Resource Adequacy – Feedback Form

Meeting Date: September 28, 2020

Date Submitted:	**Feedback Provided By:**	
2020/10/20	Organization:	Energy Storage Canada (ESC)
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Following the September 28, 2020 Resource Adequacy webinar, the Independent Electricity System Operator (IESO) is seeking feedback from stakeholders on the following items discussed during the webinar. More information related to these feedback requests can be found in the presentation, which can be accessed from the engagement web page.

Please submit feedback to engagement@ieso.ca by October 20, 2020. If you wish to provide confidential feedback, please submit as a separate document, marked "Confidential". Otherwise, to promote transparency, feedback that is not marked "Confidential" will be posted on the engagement webpage.

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Stakeholder Feedback Table

IESO Requests	Stakeholder Feedback
Principles to Guide the Resource Adequacy Framework Conversation	
The IESO proposes to use the MRP guiding principles to guide the discussion with stakeholders on the development of a high-level Resource Adequacy framework. Are there other principles that should be considered throughout this discussion?	ESC continues to be supportive of the MRP guiding principles in general. We recommend the following be incorporated into the interpretation of the principles: 1) *Efficiency* – unlocking the value and optimizing the use of existing infrastructure (e.g., energy storage can be used to improve the utilization of existing assets) 2) *Competition* – ability to compete on a level playing field and access to revenue streams of services and products that can be provided (e.g., IESO's long-term design vision for energy storage is proposed to be implemented post-MRP) 3) *Implementability* – plan for incorporating changes to the market is developed with input from stakeholders 4) *Certainty* – confidence in the market and procurement processes, timing, system needs, and targets 5) *Transparency* – particularly with respect to planning and projected future system needs
Draft Resource Adequacy Framework	
Do these three capacity acquisition timeframes (commitment and forward periods) provide sufficient options for meeting the needs of your resource type?	At a high-level, these timeframes are sufficient for most energy storage technologies, however longer timeframes are preferable for certain resources with longer-development cycles and asset-lifetimes. Short-term commitment periods and forward periods may be suitable for existing energy storage where upgrades are not required. Multi-year commitments and forward periods of 3-4 years may be sufficient for certain energy storage projects. ESC agrees that longer-term commitment periods and forward periods are required new build projects or upgrades to existing resources, including energy storage projects that meet such criteria.
Which option(s) are most suited to your resource type?	Overall, ECS recommends the use of competitive RFP/Contracts over Capacity Auctions, especially for new projects or projects requiring upgrades. Energy storage assets can be designed with operating lives of 20 years or more.

	ESC understands that the IESO is proposing that existing energy storage assets would continue to be eligible to participate in annual Capacity Auctions. Capacity Auctions with enhancements and RFP/Contracts may be appropriate for new energy storage technologies (e.g., batteries, compressed air storage). Long-term contracts may be appropriate for certain energy storage technologies with larger capital and operating cost such (e.g., pumped storage).
Based on timing when various mechanisms are going to be available, do you see timing gaps when a resource needs a mechanism before that mechanism is ready?	ESC recently published the paper "Unlocking Potential: An Economic Valuation of Energy Storage in Ontario" which provides a detailed analysis demonstrating that 1000 MW of energy storage can provide between $774 million to $2 billion in net savings under a base case and high estimate, respectively. Given the inability to fully integrate energy storage within Ontario's electricity market, in order to unlock the system-wide value of energy storage now, the IESO should contract for the full suite of services that energy storage can deliver, and should enable the co-optimized operation of these storage resources. This would allow for full realization of the savings potential for customers, which cannot be achieved within the current market design and structure. Therefore, we recommend that the IESO move forward with options to competitively procure energy storage at the earliest opportunity to achieve savings for customers in the near term.
Resource Adequacy Engagement Plan	
What needs to be considered in future engagement phases to develop the details of the mechanisms in the framework?	ESC recommends that future engagement phases include: • Clear coordination with the Capacity Auction Engagement stream (i.e., amendments to market rules, timeframe for annual auctions, eligibility of resources, capacity qualifications, etc.) • Coordination with IESO's Long-Term Design Vision including changes to ensure that the full value of energy storage is realized, particularly as the IESO only proposes to procure "unbundled capacity" in the short- to medium terms • Establishment of transparent planning and decision-making framework (including governance and oversight) related to the use of each type of procurement mechanism and establishment of procurement targets
What other areas need to be discussed with stakeholders to operationalize the framework?	The framework should ensure flexibility to respond to emerging trends in the electricity sector. For example, FERC Order 2222 will create new opportunities for distributed energy resources (including directly connected energy storage and behind the meter

	energy storage) participation in wholesale markets, including as part of aggregated facilities. The framework should ensure competition on a level-playing field for all resources and continue to assess the barriers in the market that prevent the efficient participation of resources in the market.

Unlocking Potential: An Economic Valuation of Energy Storage in Ontario

A Report by Power Advisory LLC Commissioned by Energy Storage Canada
July 2020

ENERGY STORAGE CANADA

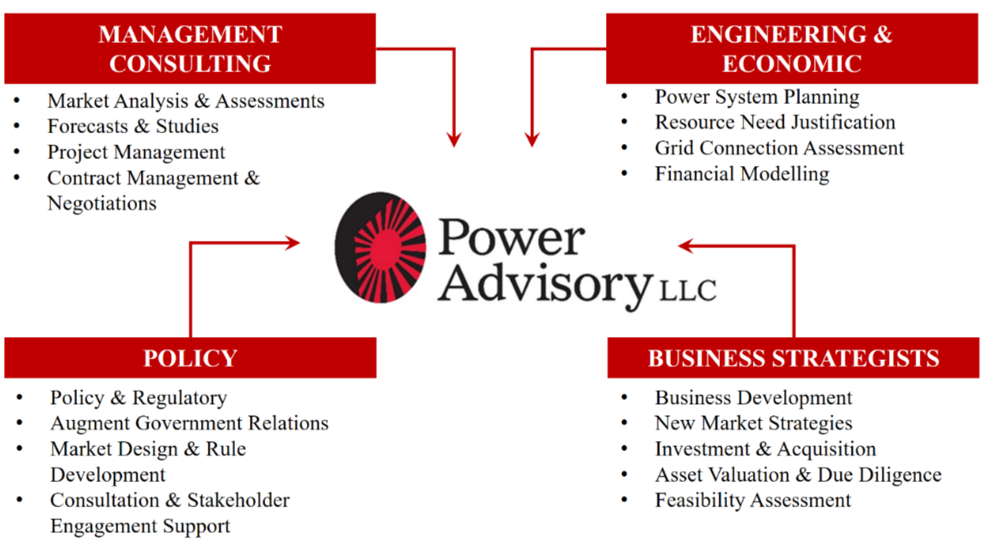
Energy Storage Canada (ESC) is the national association for the energy storage industry in Canada. Our membership represents all players along the energy storage value chain – technology providers, project developers, investors and operators, utilities, electricity distribution companies and NGOs. We represent some of the largest energy companies in Canada as well as some of the smallest and most innovative clean-tech organizations.

ESC focuses on advancing opportunities and building the market for energy storage through advocacy, networking and stakeholder education. Our mission is to advance the energy storage industry in Canada through collaboration, education, policy development and research. ESC takes an unbiased view with respect to the range of available storage technologies and is supported by the contributions of our active members.

For more information visit www.energystoragecanada.org

POWER ADVISORY LLC

Power Advisory is an established electricity market-focused management consulting firm. We specialize in market analysis, market design, policy development, business strategy, power procurement, regulatory and litigation support, and project development and feasibility assessment in North American electricity markets. We offer considerable experience advising industry associations, generators, energy storage providers, transmitters, distributors, technology providers, investors, financial institutions, customers, regulators, government agencies, and governments on a wide range of matters across North American electricity markets, with robust and in-depth experience in Ontario.



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EXECUTIVE SUMMARY

Energy storage can provide immediate, tangible savings, and benefits across Ontario's power system. Some of the savings are attributed to the inherent characteristics of energy storage, while others are a result of several unique characteristics of Ontario's electricity market and regulatory structure.

Over the next decade, this report shows that the introduction of at least 1,000 MW of energy storage can provide as much as $2.7 billion in total savings for Ontario's electricity customers, and that the savings could reach upwards of $4 billion (see Figure 1). While these savings account for only a small portion of total system costs, they are nevertheless material. In large part, these savings are a direct result of more efficient utilization of the province's long-term generation assets, many of which were added to the system over the last decade or are currently being refurbished for the coming decades.

From a net savings perspective, based on an installed cost of $200,000 per MW per year, energy storage can provide $774 million to $2 billion in savings under a base case and a high estimate case, respectively. These savings will help lower costs to Ontario's electricity customers over the next decade. Energy storage assets can also be designed with operating lives of 20 years or more, and could therefore provide savings to Ontario extending beyond the 10-year horizon.

The potential savings from energy storage are categorized into three service types:

- **Wholesale Market:** Energy storage can provide a range of wholesale market savings, including energy arbitrage, reduced prevalence of Surplus Baseload Generation, reduced need for flexibility and cost-guarantee procurement mechanisms, lower ancillary service costs, and increased participation in Capacity Auctions. In total, energy storage can provide $1.1 billion to $3.1 billion in gross savings in the wholesale market.

- **Maximize Transmission and Distribution Investment:** Energy storage investments can be made at specific locations on the grid to better utilize existing transmission and distribution assets. Based on current power system planning outlooks and historical investment trends, energy storage can provide $457 million to $840 million in gross savings over the next decade.

- **Direct-to-Customer Savings:** Energy storage can help electricity customers manage individual costs by shifting peak consumption, resulting in lower Time-of-Use rates and reduced demand charges. Energy storage can also help shift renewable energy output – largely from solar generators – from low-value to high-value hours.

Energy storage can provide a number of more qualitative benefits – many of which will also produce savings, but have not been estimated as part of this report. The benefits include reduced greenhouse gas emissions, lower transmission congestion, increased electricity exports and import values and improved power quality.

Ultimately, energy storage can help manage many of the unique characteristics of Ontario's electricity grid, as well as the operational challenges that have accompanied the transition from a traditional grid to one with fewer emissions and greater variability. It can do that while lowering system costs by increasing the utilization of existing investments. While this analysis highlights the value of energy storage in Ontario, more detailed modeling should be considered as part of the next steps.

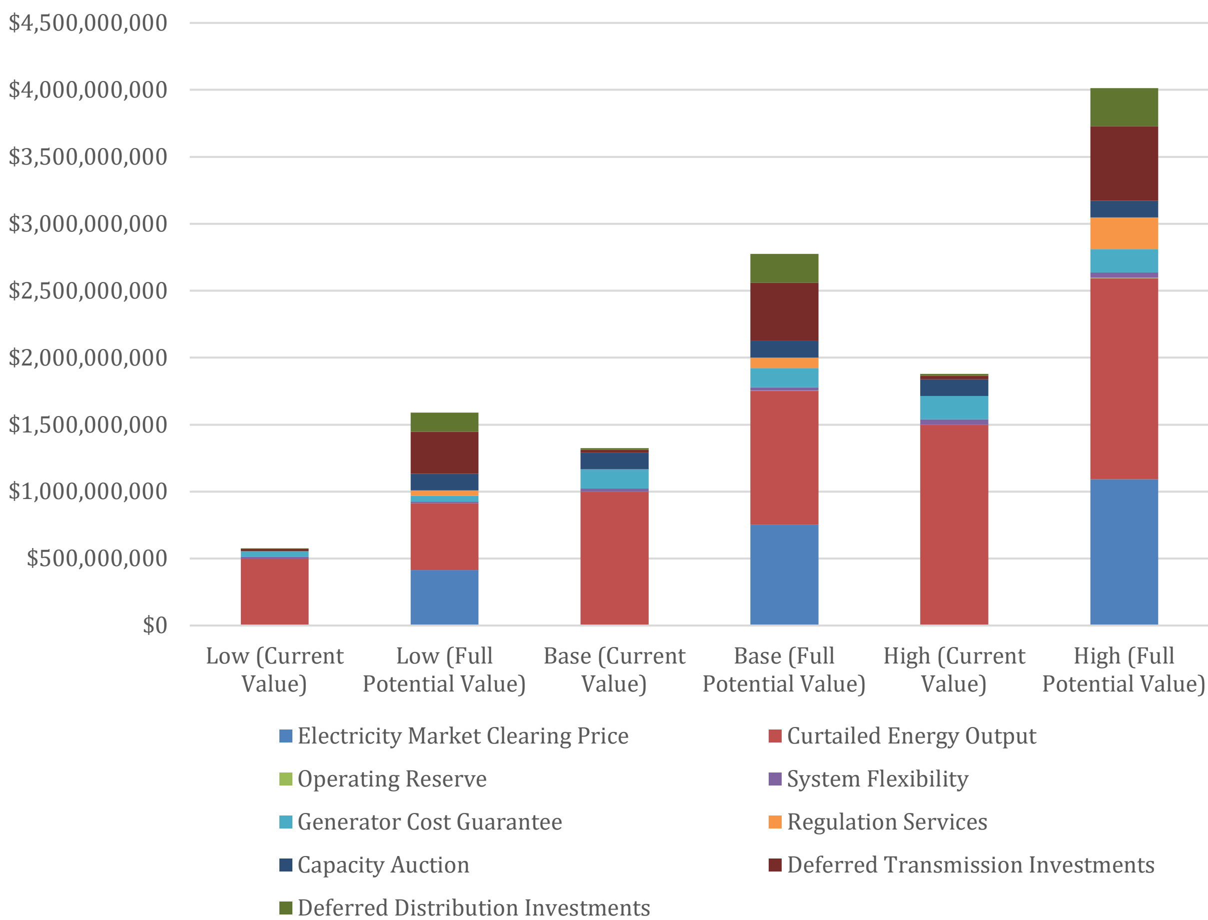

Figure 1. Energy Storage Value in Ontario Under Low, Base, and High Scenarios

Energy storage can offer savings immediately, but a variety of barriers are hindering realization of its full value in Ontario. These barriers can begin to be addressed in the following ways:

1. Given the current inability to fully integrate energy storage within Ontario's electricity market, and in order to unlock the system-wide value of energy storage now, the Independent Electricity System Operator (IESO) should contract for the full suite of services energy storage can deliver, and should enable the co-optimized operation of these storage resources. This would allow for full realization of the savings potential for customers, which cannot be achieved within the current market design and structure.

2. In parallel, the IESO, the regulators and utilities should establish enduring, cost-effective and competitive methods to integrate energy storage. This will need to entail:

    a. relying on current proposals for Capacity Auctions and ensuring energy storage's future participation;

    b. determining how to optimize existing assets by, for example, co-locating energy storage with operating renewable generation and other baseload generation facilities;

    c. ensuring that the Ontario Energy Board (OEB) and the IESO coordinate efforts to fully extract all value from non-wires solutions and wholesale market participation; and

    d. establishing an OEB-IESO committee with a clear and reasonable timeline and set of objectives for the full integration of energy storage.

3. Building off recent changes to default supply rates for applicable electricity customers, and of deferral of Global Adjustment (GA) charges for other customers, both electricity pricing for customers and GA cost allocation among customer classes should be reformed. This will need to entail:

    a. recognizing that the current fixed-cost recovery method offsets a portion of the potential savings from integrating energy storage;

    b. encouraging the IESO and OEB, along with stakeholders and the province, to determine a method of recovering fixed costs that is both fair and transparent, but also relies on efficient price signals; and

    c. recognizing that price signals are the most transparent means of extracting energy storage's system-wide benefits.

4. OEB consultations should be launched in an effort to better incent rate-regulated utilities to deploy non-wires solutions, by providing guidance around asset planning, cost allocation and renumeration, among other issues. The consultations would result in guidance from the OEB to utilities and energy storage providers on matters such as planning, cost allocation, remuneration, and pathways for regulated utilities to partner with the private sector.

