

# IESO Report: Energy Storage

March 2016

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# Executive Summary

The Minister of Energy issued a letter to the IESO on April 22, 2015, requesting that: “The IESO should review the outcomes of the 50 MW energy storage procurement and incorporate resulting learnings, along with any other relevant analyses or new knowledge, into a March 1, 2016, report back to the Ministry of Energy on options for integration of energy storage into Ontario’s electricity market and market based procurements, as deemed appropriate based on system need.”

Subsequently, on May 1, 2015, the Minister informed Energy Storage Ontario (ESO) that: “The IESO will work with ESO and other stakeholders as necessary to develop a scope and focus of a bulk system storage study.”

In response to the Minister’s letters, the IESO consulted with ESO to understand the current status of energy storage technologies and to receive feedback on the scope of the IESO study.

This energy storage report presents the IESO’s response to the Minister’s requests and includes lessons from past IESO procurements of energy storage and presents potential opportunities and challenges for energy storage providers. More specifically, it identifies the operational and reliability system needs brought about by changes to the generation mix over the next few years and the potential for energy storage technologies to address those needs.



## Key Findings

1. Energy storage facilities can provide a wide range of services needed to reliably operate the power system in Ontario including: regulation, voltage control, operating reserve, and flexibility. However, energy storage is not the only option for providing these services.
  - To enable energy storage to provide these services, the facilities must be appropriately sized and located in those areas of the system where they can provide these services without restrictions or limitations.
  - This study did not assess whether or not energy storage was the most economic option for providing these services. However, based on recent procurement experience, it is expected that energy storage might be able to provide regulation services at a cost that is comparable to the cost of traditional providers (e.g. hydroelectric generators).

2. Up to the early 2020s, energy storage technologies that withdraw surplus electrical energy from the grid and later re-inject that energy back into the grid can be used to manage some surplus baseload generation (SBG). However, there would be limited benefit in using energy storage technologies that store energy for only a short time period (i.e. days). There are greater opportunities for energy storage technologies that are capable of storing energy for longer periods of time (i.e., months).

In this same timeframe, energy storage technologies that only withdraw electricity from the grid, like other loads, but store it for use in an industrial, commercial or residential process or to displace a secondary form of energy (e.g. electric vehicles) would be more effective at managing SBG conditions.

Beyond this timeframe, the opportunity for storage to manage SBG depends on a number of dynamic factors including: electricity demand, weather, value of carbon, consumer behaviour, and planned nuclear refurbishment and outage timelines.

3. Future procurements are expected to return better value if they target specific services (i.e., regulation, voltage control and capacity) instead of specific technologies. Although energy storage can provide many services needed to reliably operate the power system, storage isn't the only option for meeting those needs. Ultimately, the best option for meeting a specific need should be determined through a procurement that targets the need and allows multiple technologies to compete.

## **Lessons Learned from the IESO Procurements**

While the IESO has significant experience with hydroelectric-based energy storage, the energy storage technologies brought online through the (2012) Alternate Technologies for Regulation (ATR) procurement are still new and provide learning opportunities for both the IESO and their providers. The two phases of the energy storage procurement emanating from the 2013 Long-Term Energy Plan are now complete; however, the first of those projects is not expected online until Q3 2016.

Important lessons learned to this point are:

- When deploying a new energy storage facility, potential limitations imposed by the transmission system around its connection point, for all modes of expected operation, must be considered to determine the availability of services and to select and properly size the technology.
- Procurements that target specific services (such as the ATR procurement) generally return better value (technical performance and diversity) than procurements that target specific technologies. This is because procurements that target specific services enable a variety of technologies to compete to provide that service, allowing the selection of the most effective and economic solutions.
- Properly sized and located fast-acting energy storage technologies can effectively provide regulation, as long as they complement a portfolio that includes traditional regulation technologies that are not energy limited.

- The losses incurred when converting energy from one form to another and energy losses from storage (e.g., leakage, diffusion) are important aspects to be taken into account when selecting energy storage technologies to provide specific services. For example, technologies with relatively higher conversion losses could be helpful in managing SBG, while they may be potentially wasteful when providing regulation.

Energy storage technologies that are capable of providing multiple services are more likely to become economically viable, as presented in the [DOE Grid Energy Storage](#) report - December 2013 and [DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA](#).

It is recommended that energy storage providers seeking to connect facilities to the IESO-controlled grid target those areas of the province where they can provide multiple services to the IESO-controlled grid, the IESO-administered markets and local market participants.

## Opportunities for Energy Storage in Ontario

Based on how they interact with the electricity system, we classified energy storage technologies as follows:

- **Type 1** – Energy storage technologies that are capable of withdrawing electrical energy (electricity) from the grid, storing such energy for a period of time and then re-injecting this energy back into the grid (minus reasonable losses). Examples include, but are not limited to, flywheels, batteries, compressed air and pumped hydroelectric.
- **Type 2** – Energy storage technologies that withdraw electricity from the grid and store the energy for a period of time. However, instead of injecting it back into the grid, they use the stored energy to displace electricity consumption (demand) of their host facility at a later time. Examples include, but are not limited to, heat storage or ice production for space heating or cooling.
- **Type 3** – Energy storage technologies that only withdraw electricity from the grid like other loads but convert it into a storable form of energy or fuel that is subsequently used in an industrial, commercial or residential process or to displace a secondary form of energy. They're generally integrated with a host process that uses that secondary form of energy directly or are connected to a transmission or distribution network for their secondary form of energy (e.g., natural gas, steam or coolant). Examples include, but are not limited to, fuel production (hydrogen or methane), steam production and electric vehicles.



This classification is important to understand the opportunities available for different energy storage technologies to provide services in Ontario.

1. **Are there opportunities for energy time-shift?** Up to the early 2020s, there are opportunities to shift energy using energy storage technologies that withdraw primarily carbon-free surplus electrical energy from the grid and later re-inject that energy back into the grid (Type 1) or displace electricity consumption (Type 2). For energy storage technologies that store energy for a short time period (say, days to complete a storage cycle<sup>1</sup>), these opportunities are expected to be limited because while there is an opportunity to withdraw energy, it would be difficult to inject/displace it given limited non-SBG periods.

The opportunities increase for energy storage technologies that store energy for a longer time period (weeks or months to complete a storage cycle) – say, from the fall to the winter. For storage technologies with longer storage cycles, there would be an opportunity to mitigate, approximately, 25% of the expected annual SBG; however, a longer storage cycle requires more capability to store the energy, which may be costly.

2. **Are there opportunities for energy storage devices that convert electricity absorbed from the grid into a different storable form of energy or fuel?** Up to the early 2020s, we expect to continue to see sustained periods of SBG. Some energy storage technologies withdraw electrical energy from the grid and convert it to another form (Type 3). These energy storage technologies appear strictly as a load to the electricity system and can be used effectively during periods of SBG when it is easy to withdraw energy from the grid.
3. **Are there opportunities to address system needs?** Energy storage can help address the following system needs; however, there may be other technologies that can also help meet these needs. The Energy Storage Report does not attempt to determine the most effective or economic technology option:
  - **Are there opportunities to provide regulation?** Regulation is the ancillary service required to control power system frequency and maintain the balance between load and generation on a second-by-second basis. Key inputs into the IESO's five-minute dispatch decisions include the Ontario electricity demand forecast and the forecast of the output from the wind and solar generators (also collectively known as "variable generators"). Errors in these forecasts, as well as other anomalies, are compensated for by the regulation service<sup>2</sup>. While the accuracy of our forecasts is consistent with industry norms, the increase in size of the variable generation (VG) fleet and a more engaged consumer base is expected to result in a larger forecast uncertainty, which is likely to increase the amount of regulation service required. Properly sized and located energy storage facilities can successfully meet Ontario's regulation needs in combination with technologies that traditionally provide regulation service.

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<sup>1</sup> A single storage cycle comprises withdrawing energy until the storage device is full, holding that energy, and then discharging the energy until the device is empty once again.

<sup>2</sup> The IESO contracts with a number of Ontario generators to provide regulation service. This service enables the IESO to adjust the output of specific Ontario generators on a second-by-second basis in response to instantaneous changes in the Ontario supply-demand balance.



