dispatchable energy storage facility. By doing so, it will bring better market depth and liquidity for real-time energy trading from energy storage resources. This may be particularly valuable during the interim period, should energy storage resources become a fast-growing segment of the wholesale market before the IESO can put a permanent state-of-charge framework in place.

The SoC 1 design feature specifically helps to ensure reliability by structuring energy storage bids and offers in a manner that helps prevent the IESO's dispatch scheduling and optimization (DSO) algorithm from simultaneously dispatching the load and generation resources comprising a dispatchable energy storage facility.

2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

The no overlap rule put forward in SoC 1 effectively creates a continuous bid/offer curve for charging/discharging – similar to methods now being implemented in several U.S. jurisdictions. Some of these jurisdictions are still in the process of refining and deploying such frameworks, but a well-documented example can be found at the system operator, PJM Interconnection where continuous offer curves can be submitted, spanning the energy storage resource's maximum charging to maximum discharging range[10]. The Electric Power Research Institute (EPRI) Energy Systems Integration Group (ESIG) also maintains current information on their website as U.S. system operators continue to implement their energy storage integration frameworks. Once the IESO develops a single resource model for energy storage facilities, dispatchable facilities using this design feature during the interim period should be able to more seamlessly transition to the enduring arrangements.

[10] In PJM, this is also dependent upon the mode of operation the storage resource select, which can include continuous operation from charge to discharge, charging-only, and discharging only. See also PJM Manual 11, *PJM Manual 11: Energy & Ancillary Services Market Operations, Revision: 108*, Effective Date: December 3, 2019 and *PJM Markets Gateway User Guide*

3. Maximize the chances of timely implementation

The SoC 1 design feature does not require a software tool change in order to implemented. This method of bidding/offering can be deployed immediately following the necessary changes to IESO Market Rules and market manuals through the IESO's baseline management process.

2.7.7. Design feature SoC 2 – addressing potential changes to SoC-limited bids and offers

Under this design feature, dispatchable energy storage facilities, including dispatchable energy storage facilities participating in the capacity auction, would be expected to follow this specific requirement to ensure that the facility has adequate state of charge for both the underlying dispatchable load resource and dispatchable generation resource prior to the end of the "mandatory window" described in the IESO Market Rules.

The period from two hours up until 10 minutes before the dispatch hour is called the "mandatory window". In most cases, market participants may only make limited changes to dispatch data during this window, and only with IESO approval. Further description of the usual application of this process may be found in the Market Manual 4.2. However, chapter 7, section 3.3.6 of the IESO Market Rules allows the IESO to exempt individual facilities from this restriction where such changes might prevent damage to equipment.

Self-managed state-of-charge (SoC) construct

Design feature SoC 2 is a type of self-managed SoC construct, as defined at the beginning of this section for the interim period. As such, this feature:

- Allows the market participant to determine if their facility has a sufficient state-of-charge level to meet potential dispatch instructions from the IESO during the pending dispatch hour – under this arrangement the IESO will not dictate a specific SoC level to determine the choices outlined in the decision tree set out in design feature SoC 2
- Provides sufficient capability for the market participant to signal any restrictions regarding their state of charge to the IESO by no later than then end of the mandatory window – i.e., at 10 minutes prior to the commencement of the dispatch hour
- Requires the market participants to ensure that their decisions on using this framework are subject to the IESO compliance supervision and enforcement framework as generally set out in:
    - IESO Market Rules, chapter 3 (general framework) and appendix 3.1 (Application of Enforcement Actions)

- IESO Market Rules, chapter 7 section 7 (dispatch instructions and compliance with dispatch instructions)
- Any interpretation bulletins where the IESO sets out specific parameters such as compliance deadbands, including, but not necessarily confined to, IESO Interpretation Bulletin IMO_MKRI_0001, Compliance with Dispatch Instructions Issued to Dispatchable Facilities

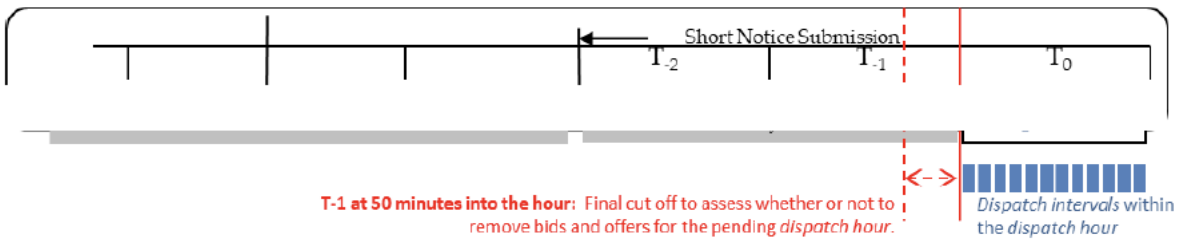
Market rule amendment to support this design feature

Under this design feature, the Market Rule construct enabling dispatch data changes within the mandatory window will be supplemented by an additional amendment to explicitly recognize the need to amend dispatch data for reasons related to state-of-charge limitations for an energy storage facility.

Mandatory window timeframe

Under this design feature, market participants must assess whether or not they should remove or adjust their bids and/or offers for a dispatchable storage facility at least 10 minutes prior to the start of the dispatch hour to which they pertain. IESO Market Manual 4, part 4.2 discusses the mandatory window in detail. An example of the two-hour mandatory window for a given dispatch hour is illustrated below.

