ASA

Alberta Storage Alliance

ENERGY STORAGE

UNLOCKING THE VALUE FOR ALBERTA'S GRID

EXECUTIVE SUMMARY

OBJECTIVE

In November 2015, the Alberta government announced a new Climate Leadership Plan; central to the plan is transitioning the province's energy generation away from coal and towards renewables. This decision will have numerous impacts on the current electricity system, such as grid stability. Energy storage can play an important role in navigating this transition by providing reliable solutions to many of the challenges that may arise. This paper seeks to outline the role that energy storage can play, and recommend policies and strategies for the implementation of storage projects in Alberta.

STORAGE AS A SOLUTION TO ALBERTA'S ELECTRICITY SYSTEM CHALLENGES

There are four key areas where Alberta's Electricity System will need solutions as additional renewable generation is built and coal generation is retired:

1. Renewables integration;
2. Price volatility;
3. Supply adequacy; and
4. Grid reliability.

Energy storage has the ability to address all four key challenges by removing excess electricity from the grid and returning it at an optimal time. The successful deployment of energy storage in electricity systems around the world has demonstrated its ability to swiftly react to system needs, making storage a compelling solution for Alberta's electricity system.

BARRIERS TO IMPLEMENTATION

The current market signals are not sufficient for the wide-scale deployment of energy storage in Alberta. Current market rules punitively double charge storage by treating it as both a generator and a load. Also, there is no specific ancillary services market to take advantage of storage's ability to respond to system frequency issues. Therefore, the instantaneous response capability offered by storage is not being realized due to current regulation and market models.

KEY RECOMMENDATIONS

The Alberta Storage Alliance (ASA) recommends the following solutions be considered:

Grid Balancing	1) The ASA will work with the AESO and regulators to identify services and applications where energy storage can offer benefits to Alberta's electric grid. As part of this collaboration, we recommend conducting a *Needs Identification Process* to determine what services (existing or new) are required to help maintain a reliable electric grid going forward. 2) The ASA and AESO should conduct an assessment regarding whether assets solely providing system stability services should be exempt from certain investment prohibitive tariffs. For example, a standard Transmission Service rate for grid-connected storage offering only Operating Reserves (OR) would avoid "double charging" such assets under existing regulations and tariffs. 3) Energy storage should be allowed to participate in the energy and ancillary services markets, via small revisions to the AESO market rules, as any other capable technology that satisfies appropriate technical requirements. This rule development should be accelerated to allow energy storage inclusion in the Alberta market.
T&D Deferral	4) During system planning, the AESO should give due consideration to other assets (such as energy storage) that can alleviate system burden as an alternative to "wires" solutions for transmission upgrades.
Behind-the-Meter	5) The ASA can help develop a straightforward and transparent process to expedite behind-the-meter energy storage interconnections (for both residential and industrial customers).
Emissions Reduction Services	6) The Alberta Department of Energy should continue to allocate funds from its carbon emissions levies to accelerate the deployment of technologies offering greenhouse gas emissions reduction benefits. Funding energy storage projects is an important means of enabling the integration of more renewable energy.

THE ALBERTA STORAGE ALLIANCE

A consortium of experts from across the energy industry have come together to recommend this strategy for Alberta to leverage energy storage technology within its electricity market. The Alberta Storage Alliance ("ASA") is made up of technology developers, project developers, utilities, research groups, energy consultants and power generators. Currently the ASA is an ad hoc coalition dedicated to furthering the use of energy storage in Alberta, and over time the ASA may become a permanent advocate, similar to IPCAA and IPPSA, for the energy storage industry.

The purpose of the ASA is to draw on the expertise of its members and act as a unified voice for energy storage in the province of Alberta. The group will action a number of activities such as government advocacy, policy recommendations, value proposition studies, and technology information surveys.

The Key Principles set out for the ASA are as follows:

1) A common goal to advance energy storage in the Alberta market.
2) Technology neutrality to focus on the growth of the energy storage market as a whole rather than promote one particular technology.
3) Positive and open minded participation.
4) Mutual benefits through collaboration amongst competitors in the interest of energy storage market development.

GLOSSARY OF TERMS

AESO	Alberta Electricity System Operator
ASA	Alberta Storage Alliance
AUC	Alberta Utilities Commission
CAES	Compressed Air Energy Storage
ERCOT	Electric Reliability Council of Texas
IESO	Independent Electricity System Operator
kW	Kilowatt (Unit of energy; 1 kW = 1000 watts)
Li-Ion	Lithium Ion Batteries
MISO	Midcontinent Independent System Operator
MSA	Market Surveillance Administrator
MW	Megawatt (Unit of energy; 1MW = 1000 kilowatts)
NaS	Sodium Sulfur Batteries
Ni-Cd	Nickel Cadmium Batteries
NYISO	New York Independent System Operator
PJM	Pennsylvania-New Jersey-Maryland Interconnection
SMP	System Marginal Price

Questions on this paper can be directed towards:
Geoff Osborne, Associate, NRStor Inc. gosborne@nrstor.com
Shivani Chotalia, Analyst, NRStor Inc. schotalia@nrstor.com

