TORONTO

Attachment 1: City of Toronto Energy Storage Strategy

Introduction

The energy landscape in Ontario is changing, with a larger focus on efficient, clean and reliable methods of energy generation to meet electricity demand and reduce GHG emissions. Meeting the GHG emission reduction target of 80% by 2050 will require substantial effort to achieve. With that, there is a growing interest to increase grid connected renewable generation.

There are however some challenges to renewable generation in that they do not always generate electricity when needed and are often most productive during off peak hours. For instance wind energy is a variable source of electricity that is typically generated at night.

Energy storage provides a number of benefits, the most prominent of which is the ability to balance loads by storing energy generated off peak so that it can be used during peak hours. The ability to store electricity to be used when it is needed rather than when it is generated works exceptionally well when paired with intermittent renewable energy sources. Energy storage can also help improve power quality and grid reliability amongst other benefits such as pricing arbitrage to offset time of use billing.

The Energy Storage Strategy has identified the following key strategic objectives to enter this market:

1. Monitoring energy storage technology and applications
   - Commercialization and innovation
2. Establishing partnerships
   - Identify Implementation partner such as Toronto Hydro
3. Identifying energy storage applications
   - Alignment with City climate and resiliency initiatives
4. Developing projects
   - Implementation opportunities to support City facilities
5. Building the City's energy storage network
   - Stakeholder engagement with local post-secondary institutions and industry stakeholders

By focusing on these objectives, the City will be in a position to effectively access the value streams of energy storage and maximize outcomes.

Monitoring Energy Storage Technology and Applications

The energy storage industry is developing at an increasing rate and it is important for the City to understand of the different types of storage technologies and their applications. This knowledge will provide insight and guidance as the City looks to develop projects.

The rapid commercialization of energy storage technology has created new markets. Particularly noteworthy is the lithium-ion battery that has demonstrated safety and reliability and is now available from numerous global suppliers at reduced costs. The market scaling for lithium-ion batteries is comparable to LED lighting and solar panels supporting a price drop of up to 75%.

Energy storage technology developers are also working to innovate and commercialize storage technologies including compressed air, flywheels, thermal energy storage, and the use of flow batteries. Each technology has unique applications that provides a variety of co-benefits to the user and the energy distribution system. Demonstrations of these technologies have shown promising results and developers are innovating to achieve better economies of scale and applications for the mass market.

Technology Overview

Batteries

There are two main types of batteries used in energy storage applications: steady state batteries and flow batteries.

Steady state batteries are the more mature technology that includes lithium-ion and lead acid technology. These commercialized batteries have experienced a recent drop in price from $550 to $200 per kWh. Steady state batteries emit a considerable amount of heat which causes degradation when cycling which can reduce battery life and amount of charge/discharge cycles. However, the high energy density, and low maintenance needs makes them a good choice for most electrical storage applications.

Lithium-ion batteries have experienced substantial market uptake and are currently being installed for a number of applications, providing a variety of services. Installation examples of varying sizes include:

- Small: Three hundred, 6kW residential solar-PV storage systems are planned for New York City and will demonstrate how an aggregated fleet can provide facility based resiliency and flexible power to support the grid.
- Mid to Large: 7MW battery in Sault Ste. Marie region supports grid flexibility and increases the reliability and efficiency of the grid in the region.
- Utility Scale: Tesla recently proposed a 100 MW battery in Adelaide Australia that is expected to serve 1.7 million people and resolve the rolling power outages that are currently being experienced.

Toronto Hydro has also been developing energy storage projects that focus on deferral of expensive infrastructure renewal and meeting the growing needs of Toronto.

Targeting constrained areas, Toronto Hydro has developed community based projects and is currently collaborating with Metrolinx and other stakeholders on the recently introduced large scale lithium-ion battery systems (approximately 20 MW total) that will support the new Eglinton Crosstown LRT. This innovative project stores surplus power generated off peak across Ontario that can be dispatched to support the Crosstown LRT operation and reduce the daytime peak electrical demand. This approach will reduce operating costs, lower emissions, and provide emergency backup power for up to four hours.

