The debut of new energy storage technology: impact and implications for Ontario: analysis of the APPrO Technical Conference hosted in collaboration with Energy Storage Ontario (ESO), November 18-19, 2014, Toronto, Ontario

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NRC·CNRC **Energy Storage for Grid Security and Modernization**

The Debut of New Energy Storage Technology

Impact and implications for Ontario

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Acknowledgements

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1 Introduction and Objectives

In conjunction with the Association of Power Producers of Ontario's 26th Canadian Power Conference held November 18th and 19th, 2014 in Toronto, a two day technical conference was organized by APPrO, Energy Storage Ontario (ESO), Natural Resources Canada (NRCan), and National Research Council Canada (NRC) focused on deepening the understanding of energy storage.

The APPrO conference was well attended by representatives from all facets of the electric power industry including: federal and provincial governments, national and international research institutions, power producers, transmission and distribution companies, system operators, technology providers, financiers, and legal and engineering firms. The panelists and presenters at the conference were experienced professionals identified as leaders in their respective fields to provide both technical and business insights on two main topics:

- How energy storage can help stakeholders become more competitive in the changing Ontario power market that is evolving with the development of smart grids, increasing penetration of renewables, and improvements in conventional generation & transmission.
- Identifying the domestic supply chain capacity to develop and deploy energy storage technologies, both locally and internationally.

> "The electric power industry is undergoing transformation. Advances in the technologies for energy storage, generation and related grid functions will have profound impacts across the system. The APPrO 2014 Technical Conference focuses on the prospects and promise of new Energy Storage Technology, how it is already prompting change, and where it may go next."
>
> Excerpt from the APPrO 2014 Canadian Power Conference program

This report is intended to be used in conjunction with the APPrO Energy Storage Technical Conference proceedings (released separately), which summarize the discussions on each panel in more detail. Therefore, a familiarity with the general issues surrounding the introduction of storage, and the technical terms used is assumed. The content of this report is intended to provide context and analysis surrounding those discussions, and more specifically to:

i. To document valuable lessons learned from early storage deployments
ii. To summarize the key energy storage issues and opportunities identified during the conference
iii. To identify follow-on work that can directly advance the development and deployment of commercially viable energy storage solutions.

2 Lessons Learned From Early Energy Storage Deployments

2.1 Ontario Power Market Policies and Trends

Since 2003, Ontario has invested over $21 billion in cleaner electricity generation[1]. This has included significant deployments of renewable energy, including wind and solar generation, resulting in drastic emission reductions[2] from coal-fired generation. Due to this increase in variable generation on the grid, Ontario is increasingly investigating energy storage for grid applications. Specifically, the ability of energy storage technologies to provide a range of short and long-term balancing services such as capacity and congestion management, offer ancillary services (e.g. operating reserve, regulation, black start, voltage control, etc.), and allow deferral of major infrastructure investments have all been identified as areas for further study in Ontario[3].

Of course, being able to store energy for use on this grid is not new. Historically, Ontario has actively used long term energy storage as far back as the 1950s with the introduction of the Sir Adam Beck pumped hydro project at Niagara Falls. Between 2006 and 2014, several other organizations or working groups have been created to further investigate the possible benefits of storage. While not fully comprehensive, Table 1below lists some of these organizations and their main objectives. Readers of this report are encouraged to contact the authors with information regarding additional organizations or working groups for inclusion in future reports of this nature.

Working Group	Convening Organization	Mandate
Ontario Smart Grid Forum	Independent Electricity System Operator (IESO)	"The Ontario Smart Grid Forum includes member organizations from Ontario's utility sector, industry associations, public agencies and universities working together to develop the smart grid in Ontario and examine the many components it comprises. It is supported by the Corporate Partners Committee, which represents more than 30 private sector organizations active in the smart grid space − including, electric car markets, retailers, energy management companies, systems integrators and equipment manufacturers."[4]
Smart Grid Advisory Committee	Ontario Energy Board (OEB)	The initial objectives of the committee are to address: 1. The emergence of standard data access mechanisms (e.g., data access protocols emerging in Ontario, monitoring standards development in other jurisdictions). 2. The deployment of smart grid technologies (e.g., storage and microgrids), such as identifying deployment challenges and proposing solutions. 3. Cyber-security: The development of standards and practice in this very complex field requires the continued monitoring of developments in other jurisdictions to ensure that regulated entities in Ontario are following the best practices.

[1] Ontario Ministry of Energy, Long Term Energy Plan – Achieving Balance, December 2013
[2] Nitrogen oxides and sulfur dioxide emission reduced by 90% and 93% respectively since 2003; Ontario Ministry of Energy, Long Term Energy Plan – Achieving Balance, December 2013
[3] OPA & IESO *Energy Storage Procurement Framework*, January 31, 2014
[4] IESO Ontario Smart Grid Forum website