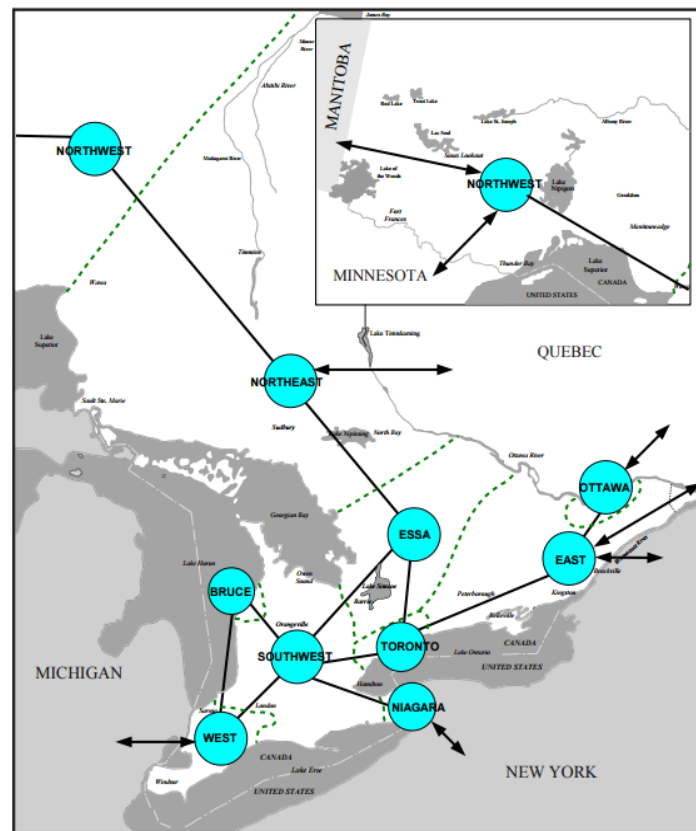
- **Is there a need for additional flexible energy supply capable of activation and delivery within a short period of time?** Over-forecasting variable generation output or under-forecasting Ontario electricity demand impacts reliability by under-committing gas generation, under-scheduling of energy imports or over-scheduling of energy exports. Since the quality of the VG forecast declines materially beyond 60 minutes out, additional flexible resources are required in Ontario that can be activated and begin energy delivery within the hour. Some energy storage technologies (typically Type 1) can provide this flexible supply if properly sized and located.
- **Are there opportunities to provide load following and ramping?** The ramping capability of the projected supply mix in the 2020 timeframe is expected to be sufficient to meet the load following and ramping needs; with a large part of the ramping capability provided by natural gas-fired generation. While Type 1 and Type 2 energy storage technologies may not be capable of fully displacing natural gas-fired generation during peak ramp periods (Ontario's ramp requirement can be as high as 9,000 MW to 10,000 MW on peak days), they can offset some of the natural-gas fired generation with a primarily carbon-free alternative.
- **Is there a need for additional operating reserve capabilities?** In the 2020 timeframe, the largest generation loss in Ontario is not expected to increase due to natural drops in variable generation production. While Northeast Power Coordinating Council's (NPCC) minimum requirement for operating reserve is based on this largest generation loss, to help manage variable generation forecast uncertainties and Ontario demand forecast anomalies, it may be necessary to carry additional 30-minute operating reserve, such as is the case today, for a variety of reasons, in ISONE and NYISO. As operating reserve is competitively procured through the IESO-administered markets, energy storage facilities that have the appropriate capability can offer both 10- and 30-minute operating reserve alongside other providers.
- **Are there opportunities to provide transmission-connected voltage control?** Additional voltage control devices are required to maintain acceptable voltage levels in the Northwest, Northeast and some parts of the Toronto, East, Southwest, West and Essa transmission zones. Transmission-connected energy storage facilities that have voltage control capability can provide voltage control services. Distribution-connected energy storage facilities that are electrically far from the transmission system are not suitable for controlling transmission voltages.
- **Can energy storage address congestion relief and defer transmission upgrades?** In Ontario's major load centers – Greater Toronto and Hamilton area (GTHA), Ottawa, Kitchener-Waterloo-Cambridge-Guelph (KWCG) – Type 1 and Type 2 energy storage technologies could alleviate transmission constraints by time-shifting energy. Specifically, they could provide this service by charging off-peak and then injecting or displacing load during peak load hours. This could help defer marginal transmission upgrade needs in these load centers.

## Locational Considerations that Limit the Ability of Energy Storage Technologies to Address System Needs

The following discussion is general in nature and applicable at the transmission zone level. **Figure 1** shows how Ontario's 10 transmission zones are connected. It should be noted that within each transmission zone, there may be local areas where a particular energy storage facility would be limited from providing certain services. This would need to be assessed on a case-by-case basis.

- The East and Southwest transmission zones are largely uncongested, with few exceptions described in the last bullet below. Energy storage facilities of all three types that are located in the non-congested areas of these zones are not expected to encounter any limitations in providing energy or ancillary services.
- The Northwest, Northeast, Bruce and Niagara transmission zones are capacity congested. Therefore, while there would be many opportunities to withdraw grid energy, there would be fewer opportunities for Type 1 and Type 2 energy storage technologies to inject or displace stored energy without aggravating congestion. These limitations may, at times, impair their ability to provide services that are required on a continuous basis, like regulation, voltage support and flexible supply, and may also affect their ability to time-shift energy. Since they act like loads, Type 3 energy storage technologies could make use of the excess generation in these zones and would be less affected when providing ancillary services.
- The West transmission zone can become congested when the local natural gas-fired generators are online or potentially during transmission outages. Any energy stored may be difficult to inject back into the system during these times. While there would be many opportunities to withdraw grid energy, opportunities for Type 1 and 2 energy storage technologies to inject or displace stored energy could be limited to those times when the natural gas-fired generators are offline or when the output of the wind is low. Since they act like loads, Type 3 energy storage technologies could make use of the excess generation in this zone.

**Figure 1: Ontario system's transmission zones**



- In the Toronto, Ottawa and Essa transmission zones, which are load congested and also in Ontario's major load centers (GTHA, KWCG), Type 3 energy storage technologies may be restricted from operating during peak hours when the transmission circuits supplying these areas are operating close to or at their capacity. These limitations may, at times, impair their ability to supply services that are required on a continuous basis, like regulation and flexible supply.

## **Application Case Studies – Regulation and Capacity**

Energy storage devices are becoming economic for providing regulation services and, in some jurisdictions, might already be. Ontario currently has 6 MW of energy storage facilities providing regulation, with another 6.79 MW expected to come online in 2017 for a total of 12.79 MW.

From experiences using energy storage for regulation across North America, there are issues associated with the energy-limited nature of these devices that need to be considered. Modifying the regulation signal being used as well as focusing on energy storage facilities with larger energy storage capacities can help to alleviate some of these issues. Both of these solutions are being pursued in jurisdictions that are actively using energy storage for regulation.

Energy storage devices are not only becoming economic for regulation, they also exhibit some performance characteristics that may not be achievable by some traditional regulation facilities; namely speed of response. IESO is actively continuing to learn more about how best to leverage these devices for regulation.

Using energy storage facilities for capacity is not a new concept; however, there are many new innovative technologies available that have not yet been used to provide this service. Using smaller, modular energy storage facilities for capacity in particular is relatively new and presents some challenges that have not yet been fully understood, such as accurately determining the effective peak capacity contribution of the asset. However, these smaller modular facilities also present some potential benefits such as being able to distribute energy over many locations directly at load centres. As energy storage costs decline, the economic viability of using energy storage for capacity is improving and may improve further if multiple services/benefit streams can be stacked along with the capacity value.

- End of Section -

# 1 Introduction

The Minister of Energy issued a letter to the IESO on April 22, 2015, requesting that: “The IESO should review the outcomes of the 50 MW energy storage procurement and incorporate resulting learnings, along with any other relevant analyses or new knowledge, into a March 1, 2016, report back to the Ministry of Energy on options for integration of energy storage into Ontario’s electricity market and market based procurements, as deemed appropriate based on system need.”

Subsequently, on May 1, 2015, the Minister informed Energy Storage Ontario (ESO) that: “The IESO will work with ESO and other stakeholders as necessary to develop a scope and focus of a bulk system storage study.”

In response to the Minister’s letters, the IESO consulted with ESO to prepare the scope of this study and understand the current status of energy storage technologies. While the IESO’s experience with hydroelectric based energy storage is vast, the fast-paced recent development of energy storage technologies is still new and continues to provide learning opportunities.

This report presents the IESO’s response to the Minister of Energy letters. It includes lessons learned from past procurements, and a description of what is needed to operate the system in the 2020 timeframe.

## 1.1 Lessons Learned from Past Procurements

The report includes a high-level summary of lessons learned from the Alternative Technologies for Regulation (ATR) procurement and from the IESO’s Grid Energy Storage Procurement Phases I and II.

## 1.2 System Needs and Opportunities for Energy Storage

Several changes are expected on the power system in the next five years. This includes the incorporation of approximately 4,800 MW of additional variable generation (VG) and 1,200 MW of new natural gas-fired generation into the supply mix, changes in load behaviour due to conservation and other demand-side initiatives and the refurbishments of Ontario nuclear generators.

Planned transmission upgrades (e.g., Clarington TS, Guelph Area Transmission Reinforcement and Leamington TS) will result in increased transfer capability thereby reducing local congestion, and as such are expected to improve the system.

An assessment was undertaken by the IESO to identify system-wide and local challenges in the 2020 timeframe. This study year was selected based on the following characteristics:

- Most planned VGs are expected to be in-service.

### Stacking Services

The more services an energy storage facility can provide, the more likely the facility will be economically viable. For example, if one storage facility was able to collect regulation revenue, as well as energy time-shifting and asset deferral benefits, this would increase the likelihood that the facility could compete with other technologies looking to provide similar services.

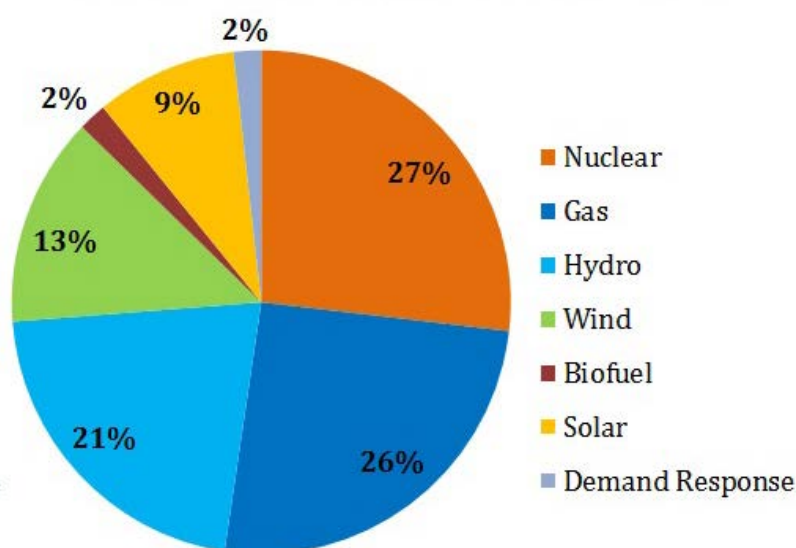
- Nuclear refurbishment sequence will have commenced.
- Provides reasonable lead time to develop solutions that may be required to address identified system needs.

The projected supply mix in Ontario in 2020 is presented in **Figure 2**.

Overall, the total installed capacity of the Ontario's generation fleet (without including demand response) is expected to increase to ~42,000 MW by 2020.

**Table 1** lists the installed transmission- and distribution-connected VG capacities that are expected to be in service in 2020:

**Figure 2: Projected installed capacity by fuel type in 2020**



**Table 1: Variable generation expected to be in service in 2020**

Category	Total (MW)	Transmission (MW)	Distribution Total (MW)	Distribution > 5 MW (MW)	Distribution < 5 MW (MW)
Solar	3,495	660	2,835	1,269	1,566
Wind	6,445	5,454	691	671	20
Total	9,940	6,114	3,526	1,940	1,586

The assessment focused on, but was not limited to, the impacts of the increased VG penetration on the following:

- Surplus baseload generation (SBG);
- Load following, ramping and dispatch flexibility;
- Regulation;
- Transmission voltage control;
- Operating reserve; and
- Zonal limitations.