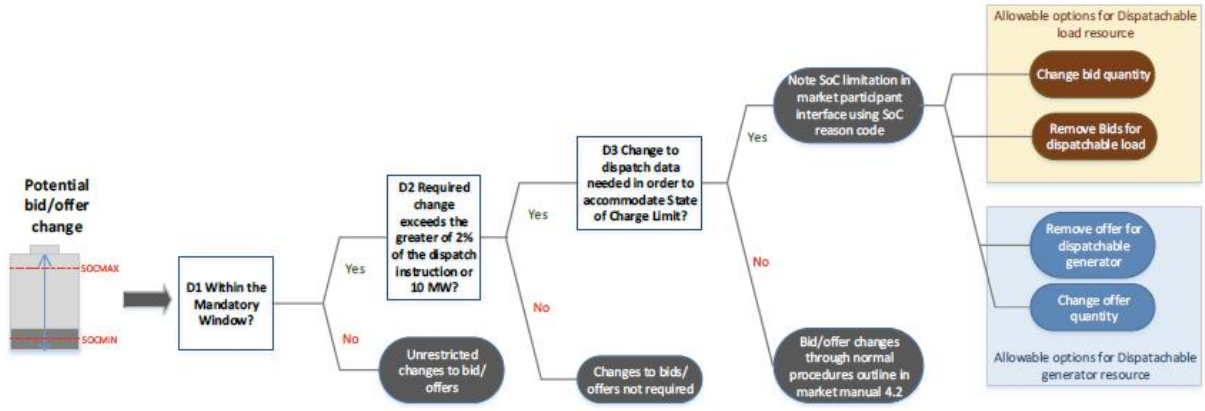
Figure 16 - Mandatory window timeframe



Outside of this mandatory window (i.e., greater than two hours before the beginning of any applicable dispatch hour), the energy storage facility may change bids and offers for either the component dispatchable load resource or dispatchable generator resource, according to the market rules and market manual provisions applicable to all dispatchable load resources and dispatchable generator resources.

Within the mandatory window, the following decision logic would apply to dispatchable energy storage facilities and dispatchable energy storage facilities participating in the capacity auction. In all cases, the decision tree below depicts the compartmentalized decisions to be taken during each mandatory window period for each pending dispatch hour immediately following that mandatory window. The decision tree is as follows.

Figure 17 - Decision tree for design feature SoC-2 within the mandatory window



The decision points and outcomes from the above framework are further detailed in Table 18.

Table 17 - Design feature SoC2 decision points and outcomes within the mandatory window

Decision point	Potential outcomes
D1 Within the mandatory window? From two hours until 10 minutes before each dispatch hour	**Yes:** Proceed to decision point D2 **No:** This design feature applies to situations involving a potential change to dispatch data and falling within the mandatory window illustrated above. The IESO Market Manual 4.2 further specifies that such changes are not applicable during: • "The current hour, • The next hour when it is less than 10 minutes to the start of the hour, and • An hour when it is reasonably expected that the dispatch data deviation will be eliminated mid-hour because the limitation will end" **Authority and market manual reference:** • IESO Market Rules, chapter 7, section 3.3 • IESO Market Manual 4.2, appendix B Under all other circumstances, outside of the DACP optimization window (see Market Manual 9.2), the market participant may make changes to their dispatch data outside of the mandatory window, subject to their day-ahead availability declaration envelope and the applicable market rules.

Decision point	Potential outcomes
D2 Required change exceeds the greater of 2% of the dispatch instruction or 10 MW[11]? There is an established threshold at which the IESO needs to be made aware of material change to dispatch data. The above threshold is authorized by the IESO Market Rules and stipulated in the IESO Market Manual 4.2	**Yes:** Proceed to decision point D3 **Authority and market manual reference:** • IESO Market Rules, chapter 7, section 3.3.8 **No:** No change to dispatch data required. **Authority and market manual reference:** • IESO Market Manual 4.2, section 2.3
D3 Change to dispatch data needed in order to accommodate state-of- charge limit? **Note:** this determination must be made by no later than 10 minutes prior to beginning of the dispatch hour to which the dispatch data applies	**Yes:** **TO BE DETERMINED BY IESO (see also, section 1.9) Allowable options for dispatchable load resources that comprise the storage facility:** 1. Change bid quantity: Under this option, the dispatchable load resource should initiate the change to the bid quantity in the market participant interface and apply the appropriate reason code. 2. Remove bids: This change will declare to the DSO that the dispatchable load resource is effectively a non-dispatchable load2 though the intended use for energy storage facilities shall be to simply ensure that the facility will not withdraw any further energy during the coming dispatch hour. In all cases, a dispatchable energy storage facility's dispatchable load resource shall operate in a manner consistent with a dispatchable resource.

[11] In some situations (e.g., when an emergency operating state is anticipated), the IESO may request that the market participants submit dispatch data that is more accurate than allowed by these criteria

Decision point	Potential outcomes
	This should be preceded by submitting an outage request into the outage management system to reflect actual capability as long as derating does not last more than two hours **Authority and market manual reference:** • IESO Market Manual 4.2, appendix B **TO BE DETERMINED BY IESO (see also, section 1.9) Allowable options for dispatchable generator resource comprising the storage facility:** 3. Change offer quantity: Under this option the dispatchable generator resource should initiate the change to the bid quantity in the market participant interface and apply the appropriate reason code 2. Remove offer: Under the procedure of Market Manual 4.2, this should be preceded by submitting an outage request into the outage management system to reflect actual capability as long as derating does not last more than two hours. **Authority and market manual reference:** • IESO Market Manual 4.2, appendix B **No:** IESO Market Manual 4.2 outlines a wide range of circumstances that might trigger a change to dispatch data, beyond a state-of- charge limitation. Some of these

Decision point	Potential outcomes
	changes may be initiated by the market participant, and in other circumstances, by the IESO. Please see Market Manual 4.2, appendix B. Any such circumstances not referenced in this design document shall be governed by the market manual provisions pertaining to the storage facility's underlying dispatchable load resource or for the dispatchable generation resource, as the case may be. **Authority and market manual reference:** • IESO Market Manual 4.2 - various sections

Mechanics of effecting changes to dispatch data

Within the mandatory window, and using the Table 19 decision tree, each energy storage facility will adhere to the protocol set out for dispatch data changes in Market Manual 4.2. For greater certainty, this design feature does not affect the timelines and procedures for the:

- Submission of standing schedules
- Conversion of standing schedules to daily dispatch data at 6:00 a.m. on the pre-dispatch day

When submitting changes to dispatch data within the mandatory window, per the above decision table, market participants should:

[NOTE TO DRAFT – TO BE DETERMINED BY IESO – ONE OF THE OPTIONS BELOW:]

- Select the appropriate reason code, SoC designating state of charge as the cause of the required change. The use of this code will negate the need to call the IESO Control Room in order to request a bid offer change.
- Enter an outage or derating into the IESO outage management tool for the dispatchable load and/or dispatchable generator resource constituting the energy storage facility facing the state-of-charge limitation.