Working Group	Convening Organization	Mandate
		4. Interoperability: The Board expects distributors to work towards development and adoption of standards through, for example, co-ordination (e.g., common technology procurement), regional planning (e.g., common communication protocols), and links with third-party providers and industry.[5]
Energy Storage Ontario	Independent Association	"Energy Storage Ontario is the first energy storage-only alliance in Canada. It is a non-profit membership-based organization whose mission is to advance the energy storage industry in Ontario through collaboration, education, policy advocacy and research. We take an unbiased view towards technology and are supported by the contributions of our members."[6]
Canada Smart Grid Action Network	Natural Resources Canada (NRCan)	"CanmetENERGY established the Canadian Smart Grid Action Network (CSGAN) to connect national stakeholders and their work with the International Smart Grid Action Network (ISGAN). Key enablers for smart grid in Canada are connected through CSGAN to bring together the various knowledge domains associated with smart grid development, namely: research and development expertise; publicly and industry funded project results and insight; industry transition efforts and experiences; and policy."[7]
Energy Storage for Grid Security and Modernization	National Research Council Canada (NRC)	"NRC's Energy Storage for Grid Security and Modernization initiative explores energy storage technologies that are close to the load, working toward a solution that will defer the costs of transmission and distribution renewal, while stabilizing the generation of intermittent renewable energy, and enabling peak shaving and arbitrage."[8]
Advanced Energy Centre	MaRS	"The Advanced Energy Centre's mission is to foster the adoption of innovative energy technologies in Ontario and Canada, and to leverage those successes and experiences into international energy markets."[9]

Table 1 - Ontario Energy Storage Working Groups 2006-2014

These groups and organizations are often in contact with partners, both nationally and internationally, such as the Electric Power Research Institute (EPRI), United States Department of Energy (USDOE), Alberta Electricity System Operator (AESO), International Energy Agency (IEA), and many others. Certainly leveraging work completed in other jurisdictions is valuable in ensuring an efficient introduction of storage in Ontario.

Many of the results or recommendations of these groups have been included in policy documents from the Ontario Ministry of Energy (MoE), including: "Conservation First: A Renewed Vision for Energy Conservation in Ontario" discussion paper, and "Ontario's Long Term Energy Plan – Achieving Balance" (LTEP). These documents describe how grid-connected energy storage has the potential to increase the electricity system's efficiency, its reliability, and reduce ratepayer costs[10]. Specifically, Ontario's MoE has stated that it will commission an

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[5] OEB Smart Grid Advisory Committee website
[6] Energy Storage Ontario website
[7] J. Hiscock and D. Beauvais, Smart Grid in Canada 2012-2013, NRCan Report #: 2013-171 RP-ANU 411-SGPLAN
[8] NRC Energy Storage for Grid Security and Modernization program website
[9] MaRS Advanced Energy Centre website
[10] Ontario Ministry of Energy, Long Term Energy Plan – Achieving Balance, December 2013

independent study to establish the value of energy storage's many applications throughout the electricity system, and that such a study would also identify regulatory and other barriers facing energy storage project developers in Ontario's market.

To date there have been more than 30 grid-scale energy storage (ES) projects in Canada, either in development or fully operational, many of which have included funding from Sustainable Development Technology Canada (SDTC), Natural Resources Canada's Clean Energy Fund (CEF) and EcoEnergy Innovation Initiative (ecoEII), or the Ontario Smart Grid Fund (SGF). However in Ontario, several were also selected through competitive procurement processes, mainly run by the IESO or deployed by individual utilities. These projects have been installed at different locations in the grid, from small systems (<100 kW) serving commercial or industrial needs on distribution lines to larger systems (2 MW+) at the transmission or substation levels – providing a variety of services including voltage and frequency regulation, peak shaving, firming of renewable generation, and other ancillary services. The technologies utilized in these projects have included pumped hydro, compressed air energy storage (CAES), flywheels, lithium ion batteries, and hydrogen storage (power to gas).

Figure 1 – eCAMION 250kWh Community Energy Storage System, deployed on the Toronto Hydro Grid

Several participants in the technical conference noted the importance of stakeholder engaement and early technology demonstration as being critical to Ontario having attained an early lead in the energy storage industry in Canada, and increasing international recognition.

2.2 Review of Outcomes from the IESO RFP

> "Ontario is already recognized as a leader, with California and Hawaii looking to us – and our local storage innovators – for advice and support."
>
> Hon. Bob Chiarelli, Ontario Minister of Energy, APPrO 2014 Power Conference

Following the direction outlined in Ontario's Long Term Energy Plan, the Province is proceeding to systematically integrate energy storage technologies to evaluate their capabilities and benefits to the electric system, and ultimately rate payers. The Province is examining opportunities for net metering and conservation policy to support energy storage[11], and has directed the Ontario Power Authority to include a pricing structure and dispatch requirements that enable the integration of storage assets with future large renewable procurements[12]. Ontario has also

[11] Ontario Ministry of Energy, Long Term Energy Plan – Achieving Balance, December 2013
[12] MoE letter to OPA regarding Large Renewable Procurement Phase I Request for Proposals, 7 November 2014, Reference #: MC-2014-2534

participated in early demonstration projects that support emerging storage technologies with essential real-world experience. These projects will help the province and power authorities to evaluate the impact of new storage technologies in a stepwise fashion[13], and has garnered Ontario international recognition as a progressive region in modernizing its electricity system.

Driven by Ontario's LTEP, the IESO evaluated over 400 proposals according to pre-determined criteria, including technical characteristics (such as duration, ramp rate, and availability), contract term (3-10 years; favouring shorter terms) and cost (per MW and per MWh). Proposals were ranked in categories that included four geographic envelopes (northern vs. southern Ontario, congested vs. uncongested areas, and transmission vs. distribution connections) and the evaluation was designed to enable a variety of technologies. The first phase of this IESO-led procurement included 34 MW of storage to further diversify the IESO's portfolio of balancing assets, and the second phase of the process will see another 16 MW being procured in 2015 focusing on the capacity market.