The following items were out-of-scope of this study:

- Economic assessment of energy storage;
- Target energy storage quantities needed in Ontario;
- Regulatory barriers to the deployment of energy storage;

- Future contract frameworks for energy storage;
- Impact of new cap and trade policy; and
- Local and distribution system needs.

- End of Section -

## 2 Lessons Learned from Past Procurements and Energy Storage Integration

### 2.1 Summary of Procurements

#### 2.1.1 Alternative Technologies for Regulation (ATR, 2012)

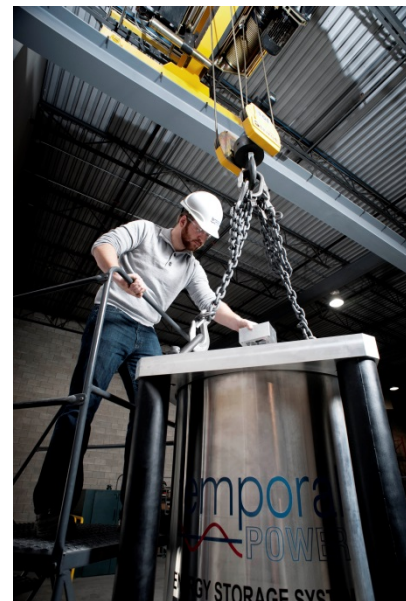
This project was designed to evaluate the ability of alternative technologies to provide regulation service relative to existing providers of regulation service in Ontario. Most of the respondents to the IESO's Request for Proposal proposed to employ energy storage technologies.

The ATR project sought technology diversity and resulted in three different technologies being selected:

- a battery facility;
- a flywheel facility; and
- a load aggregation arrangement.

All three projects have been commissioned and are currently providing the contracted regulation service.

With respect to the two energy storage facilities (a 2 MW flywheel and a 4 MW battery), both have performed very well as providers of regulation service and the IESO continues to assess their performance. As part of the contract design, the IESO has worked with each of the ATR projects to make improvements in the offered services. Consequently, the IESO has developed mutually beneficial relationships with the project proponents, enabling an exchange of knowledge and lessons learned which will lead to a better service delivery to Ontario ratepayers.



#### 2.1.2 Grid Energy Storage Procurement – Phase I (2014)

The Phase I Grid Energy Storage procurement was designed to specifically investigate the capabilities of energy storage facilities, featuring diverse technologies, to offer either or both of the following reliability services: regulation, and reactive support and voltage control (RSVC). The procurement also required that the projects be located across different electrical zones in Ontario to evaluate their effectiveness at alleviating local constraints or restrictions. Additionally, successful projects could be dispatched to explore additional bulk electricity services such as energy shifting, providing ramping support and SBC management.

Phase I received a significant amount of interest both within Ontario, nationally and internationally. Over 400 proposals were submitted in response to the Request for Proposal (RFP).

The successful proposals included the following technologies:

- Thermal energy storage;
- Stationary batteries;
- Flywheels; and
- Power-to-gas (hydrogen storage).

In Phase I of the Grid Energy Storage procurement, the IESO selected<sup>3</sup> energy storage technologies for a total of 33.54 MW from five companies, listed in **Table 2**, to provide regulation service and RSVC service. These projects are currently in the process of developing, connecting and commissioning and are expected to become operational at various stages over the course of 2016 and 2017. The first of these projects is expected to be placed in-service in Q3-2016.

### Importance of Capacity

System capacity is the maximum electric power output (or equivalent reduction in load) that can contribute to the total system peak demand. The total system capacity available to the Ontario system must be able to satisfy the expected peak demand plus a reserve requirement. Energy storage facilities have been used for capacity for decades, even here in Ontario. In 1958, the Sir Adam Beck pump generating station energy storage facility was commissioned, providing ~175 MW of capacity to the Ontario power system, capacity that it continues to provide to this day.

Similar to the ATR projects, the IESO will work with each of the grid energy storage project owners to improve the offered services over the contract term and to maximize the learnings associated with each project's grid energy storage technology.

Table 2: List of successful respondents in IESO's Phase I of the Energy Storage procurement

Proponent	Ancillary Service	Number of Projects	Technology	MW
Canadian Solar Solutions Inc.	RSVC	1	Battery	4.0
Convergent Energy and Power LLC	RSVC & Regulation	2	Battery and Flywheel	12.0
Dimplex North America LTD	Regulation	1	Thermal	0.74
Hecate Energy	RSVC	7	Battery	14.8
Hydrogenics Corp.	Regulation	1	Hydrogen	2.0
Total		12		33.54

Phase I projects will have up to 30 months to come into service and have contract terms of three years.

<sup>3</sup> For more information please consult the [Backgrounder for Energy Storage Procurement- Phase I](#) on the [IESO website](#)



### 2.1.3 Grid Energy Storage Procurement - Phase II (2015)

In Phase II of the Grid Energy Storage procurement, the IESO selected the remaining quantity of the total 50 MW grid energy storage target through a program that was focused on the capacity value of grid energy storage, along with understanding the approach to achieving arbitrage value.

Phase II provides the opportunity for the grid energy storage operators to demonstrate how they, as the operator, will direct the operation of their own facilities, based on Ontario's market signals.

Phase II involved a two-stage approach:

- A Request for Qualifications (RFQ) process that evaluated potential proponents based on technical aspects as well as their financial capability to bring a project to commercial operation:
  - 37 submissions were received;
  - 15 submissions were successful in becoming Qualified Applicants and therefore eligible to participate in the following Request for Proposals.
- A Request for Proposals (RFP) process:
  - The process was oversubscribed, with potential projects submitted representing 133 MW.
  - After a rigorous, competitive procurement process, the IESO selected<sup>4</sup> five proponents for contract offers, representing nine projects totalling 16.75 megawatts (MW).

The successful respondents and their projects are listed in **Table 3**:

Table 3: List of successful respondents in IESO's Phase II of the Energy Storage procurement

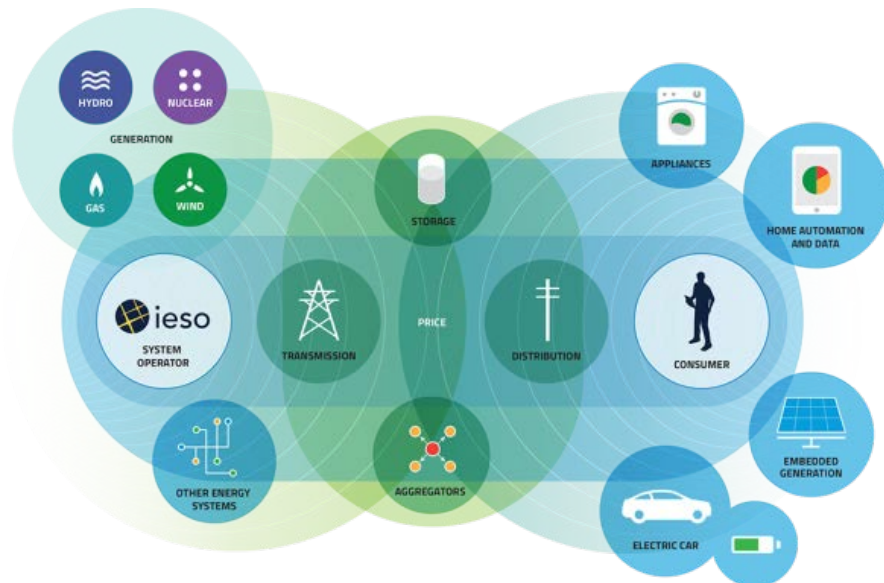
Proponent	Technology	Capacity (MW)
Ameresco Canada Inc.	Battery – Solid	2.0
Ameresco Canada Inc.	Battery – Solid	2.0
SunEdison Canada Origination LP.	Battery – Flow	2.0
SunEdison Canada Origination LP.	Battery – Flow	1.0
SunEdison Canada Origination LP.	Battery – Flow	2.0
NextEra Canada Development & Acquisitions, Inc.	Battery – Solid	2.0
NextEra Canada Development & Acquisitions, Inc.	Battery – Solid	2.0
NRStor Inc.	Compressed Air	1.75
Baseload Power Corp. (formerly 2443453 Ontario Inc.)	Battery – Flow	2.0
<b>Total</b>		<b>16.75</b>

Phase II projects will have up to 30 months to come into service and contract terms of 10 years.

<sup>4</sup> For more information please consult the [Backgrounder for Energy Storage Procurement- Phase II](#) on the [IESO website](#).

## 2.2 Integration of Energy Storage into IESO-Administered Markets

The successful ATR proponents were integrated into IESO-administered markets through the ancillary service procurement process, which involved executing a regulation service agreement. These facilities only provide regulation service and, as such, receive a regulation signal, which dispatches them to balance supply and demand on a second-by-second basis.



In the case of the Grid Energy Storage Phase I projects, respondents could choose to provide regulation service, reactive support and voltage control service or both. Additionally, successful respondents are bound by an agreement with the IESO that permits the IESO to dispatch both for their offered reliability service and other bulk energy services. Currently none of these facilities are in-service as they are being designed, built and commissioned.

The two-phase procurement was in support of the province's efforts to better understand the integration of energy storage into Ontario's electricity system and market.

## 2.3 Lessons learned from procurements

### 2.3.1 Location of the Energy Storage Project

During the development of Phase I of the 50 MW energy storage procurement, it was recognized that where an energy storage project connects may limit the services that could be provided. The Phase I energy storage procurement considered this by defining four mutually exclusive project envelopes such that they each contain areas with different electrical characteristics:

- Southern Ontario uncongested;
- Northern Ontario;
- Southern Ontario congested; and
- Southern Ontario distribution-connected.

Each envelope had a maximum capacity for procurement and available services to be provided. The concept of envelopes was further refined by restricting the connection to some transmission circuits, accounting for local area constraints.

### **2.3.2 Classification of Energy Storage Technologies**

All energy storage technologies have the ability to withdraw energy from the grid; however, not all technologies can inject energy back into the grid. Accordingly, energy storage technologies are classified based on how they interact with the electricity system as follows:

**Type 1** – Energy storage technologies that are capable of withdrawing electrical energy (electricity) from the grid, storing such energy for a period of time and then re-injecting this energy back into the grid (minus reasonable losses). Examples include, but are not limited to, flywheels, batteries, compressed air, and pumped hydroelectric.