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1. Introduction

The characteristics and capabilities of energy storage resources are well documented in academic literature, think-tank research reports, and studies across multiple jurisdictions. For example, as illustrated in Figure 2 from the Rocky Mountain Institute, energy storage can provide as many as 13 services between customers, grid operators (including utilities), and market operators.[1] Future designs and services in electricity markets will provide new areas of participation for energy storage.

In Ontario, energy storage can help maximize the benefits of existing generation and grid infrastructure. For example, energy storage can increase capacity factors of existing generation (i.e. hybrid energy systems) and shift energy production to hours when it is most needed. Energy storage also serves as an effective non-wires solution to eliminate or defer wires investment (i.e. transmission and distribution).

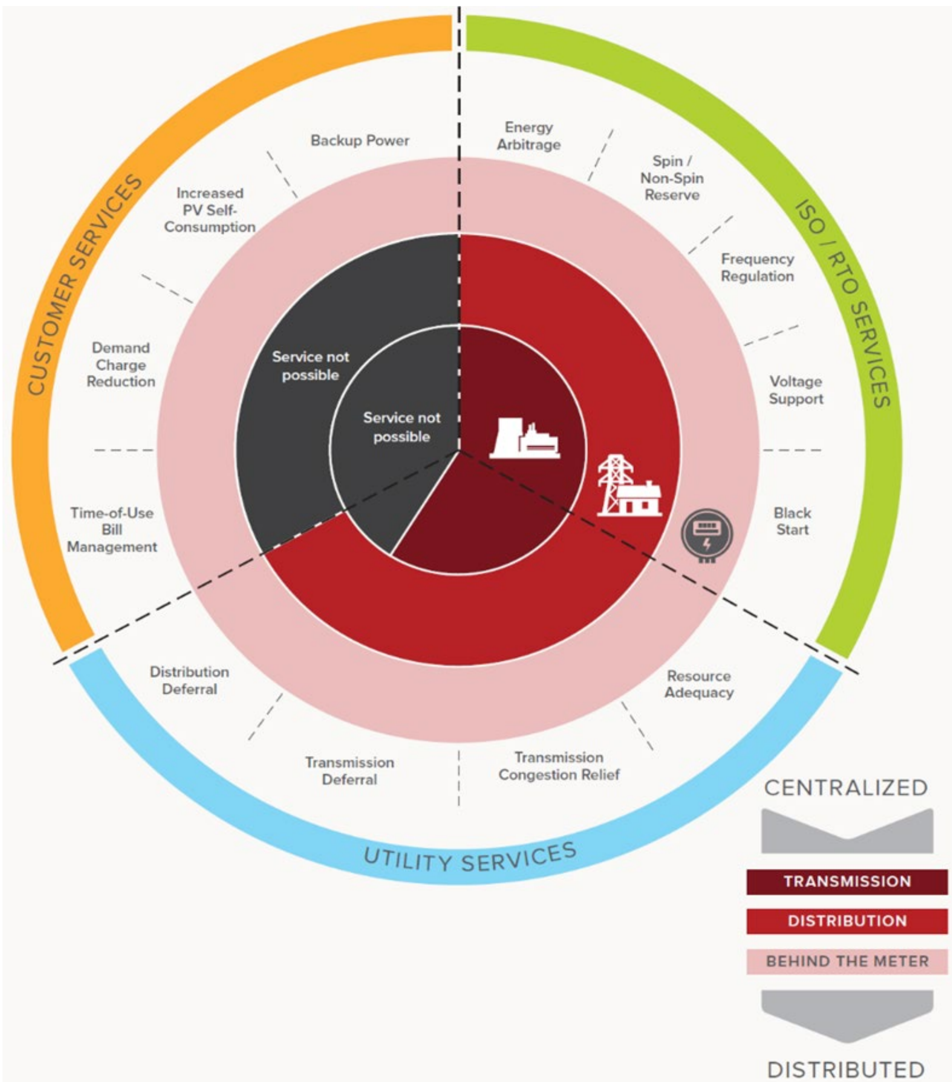

Figure 2. Energy Storage Value Attributes

[1] Garrett Fitzgerald, James Mandel, Jesse Morris, and Hervé Touati. The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid. Rocky Mountain Institute, September 2015. Retrieved from: https://rmi.org/insight/economics-battery-energy-storage/.

The purpose of this report, commissioned by Energy Storage Canada (ESC) and written by Power Advisory LLC (Power Advisory), is to quantify the benefits for Ontario's electricity customers (i.e. ratepayers) that will be realized if energy storage is fully leveraged in Ontario by:

1) Enabling energy storage to provide multiple services, particularly relative to the wholesale market;

2) Permitting energy storage to compete on a level playing field in the IESO's planned market reforms through the Market Renewal Program (MRP), Capacity Auctions, and other procurement mechanisms that may arise for resource adequacy; and

3) Facilitating use of energy storage and non-wires solutions in transmission and distribution planning.

Due to their high degree of flexibility and controllability, energy storage resources are well-suited to providing services in the wholesale market, particularly ancillary services such as frequency regulation and operating reserves. More recently, energy storage is increasingly being used to defer infrastructure investments due to its modularity (e.g. cell batteries) and ability to enhance system capacity. Customer-sited energy storage has also become widely used to manage electricity costs as technology costs have fallen. The main technology types considered in this report include: electrochemical (i.e. battery); electromechanical (e.g. flywheel, compressed air energy storage, capacitor banks, and pumped hydro); and power-to-gas. These technologies have all been deployed in Ontario:

- Batteries are one of the most widely used energy storage technologies and are the most versatile form of energy storage as they can provide a range of services, spanning the wholesale market, infrastructure deferrals, and energy management for customer-sited systems.

- Flywheels function by electrically driving a motor to spin a rotating disc mass (i.e. the flywheel) at high speeds creating kinetic energy. The most notable characteristic of flywheels is that they can cycle very quickly and are less prone to degrading, even with a large number of cycles over time, than are batteries.

- Compressed air energy storage (CAES) is a form of energy storage that uses a compressor to pressurize atmospheric air and drive it into a vessel for storage. The most common types of vessels include underground caverns, reservoirs and mines.

- Pumped hydro is the most prevalent and proven form of energy storage technology, representing a significant majority of installed capacity worldwide. It functions by pumping water from a lower reservoir to an elevated reservoir to store energy in the gravitational potential of the water. To discharge, the water from the upper reservoir is released creating kinetic energy to run a turbine and generate electricity. Because vast amounts of water can be stored in reservoirs, pumped hydro systems can store large amounts of energy.

- Capacitor banks use the magnetic field between plates as a storage medium and, similar to flywheels, can charge and discharge very quickly. Capacitor banks have no moving parts and have essentially no maintenance.

- Power-to-Gas is a flexible technology that uses the electrolysis of water to convert electrical energy into hydrogen. Power-to-Gas can be used to provide ancillary services such as rapid frequency response for electrical grid support, or utilized with a fuel cell to provide electrical power for operating reserve. The technology also enables the movement of energy from the electrical grid to the natural gas grid and back. The hydrogen produced from a Power-to-Gas process can also be blended into natural gas grids or combined with CO_2 to create renewable natural gas by methanation.

Storage technology is highly varied, and different technologies are suitable for specific purposes or use cases. For example, the response time and duration of each energy storage technology can range from real-time and sub-second increments, to durations of days, weeks and months, as illustrated in Figure 3.[2] Certain energy storage technologies are highly versatile, providing multiple services over the course of any given day and of their useful life. As illustrated in Figure 16 (see Appendix B) energy storage can use its withdrawal and injection capability to supply energy, capacity, and/or ancillary services depending on system needs throughout the day.

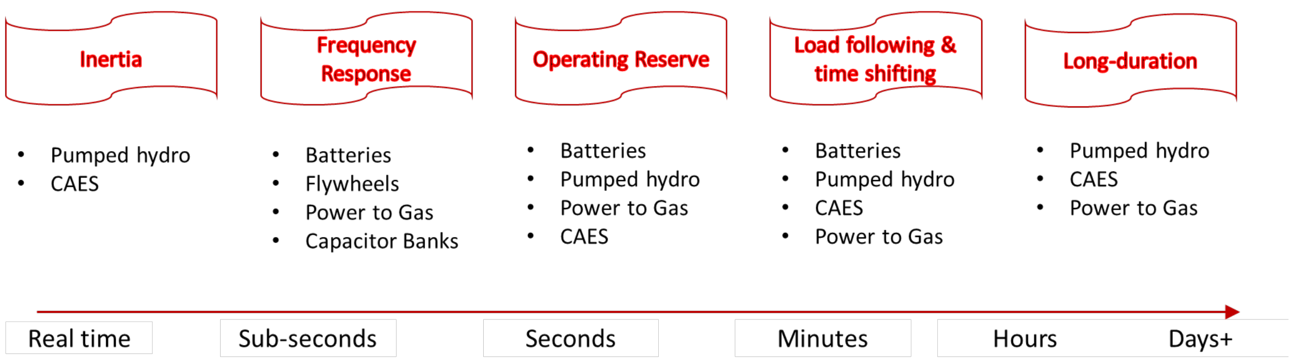

Figure 3. Time Scale of Energy Storage Technologies

[2] Figure 3 is adapted from: IRENA (2020), Electricity Storage Valuation Framework: Assessing system value and ensuring project viability, International Renewable Energy Agency, Abu Dhabi. Retrieved from: https://irena.org/publications/2020/Mar/Electricity-Storage-Valuation-Framework-2020

2. Value of Energy Storage Services and Products in Ontario

This report evaluates different services and products that may be provided by energy storage. Each of these services provides value for Ontario's electricity grid and customers, as shown in Table 1. While the bulk of this report focuses on quantitatively assessing the value energy storage may provide, certain qualitative attributes are also considered in Section 3.

As demonstrated in this section of the report, the calculated gross savings for a baseline of 1,000 MW of energy storage deployed in Ontario is between $1.5 billion and $4.0 billion (all figures are in nominal $CDN) between 2021 and 2030. Our approach to calculating gross savings considered three different scenarios: a low scenario representing a conservative view of value, a base scenario that we view are realistic assumptions, and a high scenario representing an optimistic view of value. The calculated gross savings are premised on several changes in regulatory design, and in market design and structure, to fully unlock the value of energy storage and to enable provision of multiple services, particularly as they relate to the wholesale market. We present gross savings for each scenario under current value and full potential value to demonstrate the benefit of regulatory and market design changes. A further discussion on the assumptions used as part of the calculation can be found in Appendix C.

As we elaborate in Section 4 of this report, given the current inability to fully integrate energy storage within Ontario's electricity market, and in order to unlock the system-wide value of energy storage now, the IESO should contract for the full suite of services energy storage can deliver, and should enable the co-optimized operation of these storage resources. This would allow for the full realization of the savings potential for customers, which cannot be achieved within the current market design and structure.

Table 1. Quantitative and Qualitative Values Evaluated in this Report

Wholesale Market	Electricity Infrastructure	Direct to Customers

Quantitative Estimate:
• Real-time energy (peak/off-peak arbitrage and Surplus Baseload Generation reduction)
• Ancillary services:
  o Operating reserve
  o System flexibility (excess 30-minute operating reserve
  o Regulation service
• Capacity
 	
Qualitative:
• Environmental benefits
• Transmission congestion relief (i.e. north-to-south congestion)
• Electricity exports/imports
	Quantitative Estimate:
	• Transmission upgrade deferral (i.e. capacity, local, regional)
	• Distribution upgrade deferral
	
	Qualitative:
	• Power quality enhancements (harmonics, end of line voltage drops, frequency droop)
	• Reliability services (cold load pick up, outage management, voltage stability)
	• Distributed energy resource output management
		Quantitative Estimate:
		• Time-of-Use bill management
		• Demand charge reduction (e.g. Global Adjustment, etc.)
		• Renewable output maximization
		
		Qualitative:
		• Power reliability/quality improvement

A recently completed summary by Balducci et al. (2018) compiled results of energy storage valuations studies from across the U.S.[3] Given the wide range of results, the potential benefits of energy storage are clearly case-specific and dependent on local or regional market conditions. This report therefore fully accounts for the unique characteristics of Ontario's electricity market. However, the valuations arrived at – and given due consideration of region-specific conditions - are believed to be comparable to findings from previous studies conducted in other markets.

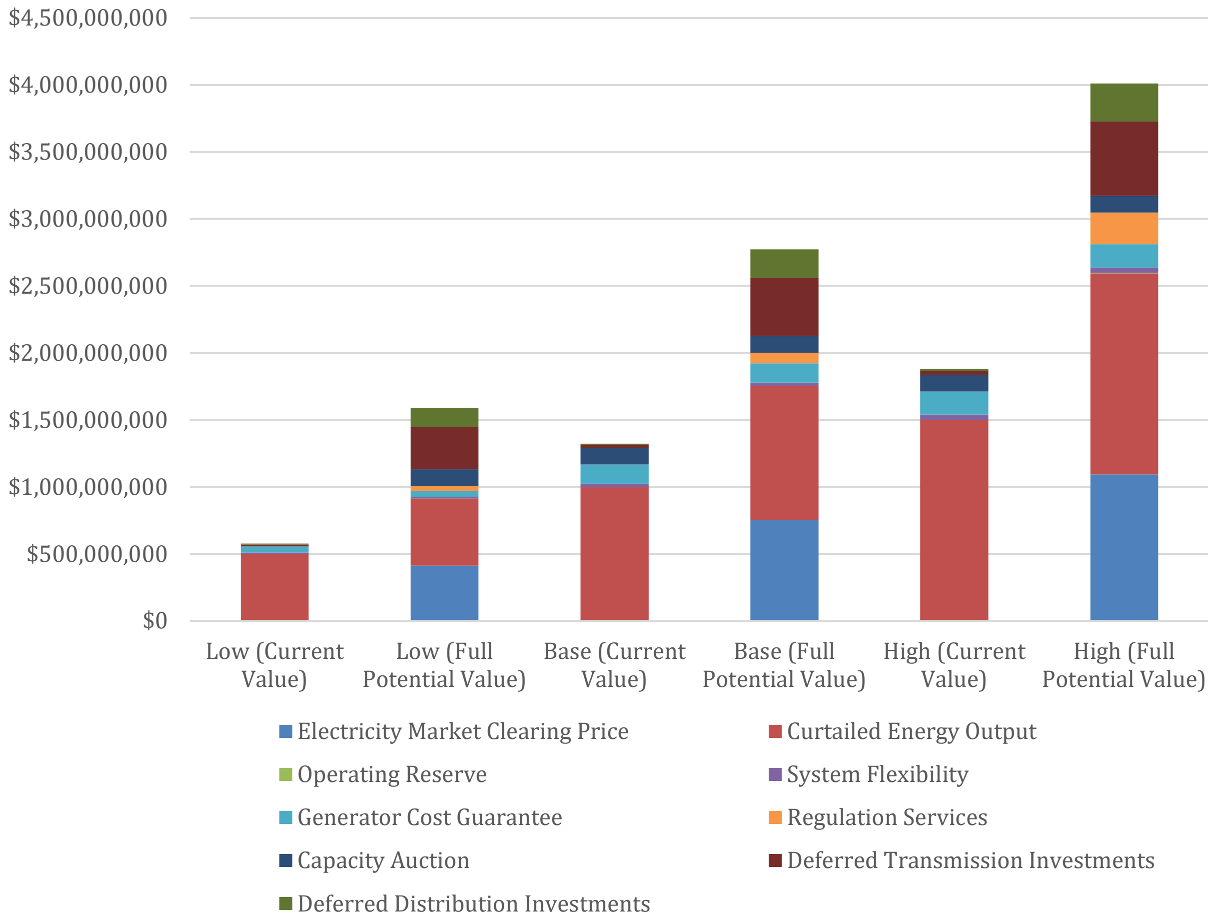

Figure 4. Energy Storage Value in Ontario Under Low, Base, and High Scenarios

The valuations shown above can be realized through the implementation of a new regulatory and market framework – one which addresses existing limitations on realization of the full value of energy storage resources in Ontario. Key among these limitations are:

- Global Adjustment (GA) charges that offset reductions in wholesale energy market clearing prices;

[3] Patrick J. Balducci, M. Jan E. Alam, Trevor D. Hardy, and Di Wu. Assigning value to energy storage systems at multiple points in an electrical grid. The Royal Society of Chemistry, 2018. Retrieved: https://pubs.rsc.org/en/content/articlehtml/2018/ee/c8ee00569a. See Figure 17, Appendix B.