The twelve projects selected in the first phase of the procurement included four different technologies from five separate vendors that must be able to respond to IESO dispatch signals to provide operating reserve, ramping, and load following in addition to the basic function of simply storing and releasing the grid's energy. The IESO's procurement terms required these projects to be built and certified within 30 months of contract award while the IESO works to determine how best to integrate these projects into their electricity system and market operations . The IESO has indicated it will be looking to identify new market mechanisms that address reliability needs, while taking into account a changing supply mix. Their goal will be to attract capabilities that the system requires to remain flexible, while remaining technology agnostic.

2.3 The Technology Provider's Experience

Due to early procurements in Ontario, as well as demonstration projects funded by federal and provincial governments, a panel of experienced project developers and technology providers were able to describe lessons learned at the 2014 APPrO energy storage symposium. Generally, these observations can be categorized as applying to either:

1) The development of the market for energy storage in Ontario (Market Readiness)
2) The development of enabling technology to enable cost efficient and effective operation when integrated into the grid (Technology Readiness).

Market Readiness Level

> "There are a lot of different applications for storage… becomes the Swiss Army knife, if you will, for the utility grid"
>
> Landis Kannberg, Pacific Northwest National Laboratory

Siting ES assets strategically on the grid is expected to maximize their value and effectiveness. As an example, local ancillary services (voltage/frequency regulation) can be provided by storage projects featuring fast response times and steeper ramp rates compared to conventional generators, while black start capability, renewables

[13] Leonard Kula, *Outcome of the IESO's Storage RFP and What's Next?*, presented at APPrO 2014 Technical Conference: Ontario Energy Storage Symposium, 18 November 2014, Toronto, Ontario

curtailment optimization, and gas generator performance optimization can be provided as part of these projects or others depending on control strategies and technology type. In this way, energy storage distributed on the transmission and distribution grid can complement conventional generating assets, and defer major infrastructure upgrades. However, in order to realize this benefit, the market must be structured to allow storage projects to compete equitably relative to incumbent technologies.

Observations related to market readiness noted by participants include:

- Since little contracting experience exists for ES projects, many early storage deployments included lengthy project permitting processes. While the issues associated with the delays varied across projects, the take-away lesson was to not underestimate the permitting process and to consider securing experienced project management support to allow technology developers to focus on core skills.
- Given the early stage of market development, little direct feedback on specific licensing barriers exists. However, the Ontario Energy Board, with the Storage Working Group of its Smart Grid Advisory Committee, is working to address some of these issues and will initially examine identified licensing barriers for ES facilities[14].
- Since ES projects are still relatively rare, their value propositions are not widely understood and therefore effective business models for monetizing their benefits are still being developed and tested. There are a number of factors that contribute to this issue, including:
    - Connection costs can vary widely depending on site-specific conditions
    - A single service (such as arbitrage) is rarely an economically viable use case, requiring project operators to stack services together in order to make a project economical. However these benefits are not currently aggregated, but instead distributed amongst the local distribution company, the System Operator, and other stakeholders.
    - Technology and application variability, as well as benefits which can accrue over very short time intervals, means that complex models are required in order to study the financial viability of an individual project.
- Novel energy storage technologies such as power to gas may have significant benefits, such as the ability to transport energy in parallel to the electricity grid, and the ability to leverage the inherently large storage capacity of the pipeline network[15]. However additional regulatory barriers exist when projects must deal with multiple regulatory bodies with different jurisdictions and any potential impact these changes may have on conventional users.
- Attracting capital and investment for the growing ES industry remains challenging, similar to other capital intensive, long term development technologies.

[14] OEB response letter to the Smart Grid Advisory Committee regarding identified barriers to energy storage integration, 5 August 2014, Reference #: EB-2013-0294.

[15] "@ 5% hydrogen by volume, the North America natural gas system can store > 66 TWh of energy." David Teichroeb, Hydrogen Energy Storage for Grid & Transportation Services, 14 May 2014, Sacramento, California

Technology Readiness Level

At a technology level, participants identified several challenges spanning the supply chain; from component-level storage cells to controller subsystems capable of the fast response times required in ES applications. The primary issues identified by participants included:

- Since most installations are completely autonomous, and rely on pre-programmed system control algorithms, a dependable communication link to the System Operator is essential for effective integration of ES. To exemplify this, continuous 2-way communication of Ontario's Automatic Generation Control (AGC) signals are required at 4 second intervals to control generation/storage assets; however this signal does not currently include the ability to exchange information about the "state-of-charge" or remaining capacity of a storage installation.

- Given the need for fast ramp rate control at the system level, the corresponding response times required by ES systems can be in the range of 100 milliseconds, with ramp rates from 50-1000 MW/minute to provide adequate control. Therefore, a robust ES control system (including battery management systems where applicable) was also described as being critical for successful implementation.

- Suppliers and integrators noted the absence of universally accepted codes and standards for emerging storage technologies. By comparison, the IESO Participant Technical Reference Manual[16] provides a well-defined communications block diagram for the AGC control arrangement for a traditional generator, and additional codes and standards exist for most every component deployed on the current electrical grid.