**Type 2** – Energy storage technologies that withdraw electricity from the grid and store the energy for a period of time. However, instead of injecting it back into the grid, they use the stored energy to displace electricity consumption (demand) of their host facility at a later time. Examples include, but are not limited to, heat storage or ice production for space heating or cooling.

**Type 3** – Energy storage technologies that only withdraw electricity from the grid like other loads, but convert it into a storable form of energy or fuel that is subsequently used in an industrial, commercial or residential process or to displace a secondary form of energy. They're generally integrated with a host process that uses that secondary form of energy directly or are connected to a transmission or distribution network for their secondary form of energy (e.g., natural gas, steam or coolant). Examples include, but are not limited to, fuel production (hydrogen or methane), steam production and electric vehicles.

Although all three types can provide services to the electricity system, the differentiation is important in establishing their connection locations and the services they can reasonably provide. For example, a project involving a Type 3 technology located in a heavily loaded area of the system could increase the load on an already constrained local transmission system, potentially restricting it from providing certain services when demand is high (e.g., regulation or flexible supply).

### **2.3.3 Service-Based vs. Technology-Based Procurement**

Procurements that target specific services (such as the ATR procurement) generally return better value (technical performance and diversity) when compared to procurements that target specific technologies. This is because service-based procurements enable a variety of technologies to compete in providing the target service(s). On the other hand, technology-based procurements target a specific group of technologies to provide the desired service(s), which may limit competition.

Technology-based procurements have the disadvantage that a clear definition is required for the targeted technologies, which prevents other technologies capable of providing the services from competing. For example, although the ATR procurement targeted alternative technologies for providing regulation service, it did not specify the type of technology. As a result, three different types of projects were successful: a load aggregator, a battery and a flywheel.

### **2.3.4 Importance of Energy Efficiency**

Most energy storage technologies are subject to losses when converting energy from one form to another. Some energy storage technologies are also subject to energy losses from storage (e.g., leakage, diffusion).

Both types of losses have to be taken into account when selecting energy storage technologies for providing specific services. For example, technologies with relatively higher conversion losses could be helpful in managing SBG, while they may be potentially wasteful when providing regulation.

### **2.3.5 Providing Regulation – Energy Limitations**

An important lesson learned from the ATR program, and an ongoing area of focus, is the effect of the energy-limited nature of energy storage facilities. An energy storage facility can only store and consequently only inject a limited amount of energy. There can be periods when energy storage facilities cannot respond to regulation signals due to their store being either completely full or empty.

In general, there are ways to facilitate energy-limited resources providing regulation: increase the amounts of energy that the facility can hold, modify the regulation signals being sent to the facility or a combination of the two.

The size of the energy storage facility can only be increased so much as both economic and technical limitations will be reached. Similarly, the regulation signals being sent can only be modified so much as they must continue to perform the job of balancing the power system.

As a result, there is growing consensus among system operators that energy storage devices can form part of the portfolio of facilities that provide regulation service, but that the portfolio must include complementary regulation suppliers (e.g., hydroelectric generation) to ensure there is sufficient energy to supply the service indefinitely.

- End of Section -

## 3 Opportunities for Energy Time-Shift

### 3.1 Background

#### 3.1.1 Surplus Baseload Generation

Surplus baseload generation (SBG) is a condition that occurs when production from baseload resources exceeds Ontario's demand. In Ontario, baseload generators generally include grid-connected wind and solar generators, nuclear generators and run-of-river hydroelectric generators.

SBG is often mitigated by economically scheduling export transactions, spilling water at hydroelectric generating stations, dispatching down VGs and by reducing the output of nuclear generators.

During periods when Ontario demand is greater than the output from baseload generators, the IESO sends dispatch signals to additional resources to increase their output, usually intermediate or peaking generators. Peaking generation is provided by simple cycle natural gas-fired generators (combustion turbines) and some hydroelectric resources, and is characterized by its ability to synchronize to the system and generate within less than 30 minutes. Intermediate generation is provided by combined cycle natural gas-fired generators, biomass generators and some hydroelectric resources. Combined cycle natural gas-fired generators have specific operational constraints: they require advanced notification and preparation time before they can operate as a dispatchable generator.

#### Effective Peak Capacity of Storage

The effective peak capacity of a resource is an important parameter for long-term planning and reliability. Effective peak capacity is defined as the resource's capacity contribution during the yearly peak demand hours.

Since energy storage is energy limited, determining its effective peak capacity is more difficult because it is a function of the energy storage facility's dispatch duration (the amount of time that the facility can operate at rated maximum output).

The relationship between energy storage facility's dispatch duration and effective peak capacity can be visualized if we consider two energy storage facilities: one that can operate at maximum output for 30 minutes and another for four hours. Since effective peak capacity can be thought of generally as how much of the peak demand can be shaved, the energy storage facility that can deliver energy for a longer duration should be able to contribute more to the peaks throughout the year. The daily demand shape can also change quite dramatically over the course of a normal year, adding further challenges to estimating effective peak capacity.

However, the takeaway is that, given the maximum power output is the same, a storage facility with a larger reservoir size provides more effective capacity on peak than a facility with a smaller reservoir.

In addition, once these facilities are online they have to remain connected at a minimum generation level for a minimum pre-determined duration. This requirement of operating no lower than the minimum

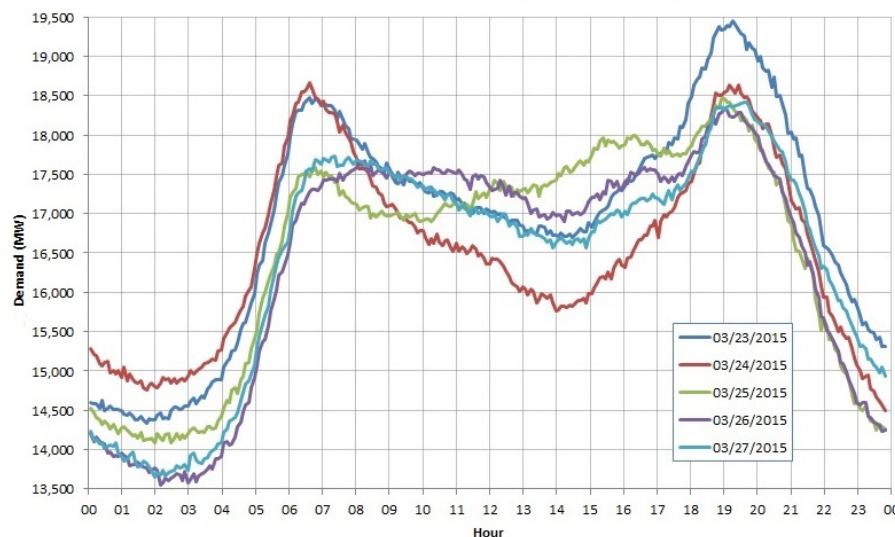
loading point for no less than the minimum run-time can result in additional surplus generation when the generator's required contribution is less than its minimum loading point or for a duration that's shorter than its minimum run-time.

### 3.1.2 Demand Profile Changes

Ontario demand profiles are changing as we continue to integrate VGs on the distribution system, particularly solar generation, which can have a considerable impact on demand during day-time hours.

**Figure 3** illustrates the changes in demand over five consecutive workdays, from March 23 to 27, 2015. These days had a similar ambient temperature, which traditionally had the largest impact on demand. However, after the incorporation of distribution-connected VG, local meteorological trends such as wind speeds and mainly solar irradiance also have a significant impact on the demand.

**Figure 3: Example of how Ontario's demand profile changed over five consecutive days in March 2015**



Of particular interest is the mid-day variation in demand, from almost a flat profile on March 26 to an almost 3,000 MW drop in demand between the morning peak and mid-day low on March 24. A drop of this magnitude can lead to mid-day SBG.

## 3.2 Analysis for 2020

Up to the early 2020s, increases in wind and solar generation will put upward pressure on SBG quantities while planned nuclear refurbishments and outages will offset that pressure. Taken alongside current demand projections, the result is an expectation that SBG will remain at comparable levels to 2014, when Ontario experienced SBG conditions 66% of the time. The seasonality of SBG is also an important factor to consider when determining whether or not storage can be used to effectively manage SBG conditions. The expectation is that the majority of the SBG will occur in periods with milder weather, such as the spring and fall.

How long SBG conditions will be at these levels beyond this timeframe will depend on many different factors that contribute to shaping the SBG profile in the early 2020s, most of which are dynamic in nature. These factors include electricity demand, weather, value of carbon, consumer behaviour, and planned

nuclear refurbishment and outage timelines. With so many variables to consider, uncertainty is inherent in any forecast of SBG conditions for this timeframe.

Beyond the mid-2020s SBG conditions are expected to be much less prevalent.

### **3.3 What this means for Energy Storage**

Up to the early 2020's, there are some opportunities for Type 1 and Type 2 energy storage technologies to shift energy by withdrawing surplus electrical energy from the grid and later injecting that energy back into the grid (Type 1) or displace electricity consumption (Type 2). For energy storage technologies that store energy over a short time period (e.g., days to complete a storage cycle<sup>5</sup>), there are limited opportunities to inject/displace electrical energy to meet Ontario electricity demand. These opportunities are more seasonal in nature, with less opportunity in the spring and fall and more opportunity in the summer and winter.

For Type 1 and Type 2 energy storage technologies that store energy over a longer time period (e.g., weeks or months to complete a storage cycle), there are more opportunities to shift energy – for example, from the fall to the winter. For storage technologies with longer storage cycles, there would be an opportunity to mitigate, approximately, 25% of the expected annual SBG; however, a longer storage cycle requires more capability to store the energy, which may be costly.

In addition, up to the early 2020s, there are opportunities for Type 3 energy storage technologies, which appear as a load to the electricity system, to withdraw electrical energy from the grid and convert it to another form of energy during periods of SBG.

Whether or not these opportunities last beyond the early 2020s depends on several factors, which are dynamic in nature and difficult to forecast, as described previously.