(See also, section 1.9)

2.7.8. Design feature SoC 2 rationale

The recommended design approach for this interim design feature addresses the Energy Storage Design Project principles discussed in section 1.8 as follows.

1. Realizing increased reliability, efficiency and competition

Design feature SoC 2generally enables energy storage participation in the RT energy market as a dispatchable energy storage facility. By doing so, it will bring better market depth and liquidity for real-time energy trading from energy storage resources. This may be particularly valuable during the interim period, should energy storage resources become a fast-growing segment of the wholesale market before the IESO can put a permanent state-of-charge framework in place.

The SoC 2 design feature specifically helps to ensure reliability by allowing energy storage facilities to declare a state-of-charge limitation during the mandatory window and effect changes to dispatch data or the use of dispatch data by the IESO's dispatch scheduling and optimization algorithm. This effectively achieves a similar result to the DSO having a state-of-charge limit within the algorithm itself.

2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

The SoC 2 rules for dispatch data changes within the Mandatory window effectively create a self-managed state-of-charge construct with similar aims and purposes as those now being employed in some U.S. wholesale markets. Once the IESO has implemented a long-term state-of-charge management framework, the IESO's DSO algorithm will be automatically able to make this determination by the minimum/maximum power levels or SoC limits submitted by the market participants. SoC 2 can then be seamlessly supplanted by the long-term framework with little change impact, other than more convenience for market participants to more accurately signal their state-of-charge to the DSO algorithm.

3. Maximize the chances of timely implementation

The SoC 2 design feature can initially be implemented as a manual process, but would benefit from an automatic approval process for dispatch data changes. The IESO is currently investigating options in that regard. This method of bidding/offering can be deployed immediately following the necessary changes to IESO Market Rules and market manuals through the IESO's baseline management process.

2.7.9. Design features SoC 1 and SoC 2 – summary of inputs, outputs and processing

Figure 18 - Summary of design features of SoC1 and SoC2

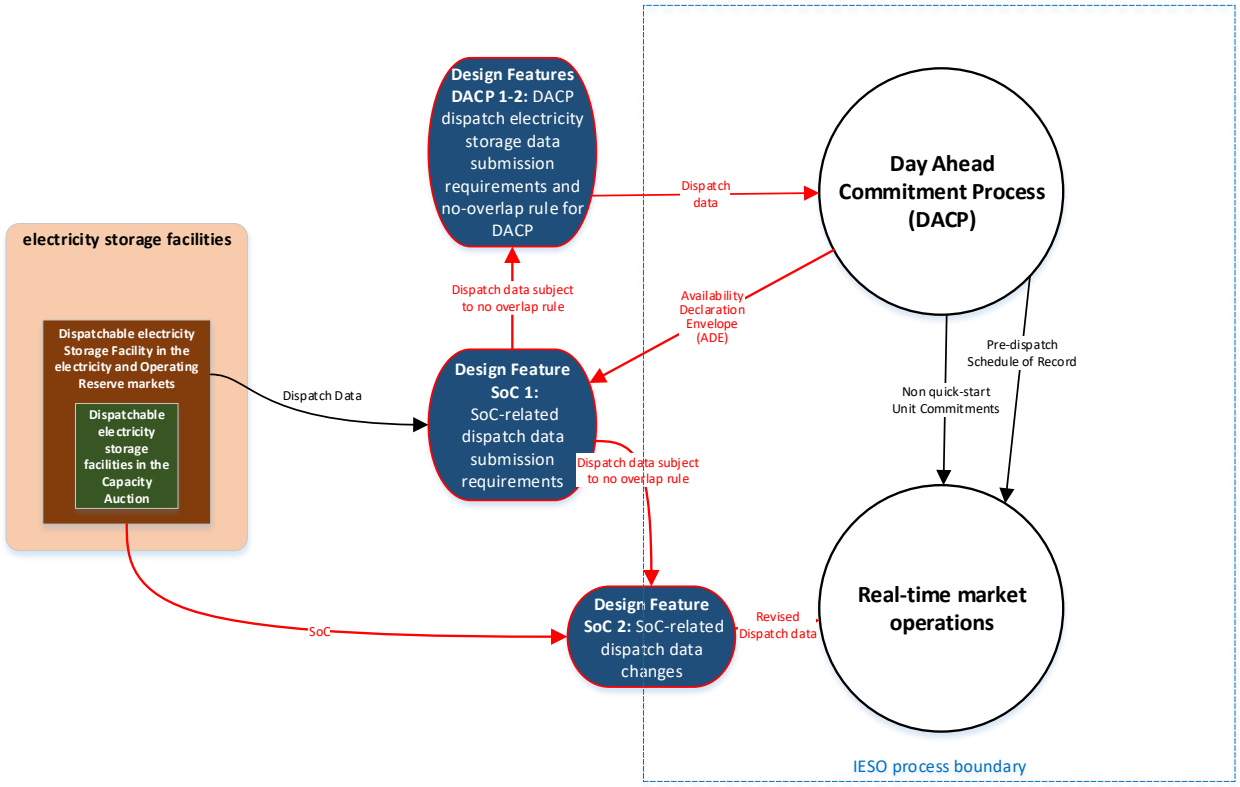


Table 18 - Design features of SoC1 and SoC2 inputs, outputs and processing

Design feature	Major process area	Requisite inputs	Processing	Outputs
SoC 1	Affects dispatch data inputs into DACP and RT market	1. DACP dispatch data 2. Real-time dispatch data 3. DACP availability declaration envelope (ADE)	Apply 'no overlap rule' to dispatch data for dispatchable facilities in the DACP and RT markets	Dispatch data adhering to no-overlap rule for use in the following design features: SoC 2 DACP 2
SoC 2	Affects dispatch data inputs into real-time market	4. Dispatch data from SoC 1 conforming to the no-overlap rule 5. Current state of charge (SoC)	Apply decision tree for dispatch data changes in the mandatory window	[TBD] Outage and derate information for use by IESO Changes to real-time bid and/or offer quantities due to SoC limitations

2.8. Real-time energy and operating reserve markets – bidding and scheduling of ESRs

Design element	Design question
RT energy and operating reserve markets: bidding and scheduling of ESRs	What guidelines or restrictions should be placed on ESRs providing operating reserve?