- Project developers noted that each utility have their own protection and control handbooks that further specify unique requirements ES control systems must comply with.

- Each storage technology has specific opportunities for cost reduction, durability and performance improvement:
    - For compressed air ES systems, a combined compressor/expander (especially including isothermal compression) was described as an opportunity for significant cost reduction.
    - For electrochemical storage technologies of all types, the inverter was identified as an area where future competition and cost normalization could lead to lower installed system costs.
    - While new lithium ion chemistries are likely to emerge, become commercial, and subsequently fall in price, the large and mature market for existing lithium ion cells is not expected to yield significant cost reductions through technology development alone. However the increased demand from both vehicle and grid applications are expected to continue to lower the installed cost of battery based storage systems.
    - For flow batteries, significant market acceptance barriers still exist due to relatively low market share, low volume production, and a low level of customer experience, despite relatively promising performance and cost projections.

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[16] IESO, Market Manual 6 Participant Technical Reference Manual, 11 September 2013, Issue 29.0, Page 61, Figure 4; IMO_Man_0024

3 Energy Storage Opportunities – Competing in a global marketplace

While it is relatively easy to study applications in Ontario or North America, one must look further abroad for the largest share of the energy storage market, where suppliers and applications in Japan, China, India, and South Korea make up over 70% of the current value in the ES marketplace[17]. With the Japanese market alone currently estimated at $1 billion and growing quickly, technology and project developers must consider their competitiveness, not just in Ontario, but within the overall global marketplace.

Canada and the United States, along with sharing a border, have collaborated on technology development and deployment for some time. Energy storage is no different, as noted by the panel participation of several representatives of US based organizations, including Ben Kaun of the Electric Power Research Institute (EPRI), Jim Greenburger of NATTBatt International, and Landis Kannberg of Pacific Northwest National Lab (PNNL), a key member of the US Department of Energy's (US DOE) Energy Storage Program.

> "We see energy storage as the silo-busting technology"
>
> Ben Kaun, Electric Power Research Institute

Both local and international participants noted that similarities and differences were apparent in Ontario's market; that while participants are subjected to the same general trends that are seen across North America and around the world, Ontario and Canada also have specific strengths and opportunities that can be leveraged to ensure global competitiveness. The following sections outline these trends and opportunities.

3.1 Trends in Energy Storage Technologies

In reviewing the state of the art in storage technology, several key observations were made by speakers in the conference:

i. Storage is not new; either from the grid perspective (pumped storage is well understood and deployed), or from the technology side, where large markets exist in consumer electronics and automotive sectors. What is new is the application of electrochemical storage to large scale grid level storage.

ii. Storage must be driven by analyzing the applications first, and then determining which technologies have the right performance and market conditions to meet the specific requirements.

iii. The technology that is "best" may not necessarily be most competitive in the marketplace due to external forces such as risk tolerance of adopters and insurers, availability of financing, or supply chain strength, among others.

iv. Economic development objectives, while well meaning, must be focused in order to be successful, and therefore may exclude some stakeholders from immediate benefit.

v. Cost and performance of energy storage systems must be compared from a fully integrated lifecycle perspective.

[17] Aisha Bukhari, *Global Opportunities for Canadian Energy Storage Firms*, presented at APPrO 2014 Technical Conference: Ontario Energy Storage Symposium, 19 November 2014, Toronto, Ontario.

Beginning with the end market in mind, several participants noted that the applications seen to be driving the adoption of storage in North America appear to be:

- Capacity constraints requiring capital investments in generation, transmission and distribution
- An increase in the utilization of variable generations resources such as wind and solar
- A requirement to improve the resiliency and the reliability of the grid

Shared experiences and analysis has shown that stacking benefits is increasingly important to create an economically viable storage project. An example is the project located on Bainbridge Island in Washington State's Puget Sound[18], where storage was reviewed as an alternative to a large transmission and distribution infrastructure upgrade that was opposed by local rate payers.

From a technical perspective, the large number of potential storage technologies ensures that a simple comparison cannot be made as to the competitiveness (including valuation) or technical readiness of individual storage technologies. A more complete review of the status of these technologies is beyond the scope of this report, and care must be taken to understand the generalities of any such assessment. However, in order to provide context to future discussions, an excerpt from the International Energy Agency's roadmap for energy storage is provided in Figure 2.