- End of Section -

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<sup>5</sup> A single storage cycle comprises withdrawing energy until the storage device is full, holding that energy, and then discharging the energy until the device is empty once again.



## 4 Reliability Needs in 2020

As discussed in section 1.2, one of the most significant changes to Ontario's supply mix over the next 5 years is the growth of the variable generation (VG) fleet. The two attributes of VG that affect system operations are:

- **Variability:** The output of VG changes according to the availability of the primary fuel (wind and sunlight) resulting in fluctuations in the plant output.
- **Uncertainty:** The magnitude and timing of VG output is less predictable than that of conventional generation.

It is important to distinguish between variability and uncertainty when discussing planning and operations of the system and market. The effects of variability differ from those related to uncertainty, and their associated mitigation measures are also different.

The IESO's Renewable Integration Initiative (RII) introduced a set of tools to address both variability (dispatch and visibility) and uncertainty (centralized forecasting) of the transmission-connected VG fleet.

The main difference between traditional generators and VGs is that traditional generators store their primary energy at the site (e.g., water in a headpond, nuclear fuel in storage, natural gas in the pipelines, etc.) and convert it into electricity based on consumers needs, while VGs have to process their primary energy (wind or sunlight) when it

becomes available. As a result, VGs may not generate when needed or may generate more than needed, resulting at times in mismatches between production and consumption. In Ontario, these mismatches are addressed by importing or exporting, dispatching natural gas-fired generation, curtailing VGs and as a last resort, reducing the output or shutting down nuclear generators.

The following sections examine potential reliability needs in the 2020 timeframe and the suitability of energy storage to meet those needs where a reliability need exists.





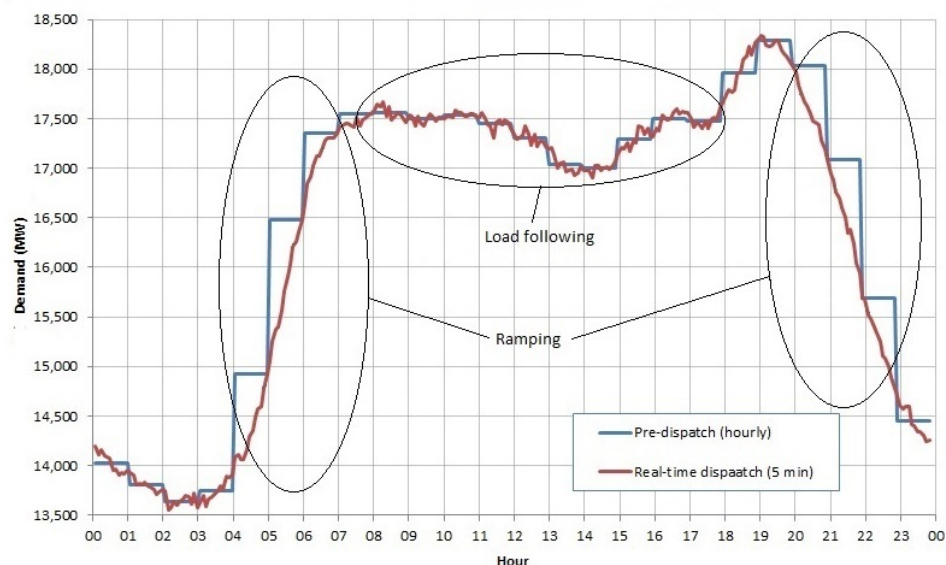
## 4.1 Need for more Ramping and Load Following Capability?

### 4.1.1 Background

Since electricity must be consumed when it is produced, the generation fleet in Ontario must have the capability to change its output as the demand for electricity fluctuates throughout the day. The generation fleet must be capable of changing its output in response to a steady increase or decrease in demand over a few hours. This is referred to as the ramping capability of the generation fleet. The generation fleet must also be capable of responding to fluctuations in Ontario demand in about a five-minute period. This is referred to as the load-following capability of the generation fleet. Finally, the generation fleet must be able to respond to the second-to-second fluctuations in demand. This is currently addressed in Ontario by Ontario generators and storage facilities that are contracted to provide regulation service. Regulation will be discussed in section 4.3 of this report.

The profile presented in **Figure 4** illustrates the concepts of load following and ramping on a typical day in Ontario. It should be noted that the load shape changes from day-to-day and season-to-season based upon a variety of factors. The figure displays both the pre-dispatch hourly demand forecast and five-minute real-time data

**Figure 4: Illustration of load following and ramping**

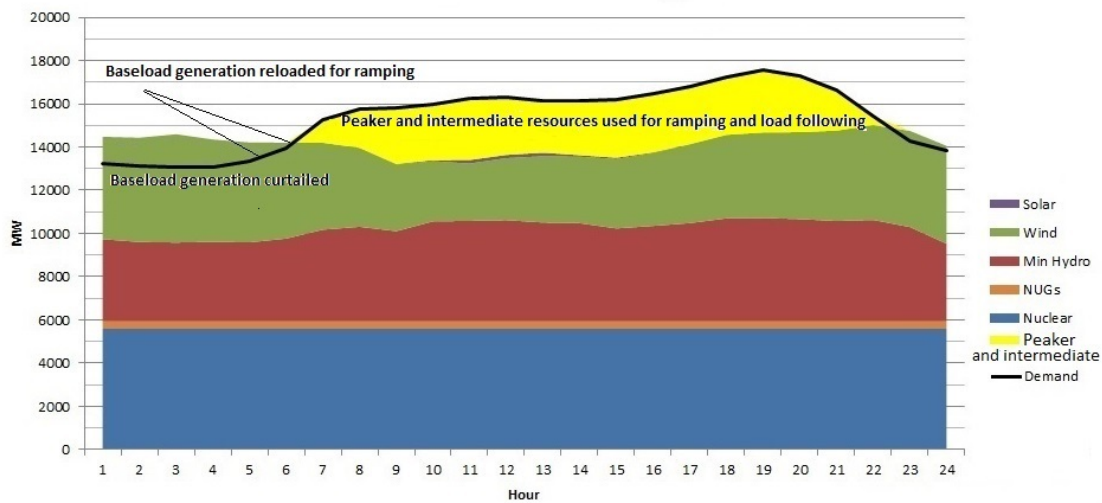


to demonstrate how resources need to be prepared ahead of time to meet the real-time changes in demand.

### 4.1.2 Analysis for 2020

**Figure 5** illustrates a day where Ontario demand was initially less than the output of Ontario's baseload generators and then increased to an amount greater than the output of the baseload generators. As such, IESO operators would first reload curtailed baseload generators during the first part of the day as Ontario demand increases. Later in the day, the intermediate fleet and/or peaking resources would come online to supply Ontario demand when it rises above the output of baseload resources. The opposite occurs after the daily peak when demand starts to fall. This analysis focuses on the latter requirement – that is, the capability of the intermediate and peaking generation to increase or reduce its output fast enough to supply the load as it ramps up and down.

**Figure 5: Example of Ontario demand ramping above the output of baseload generators**

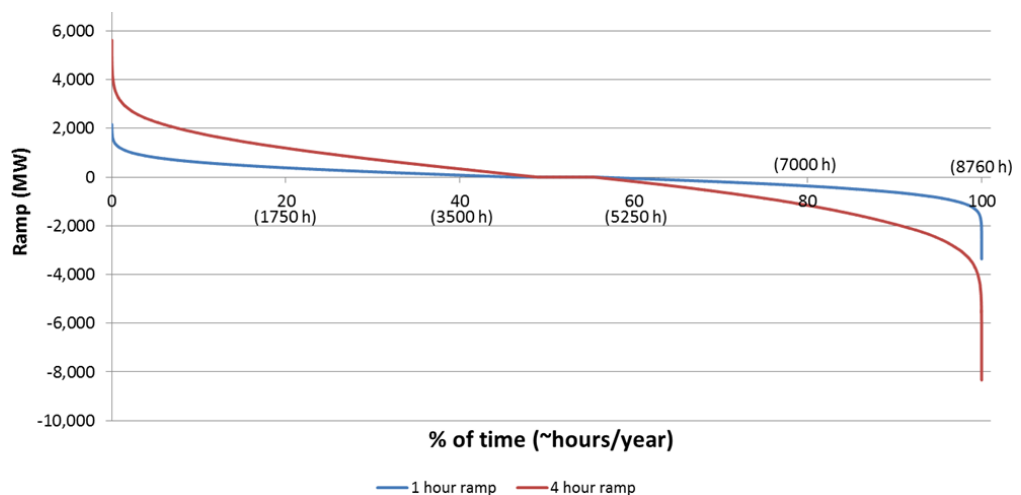


The combined ramping capacity of the thermal generation fleet (natural gas and biomass fired) projected for 2020 in Ontario is expected to be about 6,220 MW. This represents effectively the hourly ramping capability of this fleet, as most participating units can reach their maximum capacity within an hour when starting from their minimum loading point and can also reduce their output from maximum to the minimum loading point within the same period of time.

**Figure 6** shows

the duration curves of the expected changes in demand not supplied by baseload generation over a one-hour and four-hour periods. This figure shows that the ramping

**Figure 6: One-hour and four-hour ramp duration curves**



needs in 2020 over one hour are expected to be within +/- 1000 MW, 95% of the time; while the maximum one-hour ramp is expected to be about 2,200 MW. The ramping needs in 2020 over four hours are expected to be within +/- 3000 MW, 95% of the time; while the maximum four-hour ramp is expected to be about 5,600 MW.

The ramping capability of Ontario thermal generators alone is expected to be sufficient to meet the one-hour and four-hour ramping requirements in 2020. In addition, there is ramping capability available from hydroelectric generation.