- A uniform, province-wide Hourly Ontario Energy Price (HOEP) and a five-minute Market Clearing Price (MCP) that undermine the local price signals needed to drive investment and consumption decisions;
- Congestion Management Settlement Credits (CMSC) that reduce economic efficiency across the wholesale electricity market;
- IESO Dispatch Scheduling and Optimization (DSO) limitations that may not fully unlock energy storage's unique operating characteristics;
- Capacity Auction constraints that may limit the types of resources allowed to participate;
- Supply of operating reserve (OR) (a form of ancillary services) constraints that may prevent energy storage from fully participating;
- Opaque procurement of regulation services (a form of ancillary services) that does not provide clear price signals on the cost of such services;
- Regulatory uncertainty and financial disincentives for regulated utilities to invest in energy storage services directly, or to partner with unregulated private-sector energy storage partners (who in turn can attract merchant revenues and other value streams to augment customer savings); and
- Time-of-use (TOU) pricing under the Regulated Price Plan (RPP) that may not offer the necessary price spread for the economic operation of an energy storage asset.

Some of these limitations are under consideration through the IESO's MRP, which will result in the implementation of Locational Marginal Prices (LMPs) for energy and OOR, elimination of CMSC payments, and more expansive Capacity Auctions. But there is no immediate prospect for the elimination of a number of these limitations, notably high GA payments and a lack of clear regulatory guidance to utilities to pursue non-wires solutions.

Table 2. Energy Storage Savings under Current and Future Framework

Segment	Service	Current Framework	Future Framework
Wholesale Market	Real-Time Energy	Two-schedule system, uniform prices, CMSC payments, high GA payments – some limits from DSO regarding energy storage	LMPs and dispatch tool upgrades
	Capacity	Limited Capacity Auctions	Expanded Capacity Auctions and resource adequacy procurement
	Operating Reserve	Current limitations of dispatch algorithm	Full optimization with real-time energy and regulation services
	Regulation Services	Inconsistent and opaque procurement	Competitive procurement of regulation services and full optimization with real-time energy and regulation service
	System Flexibility	Increase procurement of 30-minute OR (30R) to provide flexibility	Flexible ramping product or storage participation in 30R

Electricity Infrastructure	Transmission Deferral	Limited investment due to regulatory uncertainty and negative incentive for utilities	Clear regulatory framework with respect to the treatment and procurement of non-wires solutions
	Distribution System Deferral	Limited investment due to regulatory uncertainty and negative incentive for utilities	Clear regulatory framework with respect to the treatment and procurement of non-wires solutions
Direct to Customers	TOU Bill Management	TOU pricing under RPP	TOU with enhanced Critical Peak Pricing options for customers
	Demand Charges	Fixed Demand Charges Class A GA Cost Structure	Tiered Demand Charges (i.e. different charge for usage by season and hour of the day), or Interruptible Demand Charges
	Renewable Output Maximization	Management of production to cost allocation	Better market signals on when renewable output should be shifted to times of the market that are most valued

2.1 Wholesale Market Services in Ontario

Energy storage resources can provide multiple services in Ontario's wholesale electricity market:

- **Energy arbitrage and reduction in Surplus Baseload Generation:** Energy storage resources engage in energy arbitrage, which entails charging in low-value (i.e. low-price) hours and discharging in high-value hours. As discussed at length in this report, Ontario has a significant amount of Surplus Baseload Generation (SBG) in off-peak hours. Energy storage can shift a percentage of this surplus energy to peak hours, reduce the need to dispatch high-cost resources, and lower market clearing prices for the benefit of all customers.

- **Operating Reserve:** Energy storage resources can participate in the OR market,[4] both as a load (e.g. dispatchable load) when charging in low-value hours, and as a generator.

- **System Flexibility:** Given the capability of energy storage resources to react nearly instantaneously to real-time conditions, they can provide greater flexibility to grid and market operators and reduce the need for procurement mechanisms targeting flexibility.

- **Regulation Services:** Energy storage resources often provide frequency control services[5] (i.e. regulation services) in wholesale electricity markets around the world. As noted, energy storage assets are typically designed to react nearly instantaneously to conditions on the grid, making them an ideal resource for regulation services.

- **Capacity:** Given the ability of energy storage to participate in the wholesale electricity markets, it can also participate in system operator-led capacity procurements, such as auctions and contracts, to ensure power-system resource adequacy. Capacity Auctions and procurement contracts provide energy storage assets with an additional revenue stream – very often tied to

[4] OR is an electricity supply or demand reduction that can be dispatched on short notice in the event of unexpected discrepancy between generation and load.

[5] In order to synchronize generation on the electricity grid, the frequency of the electrical current must be maintained within tight tolerance bounds.

requirements to be available during defined hours or days – while also helping to meet system-wide reliability requirements.

Table 3. Wholesale Market Quantitative Assessment 2021-2030

Wholesale Market	Methodology	Findings
Real-time Energy (arbitrage/SBG)	• Estimate (at high level) energy arbitrage value between daily peak and off-peak prices. • High-level offer curve shows how energy arbitrage can reduce overall system costs. Savings become more pronounced as Ontario moves towards LMPs and a decrease in GA charges.	• System-wide savings from reduced market clearing price in peak hours range from $413 million to $1.09 billion. • Savings from reduced curtailed energy output range from $500 million to $1.5 billion.
OR	• Calculate the impact of storage resources lowering OR supply curve, while generating within both the 10-minute OR and 30R markets.	• Reduced OR costs when energy storage is able to generate can provide much greater value, potentially $100+ million, but requires further system modeling to estimate more precisely.
System Flexibility (excess 30R)	• Calculate costs of IESO's OR Flexibility Mechanism and reduce it by amount of storage installed on the system. The IESO currently procures 200 MW of additional 30R when it requires greater flexibility. The introduction of storage may be able to reduce the need for this procurement.	• The reduced need for flexibility procurement can provide $11.7 million to $39.5 million in savings.
Regulation Services	• As regulation services are increased, storage can potentially reduce regulation costs.	• A reduction in regulation costs can provide $39.3 million to $236.3 million in savings.
Capacity	• Storage will compete in upcoming Capacity Auctions and offer below forecasted clearing price.	• Energy storage participation in the Capacity Auction can provide up to $124 million in savings.

2.1.1 Energy Arbitrage and Reduction in SBG

Energy storage provides system-wide savings to all customers when engaging in energy arbitrage by lowering peak prices. Our analysis found that in 2019, if 1,000 MW (4,000 MWh) of energy storage with a 90 per cent efficiency rating (i.e. for every MW of charging, the unit will discharge 0.9 MW) participated in Ontario's wholesale electricity market, it would have provided between $31 million to $84 million in system-wide savings in the form of lower on-peak market clearing prices. This is a high-level estimate and is not based on a dynamic, simulated dispatch model. Over the 2021-2030 timeframe, these savings range from $413 million to $1.09 billion. Note that these savings do not flow directly to energy storage facilities but instead flow to all customers in the form of reduced energy prices in the wholesale market.

2.1.1.1 What is Energy Arbitrage and How Does it Relate to Energy Storage?

Energy storage resources in Ontario and other wholesale electricity markets can engage in what is known as energy “arbitrage”. Arbitrage is the buying of a good in a low-price market and the selling of it in a higher price market – and earning the spread between the two. In the context of energy storage facilities, it means charging or storing energy in low price hours and selling that stored energy at a later point when prices are higher. While some generators are capable of storing energy – some hydroelectric generators, for example, can pool a limited amount of water behind the dam and release it (generate) in later hours – most facilities are incapable of large-scale storage. As a result, a significant portion of installed generation capacity in Ontario – particularly baseload hydroelectric, wind, and nuclear – will continue to generate in hours when demand and market clearing prices are low.

Ontario has a significant amount of inflexible installed generation capacity, which has led to many hours when energy is either exported at low or negative prices or facilities are curtailed (i.e. their energy is not accepted onto the grid by the system operator). Most curtailed energy continues to be paid its contracted or rate-regulated amount. The lack of large-scale storage is among the factors that ensures that HOEP is typically depressed in hours when demand is low and that baseload generation is high. Conversely, HOEP increases in hours when costs are higher, and “peaking” generators are dispatched to meet greater demand. Energy storage can reduce price volatility by shifting energy throughout the day or over multiple days. On any given day, energy storage resources would be expected to charge in the early morning hours when prices are low and to discharge later in the day when prices are higher – arbitraging the price spread that is common in Ontario and other wholesale markets.[6]

By actively participating in the wholesale electricity market, energy storage resources earn the spread from buying energy in low-price hours and selling it in high-price hours.[7]

Beyond simple arbitrage on an hourly basis, many energy storage resources can react quickly in response to unexpected intra-hour changes on the grid that produce rapid and dramatic price spikes. Take November 19, 2019, as an example. On that day, the five-minute market clearing price spiked to $2,000/MWh between 8:00 and 9:00 A.M – up from $0/MWh just three hours earlier. In that hour alone, prices spiked from $144/MWh to $2,000/MWh within five minutes. Energy storage resources can respond rapidly to five-minute dispatch signals. As a result, they are capable of rapidly discharging (generating) in response to prices, mitigating the financial impact of the price spike for electricity customers.

2.1.1.2 Ontario’s Ongoing SBG Problem

Ontario’s baseload generating resources often provide more energy output (i.e. supply) than there is demand in the province. When this occurs, the province is experiencing SBG. In many instances, this is resolved by exporting surplus energy to neighbouring jurisdictions such as New York, Michigan, and Quebec. In other times, when SBG is greater than intertie capacity into other markets or when adjacent markets are already sufficiently supplied by low marginal cost generation, the IESO must curtail specific resources, predominantly energy from hydroelectric, nuclear, and wind generators. Typically, in hours of

[6] The very lowest average HOEPs in 2019 are in hours 2, 3, 4, and 5, while the four highest average HOEPs are in hours 17, 18, 19, and 20.

[7] Note that this report’s arbitrage analysis does not include GA charges or other demand charges, which may impact the profitability of energy arbitrage in Ontario.

SBG – when nearly all of that surplus supply is coming from resources with low or zero marginal cost – prices will trend to $0/MWh or negative.

For this analysis, SBG is defined as hours when energy output from nuclear, hydroelectric, and wind generators is greater than domestic demand. This does not include energy that has been curtailed by the IESO and, as a result, underestimates the actual number of SBG hours. Nonetheless, in 2019, there were 5,110 hours – or about 58 per cent of all hours in the year – when energy output from these baseload generators in Ontario was greater than provincial demand. SBG conditions were prevalent in nearly all hours when HOEP was $0/MWh or below. In total there were 1,733 hours when HOEP was $/MWh or negative, with SBG occurring in 1,709 of those hours.

Table 4. Negative HOEP and SBG in 2019

	Total Number of Hours in 2019	% of All Hours
Hours where HOEP is $0/MWh or less	1733	20%
Hours total SBG (nuclear, hydro and wind output greater than Ontario demand)	5110	58%
Number of hours of limited SBG (i.e. nuclear and hydro energy output greater than Ontario demand)	2865	33%
Number of hours when HOEP is $0/MWh and SBG was also occurring	1709	20%

As noted previously, hours where SBG is prevalent typically correspond with hours when prices are $0/MWh or below. Figure 5 highlights this. The early morning hours experience the most severe SBG conditions. These hours also have the lowest average HOEP. Conversely, hours with highest average HOEP are the same hours when demand is met by dispatching higher-cost generators – predominantly gas-fired generators, peaking hydroelectric generating units, and imports. Figure 5 below plots the difference between demand in Ontario and energy output from nuclear, hydroelectric, and wind generators. In hours where the chart is negative, Ontario demand is, on average, below output from these resources and the province is experiencing SBG. Conversely, in hours where the chart is positive, demand is being met by energy output from higher-cost generators.

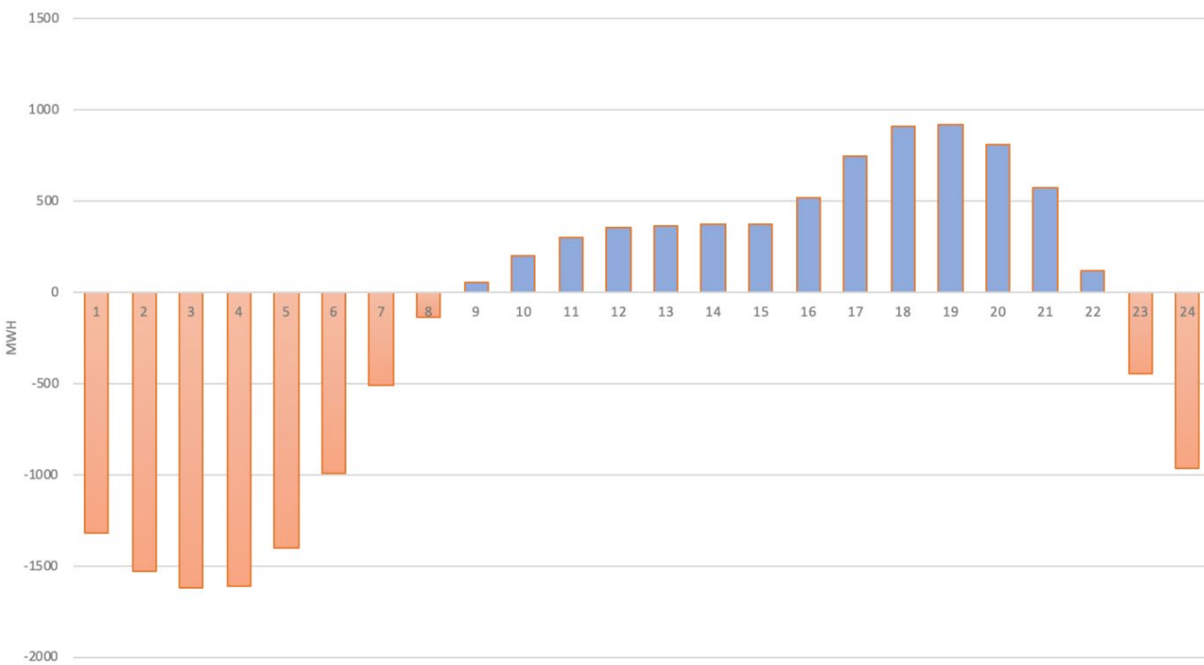

Figure 5. Ontario Demand Compared to Nuclear, Hydro, and Wind Energy Output

Additionally, nearly all variable generators (VGs) – wind and solar – are paid nearly their full contracted price in hours when they are curtailed by the IESO. Most hydroelectric generators are made financially whole to a similar extent. The IESO does not publish detailed data on curtailed energy but does provide an annual total of 3.2 TWh of curtailed energy in 2019. Regarding VGs specifically, 2.6 TWh of energy was curtailed, accounting for 18 per cent of the total energy output from all VGs. While the IESO does not publish granular data, most if not all of that curtailment would have occurred in hours when prices were $0/MWh or negative and SBG was prevalent. In these cases, electricity customers are paying for energy that, to a large extent, goes to waste. If all of that energy came from generators with a Feed-in-Tariff contract, the cost of the curtailed energy from VGs was more than $348 million in 2019 alone. Our analysis assumes that this cost can be reduced by $50 to $150 million annually, but note that there is little granular data upon which to base a full assessment of savings. The planned closing of the Pickering Nuclear Generating Station in the mid-2020s may also reduce the prevalence of SBG in Ontario.