Flow battery technologies include vanadium redox, zinc-bromine (ZN/BR), iron-chromium (Fe/Cr) and zinc-air metal combinations. Using external tanks, flow batteries store energy in chemically reactive liquids and utilize a liquid based charging system. Flow batteries have vastly increased cycle life and are expected to last longer, which demonstrates lower lifetime costs. Flow battery technology has higher upfront costs which has limited applications to larger grid scale applications. Several flow batteries have been procured in Ontario to start analyzing the technology in 2018.

Flywheel

Typical flywheel technology is meant for short-term energy storage of approximately 15 to 20 minutes. Applications using the flywheel for frequency regulation and increasing power quality have shown to create more reliability in the power market. Substantial research and development is being done to increase the storage capacity and developers including Ontario-based Temporal Power are demonstrating the technology's ability to charge and discharge for a 4 hour period.

Compressed Air

Compressed air energy storage (CAES) is comparable to pumped hydro but instead of water, air is pumped into holding chambers during off peak hours which is then released to generate electricity during times when electricity is in greater demand and more expensive. This technology was introduced in the 1970's and has recently seen a resurgence of new innovative applications.

Toronto-based Hydrostar, has developed an underwater compressed air energy storage system to convert electrical energy from the grid to compressed air using accumulators submerged below the surface of the water. When energy is needed the weight of the water pushes the compressed air back to surface where the process is reversed. The lessons learned have now been integrated into future projects including a proposed 1.75 MW compressed air project in Goderich Ontario in an unused salt mine.

Thermal Energy Storage

In its simplest form, thermal storage is similar to the water heaters commonly found in households that stores hot water for later usage. Thermal energy storage technologies can store energy as heat or cold storage. Local applications include the Ice Bear technology hosted at the Toronto Zoo. This system stores energy by making ice during off peak hours, which is then used to cool buildings during the day.

Using thermal storage, developers are currently rolling out several new innovative grid scale projects including a 3 MW aggregation project in Massachusetts, and an ice storage project in California that will be up to 26 MW.

Hydrogen

Energy storage is also driving the shift towards renewable gas sources, including the conversion of surplus renewable electricity into hydrogen for injection into the gas distribution system. Currently in development for Brunsbüttel, Germany, the project will displace fossil fuels by converting 2.4 MWh of surplus wind power into 360 cubic meters of hydrogen.

Applications of Technology

In Ontario, the Independent Electricity System Operator (IESO) has led the procurement of 56 MW of new energy storage projects. These projects will demonstrate how storage technology applications can provide a number of benefits including, grid reliability and increased adoption of intermittent renewable generation resources.

Through a phased approach, the pilot projects started in 2012 and successfully procured 6 MW of responsive energy storage. Building on the success the IESO proceeded to procure an additional 50 MW of storage including 34 MW with an expected commissioning date of 2017, and an additional 16 MW that is expected to be on-line in 2017-2018.

The IESO procurement focused on diverse technologies that could be evaluated for a range of ancillary grid services. The following is a list of the grid support services and the storage technologies procured by the IESO in Ontario.

Frequency Regulation: acts on a second-to-second basis to match generation to demand and helps correct variations in power system.

- Flywheel:
  - 2 MW system procured in 2012
  - 5 MW system procured in 2014
- Thermal:
  - 0.74 MW system procured in 2014
- Hydrogen:
  - 2 MW system procured in 2014

Reactive support and voltage control (**RSVC):** is needed to maintain voltages and support the flow of electricity along power lines.

- Solid State Battery:
    - 4 MW system procured in 2012
- Solid State Battery:
    - 23.8 MW procured in 2014
- Flow Battery:
    - 2 MW procured in 2014

Hybrid Grid Support: technology that may be called upon to provide other various services.