TABLE OF CONTENTS

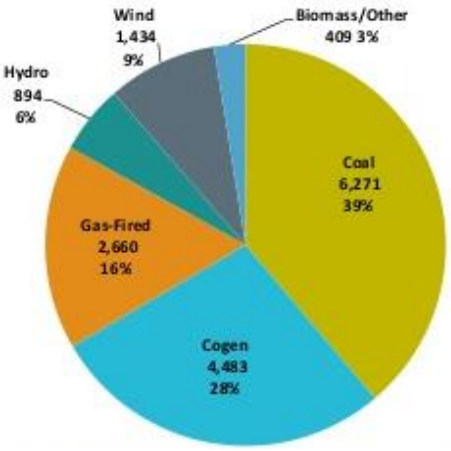
INTRODUCTION

In November 2015, Alberta announced a new **Climate Leadership Plan** in response to the environmental challenges being faced. Central to the plan is transitioning the province's energy generation away from coal and towards renewables. This decision will have numerous impacts on the current electricity system stability. Energy storage can play an important role in order to navigate this transition by providing reliable solutions to many of the challenges that may arise. Energy storage technologies can be used to remove electricity from the grid and redeploy it at a more optimal time. This document seeks to outline the role that energy storage can play, and recommend policies and strategies for the implementation of storage projects in Alberta. It will also provide background information on the various energy storage technologies that exist, and the structure of the Alberta electricity market.

TIMES OF TRANSITION: SYSTEM CHALLENGES IN ALBERTA

While Alberta's transition towards renewable energy is a positive step in fighting climate change, it may also introduce challenges with system reliability of the electricity grid. Alberta's current installed generation capacity is approximately 38.5% coal-fired. Another 43.6% of installed capacity is natural gas; the remainder includes 9.0% wind, 5.5% hydro, 2.8% biomass and 0.6% waste heat, as shown in *Figure 1*. Shutting down all of the coal plants will require a displacement of more than 6,250 MW.[1] According to government announcements, up to two thirds of the displaced coal could be replaced by renewable energy – amounting to an increase in renewable generation to 30% of the supply mix by 2030.[2]

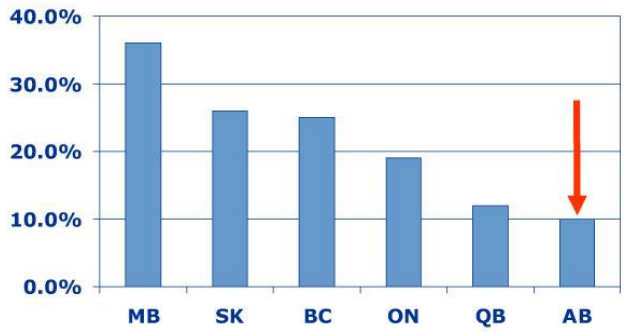
Figure 1: Alberta's Installed Generation (MW and % of installed capacity)[3]



A significant increase in intermittent renewable generation will require balancing and grid support services, especially given that Alberta has limited interconnection capacity with neighbouring markets. *Figure 2* shows that Alberta's interconnection capacity is constrained compared to other provinces. Energy storage is capable of providing ancillary services and demand response, key elements required to support increased penetrations of renewable generation.

[1] Alberta Energy: Electricity Supply
[2] Alberta Climate Leadership Plan
[3] AESO 2014 Market Statistics

Figure 2: Interconnection Capacity as a Percentage of Peak Load (2011)



The four key challenges facing Alberta's electric system transition are as follows:

1. **Renewables integration.** The variable nature of renewable energy means that it is not always possible to control what time of day and in what quantity of electricity is produced. As a result, there will be a need for replacement generation when renewable generation is unavailable.
2. **Price volatility**. Alberta's "energy-only" market based electricity system provides little security around energy pricing and can feature high price volatility. With the significant addition of variable renewable generation, price volatility is expected to be even higher. The tendency for renewable energy prices to trend downwards, due to low marginal production costs, can lead to electricity prices that are uneconomic for all generators lasting for extended periods of time.
3. **Supply adequacy**. The variable nature of renewable energy could result in instances where renewable generation exceeds consumption during periods of lower Alberta demand. Investing in interprovincial transmission infrastructure can be a costly method to maintain the system's integrity and reliability.
4. **Grid reliability**. Large coal generating stations provide inertia to the system which keeps the frequency stable (i.e., keeps lights from flickering). With coal plants being retired and a significant portion of their production being replaced by renewables, Alberta must ensure that the grid remains reliable.

STORAGE AS A SOLUTION

Energy storage has the ability to address all four of these issues and will become an important piece of Alberta's energy system as it shifts its energy supply mix going forward. The ability to store electricity and re-deploy it on the grid at an optimal time can play an important role in balancing supply and demand, and maintaining a clean and reliable source of energy for all consumers.

1. **Renewables integration.** Energy storage can provide services, such as firming and ramping, needed to improve the system's flexibility and smooth the transitions during shifting levels of generation.
2. **Price volatility**. Energy storage has the ability to reduce price volatility by creating a price floor for generators. Reducing price volatility is beneficial for planning for consumers, generators, and the system as a whole.
3. **Supply adequacy**. Rather than investing in interprovincial transmission infrastructure, long duration energy storage can provide dispatchable load and supply. This would allow Alberta greater energy independence, while also enabling dispatchable exports to assist neighboring provinces and states during major power system events, which are the most profitable situations for power export.