2.8.1. Design issue overview

In the absence of a SoC management construct, dispatchable energy storage facilities will need sufficient guidance to ensure they can meet the essential market rule requirements for providing operating reserve. The IESO does not have the authority to lower the quality of operating reserve in order to allow energy storage participation. This creates two challenges to be overcome:

3. The energy storage facility market participant will need to ensure that the dispatchable load resource and dispatchable generation resource comprising the energy storage facility are never scheduled or activated for operating reserve at the same time.
4. The energy storage facility market participant will need to ensure that the provision of operating reserve meets the market rules-prescribed minimum standard of at least one hour after activation under any possible scenario of activation from 0 to 59 minutes into each dispatch hour.

The guidance under the three design features described in this section is directly aimed at overcoming these two challenges.

2.8.2. Applicability of these design features

The design features outlined in this section are applicable to:

- **Dispatchable energy storage facilities** in the RT energy market, which may be authorized and registered to provide operating reserve
- **Dispatchable energy storage facilities participating in the capacity auction** – which may be authorized and registered to provide operating reserve. However, this [this what?] is subject to meeting all applicable obligations stemming from the Capacity Auction, which may preclude the provision of operating reserve during certain delivery hours if that affects delivered capacity.

The design features will be deployed as a series of restrictions on the submission of operating reserve offers from the dispatchable generator resource or dispatchable load resource comprising a dispatchable storage facility. The above facilities will be subject to all existing market rules regarding the provision of operating reserve and subject to the same penalties and sanctions that other types of facilities are subject to. Of particular importance in that regard is that the IESO will continue to reserve the right afforded to it under the market rules to disqualify any registered facility from providing operating reserve that fails to provide the necessary service.

From IESO Market Rules, chapter 7, section 7.5.9:

7.5.9 In addition to any other sanction or consequence provided for in these market rules, the IESO may disqualify from future participation in the operating reserve market any registered facilities that consistently fail to produce energy when called upon in accordance with chapter 7.

2.8.3. Design features in summary

The remainder of this section will discuss the following design features in detail.

Design feature O.R. 1 – no simultaneous offers of operating reserve from the two resources comprising a dispatchable energy storage facility

This design feature recognizes the practical reality that a dispatchable energy storage facility is in fact a single facility and that the two underlying load and generation resources cannot provide operating reserve at the same moment in time. They can however, provide operating reserve at separate, non-overlapping times that are further detailed in this design feature.

Design feature O.R. 2 – operating reserve requirements specific to a dispatchable load resource comprising a dispatchable energy storage facility

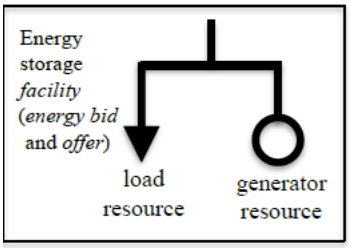
Under this design feature the dispatchable load resource comprising a dispatchable energy storage facility must have at least 70 minutes of remaining state-of-charge to withdraw energy over the remaining 10 minutes of the mandatory window and the ensuing dispatch hour. This will ensure that the facility can provide loading relief at any time during the ensuing dispatch hour, if called upon to provide operating reserve (see example below).

Design feature O.R. 3 – operating reserve requirements specific to a dispatchable generator resource comprising a dispatchable energy storage facility

Under this design feature the dispatchable generator resource comprising a dispatchable energy storage facility must have at least 130 minutes of remaining state-of-charge to withdraw energy over the remaining 10 minutes of the mandatory window, the ensuing dispatch hour and the

additional dispatch hour that follows. This will ensure that the facility can provide energy for at least one hour at any time during the ensuing dispatch hour and into the subsequent dispatch hour, if called upon to provide operating reserve (see example below).

2.8.4. Design feature O.R. 1 – no simultaneous offers of operating reserve from the two resources comprising a dispatchable electricity storage facility



To avoid a dispatch that conflicts with the operating reserve activation, no operating reserve may be offered by the energy storage facility if that facility has a simultaneous bid and offer in the energy market in a particular dispatch hour. If one of the resources were activated for operating reserve in the last two dispatch intervals of the dispatch hour, it would not be possible to change or remove the bid or offer for the next dispatch hour, a necessary action to avoid a dispatch that conflicts with the operating reserve activation.

2.8.5. Design feature O.R. 1 rationale

The recommended design approach for this interim design feature addresses the Energy Storage Design Project principles discussed in section 1.8 as follows.

1. Realizing increased reliability, efficiency and competition

This design feature generally enables energy storage participation in the real-time operating reserve market as a dispatchable energy storage facility. By doing so, it will bring better market depth and liquidity for real-time energy trading from energy storage resources. This may be particularly valuable during the interim period, should energy storage resources become a fast-growing segment of the wholesale market before the IESO can put a permanent state-of-charge framework in place.

The O.R. 1 design feature helps to ensure reliability by structuring energy storage bids and offers in a manner that helps prevent the IESO's dispatch scheduling and optimization (DSO) algorithm from simultaneously scheduling the load and generation resources that comprise a dispatchable energy storage facility for operating reserve.

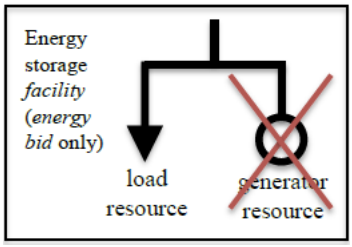
2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

This design feature will enable a temporary mechanism for energy storage features to participate in the operating reserve market. This serves a similar objective of FERC Order 841 to provide equal access to all wholesale market product categories for energy storage facilities. This mechanism effectively implements a self-managed state-of-charge construct for operating reserve to be used during the interim period, until the long-term state-of-change management framework is put in place.