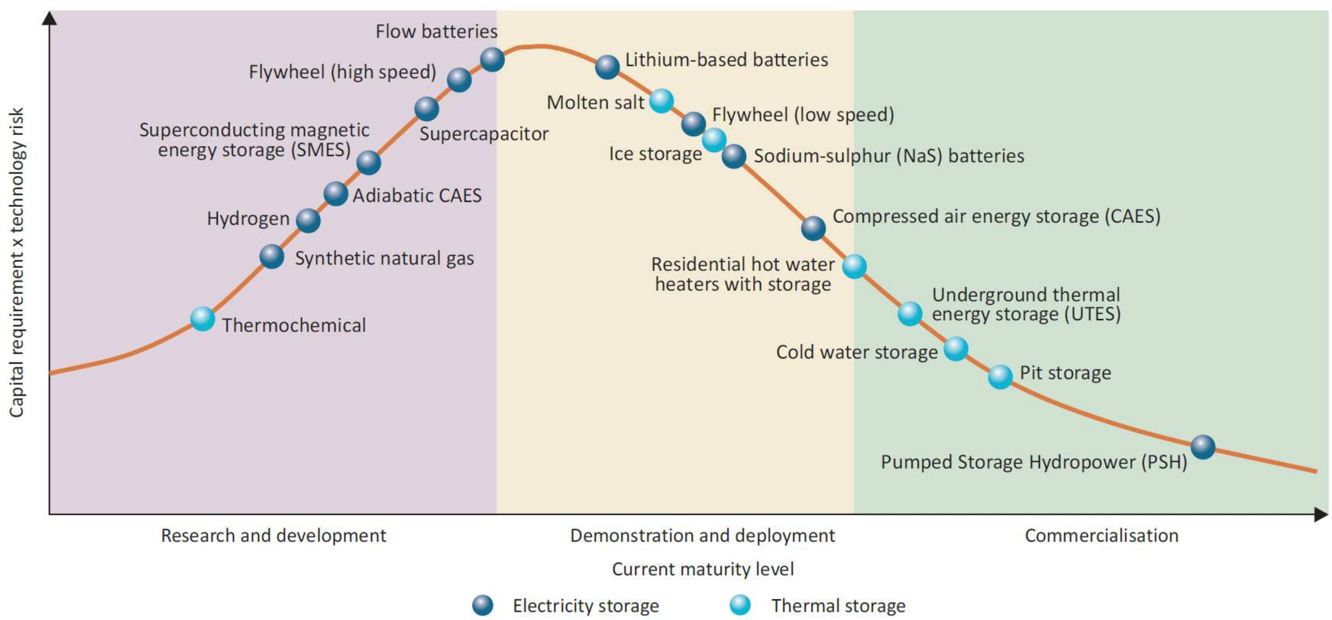

Figure 2 – Overview of Capital Cost and Technical Risk of Individual Storage Technologies[19].

[18] P. Balducci, C. Jin, D. Wu, M. Kintner-Mayer, P. Leslie, C. Daitch, A. Marshall, "Assessment of Energy Storage Alternatives in the Puget Sound Energy System – Volume 1: Financial Feasibility Analysis" December 2013, US DOE PNNL-23040

[19] OECD/IEA 2014 *Technology Roadmap – Energy Storage*, IEA Publishing. http://www.iea.org/t&c/termsandconditions/

3.2 Ontario's Innovation Capacity

Ontario has companies and stakeholders spread across multiple storage technologies and segments of the energy storage value chain. These organizations were well represented at the conference by attendees from private industry spread across the value chain; governments at the municipal, provincial and federal levels; and other market enablers such as associations, innovation hubs and incubators.

As the applications and technologies for storage are increasingly well defined, discussion is shifting to focus on how policy or regulation can be appropriately implemented in order to support the deployment of a new technology such as storage, while not unfairly penalizing incumbent or future technologies. In energy storage, similar to many other technologies, the private and public sector roles and responsibilities change as technical and market risk is reduced. Government entities move from that of "providing scientific and technology advances during the early stages of technology development to one of independent analyst, convener, and facilitator addressing common issues affecting technology adoption."[20] Industry on the other hand, starts to accept the market risks and exploit the opportunities presented by the new market or technology.

Participants noted several specific opportunities exist for Ontario to maximize the value created by the early adoption of energy storage, while modernizing the electricity grid:

- As indicated by Ontario's Smart Grid Advisory Committee report[21], the biggest challenge to establish an energy storage framework for Ontario is to come up with a benefit structure that works fairly for utilities and consumers. As noted earlier, the OEB can rely on data collected from the two phases of the IESO energy storage procurement to inform future processes on other issues identified as barriers for the sector.

- With Ontario's medium to long term goal of lowering the cost of clean energy and reducing greenhouse gas (GHG) emissions, electrical storage technologies can be seen as a mechanism to protect and extend public investments, while becoming a preferred market entry point for new grid storage technologies, and play an important role in determining Ontario's and Canada's competitive advantage.

- A failure analysis of storage systems to date reveals that most failures were not in the storage medium itself, which has typically undergone significant development and testing in parallel markets, but in how the components were integrated and controlled[22]. This, combined with significant opportunities for cost reduction that exist in the integration and balance of system of energy storage installations suggests an increased need for standardization of components and grid interface requirements.

- Given the need to increase the volume of production, and reduce cost while improving reliability, a sigpportunity exists to leverage manufacturing and system integration experience in adjacent sectors (such as automotive manufacturing, industrial controls and integration) in order to ensure lower overall failure rates, and higher value addition to ES in grid applications.

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[20] U.S. Department of Energy, Grid Energy Storage, December 2013

[21] OEB Smart Grid Advisory Committee 2013 Storage Working Group Report

[22] Ben Kaun, *Energy Storage Development Status and Opportunities for Advancement*, presented at APPrO 2014 Technical Conference: Ontario Energy Storage Symposium, 19 November 2014, Toronto, Ontario.

- Many complexities exist in developing energy storage integration framework and thus long term investment in R&D may be required. Ontario's universities and research organizations (along with their national and international partners) can play a vital role in resolving these issues, and passing more mature energy storage solutions to other value chain participants.