2.1.1.3 Energy Storage and Ontario's Negative Price Phenomenon

Ontario's more than decade-long generation capacity surplus – with a large portion of that capacity installed as baseload resources with $0/MWh or low marginal cost – has resulted in a steady decrease in HOEP. More specifically, the number of hours in which HOEP is $0/MWh or negative has increased through that time. Ontario's wholesale electricity market has a number of unique features, making a direct comparison to other wholesale markets in North America difficult. It is nevertheless worth noting that the Ontario wholesale market experiences $0/MWh or negative prices far more often than neighbouring jurisdictions (see Table 6).

Table 5. Negative Prices in Ontario Compared to Neighbouring Jurisdictions

	IESO	NYISO	MISO	ISO-NE	PJM
Hours in 2019 when wholesale electricity prices were $0/MWh or less	1,733	21	2	52	4

2.1.1.4 How Does Energy Storage Provide Savings in the Wholesale Market?

Energy storage's value in the wholesale electricity market comes from moving energy from low-value to high-value hours. In doing so, it provides system-wide savings for all customers. While this is not unique to Ontario, the province's supply mix and market conditions, as detailed in the previous section, make this value proposition particularly pronounced in Ontario. Energy storage's full value is particularly noticeable when compared against a typical supply curve in Ontario.

A supply curve is a set of offers from generators stacked from lowest to highest based primarily on their marginal cost of production. When generators offer into the wholesale electricity market at their marginal cost, they offer at the cost it takes to produce the next unit of energy. HOEP is set at the price of the last generating resource required to meet demand, and all generators are then paid this price.

As discussed in previous sections, Ontario has a large amount of installed generation capacity with low or zero marginal cost – including nuclear, hydroelectric, and VGs. In low-demand hours, such as the overnight and early morning hours, energy output from those resources is often greater than demand – with that output either being exported at low prices or curtailed by the IESO. In these hours, demand from an energy storage resource is expected to have little impact on HOEP, as the increase in demand will likely be met by zero or low marginal cost generators. Conversely, in high demand hours, demand is often met by higher-cost thermal units and, as a result, stored energy from low-price hours can undercut these facilities and, in the process, reduce HOEP paid by all customers. This is a system-wide savings for all customers.

The following figure provides an example of a shift in the demand curve in off-peak hours due to energy storage charging, and a corresponding decrease in demand in peak hours when an energy storage resource would discharge. Note that in reality, when an energy storage resource discharges (generates) it would move the supply curve, not demand, but the impact on market clearing prices would be the same.

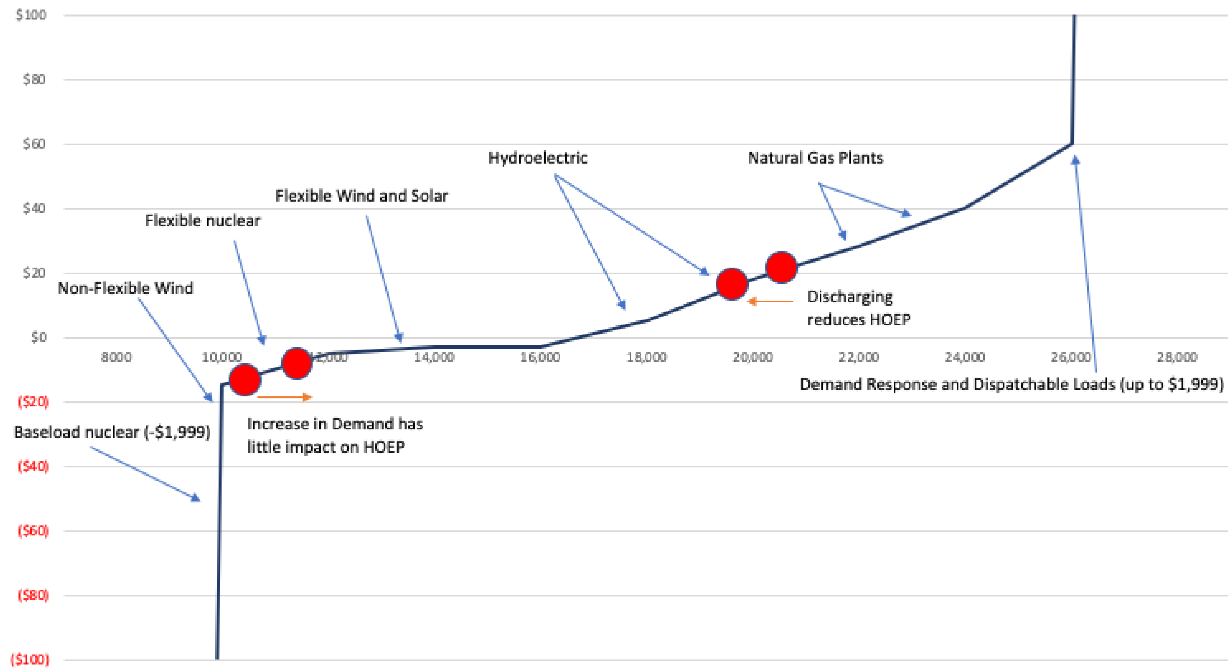

Figure 6. Supply Curve in Ontario

2.1.2 Savings in the Operating Reserve Markets

Energy storage resources are expected to participate as loads in the OR market when charging and as generators when sitting in stand-by mode and capable of generating. Given the low operating and opportunity cost of energy storage resources when participating as a load during low-price hours, we estimate that they would reduce the market clearing price of OR paid by all customers. Over the 2021-2030 timeframe these savings could reach up to $4.8 million.

OR is stand-by power that IESO can dispatch in response to unexpected conditions on the grid – a sudden outage at a generation facility, for example. Currently, there are three types of OR: 10-minute spinning (10S); 10-minute non-spinning (10N); and, 30-minute reserve (30R). It is expected that energy storage resources can participate in the OR market and supply all three types of OR.

The analysis assumes that energy storage resources participate in the 10S market as a load in the hours when they are charging – although energy storage can also act as a generator. Given that OR and the energy markets are co-optimized, the system-wide value of savings in these low-price hours is limited. Energy storage resources are capable of participating in all OR markets, but were only assessed in the 10S market for this analysis. Due to the near instantaneous response time of energy storage, it can easily meet the 10-minute response time requirements of 10S OR in all hours of the day as a generator, even though the storage resources would technically not be spinning.

2.1.3 Savings Through Reduced use of Flexibility Mechanism

Our analysis assumes that at least some – if not all – of the procurement related to the IESO's Flexibility Mechanism may not be needed given energy storage's inherent ability to quickly respond to unexpected changes on the grid. Over the 2021-2030 timeframe these savings could range from $11.6 million to $39.5 million.

Ontario’s electricity grid has undergone significant changes over the last decade. As part of these changes, the province has introduced a large number of VGs. Due to the variable nature of these resources – their energy output is based on ambient weather conditions that can change instantaneously – their large-scale introduction has resulted in the need for greater system-wide flexibility. In 2016, the IESO began a public consultation on how ensure greater flexibility in order to manage VGs.

In 2018, the IESO formalized its approach, which sees it procure 200 MW of additional 30R in hours when it forecasts the need for greater flexibility. The IESO has not publicly provided data on how often it uses this Flexibility Mechanism or on its total cost. While the IESO initially expected that it would not require the Flexibility Mechanism past 2023, it now expects it to use it indefinitely. Energy storage can reduce the need for this form of procurement.

2.1.4 Reducing the Cost to Ratepayers of Cost Guarantee Programs

Our analysis suggests that energy storage could reduce the need for and reliance on the Real-Time Generator Cost Guarantee (RT-GCG) program within the wholesale market, given the ability of energy storage to react quickly to unexpected events without requiring hours to reach a “warm” state. Over the 2021-2030 timeframe these savings could range from $43.4 million to $173.7 million.

The IESO operates a number of programs that guarantee the start-up and other costs for gas-fired generators to ensure these facilities are available to the IESO to maintain grid reliability. Cost guarantee programs such as the RT-GCG have been a part of Ontario’s electricity market since 2003 and are also common in other wholesale electricity markets. The Market Surveillance Panel – a panel overseen by the OEB that monitors, investigates, and reports on the wholesale electricity market – has repeatedly analysed the guarantee programs and provided recommendations to reduce costs associated with them. It has quantified IESO RT-GCG payments to generators in 2019 at $33 million.

An increase in energy storage capacity in Ontario should reduce the need and reliance on guarantee programs, particularly the RT-GCG. Energy storage has well known capabilities to react to unexpected and rapid changes in demand or supply in real-time. Furthermore, unlike gas-fired generators, once energy storage has been charged in off-peak hours, it can react nearly instantaneously and requires neither start-up costs nor hours of time to reach a safe operating state. Gas-fired generators also require minimum run times, resulting in them operating for longer periods of time than may be economic, and adding to the SBG challenges described earlier.

2.1.5 Reducing the Cost of Providing Regulation Services

Energy storage resources are particularly well-suited to provide regulation service. The Hornsdale Power Reserve facility in Australia, for example, has provided more accurate and responsive regulation services at a lower cost than traditional thermal generators. Over the 2021-2030 timeframe these savings could range from $39.4 million to $236.3 million.

In order to maintain the reliability of the grid, the IESO must ensure that energy output from generators matches total load. In order to correct for variations, the IESO contractually procures regulation services. Resources supplying regulation services are paid to have their energy output adjusted by the IESO in real-time as needed to maintain the reliability of the grid. In 2019, the IESO paid more than $60 million for regulation services, and it has stated publicly that it intends to procure a greater amount of such services in the future.

Energy storage resources can provide effective regulation services due to their fast-response capabilities. As mentioned, in Australia the Hornsdale Power Reserve – a 100 MW Tesla storage facility – has provided more accurate and responsive regulation service than traditional thermal generators. Additionally, it has been able to provide this service at a lower cost – as much as 91 per cent cheaper in certain instances.[8] Similarly, in Ontario, the NRStor two MW Minto Flywheel facility has demonstrated a performance that is two-times more effective than traditional assets.

2.1.6 Savings in the Capacity Auction from Greater Energy Storage Participation

Energy storage resources can offer a fixed amount of capacity as part of the IESO's Capacity Auctions. Currently, Capacity Auctions are limited to demand response (DR) resources, but future Capacity Auctions will permit participation from other select resource types, including some forms of energy storage. This analysis assumes that energy storage facilities participate in Capacity Auctions from 2023 to 2030. Based on a current forecast for clearing prices and procurement amounts, energy storage facilities are expected to reduce the Capacity Auction clearing price by five per cent annually, providing $124 million in savings.

IESO estimates of needed supply capacity to be procured through Capacity Auctions are prone to uncertainty. Further, even though some energy storage resources will be permitted to participate within Capacity Auctions, it is not certain when energy storage resources will fully participate. Instead, energy storage resources may offer only a portion of their available surplus capacity that is not being used to provide other services (i.e. arbitrage, regulation, reliability, etc.).

In addition to stand-alone energy storage, there is opportunity for energy storage to be co-located with existing VGs (approximately 7,000 MW of which are in operation in Ontario) and other generation sites to provide additional capacity toward resource adequacy requirements. Recent studies[9] have indicated the value of co-locating energy storage with VGs, including cost synergies and market value synergies, while recognizing the need to consider operational and siting constraints and the need to address market and regulatory uncertainty that currently hinders hybrid generation systems.

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[8] See Arena Insights Forum presentation, November 2018. https://arena.gov.au/knowledge-bank/arena-insights-forum-november-2018-lsp-summary/

[9] A. Gorman, A. Mills, M. Bolinger, A. Wiser, N.G. Singh, E. Ela, E. O'Shaughnessy. Motivations and options for deploying hybrid generator-plus-battery projects within the bulk power system. The Electricity Journal, Volume 33, Issue 5. 2020. Retrieved from https://www.sciencedirect.com/science/article/pii/S1040619020300312

2.2 Electricity Infrastructure Savings in Ontario

Energy storage resources can reduce costs in the transmission and distribution sectors in Ontario by:

- **Deferment of Transmission Assets:** The installation of energy storage resources at specific locations on the grid can increase the utilization of existing transmission assets and defer new investments required for system needs based on regional planning requirements.
- **Deferment of Distribution Assets:** Energy storage resources can increase the utilization of existing distribution assets and defer new investments throughout a distributor's service territory and also augment distribution system planning.

Table 6. Electricity Infrastructure Quantitative Assessment 2021-2030

Electricity Infrastructure	Methodology	Findings
Deferment of Transmission Assets	• Review regional planning documents and identify system needs for thermal capacity overload • Assess deferment potential of traditional electricity infrastructure (e.g. transmission station) by deploying energy storage resources • Cost savings derived from avoided amortization payment of traditional electricity infrastructure until a utilization threshold is achieved (i.e. percentage of excess demand to total traditional investment capacity)	• Savings from deferred transmission investment range from \$314 million to \$556 million
Deferment of Distribution Assets	• Determine amount of gross capital expenditures that are spent on system expansions using the system service category of distributor spending • Forecast future capital expenditures based on historic relationship of capital expenditures to load growth • Calculate cost savings of deferred capital expenditures using energy storage facilities located within the distributor service territory	• Savings from deferred distribution investment range from \$142 million to \$284 million

2.2.1 Electricity Infrastructure and Non-Wires Solutions

Energy storage can be used by grid owners and operators as non-wires solutions to address power system needs. Compared to traditional transmission and distribution investments, non-wires solutions provide greater flexibility as well as the ability to offset installed costs with additional revenue streams (derived from wholesale markets and direct-to-customer savings). Energy storage may be an attractive solution for utilities if the savings from deferred investments are stacked with other value streams.

Realizing cost savings from the deferment of traditional transmission and distribution (T&D) investments is not fully enabled in Ontario's current regulatory framework. Regulated utilities do not have sufficient guidance for the treatment of revenues derived from wholesale markets through the operations of energy storage solutions. Given this lack of clarity, utilities discount these potential revenues, and therefore energy storage solutions may be deemed uneconomic compared to traditional utility T&D investments.

Regulated utilities, including some ESC members, have a responsibility to consider least-cost options within their distribution system plans, including balancing investments in operations and maintenance with capital expenditures. Further guidance would be helpful for the entire sector. For example, instead of making an investment in a traditional wires solution, a utility could contract for services from an unregulated entity if the services obtained meet reliability and system needs. Under this arrangement, a utility could procure services from an energy storage operator, the owner of which would have the flexibility to offer excess capabilities (such as supply of ancillary services) to the wholesale market or other customers. The unregulated energy storage operator would be incented to maximize revenues from other value streams, in order to provide the most competitive offering to regulated utilities, and would bear the risks associated with those additional revenues.

While Ontario's Local Distribution Companies (LDCs) are subject to performance-based regulation, their revenue requirements and return expectations are primarily based on capital expenditures. LDCs do not earn a regulated rate of return when implementing service-based solutions. In contrast, other jurisdictions[10] have recognized the need to re-align regulated utility revenue-setting mechanisms and profit incentives, to ensure they do not impede identification and adoption of innovative solutions, such as those available from energy storage.

The analysis suggests that the gross savings potential for deferred regional T&D investments could range from $315 million to $556 million over the next decade. For deferred distribution capital expenditures, gross savings could range from $142 million to $284 million over the same time period.

2.2.2 Energy Storage Deferment Potential for Electricity Infrastructure

Most T&D assets are constructed to meet peak power system needs. Energy storage can be used to reduce capacity overloads during peak demand periods and increase the utilization of the existing power system. This defers the need for new T&D investments to meet demand growth expectations and offers potential savings for Ontario electricity customers.

Energy storage-based T&D capacity reductions come in various sizes and configurations. For example, a large energy storage facility could be sited at an existing transmission station to remove the capacity overload of its transformers. Alternatively, an aggregation of energy storage alongside customers could be used to reduce demand and strain on the distribution system. When the energy storage facilities are not reducing peak demand on a regional or local power system, the energy storage facilities could provide additional supply and services, within wholesale markets and/or direct to customers.

[10] See for example discussions held by the OEB at its consultations related to utility remuneration in August and September 2019: https://www.oeb.ca/industry/policy-initiatives-and-consultations/utility-remuneration.