- Solid State Battery:
    - 8 MW system procured in 2015
- Flow Battery:
    - 7 MW system procured in 2015
- Compressed Air:
    - 1.75 MW system was procured in 2015

Establishing Partnerships

There is value in collaboration and the City will look to establish partnerships to identify and develop energy storage projects at City facilities.

The strategic direction is to identify storage development partner(s) who will work with the City to assess Toronto's unique needs and requirements of storage in specific local communities.

The Environment & Energy Division (EED) will evaluate methods to support local installations including access to strategic partnerships to contribute to the City's climate change and resiliency objectives.

Acting on the success of existing partnerships with the City, Toronto Hydro has expressed interest in potential collaboration on energy storage projects. Evaluation of the co-benefits for both organizations will be done to enhance services and defer costs associated with asset upgrades.

When appropriate the EED will assist the Economic Development & Culture Division with energy storage related projects that apply to the Green Market Acceleration Program (GMAP). The GMAP Program invites developers with innovative green technology to collaboratively develop demonstration projects.

Identifying Energy Storage Applications

There are a number of City wide initiatives that align with energy storage including TOCore and ResilientTO. The TransformTO 'Leading by Example' strategy for internal City facilities also exemplifies the alignment and opportunity to value stack the benefits of energy storage to maximize City initiatives.

Energy storage technology solutions are being evaluated to provide low carbon long term utility savings for rate payers. Electricity distribution companies and electricity supply operators are investigating innovative demand management solutions to avoid the costs of expensive infrastructure modernization and /or new generation.

Driven by the high value of energy storage, many US cities and states have set 2020 energy storage targets including:

- California: 1,325 MW
- New York City: 100 MW
- Massachusetts: 200 MW

To achieve desired GHG reductions, TransformTO models included a recommended Toronto target of 100 MW of energy storage by 2025, scaling up to 1,000 MW by 2050.

The City has a number of initiatives and objectives that align well with energy storage that are outlined below:

Energy storage provides the opportunity to store renewable energy to be dispatched when needed rather than at the time of generation. This innovative solution supports the increasing renewable capacity expected to help meet carbon reduction targets. With the Ministry of Energy's recent announcement to expand the net-metering program to include energy storage the City will have new opportunities for solar/storage solutions at City facilities.

Investments in energy storage can result in significant utility savings. The added versatility provides utility cost savings benefits including peak demand shaving when a facility shifts electrical demand to off peak times to reduce demand charges. Sites can also earn revenue from demand response by responding to a notification from transmission and distribution stakeholders who request battery charge or discharge. Storage technologies with low degradation rates can earn an arbitrage savings by buying power produced at night and using the power during the higher priced daytime hours.

City growth and development plans, including TOCore and the Toronto Green Standard, introduced new low carbon regulations and are seeking increased development of micro grids and net zero buildings. The development of new low carbon/net- zero carbon communities will rely on dispatch-able low carbon thermal or electrical energy sources. Utilizing energy storage systems, homeowners and/or district energy providers can use the stored low carbon energy during periods of peak demand or when the system's renewable generator is unavailable.

Energy storage applications also provide resiliency. Facility managers can use energy storage to remain operational during short term electrical power outage. Using forecasting modeling technology, site operators can size a battery for critical electrical loads. Storage's unique capacity for modular sizing has shown capital and operational cost savings when compared to investing in natural gas/diesel emergency generators.

Energy storage development can support local distribution companies to defer potential costly electrical grid system upgrades. Neighbourhoods with network constraints associated with increased electrical demand from growth and electric vehicle charging can now use a low cost energy storage to meet the customer's real time electrical demand.

Developing Projects

Developing new energy storage projects at the City will require thorough analysis and business cases to evaluate how all stakeholders will access the available value streams.