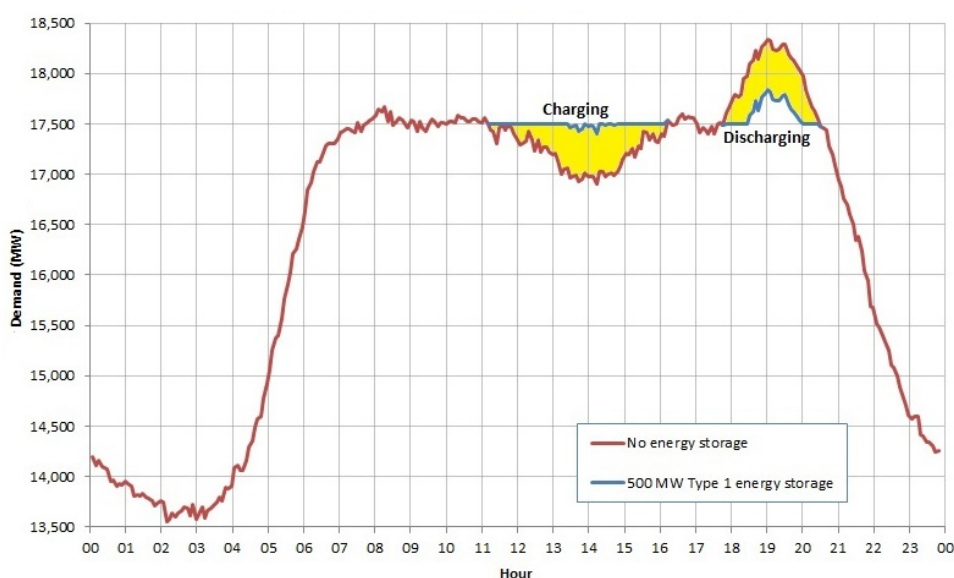
#### 4.1.3 What this means for energy storage

In general, the existing resource fleet is sufficient to address Ontario's ramping needs in 2020.

Energy storage could help with load following by compensating for some limitations of the combined cycle gas generators as illustrated in the example presented in **Figure 7**. The example focuses on the period from 08:00 to 20:30, which is outside of the main daily ramps. To address the demand changes during this timeframe, generators, demand side management, demand response, energy storage or a combination of all could be used.

Of particular interest is the dip in demand between 12:00 and 16:00 that may, in part, be attributed to an increase in the output of distribution-connected solar generation. Assuming that a combined cycle gas-fired generator with a six-hour minimum run-time was brought online towards the end of the morning ramp-up (about 7:00) to meet the

**Figure 7: Example of using Type 1 energy storage to energy time-shift**



morning peak occurring around 8:15; this generator would have to run past the point where its output is no longer needed (12:00). Having the generator come offline after its minimum run-time is complete at 13:00 to avoid further compounding surplus generation is an option; however this would make it unavailable for the evening peak (would have to stay offline until 21:00 to satisfy its minimum down time). Another generator would need to be dispatched – typically, the next higher-priced resource in the generation stack. Another option would be to keep the first generator online over the mid-day dip to have it available for the evening peak and address the surplus energy either by economically increasing exports, curtailing less expensive generators that have no operational limitations, calling upon some dispatchable loads to increase their consumption or a combination of all.

A hypothetical 500 MW, 1500 MWh energy storage facility involving a Type 1 technology could be used to raise the demand profile by charging from 11:00 to 16:00 and then to lower the evening peak by

discharging from 18:00 to 21:30. For simplicity, this energy storage facility was assumed to have 75% round-trip energy conversion efficiency and no stand-by (self-discharge) losses.

Under this scenario, the aforementioned combined cycle gas generator could remain online during the mid-day dip in Ontario demand to subsequently support the evening peak without exacerbating the surplus generation conditions and subsequently go offline when no longer needed. The evening peak, as seen by the rest of the generation fleet, would also be 500 MW lower, an indication that an additional gas-fired generator may not need to be brought on-line for that purpose (which would save start-up costs). This type of operation may also reduce the potential surplus generation conditions caused by a natural gas-fired generator that is brought online to support the evening peak and that would have to remain online for its minimum run-time while the demand ramps down.

This example shows that small amounts of energy storage could be useful to help manage the generation fleet by providing flexibility to address demand fluctuations and overcoming the inflexibility of the intermediate fleet brought about by high minimum loading points and long minimum run-times.

## 4.2 Need For Flexible Energy Supply?

### 4.2.1 Background

Variable generation forecasts are inputs into market-based decision tools. The uncertainty in these forecasts affects the commitment decisions, such as: natural gas-fired generation commitment in the day-ahead (DACP) and day-at-hand (~5 hour-ahead pre-dispatch) sequences, and scheduling of imports and exports in the hour-ahead pre-dispatch sequence.

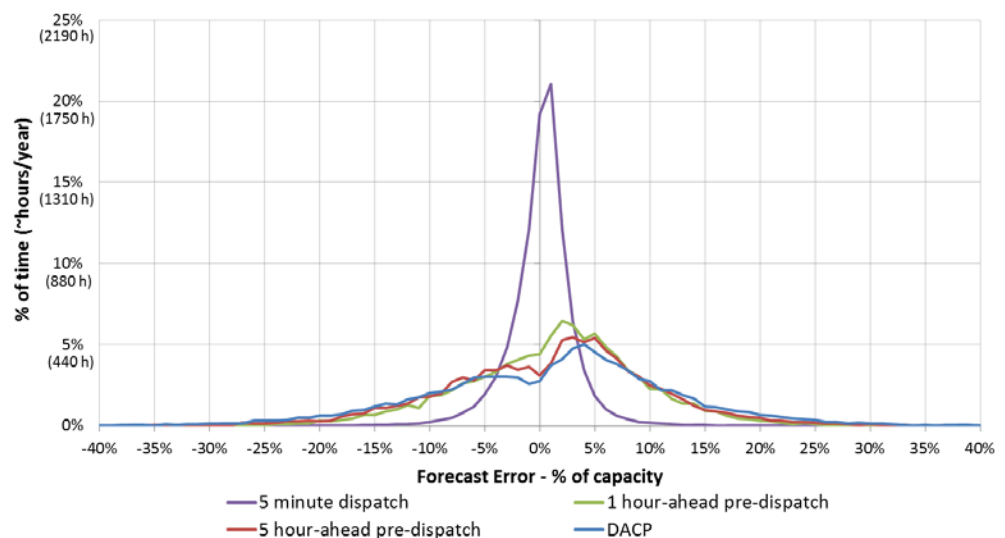
Flexibility is the ability of resources to respond quickly to changes in demand or to make up for changes in operational conditions and uncertainties in forecasts.

### 4.2.2 Analysis for 2020

**Figure 8** presents a sample of the variable generation forecast error distribution for the hour-ahead pre-dispatch, five hour-ahead pre-dispatch, day-ahead (DACP) and the five minute-dispatch forecasts, expressed as a percentage of the variable generation fleet capacity.

The figure illustrates that the variable

**Figure 8: Distribution of variable generation forecast uncertainty (error) within different timeframes**



generation forecast is not appreciably more accurate over the period from the DACP to the hour-ahead pre-dispatch. However, the forecast improves substantially within the hour-ahead pre-dispatch to five minute-dispatch time frame, which is when the most effective decisions can be made.

Variable generation forecast errors can lead to either over-forecasting or under-forecasting. Under-forecasting the variable generation fleet within the day-ahead and pre-dispatch sequences can result in over-commitment of the natural gas-fired generation facilities and under-scheduling of exports, which is not a reliability concern as it can be addressed by dispatching down transmission-connected variable generation.

Over-forecasting on the other hand, can result in under-commitment of natural gas-fired generation facilities and over-scheduling of exports, which is a reliability concern since there may not be enough generators on line to supply demand. Today's supply mix has limited flexibility to effectively compensate when the hourly pre-dispatch runs don't bring the necessary resources on line. For example, the York Energy Centre (YEC; ~400 MW), which is a single-cycle natural gas-fired generator, is the only peaking natural gas-fired generating station that is able to synchronize and reach full output within less than 30 minutes. All other natural gas-fired generators are combined-cycle generators and require several hours to synchronize and reach full output, as explained in section 3.1.1. In addition, most of the hydroelectric fleet that is not subject to technical or transmission constraints already operates at capacity.

As Ontario moves towards the targeted ~10,000 MW of wind and solar capacity, the amount of time the capacity of YEC may not be sufficient to compensate for under-commitments due to the over-forecast of variable generation fleet will increase.

#### **4.2.3 What this means for energy storage**

Over-forecasted variable generation output impacts reliability by under-committing gas generation, under-scheduling of energy imports or over-scheduling of energy exports. Since the quality of the VG forecast declines materially beyond 60 minutes out, additional flexible resources are required in Ontario that can be activated and begin energy delivery within a short period of time. Some energy storage technologies (typically Type 1) can provide this flexible supply if properly sized and located.

### **4.3 Need for Additional Regulation?**

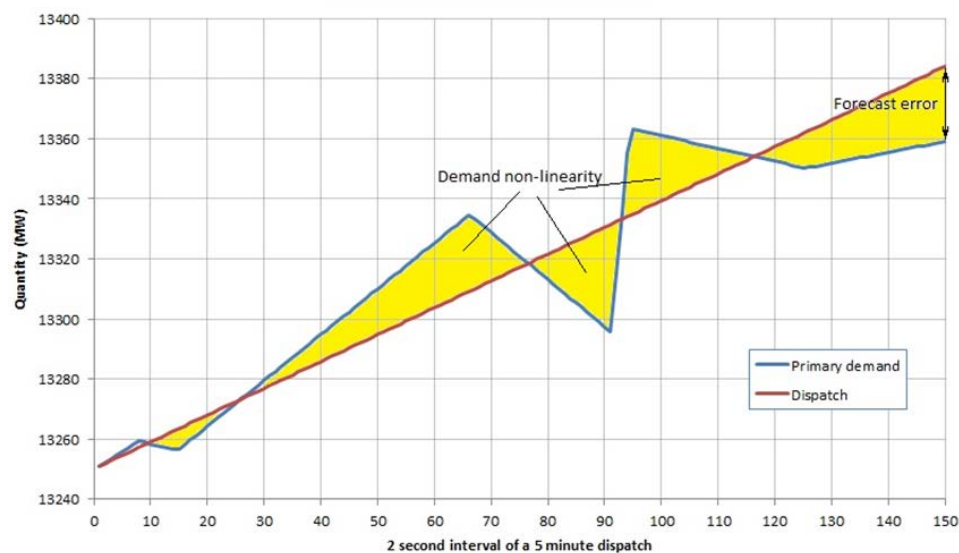
#### **4.3.1 Background**

Regulation service is required to control power system frequency and maintain the balance between load and generation on a second-by-second basis. The IESO uses automatic generation control (AGC) to automatically adjust the output of specific generation facilities that are contracted by the IESO to provide regulation service. The AGC processor continuously monitors the area control error (ACE) – that is the instantaneous difference between actual and scheduled interchange – and takes into account the effects of frequency bias to derive the AGC signal. The output change at AGC facilities maintain ACE and frequency within the ranges required by applicable North American Electric Reliability Corporation (NERC) standards.