- Organizations such as NRC, US DOE, and EPRI through the Energy Storage Integration Council (ESIC) can, (and do) collaborate to ensure that lessons learned in previous technology deployments are implemented in new storage deployments both nationally and internationally, as well as ensure that a critical mass of resources are brought to bear to the technical challenges, while reducing overlap and rework.

3.3 Leveraging Local Success for Global Competitiveness

Increased experience from deployment from successful companies such as Solar City and Tesla are no accident, and the oft-mentioned battery "gigafactory" is a good example of the synergies that might be possible between storage technologies in other markets. Several participants noted that energy storage solutions are currently cost effective in certain applications, and the international market continues to grow. Also noted was that the policy of Ontario, to foster smart grid innovation (with a focus on commercialization), including energy storage technologies, and the related economic development opportunities it entails seems to hold promise.

To support this development, an increased focus on the broader supply chain and effective road mapping tools were noted as ways to help de-risk future deployment. For the risk-adverse utility industry, there is no substitute for experience gathered from proven hardware that is the ground operating reliably. Therefore, to overcome this "chicken or egg" dilemma, data and experience sharing from demonstration projects is critical in shaping the policies and regulations than can support the storage industry. For instance, a panelist found that Alberta had found that modelling storage as a service to the system at large, rather than as an optimization for a given windfarm, resulted in a more viable business model[23]. In all cases, the need for technical risk reduction is greater than the number of participants or resources available, and therefore increased specificity on the key steps to be taken is incredibly important, as is collaboration among the resources that have a mandate to support this growing sector.

With the deployment rate of storage assets still ramping up and the continual development of new storage technologies continuing in a risk-adverse utility environment, the global challenges and opportunities are expected to endure a few years more. Longer term investments in this space, with an eye to global markets look to present a clear opportunity for Ontario to exploit its competitive advantages through collaboration between academia, government, and industry for the foreseeable future. However, further work will be required in order to fully map and understand the areas of strength in Ontario, and identify how all market participants can fully engage in a synergistic rather than duplicative manner.

[23] Described by David Teichroeb during a panel discussion at the APPrO 2014 Technical Conference: Ontario Energy Storage Symposium, 18 November 2014, Toronto, Ontario.

4 Recommendations and Next Steps

Based on the presentations and discussions at the conference, several key opportunities were discussed as enabling the competitiveness of Ontario's energy storage sector:

i. Development of an energy storage technology roadmap for Ontario
ii. Supporting the development of energy storage codes, standards and regulations
iii. Strengthening the energy storage supply chain by:
    a. Long term energy storage research, development, and deployment
    b. Increasing supply chain knowledge, collaboration and participation

These opportunities are detailed in the following sections.

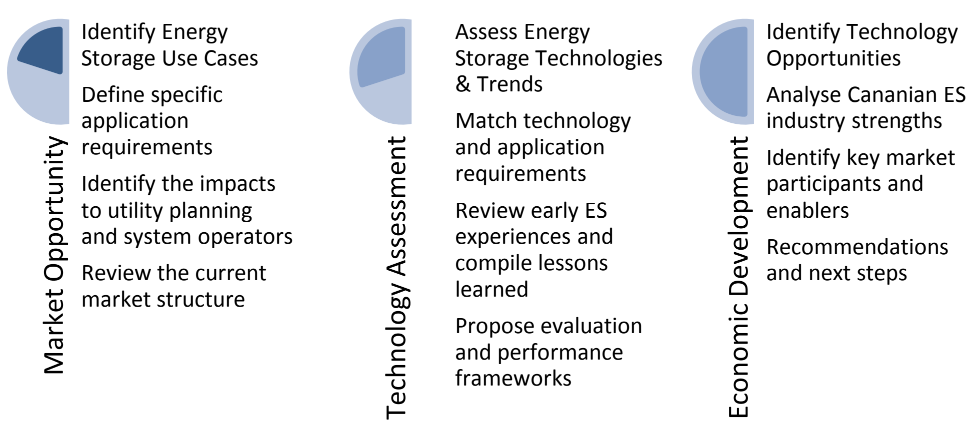
4.1 Development of an Energy Storage Technology Roadmap for Ontario

Much work has been completed in recent years, particularly in the US, to identify the many potential value streams associated with energy storage deployment and evaluate them in multiple applications using advanced valuation tools and demonstrations. While these studies have enhanced the general knowledge base of the industry as a whole, gaps still exist in specific jurisdictions where market dynamics, supply mix and regulatory structures are unique. For Ontario, these gaps can only be filled through an in-depth analysis of how the benefits of energy storage can be realized based on the unique attributes of Ontario's electricity market structure, the maturity level of relevant ES technologies, and the capabilities and capacities that exist within the manufacturing and technology industries to meet market demand.

The development of an energy storage technology roadmap is expected to provide:

- clear options to market and regulatory agencies that results in fair, effective and low cost mechanisms to integrate storage
- a clear understanding of storage technology, including an assessment of state of the art and the value proposition on the Ontario grid
- increased engagement of the electricity and manufacturing sectors in new technology commercialization, both for local use and export opportunities

In order to accomplish this, a three pillar structure is proposed including detailed analysis of the market opportunity, an assessment of the ability for energy storage technology to contribute to resolving current market challenges, and a review of the opportunity to enable Ontario's economic development.