The EED has initiated the analysis of potential energy storage projects at City facilities and is currently reviewing technical details including utility consumption data from several Toronto Paramedics stations to size a small system. This proposed 5-15 kW system will be paired with solar PV to create a resilient solar-storage application to provide backup power during the event of a utility outage. Once operational the system will also be used to demonstrate the technology's effectiveness in reducing emissions by storing renewable energy for use during peak periods.

The City has identified that energy storage applications at large facilities (greater than 40,000 sq. ft.) with electrical demand greater than 1 MW could provide substantial utility cost savings associated with high peak demand charges. The City has met with energy storage developers to learn more about installations tailored for peak demand shaving applications. Sample business cases have also been provided for integrating a large 1 MW systems to support the reduction of peak demand charges.

Achieving the City's Energy Storage Strategy objectives is contingent on identifying partners and funding sources to support the business case valuation. The City has begun to evaluate Federal and Provincial grant opportunities including Ontario's Cap and Trade funding and the Federal governments recently introduced Green Infrastructure Phase II focused on smart grid integration to reduce emissions. Funding may also be available through the IESO or other local utility partners and will be verified before any project investment.

Building the City's Energy Storage Network

The City is working to facilitate collaborations with neighboring municipalities who have similar goals and challenges. Canadian municipalities have had limited involvement and influence on energy storage regulatory policies. Together cities can set achievable targets and build on experiences to identify new regulations to support energy storage.

The City will also be working to learn more about regulatory barriers and focus on aligning stakeholders to identify opportunities to remove roadblocks and increase energy storage uptake.

Collaboration with Local Post-Secondary Institutions

Ryerson and York Universities are part of the NSERC Energy Storage Technology (NEST) Network. Led by Ryerson University, NEST supports research and development towards the commercialization of Canadian energy storage technologies. The program introduced 24 projects with 4 research themes: 1) Energy Storage Technologies, 2) Power Electronics Converters, 3) Power System Integration and 4) Economics and Policy.

The City has consulted with Ryerson University on energy storage technologies, economics and policy themes. As the NEST Network matures and projects begin development the City will liaise with representatives to adapt City projects to the evolving industry.

Collaboration with NRC

Industry stakeholders led by Natural Research Council (NRC) Canada's Energy Storage for Grid Security and Modernization program supports the energy industry to tackle the greatest obstacles to adopting energy storage technologies including durability cost and risks associated with development in Canada.

The City is actively working with NRC to access the ES-Select™ Canada tool. Currently in beta testing users can access the tool to compare and rank energy storage technologies for a range of applications. The tool calculates financial outputs that include cash flow, cumulative cost benefits, and net present values allowing users to select the optimal technology.

NRC is also currently developing provincial energy storage roadmaps to support the development and integration of energy storage. NRC's first roadmap for Alberta is expected to be released in September 2017. Roadmaps will be released, province-by-province, with Ontario's roadmap expected in spring 2018. These detailed plans will provide stakeholders with a model to confirm the grid's technical upgrade requirements as well as a detailed regulatory assessment. Energy storage developers will be able to access the NRC roadmaps as a guide to investing in energy storage infrastructure for the local grid. The City plans on continued collaboration to support this initiative and contribute to policy development when appropriate.

Conclusion

This strategy was designed to provide the City with the knowledge and guidance to support a smarter, cleaner and more efficient electrical grid. Successful implementation of the Energy Storage Strategy is an innovative and cost effective way to enable the City to lead by example and achieve the GHG reduction targets set out in the TransformTO Climate Action Plan. The five strategic objectives are:

1. Monitoring energy storage technology and applications
2. Establishing partnerships
3. Identifying energy storage applications
4. Developing projects
5. Building the City's energy storage network

Energy storage technology is rapidly changing municipal electrical grid by supporting the increased demand for electricity and the integration of new renewable energy resources. The commercialization of energy storage has reduced costs and increased availability of various storage technologies. In partnership with the local utility and other stakeholders the City will use energy storage to reduce GHG emissions and integrate new renewable generation, as well as defer expensive grid upgrades and support more affordable energy solutions.