Many energy storage technologies are scalable and can adjust their capacity reduction potential on an annual basis with minimum additional costs. The amount of energy storage deployed can therefore remain aligned with power system needs and quickly adjust to demand forecast changes, such as the lower demand due to the economic impacts of COVID-19. Scalability of energy storage can greatly reduce the risk of stranded T&D assets that must be funded by electricity customers.

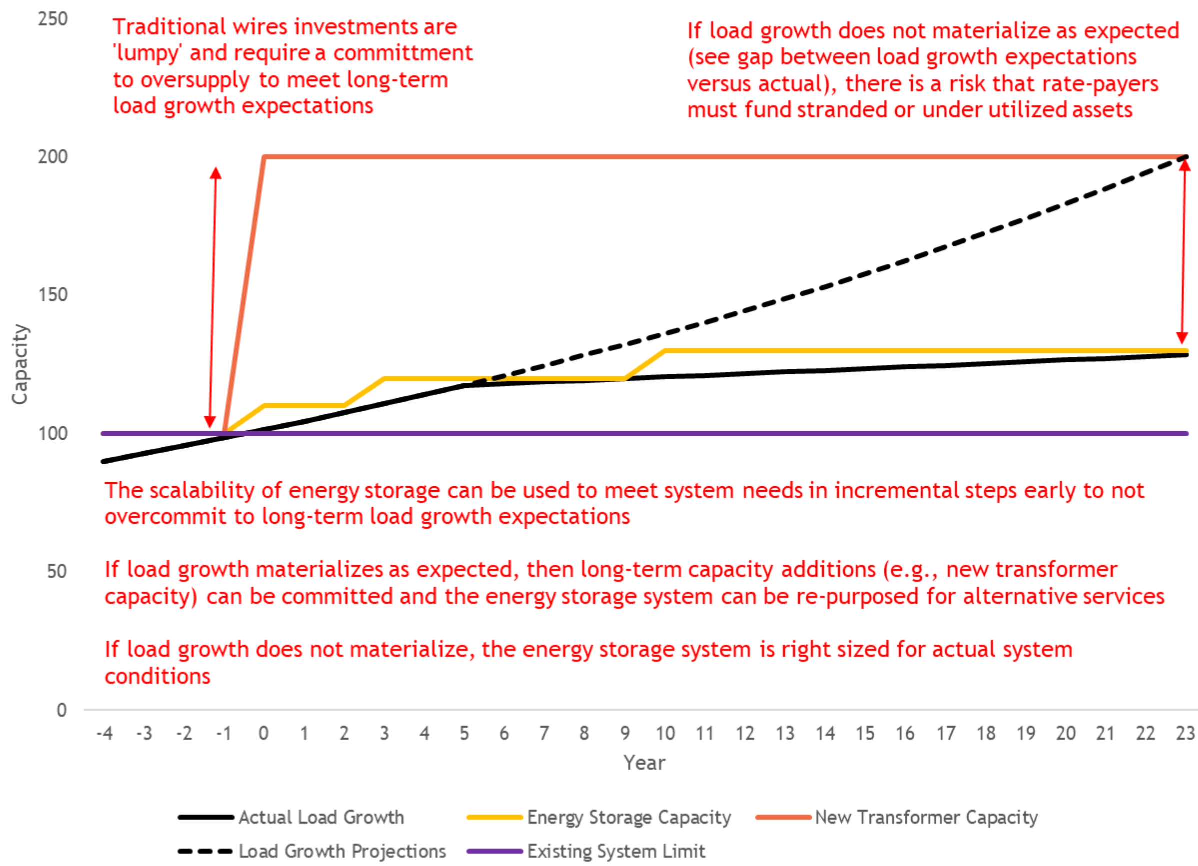


Figure 7. Illustrated Example of Energy Storage Scalability

2.2.3 Regional Planning Deferment Potential

Regional planning activities – such as Integrated Regional Resource Plans (IRRPs), Regional Infrastructure Plans, and Need Assessments – are performed to determine power system needs based on demand forecasts, existing system capacity, asset end-of-life risks, and other inputs. Regional planning documents can identify opportunities to increase the utilization of existing T&D assets and to defer new investments through the deployment of energy storage.

Regional planning documents were reviewed to identify sub-regions or local areas[11] where power system needs are primarily expected to be determined by thermal capacity overload (e.g. demand is expected to exceed the Limited Time Rating of a transmission station). End-of-life and system stability system needs

[11] As referenced in earlier sections of this report, "zones" refer to IESO-defined transmission zones, whereas "regions" and "areas" refer to IESO- and LDC-defined power system planning locations and customer service territories. "Zones" are not the same electrical or geographic locations as "regions" and "areas" – all are distinct and are used within proper contexts throughout this report.

were not accounted for within this analysis due to the case-by-case nature of such needs, and limited information availability in public regional planning documents. A model of demand growth expectations and estimates of existing system capacity for each identified sub-region was constructed. New T&D investments typically come in the form of fixed capacity blocks, such as a new transformer station with a capacity of 150 MW. Depending on demand growth expectations, initial utilization of new T&D investments could be low and provide an opportunity for energy storage to defer investments until higher utilization can be ensured. The table below provides a summary of the sub-regions used in the model including need date and demand growth rates.

Table 7. Ontario Planning Sub-Regions Used in Analysis

Region	Sub-region	Need Date	Demand Growth Rate (2020-2030)
York	Markham-Richmond Hill	2025	2.0%
GTA East	Pickering-Ajax-Whitby 27.6	2021	8.3%
Toronto	Manby	2026	0.7%
Windsor-Essex	Windsor-Essex	2025	6.0%
Ottawa	Southeast Ottawa	2022	8.6%
Peterborough-Kingston	Belleville Transformer Station (TS)	2026	0.6%
Peterborough-Kingston	Gardiner TS	2026	0.6%
Muskoka	Barrie TS	2025	7.4%
Muskoka	Everett TS	2027	2.6%
Muskoka	Waubaushene TS	2020	0.7%
Muskoka	Parry Sound TS	2029	0.6%
Bruce	L7S	2022	2.3%
KWCG	Campbell TS	2027	1.5%
KWCG	Scheifele TS	2026	1.5%
GTA West	H29/H30	2022	1.4%

Sub-regions with slow demand growth likely have excellent potential for long-term deferment by energy storage. Traditional T&D investments are likely to remain the best option for fast growing sub-regions. Development and long-lead asset time constraints were not considered in the analysis.

The model tested the ability of energy storage to defer T&D investments under various sizes of new capacity additions, ranges of T&D investment costs, minimum utilization thresholds, and utility working costs of capital. Savings potential for deferment of new traditional T&D investments is based on the avoidance of the annual amortization payments of the investments. Annual amortization payments were calculated using typical utility cost of capital.

2.2.4 Distribution Capital Expenditure Deferment

LDC capital expenditures pay for the maintenance, upgrading, and expansion of distribution networks. Capital expenditures are driven by power system needs including safety, reliability standards, and demand growth. A subset of annual spending is used to expand distribution systems for thermal capacity needs and/or outage management requirements. Energy storage can be used to defer system expansion investments, particularly when demand exceeds existing system capacity by a small amount or for short durations.

The OEB defines system service as "modifications to a distributor's distribution system to ensure the distribution system continues to meet distributor operational objectives while addressing anticipated future customer electricity service requirements". At a high-level, system service is a fair representation of system expansion spending to meet future customer needs.

System service as a percentage of total distribution capital expenditures for the four largest LDCs in the province (Hydro One, Toronto Hydro, Alectra and Hydro Ottawa) equals roughly 12 per cent based on historic and forecasted spending. The 12 per cent value for system service includes a discount for customer capital contributions. The system service percentage was further discounted to reflect capital spending captured in the regional planning deferment analysis (e.g. capital expenditures for new transmission stations), and to reflect system service spending for non-capacity based investments such as protection and control, distribution system automation, and so on. This analytical approach is conservative and reasonable given the uniqueness of each distribution service territory.

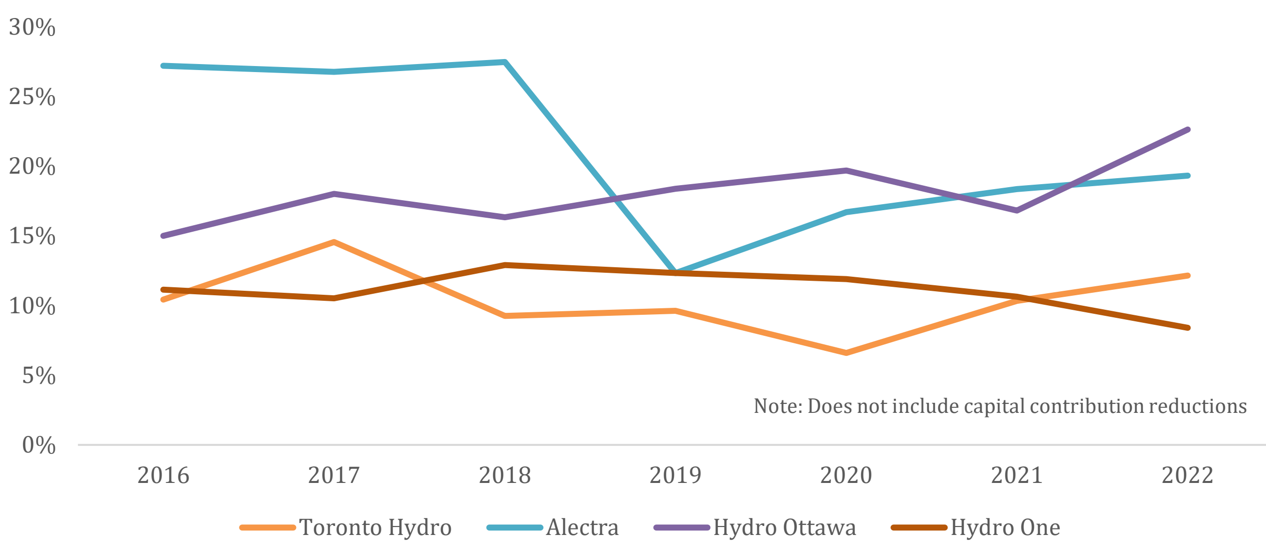


Figure 8. System Service as Percentage of Total Expenditures

A forecast of future distribution capital expenditures was developed based on historic trends in capital expenditures and load growth for the province. A forecast of peak demand derived from the IESO's 2020 Annual Planning Outlook, adjusted for near-term impacts of COVID-19, was also an input in the analysis. It was assumed that between 10 per cent and 20 per cent of system service spending could be deferred annually by the deployment of energy storage.

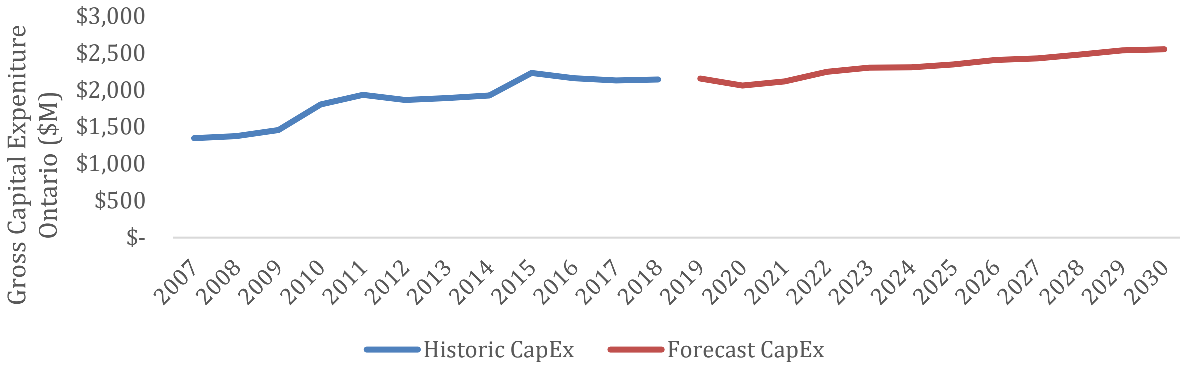


Figure 9. Historic and Forecast Distribution Capital Expenditure

2.3 Direct-to-Customers Savings in Ontario

Energy storage can provide savings to individual customers through means including:

- **TOU Bill Management**: Energy storage resources can mitigate price differences between peak and off-peak prices and reduce the total bill for small-volume customers.
- **Demand Charge Reduction**: Energy storage resources can potentially reduce demand charges for small and large-volume customers by lowering consumption during peak demand hours.
- **Renewable Energy Output Optimization**: Energy storage resources can shift renewable energy output – largely from solar generators – from low-value to high-value hours.

Table 8. Direct to Customer Quantitative Assessment

Direct to Customers	Methodology	Findings
TOU Bill Management	• Calculate energy arbitrage value between off-peak and on-peak rates for RPP customers • Calculate energy arbitrage value between off-peak and on-peak rates for Class B customers	• Average annual savings for typical RPP customer is $102/year • Very limited savings were found for Class B customers due to the flat GA energy rate
Demand Charge Reduction (including GA)	• Estimate demand charge (i.e. transmission and distribution) reduction value under different customer load profiles (e.g. narrow peak demand versus flat load demand) • Estimate Class A cost savings for lowering Peak Demand Factor (PDF) to reduce GA costs	• Depending on location of the customer and the monthly peak demand profile, the savings range from $60/kW-year to $260/kW-year, with the average savings for large LDCs of $122/kW-year • Annual average Class A savings were calculated at over $500/kW-year assuming all five coincidental peak (5CP) hours
Renewable Output Maximization	• Estimate the value in shifting renewable energy output, namely solar energy, to higher price time periods (e.g. shifting energy output from off-peak hours to on-peak hours)	• Savings for RPP customers were calculated to be close to the savings calculated for TOU bill management (i.e. $102/year)

2.3.1 Meeting Customer Energy Needs

Locating BTM energy storage at customer sites can offer a host of benefits. Customers can use energy storage to reduce energy consumption during high-price hours or to reduce demand charges. For customers with power quality issues or who require a higher standard, energy storage with inverter-based connections can provide power quality enhancements. The core benefit for customers is that energy storage located BTM can allow customers to manage consumption from the electricity grid independently of their consumption needs. Cycling an energy storage facility adjusts the hourly consumption profile of a customer from the grid while meeting all consumption requirements. This benefit is particularly important for customers with inflexible loads that cannot reduce consumption upon demand in response to wholesale market price signals.

2.3.2 TOU Bill Management – RPP Customers

Under TOU billing, RPP customers in Ontario (residential and small business customers) pay a lower price to consume energy during off-peak hours and a higher price for consumption during on-peak hours. Energy storage BTM can be cycled to withdraw during off-peak hours and inject during on-peak periods, shifting a customer's on-peak consumption to off-peak hours and resulting in bill savings.

A forecast of TOU energy rates under the RPP TOU price framework was developed. TOU rates are applied on all days that are not weekends or holidays, amounting typically to 251 days a year. TOU-related savings for customers are a function of consumption shifted from on-peak hours to off-peak hours, less any cycling losses. The analysis of savings was conducted prior to the recent Ontario government announcements of the suspension of TOU (and future opt-out provisions starting November 1, 2020); without a price differential energy storage can provide no value to customers since cycling losses will result in adding costs to customer bills.

2.3.3 Bill Management – Class B Customers

For medium-sized customers (i.e. Class B customers that are not RPP customers), wholesale electricity prices are composed of HOEP and GA. The GA rate for Class B customers is a flat rate (i.e. $/MWh) that is adjusted each month; therefore, cycling losses from BTM energy storage result in a cost to the customer. This greatly limits the potential for energy arbitrage cost savings on HOEP price fluctuations for Class B customers. The cycling losses mean energy storage must target higher priced hours for HOEP and be highly accurate to offer cost savings for customers. This is not the case for Class A customers where they had been managing their GA costs via the Industrial Conservation Initiative (ICI), and were therefore better able to achieve energy arbitrage cost savings. However, if cost allocation is adjusted for Class B customers, energy storage can further help these customers manage electricity costs.[12]

2.3.4 Demand Charge Reduction

Energy storage can provide customer savings by reducing demand charges for delivery (i.e. T&D costs). Demand-based billing is only applicable to larger customers (>50 kW), at varying rates as shown below in Figure 10.