**Figure 9** shows an example of the two likely situations when AGC actions are required:

- Addresses non-linearity in demand within the five-minute dispatch interval, and
- Compensates for forecast uncertainty (demand forecast, VG forecast, units off-schedule, etc.) at the end of the five-minute dispatch interval.

**Figure 9: Example of regulation during five-minute dispatch**



The introduction of the centralized forecast service by the IESO in 2013 reduced the impact of VG output uncertainty. This forecast includes a five-minute output forecast for transmission-connected VG resources that is provided every five minutes and extends two hours into the future. While centralized VG forecasts are generally more accurate than individually produced forecasts, they cannot completely eliminate the uncertainty, and the remaining uncertainty directly impacts the amount of regulation required. Regulation may also be required to respond to changes in load behaviour after accounting for distribution and customer-side connected variable generation. As the size of the VG fleet increases, the magnitude of the uncertainty in the five-minute timeframe is also expected to increase.

#### 4.3.2 Analysis for 2020

The expansion of the VG fleet is expected to introduce higher levels of uncertainty in real-time operations, as discussed in section 4.3.1. The IESO continuously monitors the required parameters to identify any changes that may impact its ability to

#### Common Practice

Some system operators in U.S. jurisdictions have developed regulation signals specifically for energy storage facilities. A key feature of these specialized signals is to aim for “energy neutrality” every five to 15 minutes. Generally, these system operators define energy neutrality to mean that the energy dispatched above and below the midpoints are approximately equal to one another over five to 15 minutes. The signal is designed so that energy storage facilities can provide more correction in shorter timeframes than traditional regulation. The intended effect is to keep the energy storage facility within its energy constrained operating limits while providing useful service to the grid. Another important consideration here is that these faster signals will move the facilities more, potentially incurring larger operating costs and shortening asset life.



meet the requirements of the NERC standard for regulation and will initiate appropriate actions if and when they are needed.

### 4.3.3 What this means for energy storage

A key input into the IESO's five-minute dispatch decisions is the forecast of the output from the VGs. Uncertainty in this forecast is compensated for by regulation service<sup>6</sup>. While the accuracy of this variable generation forecast is consistent with industry norms, the increase in size of the variable generation fleet is expected to result in a larger forecast uncertainty (MW), which can lead to increased regulation service requirements. Properly sized and located energy storage facilities can successfully provide regulation service. However, due to the energy limitations of storage devices – specifically, because they can empty or fill completely – storage must be combined with technologies that traditionally provide regulation service to meet Ontario's regulation needs.

## 4.4 Need for Additional Operating Reserve?

### 4.4.1 Background

Operating reserve is generation or load reduction capacity that can be called upon on short notice by the IESO to replace scheduled generation that becomes unavailable as a result of an unexpected outage or to augment scheduled generation as a result of unexpected demand increases, or other contingencies.

The IESO must schedule enough Operating Reserve to satisfy Northeast Power Coordinating Council's (NPCC) reserve requirements. The 10-minute reserve requirement is equal to the first-contingency loss (the contingency resulting in the largest loss of generation). The 30-minute reserve requirement is equal to half of the second contingency loss.

The IESO procures two types of operating reserve:

- Spinning Reserve (Synchronized) – Generation capacity that is quick-start<sup>7</sup> or online but not fully loaded and that can respond within 10 minutes.

### Economics for Regulation

The cost of energy storage has been steadily declining and is projected to continue to decline past the 2020 timeframe. As the cost of these technologies decreases, so too does their cost of providing regulation. In some U.S. markets, the hourly prices are such that storage developers are able to finance an energy storage project on regulation revenue alone. In these jurisdictions, more than 100 MW of merchant energy storage is already participating in their regulation markets, with another 100-500 MW expected to be coming online in the next few years. It appears that it is already economic for energy storage to compete for regulation service in these jurisdictions.

<sup>6</sup> The IESO contracts with a number of Ontario generators to provide regulation service. This service enables the IESO to adjust the output of specific Ontario generators on a second-by-second basis in response to instantaneous changes in the Ontario supply-demand balance.

<sup>7</sup> A quick-start generator can receive a dispatch signal from the IESO, close its breaker and increase the output of the generator such that it meets its dispatch target within that five-minute dispatch interval.

- Non-Spinning Reserve (Non-synchronized) – Generation capacity that may be offline or that comprises a block of curtailable and/or interruptible loads and that can be available within 10 to 30 minutes.

In the previous section, we discussed the need for additional flexible generation to help manage forecast errors. One way of ensuring that this flexible generation is available when needed, is to schedule it as 30-minute operating reserve, which would be in addition to the operating reserve carried to meet NPCC requirements. Notwithstanding this potential need for additional operating reserve above NPCC requirements, the following analysis determines whether or not the largest generation loss in Ontario will increase as more variable generation connects in the province and if that would result in a need for more operating reserve to meet NPCC's minimum requirements.

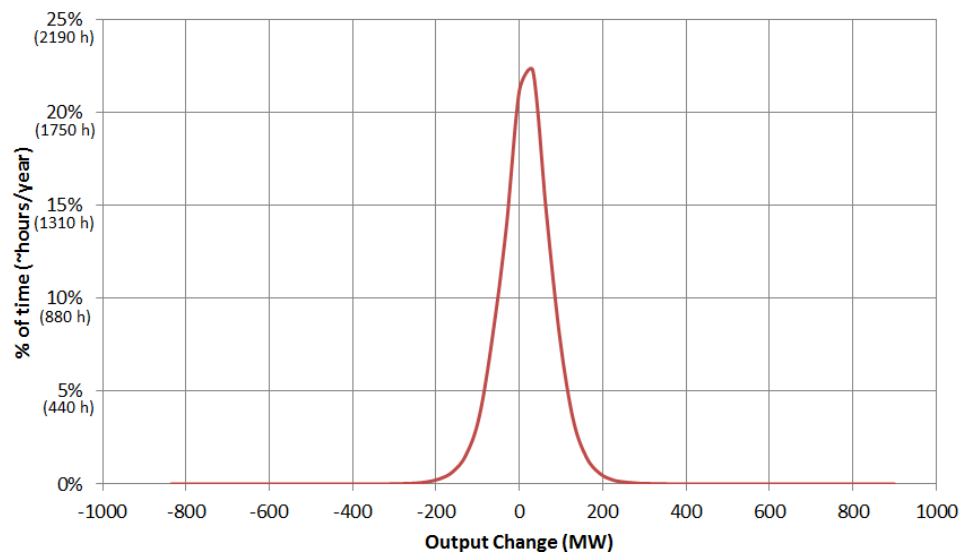
#### 4.4.2 Analysis for 2020

**Figure 10** shows a distribution of the changes in the output of the VG fleet over a 10-minute period in 2020. Our analysis shows that the majority of the 10-minute variability in 2020 will be within 200 MW. The figure shows that 99% of the time, the output changes will be within +/- 160 MW, with the maximum natural drop in VG production being approximately 835 MW.

The 835 MW drop in VG production, a one-in-10 year event, is less than the existing minimum first contingency loss in Ontario (the capacity of a Darlington unit). Therefore, the largest generation loss in Ontario will not increase as more variable generation connects in the province – therefore, we do not anticipate a requirement to

increase the amount of 10-minute operating reserve scheduled in Ontario for this reason.

**Figure 10: Distribution of variable generation output changes over 10 minutes projected for 2020**



#### 4.4.3 What this means for energy storage

In 2020, the largest generation loss in Ontario is not expected to increase due to natural drops in variable generation production. Nevertheless, to help manage variable generation forecast uncertainties, it may be necessary to carry additional 30-minute operating reserve. As operating reserve is competitively procured through the IESO-administered markets, energy storage facilities that have the appropriate capability can offer both 10- and 30-minute operating reserve alongside other providers.



## 4.5 Need for Additional Voltage Control?

### 4.5.1 Background

Increased distribution-connected VG reduces electricity consumers' reliance on centralized generation facilities and the transmission system, leaving, at times, long transmission circuits under light load conditions. This situation could potentially result in difficulty controlling high voltages on some parts of the transmission system.

This phenomenon already affects parts of downtown Toronto, the northwest GTA and Eastern Ontario as shown in **Figure 11**. In these areas, after exhausting the usual high voltage mitigation measures (i.e., removing capacitors from service, bringing shunt reactors into service, changing transformer taps), the IESO has to take supplementary measures such as removing some lightly loaded transmission circuits from service. Taking transmission circuits out of service is not preferred – it reduces the robustness of the transmission system and increases transmission switching. A higher switching frequency increases wear and tear of the switching equipment and increases the risk of not having the transmission circuits available (due to stuck breaker conditions, for example) when electricity demand increases.

Additional reactive control is needed in those areas to help manage high voltage situations and reduce the need to remove transmission circuits from service.

**Figure 11: Area with potential high voltage issues in southern Ontario**



The retirement of Pickering Nuclear Generating Station, which currently provides significant dynamic voltage control in the highlighted area, is expected to exacerbate the aforementioned voltage issues.

### 4.5.2 What this means for energy storage

Transmission-connected energy storage facilities that have voltage control capability can provide voltage control services on these parts of the system. However, distribution-connected energy storage devices that are electrically far from the transmission system are not suitable for controlling transmission voltages.

- End of Section -

## 5 Zonal Considerations

### 5.1 Background

Transmission congestion occurs when least-cost energy cannot be delivered to all or some loads because transmission facilities don't have sufficient capability to deliver that energy. Transmission congestion in Ontario can result in congestion management settlement credits (CMSC) being paid to specific market participants that cannot provide their economical priced energy and to those dispatched uneconomically on the other side of the congested interface to supply the demand.

The Ontario transmission system is divided into 10 transmission zones, which are connected by transmission interfaces, as illustrated in **Figure 1**.