Across all three pillars, in order to support the short term deployment of storage technologies and long term sustainability of the grid-scale storage sector in Ontario, engagement of key stakeholders such as storage technology vendors, system integrators, regulators, power producers, and policy makers will be critical.

4.2 Supporting the development of Energy Storage Codes, Standards and Regulations

The Energy Storage Procurement Framework released by Ontario's Independent Electricity System Operator (IESO) and the Ontario Power Authority in January, 2014 provided the following objectives[24]:

- Maximize learnings about the various end-use services that energy storage solutions can provide
- Explore potential frameworks for competitive procurements, market mechanisms, and the commercial arrangements for energy storage solutions
- Learn how to effectively and efficiently integrate energy storage resources into the Ontario electricity market, understand its potential roles in the sector and meet system operator needs
- Identify the main regulatory and other barriers preventing energy storage technologies from competing in the energy market

In parallel with these activities, various other initiatives are underway nationally and internationally to bring together multiple stakeholders and projects to ensure greater leverage of individual efforts, and reduced duplication. Most notably, key initiatives include: The energy storage program at the Electric Power Research Institute (EPRI), which together with utilities, integrators, research organizations, and industry experts created the Energy Storage Integration Council (ESIC), and work at standards agencies such as CSA Group, International Electrotechnical Commission (IEC), Standards Council of Canada, and others.

Specifically, the following gaps identified by previous energy storage demonstration projects in Canada must be addressed:

- Lessons learned from demonstration projects during procurement and operation have not been widely disseminated and utilized to improve future procurements.
- Data collection and analyses performed during demonstration projects lack detail at the operational level to provide insight into power system planning and ES system dispatch.
- Lack of understanding of current codes and standards are affecting the deployment and operation of ES on the electrical grid, and therefore the deployment of renewable energy sources.
- Codes and standards have not been effectively utilized to address cost barriers due to technology and project specific recurring engineering.
- Harmonization of codes and standards across North America, and internationally is generally inconsistent, with no clear path forward for adoption

Organizations must collaborate to monitor existing demonstration projects, and drive the lessons learned to improve codes, standards and regulations. This can be accomplished in partnership with national and international standards agencies, and is expected to ensure that future storage procurements would have lowered risks in framework development, reduced uncertainty for project proponents, and improved evaluation and dissemination of project information.

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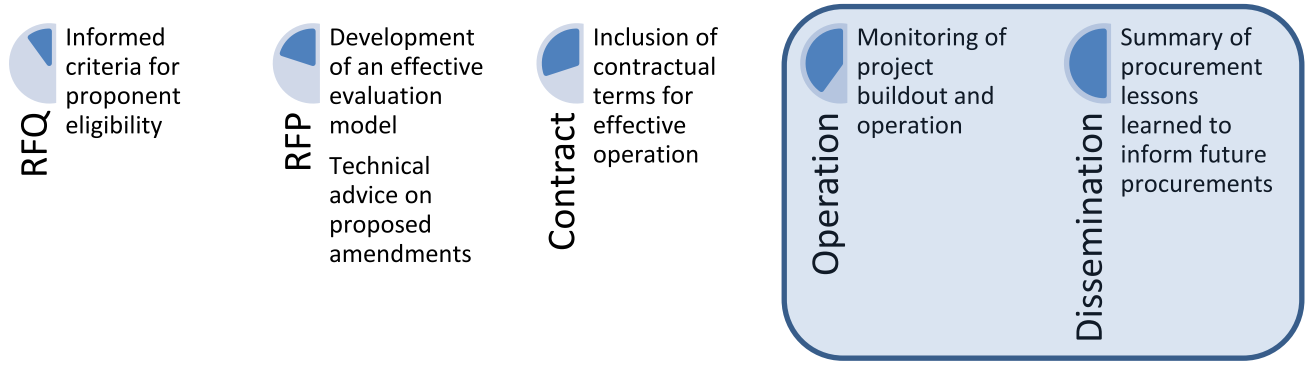
[24] OPA & IESO *Energy Storage Procurement Framework*, January 31, 2014



4.3 Strengthening the Energy Storage Supply Chain

4.3.1 Long Term Energy Storage Research, Development and, Deployment

Canada is a pioneer in the development of technologies and products for power generation, transmission and distribution, such as the first AC power systems in Niagara, and leading-edge software such as PSCAD, and Simulink. Canada's natural resources and energy industry are national economic drivers and have afforded Canadians reliable, well-running electricity systems. Recent pressures to increase renewable generation portfolios have led electricity system planners to look towards new technologies including ES. Advancements over the last three decades in ES technologies and power electronics have made ES technically and commercially feasible. One option for continued longer term research and development is harnessing the capabilities of Canada's academic institutions. As an example, the proposed NSERC Energy Storage Technology Network's (NEST Network), led by Ryerson University, would assembly a team of 32 Scientific Researchers from 15 universities and government research laboratories across Canada, and 16 partner organizations representing industry, utilities, government agencies, and universities.