[12] The discussion relating to the ICI does not factor in the June 26, 2020 Ontario government announcement available here: https://news.ontario.ca/mndmf/en/2020/06/ontario-provides-stable-electricity-pricing-for-industrial-and-commercial-companies.html.

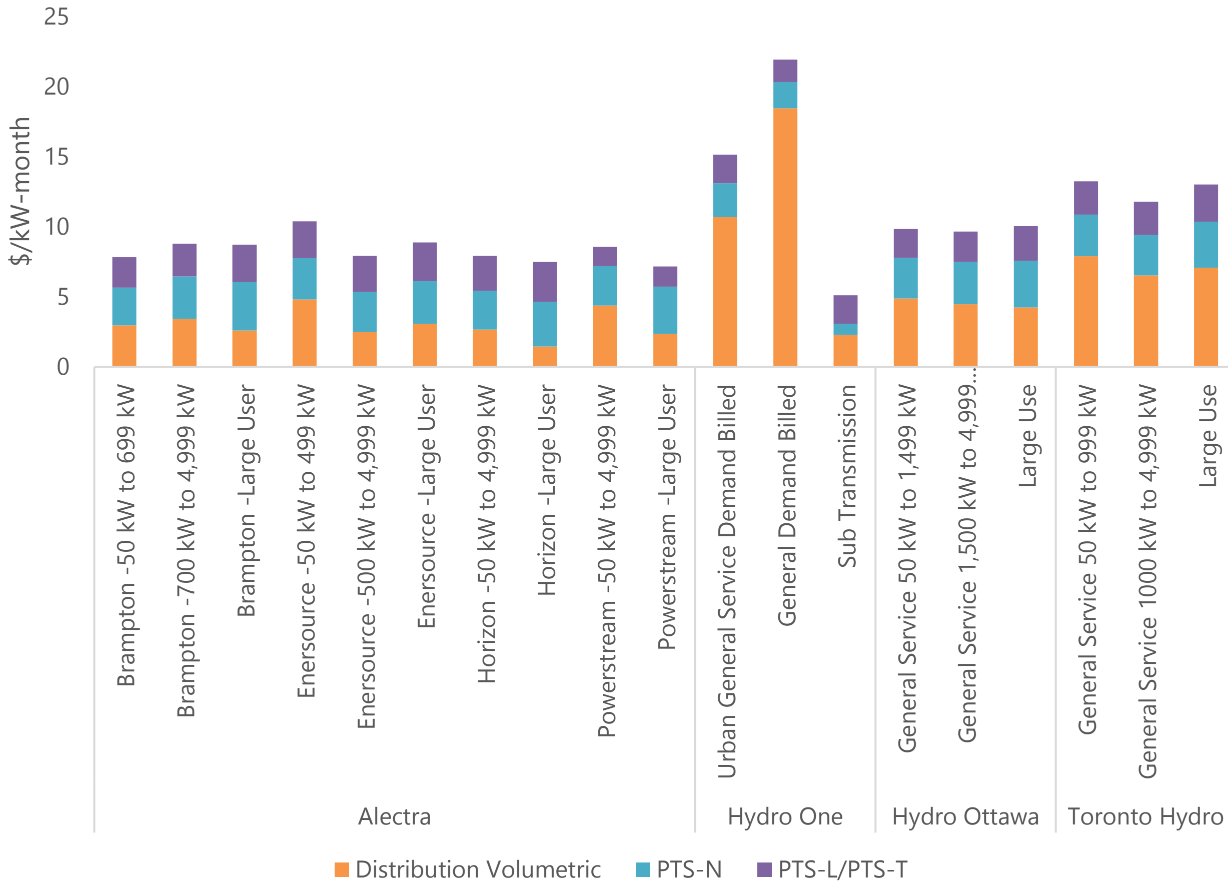


Figure 10. Demand Charges for Select Ontario LDCs

The ability to achieve cost savings for customers is heavily influenced by customers' peak demand load energy-consumption profiles. Customers with flat consumption profiles may not be able to reduce demand in all hours and capture savings. If there is little difference between a customer's peak hour and average consumption, cost savings are minimal. On the other hand, customers with a narrow peak can reduce energy consumption with a reasonable duration.

While not included in the quantitative analysis of this report, any demand charges paid by an energy storage facility may amount to new revenue to be allocated to Ontario's customers, paid for by the energy storage facility as a new electricity customer, even though energy storage would not be charging at times of system peak. As such, in most cases this increases regulated utilities' revenues without increasing their rate base, thereby lowering demand charges for all other customers in Ontario.

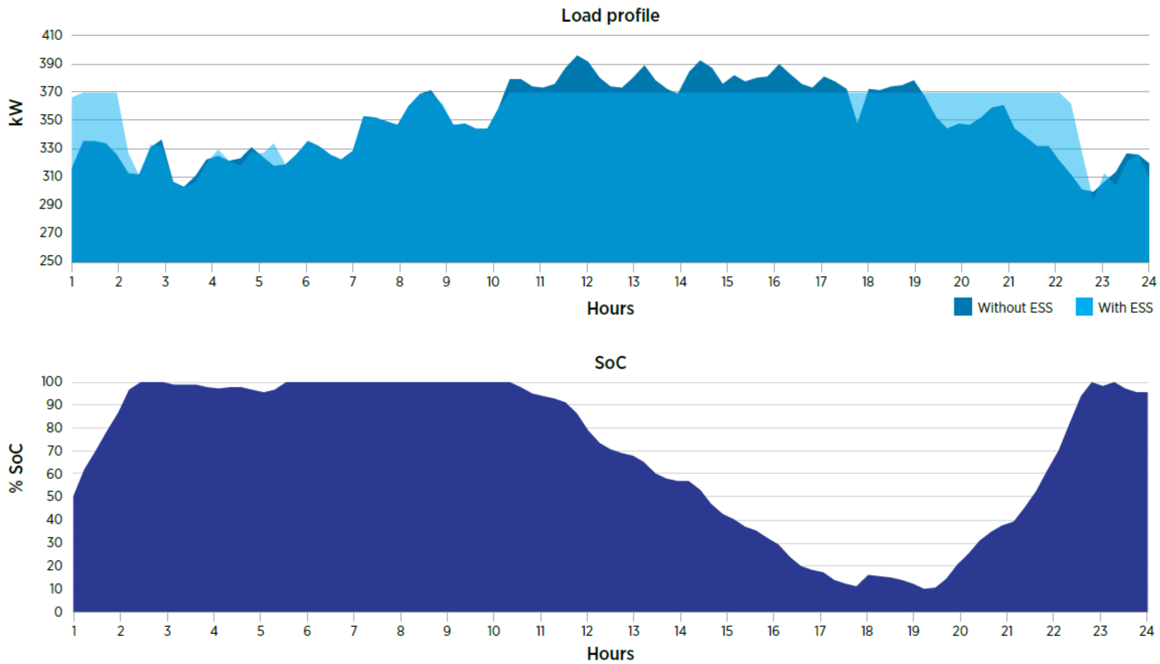


Figure 11. Reduction in Customer Peak Load[13]

2.3.5 Class A GA Cost Reductions

Energy storage can be used by Class A customers (i.e. large commercial and industrial customers) to reduce their Peak Demand Factor (PDF), which determines how much GA customers pay on a monthly basis for the following year. A PDF is determined by a Class A customer's energy consumption during the five coincidental peak (5CP) hours of a year – and a BTM energy storage facility can reduce 5CP consumption. Class A customers are typically large employers in the province and their ability to reduce GA costs has been identified[14] as an important factor in their global competitiveness.

[13] IRENA, 2020. Electricity Storage Valuation Framework: Assessing system value and ensuring project viability, IRENA, Abu Dhabi. Retrieved from: https://irena.org/publications/2020/Mar/Electricity-Storage-Valuation-Framework-2020

[14] Government of Ontario, 2019. Consultation on Industrial Electricity Prices. Retrieved from: https://files.ontario.ca/endm-industrial-consultations-what-we-heard-en-2019-11.pdf

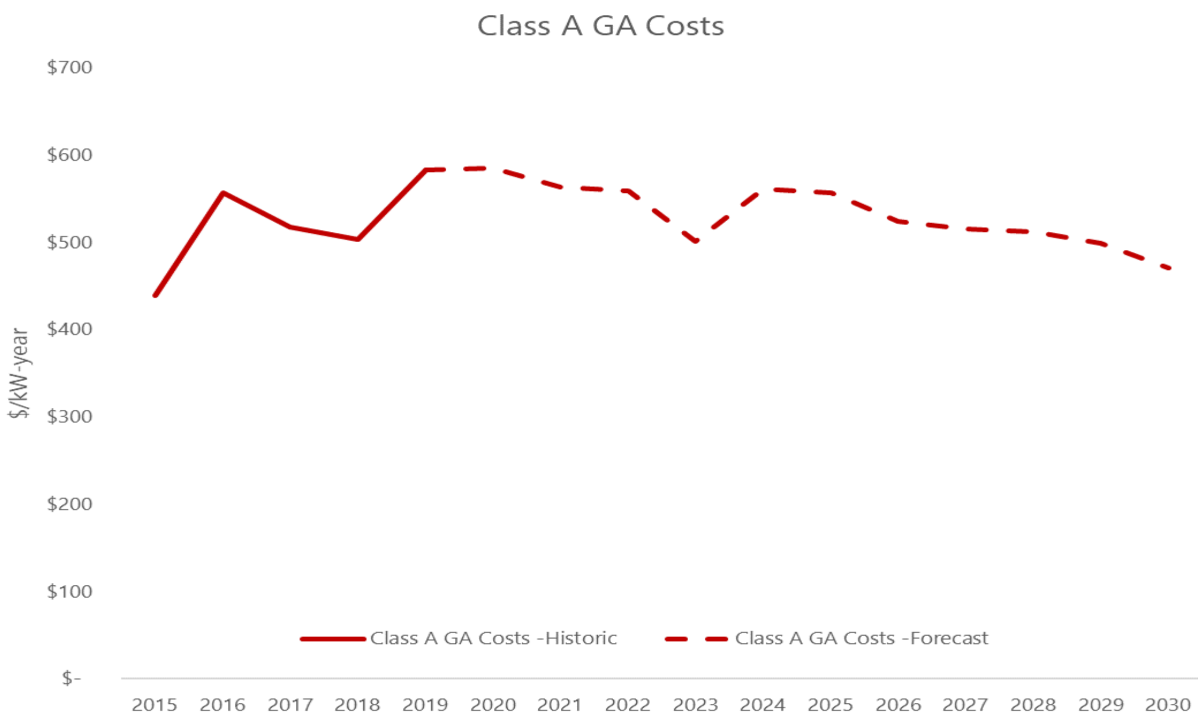


Figure 12. Class A GA Costs

It should be noted that the Ontario government's June 26, 2020 announcement[15] has implications for the ICI and for the potential use of energy storage to lower GA costs in some circumstances and for some customers.

2.3.6 Maximizing Renewable Energy Output

For BTM VGs owned by customers under the RPP (e.g. net-metered solar generation for residential customers), our estimated value is close to the estimated savings for TOU bill management, since shifting energy production from off-peak to on-peak is the same as a stand-alone energy storage facility cycling off-peak to on-peak. There is a small value associated with shifting off-peak energy production from weekends to Monday. For Class B customers, renewable energy output optimization will be limited by the flat monthly GA cost; in other words, the cycling losses of charging and discharging outweigh the value of shifting energy injection from variable generators in most instances.

Overall, without changes to the regulatory framework (e.g. critical peak pricing, wider range between on-peak and off-peak TOU rates, elimination of Class B flat GA rate, etc.) the value of storage-based optimization of BTM VGs is limited in Ontario.

[15] https://news.ontario.ca/mndmf/en/2020/06/ontario-provides-stable-electricity-pricing-for-industrial-and-commercial-companies.html

3. Qualitative Benefits

Energy Storage facilities can provide a number of qualitative benefits. While these benefits have not been assigned a monetary value, in most cases they will provide additional system-wide savings to customers.

According to the IESO, "Distributed energy resources are transforming the electricity sector in Ontario and in other jurisdictions around the world. Traditionally, electricity systems have relied on power from large generators, transmitted across long distances into communities, businesses, and homes. Distributed energy resources (DERs) are beginning to up-end this traditional framework. Drivers like decreasing costs and emerging customer preferences are converging to make smaller distribution-connected resources an increasingly viable alternative to the status quo.[16]

The Ontario residential energy-storage market is set to grow significantly in the coming years and is estimated by ESC to represent a potential market of up to several hundred thousand customers in Canada in the next decade. The final outcome of Alectra's market penetration analysis for the base case of the PowerHouse pilot found that the adoption of the program could feasibly reach approximately 30,000 residential homes by 2031 in its service territory alone, which would represent 140 MW of localized and dependable capacity.

3.1 Environmental Benefits

While Ontario has made notable strides to reduce the carbon footprint of its electricity generation fleet, it continues to have a significant amount of gas-fired generation capacity. These resources provide flexibility to grid and market operators, ensuring reliability in the face of unexpected changes or forecasting errors, as well as supplying peak capacity when demand in the province is at its highest. Gas-fired generators – while cleaner than the province's traditional coal-fired generators – do nevertheless emit greenhouse gases.

Energy storage resources can lessen the reliance on gas-fired generators in the short-term, while also reducing the amount of gas-fired generation capacity required in the long-term. In the short-term, and as described in the previous section, energy storage resources can displace the use of gas-fired generators to address reliability concerns, and with lower start-up costs and less lead-time. In the long-term, energy storage resources can shift Ontario's baseload generation to better align with energy consumption patterns. As described in this report, Ontario's supply mix often generates surplus energy in hours when demand is lowest, while requiring use of higher cost gas-fired generating units in peak demand hours. Time-shifting of energy output can reduce the long-term need for these resources as part of Ontario's overall supply mix. Less use of gas-fired generation will directly reduce carbon dioxide emissions and help Ontario meet its carbon dioxide emission reduction targets. In the process, energy storage will also reduce the amount of carbon tax paid in Ontario by electricity customers and provide a partial economic hedge against both future increases in carbon tax rates and potential increases in the cost of natural gas.

[16] IESO (2020). Innovation and Sector Evolution White Paper Series: Non-Wires Alternatives Using Energy and Capacity Markets. Retrieved from: http://www.ieso.ca/Get-Involved/Innovation/Coordinating-DERs-used-as-non-wires-alternatives

In the long-term, as existing gas-fired generators reach end of life, it is likely that energy storage can fill some portion of the 9,000 MW market need for capacity and ancillary services, effectively replacing some portion of gas-fired generation on the Ontario grid.[17]

3.2 Reduced Transmission Congestion Benefits

Ontario is expected to continue to have a significant amount of installed generation capacity located in both the northwest and northeast of the province, while major load centres will remain in the south. As such, transmission congestion on the province's grid will continue to limit energy flows, leading to curtailed energy output. While planned transmission investments may mitigate this curtailment to some extent, it is expected to persist over the medium- and long-term horizon.

Targeted energy storage facilities can reduce the amount of curtailed energy output and shift that energy to either hours when transmission lines are uncongested or to higher-value hours, or to some combination of the two. Shifting energy to reduce transmission congestion can increase the efficient utilization of the province's generation assets – lowering customer costs in the long-run.

3.3 Increase Export and Import Value Benefits

Over the past decade, Ontario has been a net exporter of energy. In 2019, Ontario exported 19.78 TWh of energy, compared to 6.6 TWh of imports. In many hours, as described at length throughout this report, that energy is exported at a price of $0/MWh or below. Unlike customers in Ontario, export customers do not pay GA charges, meaning energy exported at $0/MWh provides little value to Ontario's customers in the form of lowering fixed, system-wide costs. Energy storage at a sufficient scale in Ontario may improve the opportunities and economics of trading energy with neighbouring jurisdictions.