These 10 transmission zones are described further in the [Ontario Transmission System](#) document that can be found on the [Forecasts & 18-Months Outlooks](#) page of the [IESO website](#). The Ontario Transmission System document provides detailed descriptions of Ontario's transmission zones, interfaces and interconnections, including geographic representations. This section describes the opportunities for energy storage in each zone at a high level.

It should be noted that the presentation of specifics related to the Ontario transmission zones are at a high level and, generally, ignore any potential transmission limitation internal to each zone. These transmission limitations will have to be taken into consideration when deciding where to site energy storage projects. Failure to do so may result in restricted access to provide certain services or costly upgrades to the transmission system that would defeat the purpose of selecting an energy storage solution in the first place.

#### Modularity

Another feature that could make energy storage attractive for capacity is that these technologies are typically modular and have relatively small footprints. This modularity and relatively small size could enable them to be located at one or more locations in load centres. There could be benefits associated with having multiple facilities at strategic locations providing capacity, instead of one large unit in a single location.

### 5.2 Uncongested Zones

In Ontario the uncongested zones are the East and Southwest transmission zones. In these zones, the transmission system is not operated near its transfer capabilities and is used to supply local demand and transfer power to the Toronto and Ottawa zones.

The following tables list the generation capacity by fuel type in the East and Southwest transmission zones.



Table 4: East zone generation capacity by fuel type in 2015 and projection for 2020

Year	Total (MW)	Gas (MW)	Solar (MW)	Water (MW)	Wind (MW)	Biomass (MW)
2015	5,565	2,481	652	2,030	387	14
2020	6,873	3,242	928	2,071	585	48

Table 5: Southwest zone generation capacity by fuel type in 2015 and projection for 2020

Year	Total (MW)	Gas (MW)	Solar (MW)	Water (MW)	Wind (MW)	Biomass (MW)
2015	2,252	757	275	9	1,183	27
2020	2,892	790	712	10	1,327	53

While these transmission zones are not congested at a zonal level, there are areas within each zone that are load congested in the sense that they rely on transfers from outside the area to supply their peak loads, and the transmission circuits supplying these areas can operate close to or at their capacity during peak load periods. For example:

- East transmission zone: parts of the 115 kV transmission system from Peterborough to Kingston;
- Southwest transmission zone: the Kitchener-Waterloo-Cambridge-Guelph area and parts of the Burlington-Hamilton area.

### 5.2.1 What this means for energy storage

While all three types of energy storage can generally provide services in these transmission zones, there would be limited opportunities for Type 3 energy storage technologies in the load congested areas of the zones, since such technologies appear as loads to the electricity system. In these load congested areas, Type 1 and Type 2 energy storage technologies could time-shift energy by charging off-peak and then injecting or displacing load during peak load hours. This could help alleviate marginal transmission upgrade needs in these load centers.

## 5.3 Load Congested Zones

In Ontario the load congested zones are the Toronto, Ottawa and Essa zones. These zones are considered load congested because they rely on transfers from other zones to supply their peak loads, and the transmission circuits supplying these zones can operate close to or at their capacity during peak load periods.

The following tables list the generation capacity by fuel type in the Toronto, Ottawa and Essa zones.



Table 6: Toronto zone generation capacity by fuel type in 2015 and projection for 2020

Year	Total (MW)	Gas (MW)	Solar (MW)	Nuclear (MW)	Wind (MW)	Biomass (MW)
2015	8,781	1,956	145	6,618	36	26
2020	8,229	1,799	636	5,737	36	21

Table 7: Ottawa zone generation capacity by fuel type in 2015 and projection for 2020

Year	Total (MW)	Gas (MW)	Solar (MW)	Water (MW)	Biomass (MW)
2015	245	80	120	26	19
2020	252	80	127	26	19

Table 8: Essa zone generation capacity by fuel type in 2015 and projection for 2020

Year	Total (MW)	Gas (MW)	Solar (MW)	Water (MW)	Wind (MW)	Biomass (MW)
2015	1,240	393	288	505	48	6
2020	1,535	393	468	508	144	22

### 5.3.1 What this means for energy storage

There are limited opportunities for Type 3 energy storage technologies in load congested areas since these technologies appear as loads to the electricity system. In these areas, Type 1 and Type 2 energy storage technologies could time-shift energy by charging off-peak and then injecting or displacing load during peak load hours. This could help alleviate marginal transmission upgrade needs in these zones.

## 5.4 Generation Congested Zones

In Ontario the generation congested zones are the Northwest, Bruce and Niagara zones. These transmission zones are considered generation congested because the installed generation capacity in the zone is equal to or larger than the combination of demand in the zone and transfer capability out of the zone, resulting in the outgoing transmission circuits operating close to or at their capacity when the zone's generation peaks.

The following tables list the generation capacity by fuel type in the Northwest, Bruce and Niagara zones.



Table 9: Northwest generation capacity by fuel type in 2015 and projection for 2020

Year	Total (MW)	Gas (MW)	Solar (MW)	Water (MW)	Wind (MW)	Biomass (MW)
2015	1429	43	62	803	99	422
2020	1501	43	81	857	99	422

Table 10: Bruce zone generation capacity by fuel type in 2015 and projection for 2020

Year	Total (MW)	Gas (MW)	Solar (MW)	Nuclear (MW)	Wind (MW)	Water (MW)
2015	7,443	24	6	6,396	1,016	1
2020	6,698	24	83	5,574	1,016	1

Table 11: Niagara zone generation capacity by fuel type in 2015 and projection for 2020

Year	Total (MW)	Gas (MW)	Solar (MW)	Water (MW)	Wind (MW)	Biomass (MW)
2015	2,939	293	57	2,342	244	3
2020	2,958	293	76	2,342	244	3

#### 5.4.1 What this means for energy storage

Generation congested zones provide limited opportunity for Type 1 and Type 2 energy storage technologies, to inject their stored energy or displace load. Since Type 3 energy storage technologies appear as loads to the electricity system, they could make use of the excess generation in these zones.

### 5.5 Zones with Some Transfer Capability Available

In Ontario, the zones with some transfer capability available are the Northeast and West transmission zones.

The generation in the West transmission zone is comprised largely of natural gas-fired and wind generators. The transfer capability out of the zone only becomes limiting when natural gas-fired generators are online.

The generation in the Northeast transmission zone is primarily comprised of hydroelectric generators and transfers out of the Northwest zone that flow through the Northeast zone. Congestion in the Northeast is more likely than in the West as it is tied to lower-cost baseload and peaking



hydroelectric vs. generally more expensive natural gas-fired generation.

The following tables list the generation capacity by fuel type in the Northeast and West transmission zones.

Table 12: Northeast zone generation capacity by fuel type in 2015 and projection for 2020

Year	Total (MW)	Gas (MW)	Solar (MW)	Water (MW)	Wind (MW)	Biomass (MW)
2015	4,227	557	173	3,124	301	71
2020	4,233	436	220	3,209	335	33

Table 13: West zone generation capacity by fuel type in 2015 and projection for 2020

Year	Total (MW)	Gas (MW)	Solar (MW)	Wind (MW)
2015	5,145	3,309	305	1,532
2020	6,072	3,656	522	1,894

#### 5.5.1 What this means for energy storage

The West transmission zone can become congested when the zone's natural gas-fired generators are online, providing limited opportunity for energy storage technologies to inject during these times. Opportunities for Type 1 and 2 energy storage technologies would be generally limited to times when the natural gas-fired generators are not operating.

The Northeast transmission zone can become congested during periods of higher hydroelectric generation or very low demands. Opportunities for Type 1 and 2 energy storage technologies would be generally limited to times of lower hydroelectric generation.

Since Type 3 energy storage technologies appear as loads to the electricity system, they could make use of the excess generation in these zones.

- End of Section -

## 6 Conclusion

Energy storage technologies can be used to provide some of the services needed to reliably operate the power system including: regulation, voltage control, operating reserve and flexibility. Energy storage could also help improve the utilization of existing transmission and distribution assets by deferring some costs associated with their upgrades or refurbishments, as well as improve the quality of electricity supply in certain areas of the system by controlling local voltages. It is important to note that energy storage is not the only option for providing these services.

This report does not attempt to build an economic case for storage. However, based on recent procurement experience, it is expected that energy storage might be able to provide regulation service at a cost that is comparable to the cost of traditional providers (e.g. hydroelectric generators).

Up to the early 2020s, using Type 1 or Type 2 energy storage technologies that are capable of storing energy for only short periods of time (i.e., days) to time-shift energy for SBG management, would have limited benefits. However, energy storage technologies capable of storing energy for longer periods of time (i.e., months) would have more opportunity to time-shift surplus baseload energy, to supply Ontario demand. For storage technologies with longer storage cycles, there would be an opportunity to mitigate, approximately, 25% of the expected annual SBG. Type 3 energy storage technologies (e.g. electric vehicles) and other loads would have access to surplus energy that's fueled primarily by wind, solar, water and nuclear. How long these opportunities last beyond the early 2020s depends on a number of factors that will contribute to shaping the SBG profile, which are dynamic in nature. These factors include electricity demand, weather, value of carbon, consumer behaviour, and planned nuclear refurbishment and outage timelines.

In order for energy storage facilities to provide services to the power system, they need to be appropriately sized and connected at locations where existing transmission limitations do not impede their ability to provide the targeted services. To utilize the full potential of their facilities, energy storage providers seeking to connect facilities to the IESO-controlled grid should target those areas of the system where they can provide multiple services to the IESO-controlled



grid, the IESO-administered markets and local market participants. For example, incorporating energy storage within existing transmission-connected load or generation facilities would be a potential way to reduce the overall connection costs and gain access to services specific to that particular facility.

Future procurements should target specific services instead of specific technologies. Service-oriented procurements (e.g., the ATR procurement in 2012) generally return better value than those that target

specific technologies because of increased competition. Although energy storage can provide many services needed to reliably operate the power system, storage isn't the only option for meeting those needs. Ultimately, the best option for meeting a particular need should be determined through a mechanism that targets that need and allows multiple technologies to compete.

Energy storage proponents should consider that providing a single service to the electricity grid may not be sufficient to support the development of a project. Providing multiple services is common practice for other resources like generators. For example, most generators provide at least three services: energy, operating reserve and voltage control, while some can also provide regulation.

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