3. Maximize the chances of timely implementation

The O.R. 1 design feature does not require a tool change in order to implemented. Any violations of this rule will be treated as a compliance matter given the importance of operating reserve for the reliability of the IESO-controlled grid. This requirement may be deployed by the necessary changes to IESO Market Rules and Market Manuals through the IESO's baseline management process.

2.8.6. Design feature O.R. 2 – operating reserve requirements specific to a dispatchable load resource comprising a dispatchable electricity storage facility



1. The energy storage facility **load resource** may only offer operating reserve if:
    - The facility exclusively operates as a dispatchable load for the entire dispatch hour; and
    - The facility will exclusively operate as a dispatchable load in the next dispatch hour; and
    - The remaining duration of service to full state of charge is greater than or equal to 70 minutes at the end of the mandatory window (minute 50) for the dispatch hour. This may be determined by the current state-of- charge (SoC) of the facility, and the facility's energy withdrawal rate (in MW) implied by the operating reserve offer quantity. This measure ensures that in a worst-case scenario, when the facility is

activated for operating reserve in minute 59 of the dispatch hour, it will have adequate duration of service to provide loading relief for operating reserve for the next dispatch hour. Under this scenario 70 minutes includes the remaining 10 minutes of the mandatory window and the dispatch hour in which the facility was scheduled and activated to provide operating reserve.

2.8.7. Design feature O.R. 2 rationale

The recommended design approach for this interim design feature addresses the Energy Storage Design Project principles discussed in section 1.8 as follows.

1. Realizing increased reliability, efficiency and competition

Design feature O.R. 2 safeguards the integrity of operating reserve by ensuring that no dispatchable energy storage facility can offer operating reserve from the load resource comprising that facility unless it has at least a 70-minute state of charge. Under the IESO's compliance NERC standards, it must ensure that overall operating reserve requirements are met for the Ontario balancing area, and that operating reserve will provide assurance that the IESO can recover from a contingency event within stipulated timeframes.

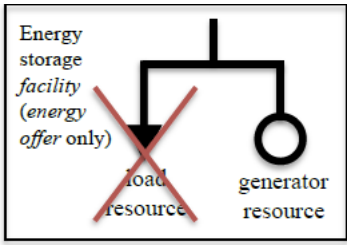
2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

This design feature will enable a temporary mechanism for energy storage features to participate in the operating reserve market. This serves a similar objective of FERC Order 841 to provide equal access to all wholesale market product categories for energy storage facilities. This mechanism effectively implements a self-managed state-of-charge construct for operating reserve to be used during the interim period, until the long-term state-of-change management framework is put in place.

3. Maximize the chances of timely implementation:

The O.R. 2 design feature does not require a tool change in order to be implemented. Any violations of this rule will be treated as a compliance matter given the importance of operating reserve for the reliability of the IESO-controlled grid. The IESO will be able to monitor and assess compliance with this rule by virtue of the state-of-charge data and operating reserve offers provided by energy storage facilities. This requirement can be deployed by the necessary changes to IESO Market Rules and market manuals through the IESO's baseline management process.

2.8.8. Design feature O.R. 3 – operating reserve requirements specific to a dispatchable generator resource comprising a dispatchable electricity storage facility



- The energy storage facility generator resource may only offer operating reserve if:
- The facility exclusively operates as a dispatchable generator for the entire dispatch hour; and
- The facility will exclusively operate as a dispatchable generator in the next dispatch hour; and
- The remaining duration of service until the storage facility is depleted of energy is greater than or equal to 130 minutes at minute 50 of the dispatch hour. This may be determined by the current state of charge (SoC) of the facility, and the facility's energy injection rate (in MW) implied by the operating reserve offer quantity. This measure ensures that in a worst-case scenario, when the facility is activated for operating reserve in minute 59 of the dispatch hour, it will have adequate duration of service to provide energy for operating reserve for the next dispatch hour.

Under this scenario 130 minutes includes: the remaining 10 minutes of the mandatory window, the dispatch hour in which the facility was scheduled and activated to provide operating reserve, and the following dispatch hour in which the facility must provide energy due to operating reserve activation for at least one hour.

2.8.9. Design feature O.R. 3 rationale

The recommended design approach for this interim design feature addresses the Energy Storage Design Project principles discussed in section 1.8 as follows.

1. Realizing increased reliability, efficiency and competition

Design feature O.R. 3 safeguards the integrity of operating reserve by ensuring that no dispatchable energy storage facility can offer operating reserve form the generation resource comprising that facility unless it has at least a 130-minute state-of-charge. Under the IESO's compliance NERC standards, it must ensure that overall operating reserve requirements are met

for the Ontario balancing area, and that operating reserve will provide assurance that the IESO can recover from a contingency event within stipulated timeframes

2. Building on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

This design feature will allow a temporary mechanism for energy storage features to participate in the operating reserve market. This serves a similar objective of FERC Order 841 to provide equal access to all wholesale market product categories for energy storage facilities. The mechanism effectively implements a self-managed state-of-charge construct for operating reserve to be used during the interim period, until the long-term state-of-change management framework is put in place.