Energy storage can provide value to Ontario's customers by storing surplus energy in off-peak hours to either meet the province's own peak needs, or to potentially export it in hours when prices in neighbouring jurisdictions are higher. When export prices are greater than $0/MWh, that revenue can offset GA charges for Ontario's customers.

The ability to import energy at times of peak demand in Ontario is limited by the both the availability of resources in neighbouring jurisdictions and the transmission intertie capacity. Bulk storage within Ontario would provide the capability to economically import energy during periods of low demand at off-peak prices over uncongested interties, and to redeploy it to meet Ontario's peak demand.

3.4 Power Quality Improvement Benefits

Power quality in the Ontario power system can be enhanced by the deployment of energy storage. Customers with sensitive loads (e.g. complex manufacturing processes) require consistent delivery of electricity at a high standard of quality. Maintaining or enhancing power quality using traditional T&D investments can be cost prohibitive for many customers. Energy storage at the customer site can be used

[17] There is currently approximately 9,000 MW of gas-fired generation under contract in Ontario.

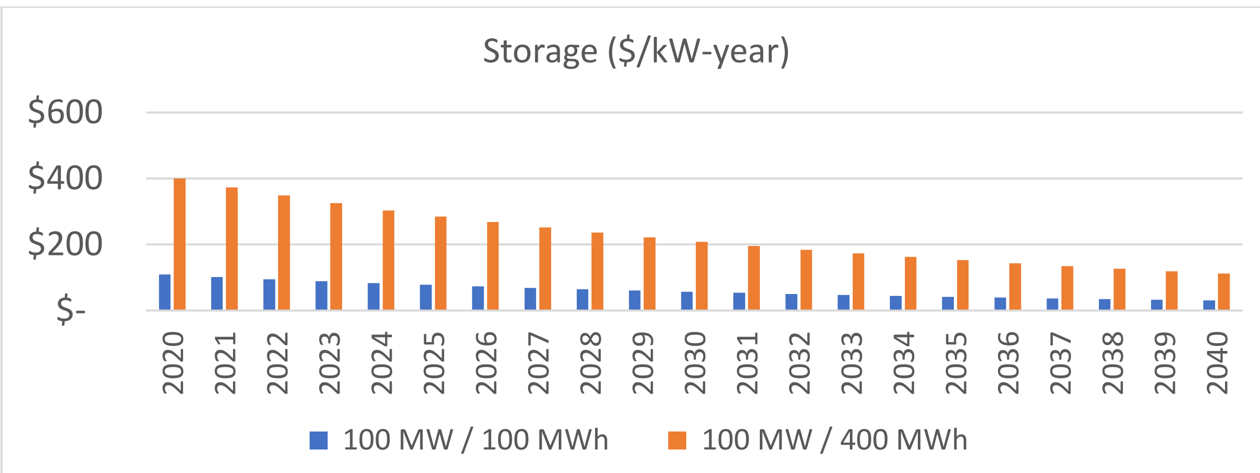
to “clean” the power quality, removing unwanted harmonics or flicker from the delivered power waveform. Similarly, voltage dips, swells or spikes can occur during power disturbances, and energy storage can be used to limit the risk of resulting power-quality degradation.

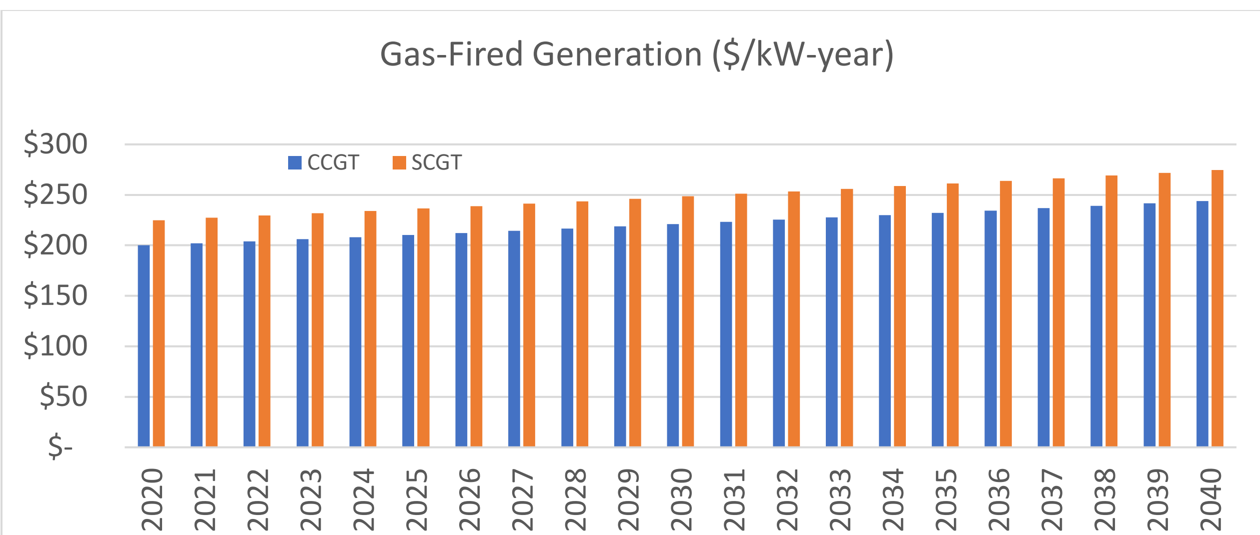
Energy storage can also be used to increase the ability of the power system to integrate renewable generation in remote locations where voltage drop concerns limit the connection capability. Energy storage located at the end of poor-performing feeders can be used to maintain voltage limits for both customers and renewable generation. Using inverter-based connections, energy storage can provide reactive power compensation to power systems to improve the efficiency of power delivery. Overall, placing energy storage in strategic locations throughout the power system can offer a cost-effective means of enhancing power quality.

4. Conclusions

4.1 Overall Value and Viability of Energy Storage in Ontario

Integrating energy storage in Ontario can provide immediate and long-term savings for electricity customers. However, there is a cost associated with developing and maintaining energy storage. The net savings can be calculated using gross savings, shown in Figure 4, and the annual revenue required to develop and maintain energy storage in Ontario. Putting an exact figure on energy storage costs depends, in large part, on the type of energy storage being installed. Based on Power Advisory's analysis and feedback from ESC members, a revenue requirement of $200,000/MW annually (or $200 million a year for a 1,000 MW system) is used in this analysis.[18] A levelized cost forecast for energy storage versus gas-fired generation within Alberta's wholesale electricity markets shows the costs of energy storage installations declining with gas-fired generation costs gradually increasing[19].





[18] Note that the estimate used is aligned with recent cost estimates from Lazard: https://www.lazard.com/perspective/lcoe2019

[19] Source: Power Advisory LLC

In any procurement exercise, it is reasonable for the administrator overseeing the procurement – in this case the IESO – to estimate gross future power system-wide savings on an annual basis, and to cap the annual contractual amount it will pay energy storage projects at (or more likely below) that gross savings amount. As a result, regulated revenues derived from the wholesale market (e.g. energy, capacity, and ancillary services) would be expected to be counted against annual contracted payments.

As outlined in Figure 13, energy storage provides a net savings of $774 million in the 2021-2030 timeframe in the base case scenario and up to $2 billion in savings in the high case scenario[20]. In addition to this value, many energy storage projects can be designed with operating lives that are 20 years or higher, so in fact the savings potential for Ontario's customers in this report is very conservative as it only assumes a 10-year period of savings.

Based on demand forecasts from the IESO, the net savings over the next decade range for $-0.28/MWh to $1.37/MWh. In the base case scenario, more than 75 per cent of these savings come from the wholesale market, while 25 per cent come from the transmission and distribution sector. Using the OEB average of 700 kWh of consumption per month for residential consumers, the annual savings amount to $4.50 to $11.50 per year in the base case and high case scenarios, respectively.

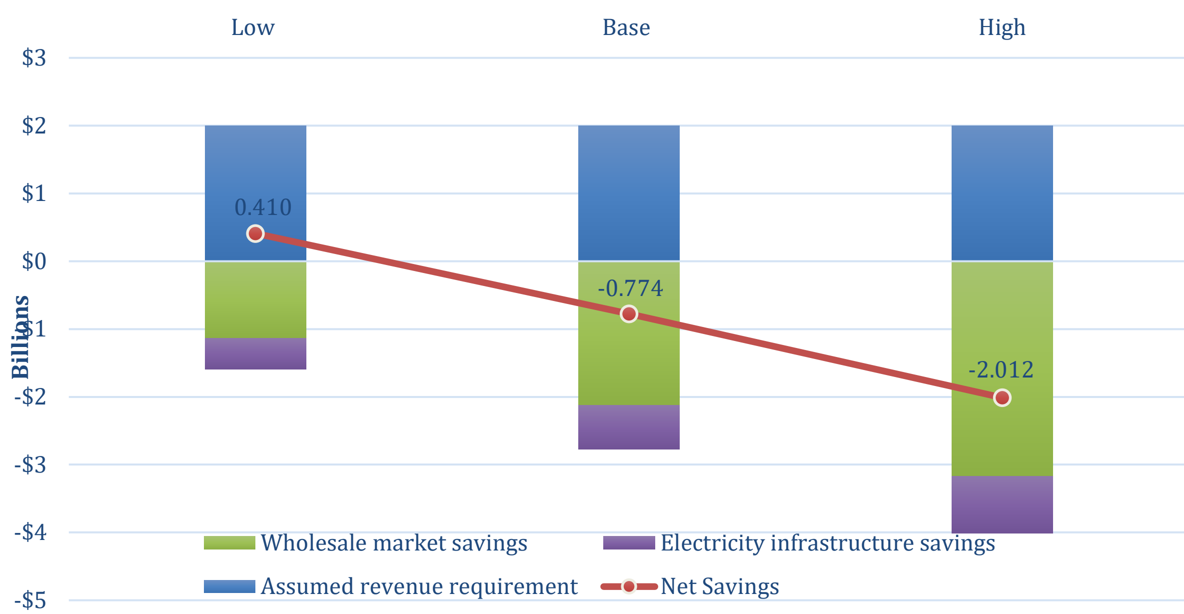


Figure 13. Net Savings from 1,000 MW of Energy Storage, 2021-2030

[20] The assumed revenue requirement is held constant for all three scenarios (i.e. $200,000/MW per year for 1000 MW). Net savings are calculated by adding the gross savings from the wholesale market and electricity infrastructure, and then subtracting the assumed revenue requirement.

4.2 Recommendations

Energy storage can offer savings immediately, but a variety of barriers are hindering realization of its full value in Ontario. These barriers can begin to be addressed in the following ways:

1. Given the current inability to fully integrate energy storage within Ontario's electricity market, and in order to unlock the system-wide value of energy storage now, the IESO should contract for the full suite of services energy storage can deliver, and should enable the co-optimized operation of these storage resources. This would allow for full realization of the savings potential for customers, which cannot be achieved within the current market design and structure.

2. In parallel, the IESO, the regulators and utilities should establish enduring, cost-effective and competitive methods to integrate energy storage. This will need to entail:
   a. relying on current proposals for Capacity Auctions and ensuring energy storage's future participation;
   b. determining how to optimize existing assets by, for example, co-locating energy storage with operating renewable generation and other baseload generation facilities;
   c. ensuring that the OEB and the IESO coordinate efforts to fully extract all value from non-wires solutions and wholesale market participation; and
   d. establishing an OEB-IESO committee with a clear and reasonable timeline and set of objectives for the full integration of energy storage.

3. Building off recent changes to default supply rates for applicable electricity customers, and off deferral of GA charges for other customers, electricity pricing for customers and GA cost allocation among customer classes should be reformed. This will need to entail:
   a. recognizing that the current fixed-cost recovery method offsets a portion of the potential savings from integrating energy storage;
   b. encouraging the IESO and OEB, along with market participants and the province, to determine a method of recovering fixed costs that is both fair and transparent, but also relies on efficient price signals; and,
   c. recognizing that price signals are the most transparent means of extracting energy storage's system-wide benefits.

4. OEB consultations should be launched in an effort to better incent rate-regulated utilities to deploy non-wires solutions by providing guidance around asset planning, cost allocation, and renumeration, among other issues. The consultations would result in guidance from the OEB to utilities and energy storage providers on matters such as planning, cost allocation, remuneration, and pathways for regulated utilities to partner with the private sector.

Both the IESO and the OEB have stakeholder engagement proceedings underway through which integration of energy storage within the wholesale market and regulated sectors is being considered. The IESO continues to move forward with the Storage Design Project (part of the Energy Storage Advisory Group[21]) and with the implementation of interim measures to better integrate stand-alone energy storage within the wholesale market, even in the absence of upgrades to IESO's DSO tools in the near-term. The IESO has also recently launched a process called Expanding Participation in Operating Reserve and Energy (EPOR-E), which is focused on participation options for, among other resource types, hybrid energy systems and DERs within the IESO's wholesale market.[22] Likewise, the OEB has begun a consultation related to utility remuneration and responding to DERs (including energy storage), however the pace and scope of those proceedings has not yet been clearly established.[23]

However, much work remains to be done to establish an enduring solution to unlock the potential of energy storage in Ontario.

To begin to unlock the system-wide value of energy storage now, the IESO should contract for the full suite of services energy storage can deliver, and enable the co-optimized operation of these storage resources so as to fully realize the savings potential for customers. These objectives cannot be achieved within the current market design and structure. This approach is consistent with other jurisdictions that have established energy storage procurements and/or targets for energy storage,[24] including:

- New York Energy Research & Development Authority (NYSEDA) programs for Bulk Storage Incentives, Retail Storage Incentives and Utility Procurement via REV Connect[25]
- Nevada Energy's 2018 RFP for Renewable Energy including Dispatchable Energy[26]
- Southern California Edison's 2019 System Reliability Request for Offers[27]
- Australia's Northern Territory's 2020 procurement of large scale-battery storage[28]

Energy storage can provide immediate, tangible savings to ratepayers and provide power system-wide benefits in Ontario. Energy Storage Canada looks forward to working with government, the IESO and the OEB to fully unlock the potential of energy storage in the province.

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[21] For more information visit: http://www.ieso.ca/en/Sector-Participants/Engagement-Initiatives/Engagements/Energy-Storage-Advisory-Group
[22] For more information visit: http://ieso.ca/Sector-Participants/Engagement-Initiatives/Engagements/Expanding-Participation-in-Operating-Reserve-and-Energy
[23] For more information visit: https://www.oeb.ca/industry/policy-initiatives-and-consultations/utility-remuneration
[24] For additional examples see Morgan Lewis Energy Storage Procurement Tracker (April 2020), retrieved from: https://www.morganlewis.com/-/media/files/document/2020/energy_storage_tracker_2020.pdf
[25] For more information visit: https://www.nyserda.ny.gov/All-Programs/Programs/Energy-Storage/Developers-Contractors-and-Vendors
[26] NV Energy RFP can be retrieved from: https://www.nvenergy.com/publish/content/dam/nvenergy/brochures_arch/about-nvenergy/doing-business-with-us/energy-supply-rfps/2018-fall-re-rfp-protocol.pdf
[27] For more information visit: https://www.sce.com/procurement/solicitations/system-reliability-rfo
[28] For more information visit: https://renewablesnow.com/news/aussie-northern-territory-announces-battery-storage-procurement-693857/

APPENDIX A – Overall Approach

The following describes the high-level methodology by which this report was prepared.

Step 1: Identify energy storage services and products that support efficient operation of Ontario's electricity system

As a first step, the value streams and services in-scope for the report were defined. The services and products were informed by a literature review and jurisdictional scan, as well as our view on the specific needs of Ontario's electricity market.