The NEST Network's mission is to bring together leading academic, industry, utility and government stakeholders to develop, test, demonstrate and ultimately commercialize innovative ES technologies (products, processes and services) through multidisciplinary and collaborative R&D. To achieve its long-term vision of creating more reliable, environmentally friendly and efficient electric power systems, NEST Network will work to increase the market penetration of Canadian made ES technologies worldwide. This mission and vision is directed at transformational change, and will be achieved by meeting goals critical to academic, public and private sector stakeholders over five years, including:

- **Fundamental Knowledge** – Generate new fundamental scientific knowledge regarding ES technologies, associated power electronics, and methods for integrating ES into power systems, while also developing new understandings about the ES market, policy, regulatory and social frameworks which govern it, and associated environmental science and engineering concerns.
- **Commercialization** – Facilitate the commercialization of innovative ES products, processes and services, including technologies with improved performance, lower cost, and improved life-span, high and low power converters and associated control systems, novel scheduling, planning and optimization algorithms and models, and new policies, standards and regulations to govern ES through collaborative R&D and technology transfer between academia, industry, utilities, and government.

- **Training** – Improve Canadian ES HQP by providing multi- and inter-disciplinary, state-of-the-art R&D training to students and professional personnel in the fundamental areas of ES technologies, power electronics, systems integration, and applied social sciences, and improving the personal and professional skills of students for future careers in industry, academia or government.
- **Partnerships** – Strengthen and deepen existing research partnerships and enable the development of new partnerships between Canadian organizations and academic researchers in order to develop new products and inform governments by providing a framework and forum for ES technology manufacturers and suppliers, users, regulators/policy makers, and academic researchers to collaborate, network, and share resources and risk, data, best practices, and lessons learned.

4.3.2 Increasing Supply Chain Knowledge, Collaboration and Participation

As previously outlined herein, Ontario companies have the skills and resources to gain a significant foothold in this rapidly emerging sector. Raw-material suppliers, technology developers, component manufacturers, system integrators and end-users, all have a role to play in achieving improvements in the cost/performance equation that will be necessary to realize the full value of energy storage technologies in the marketplace, and create lasting economic benefit to Canada. One significant step toward maximizing these benefits would involve developing a stronger domestic supply chain to serve the energy storage sector.

From a technology perspective, Canada has companies and stakeholders spread across multiple storage technologies and segments of the ES value chain. These include, but are not limited to: advanced flow batteries, advanced lead acid, compressed air energy storage (above ground), and lithium-ion batteries. This is in addition to possible game changing technologies including rechargeable metal air, flywheels and hydrogen energy storage. However, what is most important about each of these technologies is that they can be placed close to the load in order to achieve the multiple benefits and revenue streams that will make ES investments economically viable.

Given the diversity of technologies and geographic distribution of companies in the supply chain, a method is needed to connect and inform Canadian industry in the energy storage sector and identify the gaps that might exist in the supply chain. As a first step, a web based portal/database could be used by existing stakeholders to facilitate new partnerships and could provide new entrants with access to critical information, enabling them to more quickly identify where their core compentencies might be required, encouraging them to bring sought-after skills into the sector. Information supplied in the database could also provide end-users with a foundation of knowledge about where Canada's expertise fits into the global supply chain for energy storage technologies. Specifically, this intitiative would have to:

- Allow global customers and suppliers easy access to information about Canadian companies currently engaged in the development and deployment of energy storage technologies.
- Allow market enablers (federal and provincial government agencies, incubators, funders, and researchers) to convene partnerships and foster collaboration that will assist the ES sector in remaining globally competitive.
- Assist members of the Canadian energy storage supply chain, including system integrators, component and material producers in finding partners to assemble cost effective, high performance, and durable energy storage systems.

5 Summary

Many of the observations and comments received during the technical conference are corroborated by external study and market analysis by international organizations, such as that completed by Sandia Labs for the US DOE that indicated the following challenges for energy storage[25]:

- High storage cost (relative to monetizable benefits) for modular storage.
- To a large extent, pricing of electric energy and services does not enable storage owners to monetize most benefits.
- Limited regulatory 'permission' to use storage and/or to share benefits among stakeholders – especially benefits from distributed/modular storage.
- Key stakeholders have limited or no familiarity with storage technology and/or benefits.
- Infrastructure needed to control and coordinate storage, especially smaller distributed systems, is limited or does not exist.

Even with these challenges, the market opportunity for storage is expected to be relatively large; Pike Research estimated that the worldwide market for energy storage on the grid will have a compounded annual growth rate of 33%, totaling more than $24B over the next 10 years[26]. Participants in the technical conference were clear that Ontario's companies have the skills and resources to compete in the global marketplace, and that global competitiveness would be enhanced by initial local deployments. In this respect, Ontario is well underway, and further actions to strategically align and support these efforts have been proposed. While not exhaustive, the recommendations contained in this report are suggested for consideration by attendees at future similar events in order to progress from discussion to implementation, and that Ontario can realize the opportunity that energy storage presents, both to the electricity grid, but also to the entire energy storage supply chain.

> **"The possibilities that storage technologies offer can be game changing, to be sure." "…the value of storage technologies cannot be over-stated."**
>
> Hon. Bob Chiarelli, Ontario Minister of Energy, at the APPrO 2014 Power Conference

[25] Jim Eyer, Garth Corey, Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide, February 2010, DOE Sandia National Laboratories SAND2010-0815

[26] Pike Research, Energy storage on the grid, Q3 2011