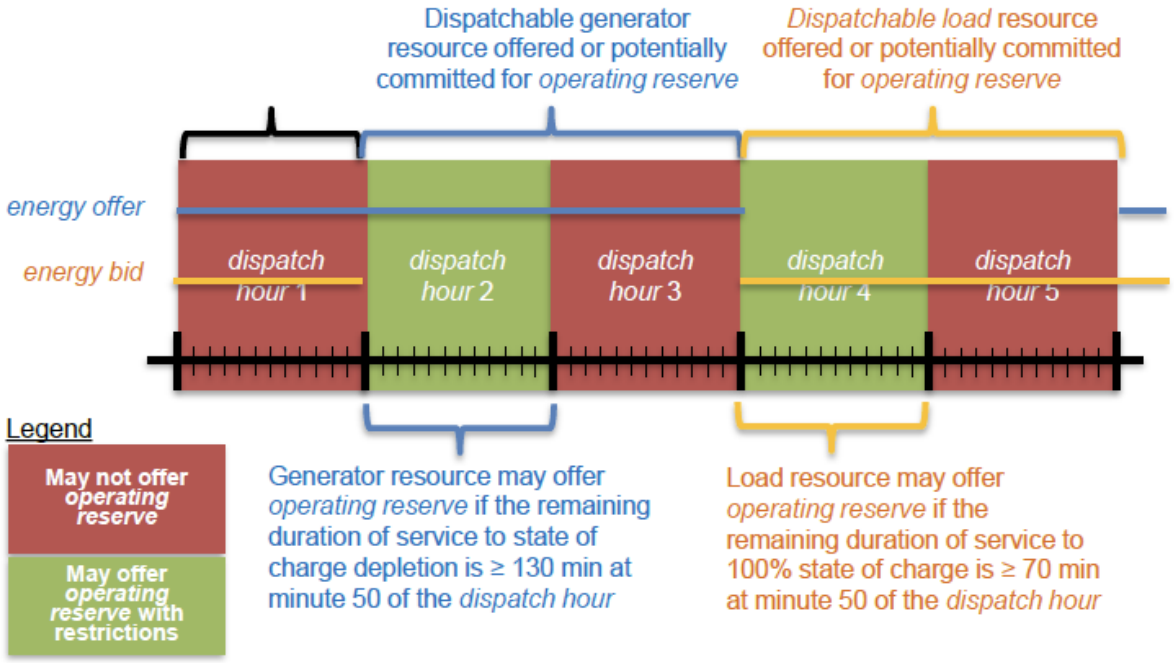
3. Maximize the chances of timely implementation

The O.R. 3 design feature does not require a tool change in order to implemented. Any violations of this rule will be treated as a compliance matter given the importance of operating reserve for the reliability of the IESO-controlled grid. The IESO will be able to monitor and assess compliance with this rule by virtue of the state-of-charge data and operating reserve offers provided by energy storage facilities. This requirement may be deployed by the necessary changes to IESO Market Rules and Market Manuals through the IESO's baseline management process.

2.8.10. Explanation and example

The example below illustrates an energy storage facility operating scenario. In dispatch hours 1, 2 and 3, the facility has an offer in the energy market, and in hours 1, 4 and 5 the facility has a bid in the energy market. In this example below, suppose that the generator resource is activated for operating reserve in the last dispatch interval of the second dispatch hour. As per the Market Rules, chapter 5, appendix 5.1, section 1.2, the facility is required to meet its obligation of having the capability to inject energy for at least one hour when activated for operating reserve. To meet this obligation, the facility must also act as a dispatchable generator in the third dispatch hour. The facility cannot have a bid in the energy market in the third dispatch hour because it cannot simultaneously follow a generator dispatch and a load dispatch in the third dispatch hour.

Figure 19 - Example of allowable bids and offers from the dispatchable load resource and dispatchable generation resource comprising the energy storage facility



Examples – Minimum duration of service requirements explained

Rationale for the 130 minutes minimum duration of service requirement for the generator resource

Consider an example where the generator resource receives an operating reserve activation in minute 59 of the second dispatch hour. The facility is obligated to have the capability to provide energy for one hour after being activated for operating reserve. Also, for the second dispatch hour, the dispatch data must be submitted 10 minutes before the dispatch hour (i.e., before minute 50 of the first dispatch hour). Therefore, it is possible that the facility is dispatched to generate power at the end of the mandatory window (from minute 50) of the first dispatch hour to minute 59 of the third dispatch hour, which is 130 minutes.

Rationale for the 70 minutes minimum duration of service requirement for the load resource

Consider an example where the load resource receives an operating reserve activation in minute 59 of the fourth dispatch hour. The facility shall turn off for the next hour to comply with the operating reserve activation. Therefore, it is possible that the facility is dispatched to consume

power at the end of the mandatory window (from minute 50) of the third dispatch hour to minute 59 of the fourth dispatch hour, which is 70 minutes.