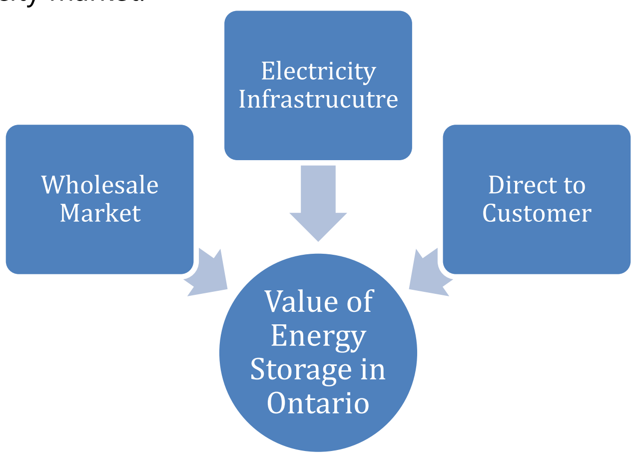


Figure 14. Components of Valuation Study

Step 2: Map specific storage technologies and their unique capabilities against the identified services and products

The next step evaluated the ability of different storage technologies to provide electricity services and products identified in Step 1. Different energy storage technologies were ranked qualitatively from "no capability" to "fully capable".

Step 3: Estimate the value of services and products provided by energy storage within Ontario's unique context

- Regarding the wholesale electricity market, a backwards-looking quantitative analysis was undertaken to determine system-wide benefits that energy storage resources could provide, notably through a reduction in market clearing prices for energy and lower-cost ancillary services. The system-wide benefits were then forecast for the next decade.
- A forward-looking quantitative analysis was undertaken to forecast potential savings derived from using energy storage to defer transmission and distribution infrastructure spending.
- A quantitative assessment of customer-specific benefits related to TOU bill management and reduced demand charges was undertaken.
- Several qualitative assessments – including environmental benefits, reduced transmission congestion, and improved power quality – were also considered.

Step 4: Develop Ontario specific scenarios to model cost-savings that would be realized through investments in energy storage resources

The value of the services energy storage can provide in Ontario's current framework was compared to the value that would be realized if energy storage were fully enabled through the market and regulatory changes recommended in this report.

Step 5: Assess overall value and viability that energy storage resources would have in Ontario

The final step put the results from Step 4 into the context of customers' electricity bills in Ontario and qualified our findings based on Ontario-specific conditions. The report concludes with recommendations to fully unlock the value of energy storage in Ontario.

APPENDIX B – Additional References

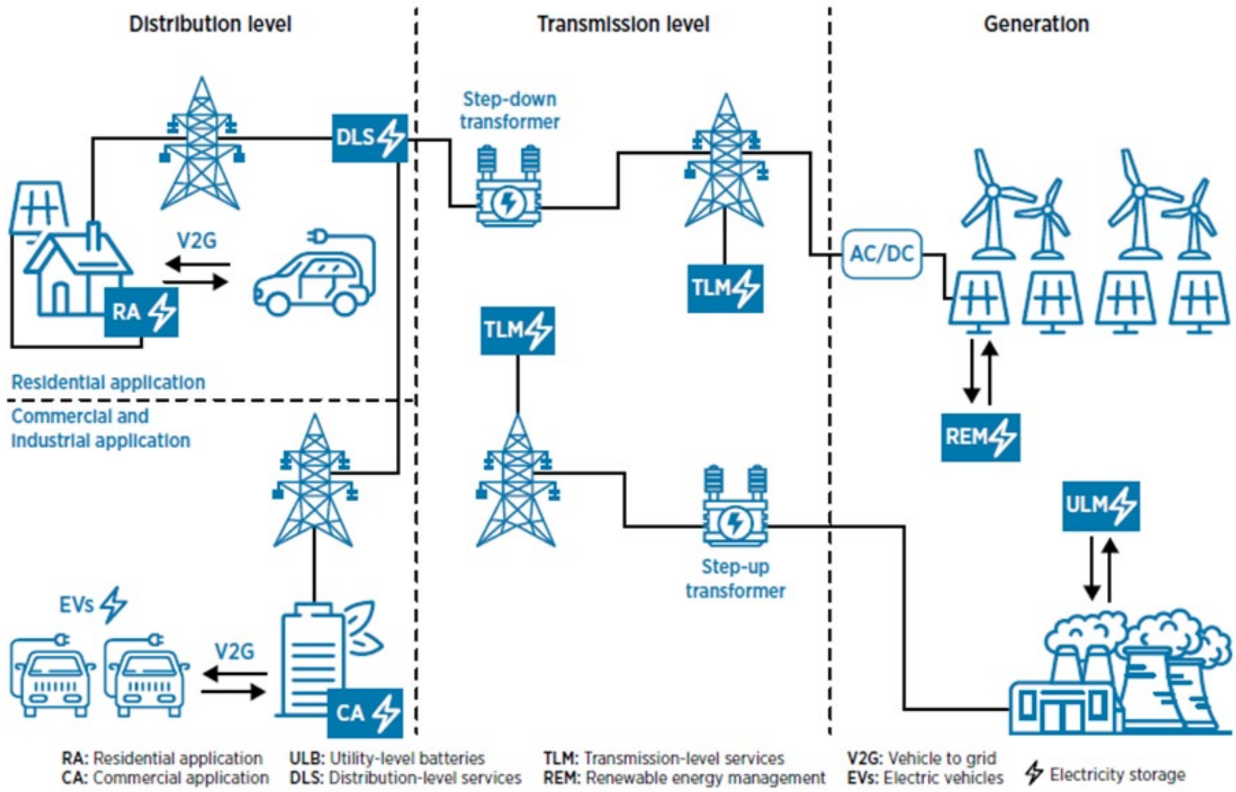
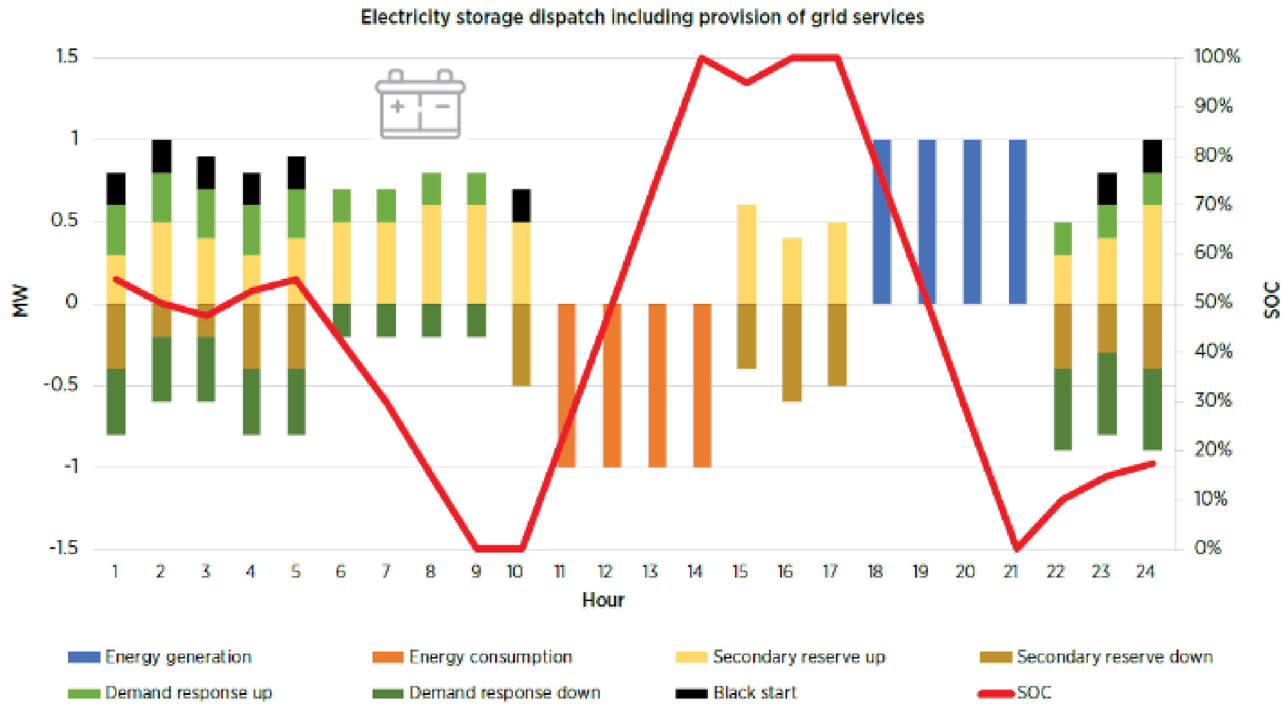


Figure 15. Energy Storage Applications Throughout Electricity Grid[29]

[29] International Renewable Energy Agency. Electricity Storage Valuation Framework: Assessing system value and ensuring project viability, International Renewable Energy Agency, Abu Dhabi, 2020. Retrieved from:

https://irena.org/publications/2020/Mar/Electricity-Storage-Valuation-Framework-2020



Note: SOC = state of charge.

Figure 15. Versatility of Energy Storage[30]

[30] IRENA. Electricity Storage Valuation Framework: Assessing system value and ensuring project viability, International Renewable Energy Agency, Abu Dhabi, 2020. Retrieved from: https://irena.org/publications/2020/Mar/Electricity-Storage-Valuation-Framework-2020

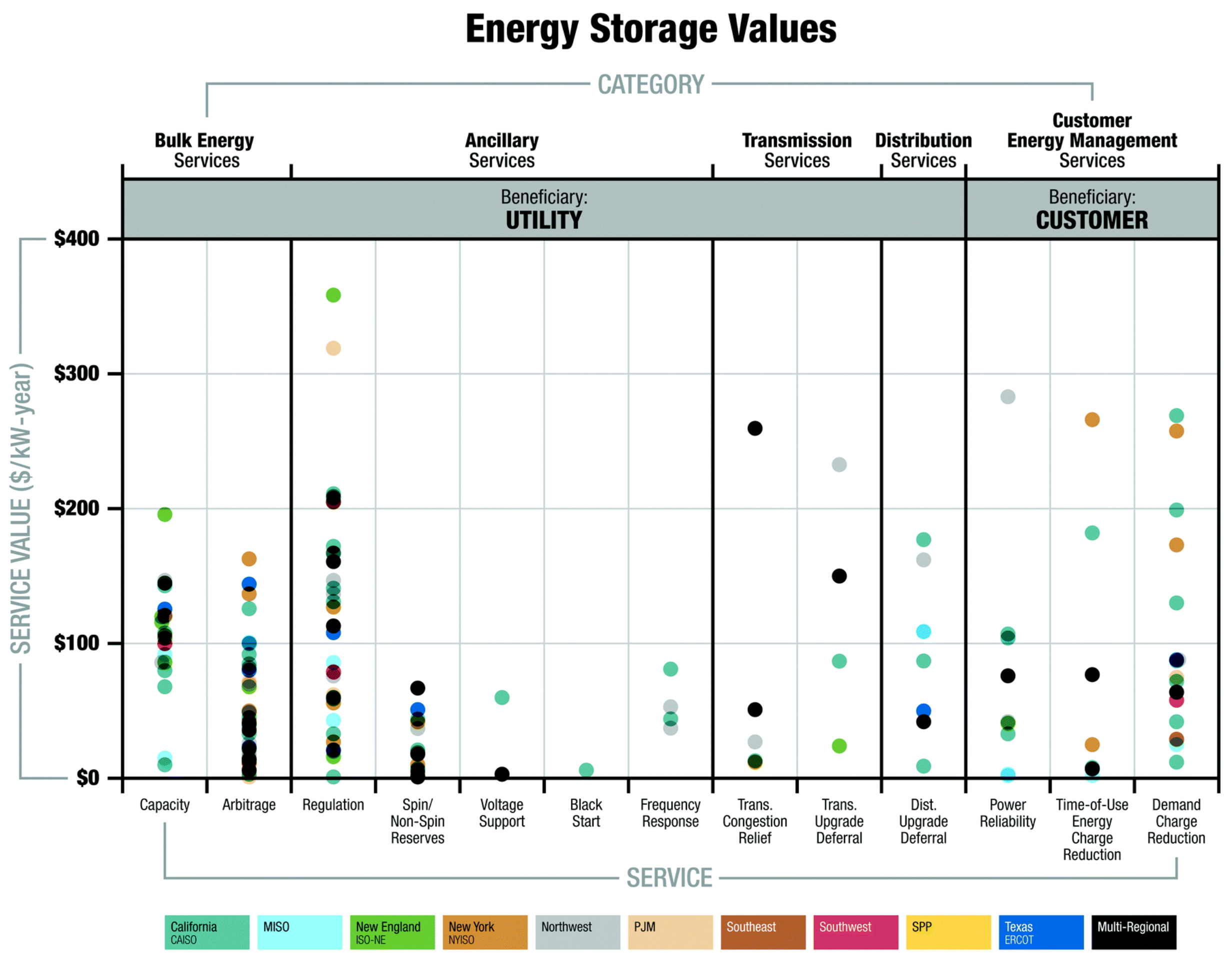


Figure 16. Summary of Valuation Studies from U.S.[31]

[31] Patrick J. Balducci, M. Jan E. Alam, Trevor D. Hardy, and Di Wu. Assigning value to energy storage systems at multiple points in an electrical grid. The Royal Society of Chemistry, 2018. Retrieved from: https://pubs.rsc.org/en/content/articlehtml/2018/ee/c8ee00569a

APPENDIX C – Wholesale Market Savings Calculation

The assumptions used as part of the calculation of 2019 benefits were as follows:

- Energy storage facilities charge in the four lowest HOEP hours on any given day. They discharge on the same day during the four highest HOEP hours. The energy storage facilities are assumed to have a 90 per cent efficiency rating.
- Energy storage only charges and discharges on days when the average of the four lowest HOEP hours is $0/MWh or below. All other days – when the average of the four lowest HOEPs are positive – are excluded from the system savings benefits calculation. In total there are 162 days when the average of the four lowest HOEP hours are $0/MWh or below.
- On days when energy storage is expected to shift, only wind energy is assumed to have been stored during low-value hours and discharged during high-value hours.
- When HOEP is on average $0/MWh or below and there is surplus wind generation – i.e. wind generation in hours when Ontario demand can be serviced by output from nuclear and hydroelectric generation alone – that generation is stored and discharged in the average of the four highest HOEP hours.
- The analysis only considers dispatch data (the "constrained" schedule). Amounts submitted in the unconstrained ("price-setting" schedule) are not considered due to limited publicly available data. The true extent of shifting could be significantly higher, as the unconstrained schedule would include spilled or curtailed energy output.
- When energy storage facilities discharge in the four peak HOEP hours, they undercut the price-setting resource by between 10 per cent and 30 per cent (20 per cent in the base scenario), lowering HOEP to the same extent. These are considered system-wide savings.
- In total, energy storage participates in SBG time-shifting in more than 160 days, or 43 per cent, in 2019.
- Operating Reserve savings are calculated by reducing the clearing price for 10S in the lowest four HOEP hours on any given day. In the low, base and high scenarios, energy storage is assumed to lower 10S prices in the four lowest-priced hours by 0%, 10% and 20%, respectively.
- RT-GCG amounts are calculated from IESO charge 183 and regulation amounts are calculated from IESO charge 454. RT-GCG payments are assumed to be reduced by 10%, 33% and 40% in the low, base and high scenarios, respectively. Regulation costs are assumed to be reduced by 5%, 10% and 30% in the low, base and high scenarios, respectively.
- The cost of the Flexibility Solution is assumed to be reduced by 25%, 50% and 75% in the low, base and high scenarios, respectively.
- Capacity costs are assumed to be reduced by 5% of the forecasted annual amount over the 2021 to 2030 time period.

The assumptions used as part of the calculation of 2021-2030 benefits were as follows:

- The difference between peak and off-peak HOEPs are forecasted to increase, on average, eight per cent annually between 2021 and 2030. Our analysis halves that amount and assumes revenues earned by reducing the market-clearing price during SBG hours increases by four per cent on average annually.

- The average forecasted HOEP between 2021-2030 is expected to increase on average by four per cent annually. For other benefits, they are escalated by four per cent annually over this time period based on the forecasted increase in HOEP.
- All figures are in nominal dollars.