2.8.11. Design features O.R. 1, O.R. 2 and O.R. 3 – summary of inputs, outputs and processing

Figure 20 - Summary of design features O.R. 1, O.R. 2 and O.R. 3

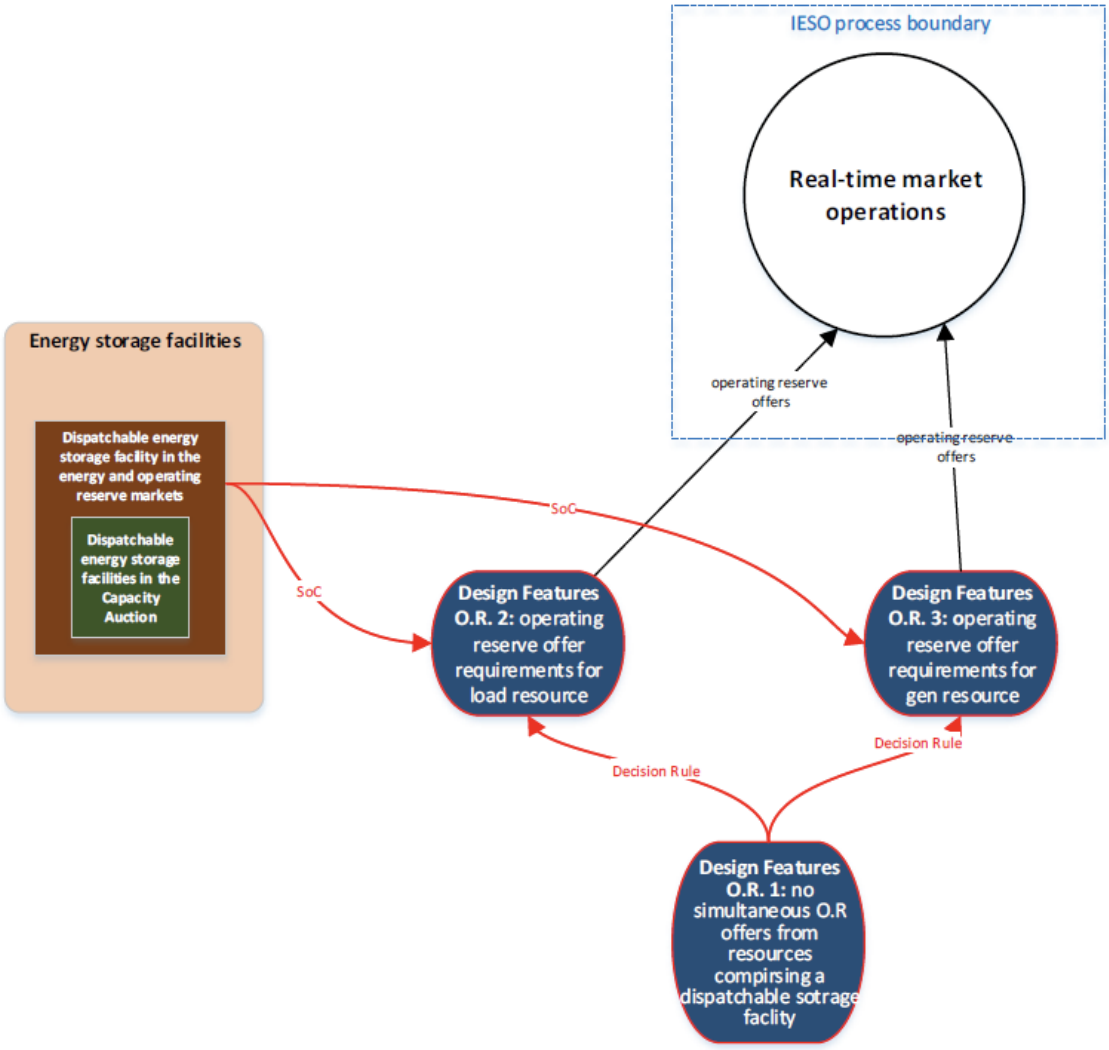


Table 19 - Design features O.R. 1, O.R. 2 and O.R. 3 inputs, outputs and processing

Design feature	Major process area	Requisite inputs	Processing	Outputs
O.R. 1	Affects dispatch data inputs into real-time market	Current state of charge (SoC) of energy storage facility as indicated by telemetered data Energy bids from dispatchable load resources that comprise a dispatchable energy storage facility Energy offers from dispatchable generation resources that comprise a dispatchable energy storage facility Operating reserve offers from dispatchable generation resources or dispatchable load resources that comprise a dispatchable energy storage facility	Ensure no simultaneous O.R. offers from both resources comprising a dispatchable energy storage facility	Operating reserve offers into the real-time market adhering to the decision rules set out in O.R. 1, O.R. 2 and O.R. 3
O.R. 2	Affects dispatch data inputs into	Current state of charge (SoC) of energy storage	Calculate remaining duration of service using	Operating reserve offers into the real-

Design feature	Major process area	Requisite inputs	Processing	Outputs
	real-time market	facility as indicated by telemetered data Energy bids from dispatchable load resources that comprise a dispatchable energy storage facility Energy offers from dispatchable generation resources that comprise a dispatchable energy storage facility Operating reserve offers from dispatchable generation resources or dispatchable load resources that comprise a dispatchable energy storage facility	SoC telemetered value, and maximum withdrawal rate implied by operating reserve offer Ensure minimum SoC rules for dispatchable load component of energy storage facility are adhered to	time market adhering to the decision rules set out in O.R. 1, O.R. 2 and O.R. 3
O.R. 3	Affects dispatch data inputs into real-time market	Current state of charge (SoC) of energy storage facility as indicated by telemetered data Energy bids from dispatchable load resources that	Calculate remaining duration of service using SoC telemetered value, and maximum injection rate implied by	Operating reserve offers into the real-time market adhering to the decision rules set out in O.R. 1,

Design feature	Major process area	Requisite inputs	Processing	Outputs
		comprise a dispatchable energy storage facility Energy offers from dispatchable generation resources that comprise a dispatchable energy storage facility Operating reserve offers from dispatchable generation resources or dispatchable load resources that comprise a dispatchable energy storage facility	operating reserve offer Ensure minimum SoC rules for the dispatchable generation component of energy storage facility are adhered to	O.R. 2 and O.R. 3

3. Long-term Implementation

3.1. Design elements and questions addressed in this chapter

NOTE TO READER: In a future edition of this document, this chapter will address design measures for the following design elements and questions.

Design element	**Design questions**
1. State-of-charge (SoC) management in RT energy market	1.1 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. Day-ahead market (DAM) and day-ahead commitment process (DACP): bidding and scheduling of ESRs	2.1 Who should optimize SoC of ESRs in the DAM: the ESR, system operator, or give ESRs the choice?
3. RT energy and operating reserve markets: bidding and scheduling of ESRs	3.1 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?
4. Ability of ESRs to set market- clearing price in the energy and operating reserve markets	4.1 Should ESRs be able to set the market-clearing price?
5. Regulation service	5.1 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?
6. Settlement and charges	6.1 Under what conditions should uplift charges stipulated by the IESO Market Rules be credited back to an ESR for energy it injected into the grid? 6.2 For settlement purposes and the application of charges, how would the IESO track whether an ESR is using the energy it

Design element	Design questions
	withdraws for participation in the regulation, energy, operating reserve market, losses or some other use?
7. Market and facility registration	7.1 How should an energy storage facility be registered into the IAMs?

Appendix A - Glossary of storage-related terms

Items highlighted in orange are relevant to long-term design measures only.

Table A -20 - 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. Certified quantities are determined during testing. $\text{Certified Duration of Service} = \frac{\text{Upper Energy Limit} - \text{Lower Energy Limit}}{P_{max}} = \frac{\text{Upper SOCMAX}_y - \text{SOCMIN}_y}{P_{max}}$	Registration Data

Term	Symbol or acronym (if applicable)	Units of measure (if applicable)	Description	Source
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 State of Charge	$ECO\_SO_{max,g}$	MWh	The dynamic, current maximum state of charge that is indicated by the market participant subject to the following constraint: $ECOSOC_{min,g}$	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
Economic Minimum State of Charge	$ECO\_SOC_{min,g}$	MWh	The dynamic, current minimum state of charge that is indicated by the market participant	Telemetered value

Term	Symbol or acronym (if applicable)	Units of measure (if applicable)	Description	Source
			subject to the following constraint: $ECOSOC_{min,g}$	
Full Power Operating Mode	$P_{max,g}$	MW	The maximum active power output for operation	Registration Data
Low Power Operating Mode	$P_{min,g}$	MW	The minimum active power output for operation	Registration Data
Lower Energy Limit	$SOC_{min,g}$	MW	The lowest certified State of Charge to which the energy storage system can be consistently discharged without damage beyond expected degradation from normal use.	Registration Data
Operating Reserve Ramp Rate	OperatingReserve $RampRate_g$	MW per minute	**From Market Rules, Appendix 7:** The single operating reserve ramp rate in MW per minute associated with g∈OFFERS.	Dispatch Data
Ramp Rate Down for dispatchable	$RampRate_{DOWN\ gJ}$	MW per minute	**From Market Rules, Appendix 7:**	Dispatch Data

Term	Symbol or acronym (if applicable)	Units of measure (if applicable)	Description	Source
generation resources			The energy ramping down rate in MW per minute associated with the jth block of GENERATIONRAMPDOWNBLOCKg for g∈OFFERS	
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 PURCHASERAMPDOWNBLOCKp for p∈BIDS	Dispatch Data
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 GENERATIONRAMPUPBLOCKg 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	Dispatch Data

Term	Symbol or acronym (if applicable)	Units of measure (if applicable)	Description	Source
			associated with the jth block of PURCHASERAMPUPBLOCKpp∈BIDS	
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 the present active power level	Derived from telemetered and registration data
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	Telemetered value

Term	Symbol or acronym (if applicable)	Units of measure (if applicable)	Description	Source
			energy storage capacity of the system	
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 - Related IESO Market Manuals

Note: This will be completed in a future edition of this document

Appendix C - Prudential Support Obligation example

(For illustrative purposes only)

Core assumptions for the examples in this appendix

Energy storage facility maximum state of charge capacity (SOCMAXg): 100 MWh

Energy storage facility full power operating mode (Pmax,g): 50 MW

Registered cycle efficiency (CycleEfficiencyg): 80%

Assumed number of daily charging cycles for prudential purposes: 3 cycles per day

Example: minimum trading limit calculation

100 MWh energy storage resource MINIMUM TRADING LIMIT	
Total daily net energy consumption	
= Estimated # of daily charging cycles × (1 - CycleEfficiency) × SOCMAX	
= 3 × (1 - 0.8) × 100 MWh	60 MWh/day
Energy exposure	
60 MWh/day × $126.37/MWh × 7 days	$53,075
Transmission exposure[12]	
NETWORK: 5 MW × $3.83/kW/month[13]	$19,150
TRANSFORMATION CONNECTION: 5 MW × $2.30/kW/month	$11,500
LINE CONNECTION: 5 MW x $0.96/kW/month	$4,800
Rural and remote settlement	

[12] Subject to prevailing transmission rates set by the Ontario Energy Board
[13] Note: the 5 MW peak use here is an assumed coincident peak demand. The storage facility may have a higher energy demand value up to 50 MW at various times during the month

100 MWh energy storage resource MINIMUM TRADING LIMIT	
$0.5/MWh × 60 MWh/day × 7 days	$210
IESO fee[14]	
$1.2402/MWh × 60 MWh/day × 7 days	$521
Uplift and ancillary services	
$4.20/MWh × 60 MWh/day × 7 days	$1,764
Subtotal	$91,020
13% (applicable taxes)	$11,833
Minimum trading limit	**= $102,853**

Note that if a market participant's actual exposure equals or exceeds their trading limit, the IESO will issue a margin call requiring the affected market participant to bring their actual exposure back within acceptable limits. While the above example assumes seven billing days, it can go up to as much as 49 days – this period takes into account the IESO's 30-day billing period, 15-day invoicing period, 2-day remittance period and 2-day review period.

[14] Subject to prevailing transmission rates set by the Ontario Energy Board

Example: default protection amount calculation

100 MWh energy storage resource DEFAULT PROTECTION AMOUNT	
Total daily energy consumption	
= Estimated # of daily charging cycles × (1 - Cycle Efficiency) × SOCMAX	
= 3 × (1 - 0.8) × 100 MWh	60 MWh/day
Energy exposure	
60 MWh/day × $126.37/MWh × 21 days	$159,226
Transmission exposure[15]	
NETWORK: 5 MW × $3.83/kW/month	$19,150
TRANSFORMATION CONNECTION: 5 MW × $2.30/kW/month	$11,500
LINE CONNECTION: 5 MW * $0.96/kW/month	$4,800
Rural and remote settlement	
$0.5/MWh × 60 MWh/day × 21 days	$630
IESO fee[16]	
$1.2402/MWh × 60 MWh/day × 21 days	$1,563
Uplift and ancillary services	
$4.20/MWh × 60 MWh/day × 21 days	$5,292
Subtotal	$202,161

[15] Subject to prevailing transmission rates set by the Ontario Energy Board
[16] Subject to prevailing transmission rates set by the Ontario Energy Board

100 MWh energy storage resource DEFAULT PROTECTION AMOUNT	
13% (applicable taxes)	$26,281
Default protection amount	**= $228,442**

Example: total prudential support obligation

100 MWh energy storage resource TOTAL PRUDENTIAL SUPPORT OBLIGATION	
Maximum net exposure	= minimum trading limit + default protection amount
	= $102,853 + $228,442
	= $331,295
Allowable reductions*	=$0
Total prudential support obligation	**= $331,295**
*Reductions can be earned through a credit rating above BB- or a good payment history for two years or more in the IAMs.	