4. **Grid reliability**. Energy storage can provide many ancillary services, including frequency regulation and voltage control, improving the stability and reliability of the electricity grid.

Energy storage must be considered as a viable alternative to building out conventional peaking generation or "wires" solutions. As storage solutions mature, costs are continuing to drop dramatically. Over the past two years, battery costs have dropped around 50%. In Ontario, energy storage costs have been competitive with traditional hydroelectric generation costs.[4] Utilizing storage as part of the solution could provide Alberta a way to minimize cost while enabling greater efficiency and matching the needs of the system.

Table 1: Dropping Costs of Energy Storage

Technology	Approximate CAPEX Cost (2014) (CDN $/kWh)	Approximate CAPEX Cost (2016) (CDN $/kWh)	Percentage Reduction
Batteries	$1,300 – 1,500	$600 - 800	-50%

CURRENT BARRIERS TO IMPLEMENTATION

With energy storage technologies developing rapidly and prices falling quickly, storage has the potential to deliver many benefits and become a core component of the grid. However, Alberta's regulations and tariffs do not currently support market participation by energy storage.

The current market signals are not sufficient for the wide-scale deployment of energy storage in Alberta. Alberta's market based system prohibits energy storage development by charging storage both as a generator and a consumer of electricity, effectively double charging storage. This is counterproductive as it can be demonstrated that storage takes electricity off the grid during periods of excess generation and/or low demand periods. This means that storage removes energy from the grid when it is underutilized, not during peak demand periods. As a result, storage does not require that additional transmission be built to serve its offtake requirements, unlike end use customers who have the ability to demand power from the grid at any time. In fact, storage contributes to the more efficient use of the transmission grid, thereby lowering transmission rates for all users.

Currently, there is no specific market to allow storage to help with responding to system frequency problems. Storage offers a unique capability to respond rapidly to reliability signals from the grid. The ASA supports collaboration with the AESO and other regulators to identify services and applications where energy storage can offer benefits to Alberta's electric grid.

ALBERTA'S PROGRESS TO DATE

Alberta's AESO has already begun investigating the value of energy storage and launched a storage initiative in September 2012. The purpose of the AESO review was to examine the effectiveness and applicability of existing market rules and technical standards with regards to energy storage technologies. In June 2013, the AESO released the Energy Storage Issue Identification Paper identifying questions that needed to be

[4] IESO Report: Energy Storage

discussed and launched an Energy Storage Work Group to identify, prioritize and discuss possible solutions.[5] Over September and October 2013, the AESO received stakeholder comments on its issue identification paper and conducted four Work Group sessions.[6] In May 2014, the AESO published a discussion paper on Energy Storage Integration showing that the Work Group sessions had resulted in determining three priority issues for energy storage in Alberta[7]:

1. Developing technical and operating requirements to connect and operate Energy Storage facilities
2. Determining the appropriate tariff rate to apply to Energy Storage facilities
3. Reviewing technical requirements for the provision of Operating Reserves considering the characteristics of Energy Storage technologies

Comments on the discussion paper were collected and an Energy Storage Integration Recommendation Paper was published in June 2015. The recommendations were to[8]:

1. Draft and file ISO Rules to address technical and operating requirements for battery storage facilities
2. Conduct an economic dispatch study to develop ISO tariff treatment options for storage's use of the transmission system
3. Maintain the minimum size requirement of 15 MW for regulating reserves and 10 MW for spinning reserves based on the results of an AESO off nominal frequency study.
4. Revise, where appropriate, ISO Rules around operating reserves to reflect how energy storage will participate
5. Examine the performance of current regulating reserve providers and assess if changing the technical requirements and/or introducing new technologies could reduce the required amount

As part of the AESO's process, questionnaires were created to collect industry information on various energy storage technologies. Information collected included technology descriptions (including capacity and durations), interconnection requirements, efficiencies, and capacity, operating and maintenance costs.

While some thorough analysis and discussion has been facilitated for each of these issues and recommendations, no final outcomes reducing barriers for Energy Storage projects have yet been reached. In June 2015, three Energy Storage projects submitted System Access Service Requests to the AESO. The projects included a 150 MW Compressed Air Energy Storage (CAES) facility, a 14 MW battery facility, and one behind-the-meter battery facility.[9] Development of inclusive regulations will grant storage the ability to participate in the market.

On June 21, 2016 the AESO issued an Invitation to Participate in Consultation on AESO 2017 ISO Tariff Application. Included in that letter were links to two studies pertaining to the impact of, and the correlation of forecast energy storage activities on the grid and to end use patterns of electricity consumption. In the letter, the AESO states that it is inviting stakeholders "to consult on list of topics to be reviewed for the 2017 tariff application, including review of initial work on energy storage tariff treatment". The ASA is pleased that the AESO has invited consultation about energy storage as part of its 2017 Rate Application.

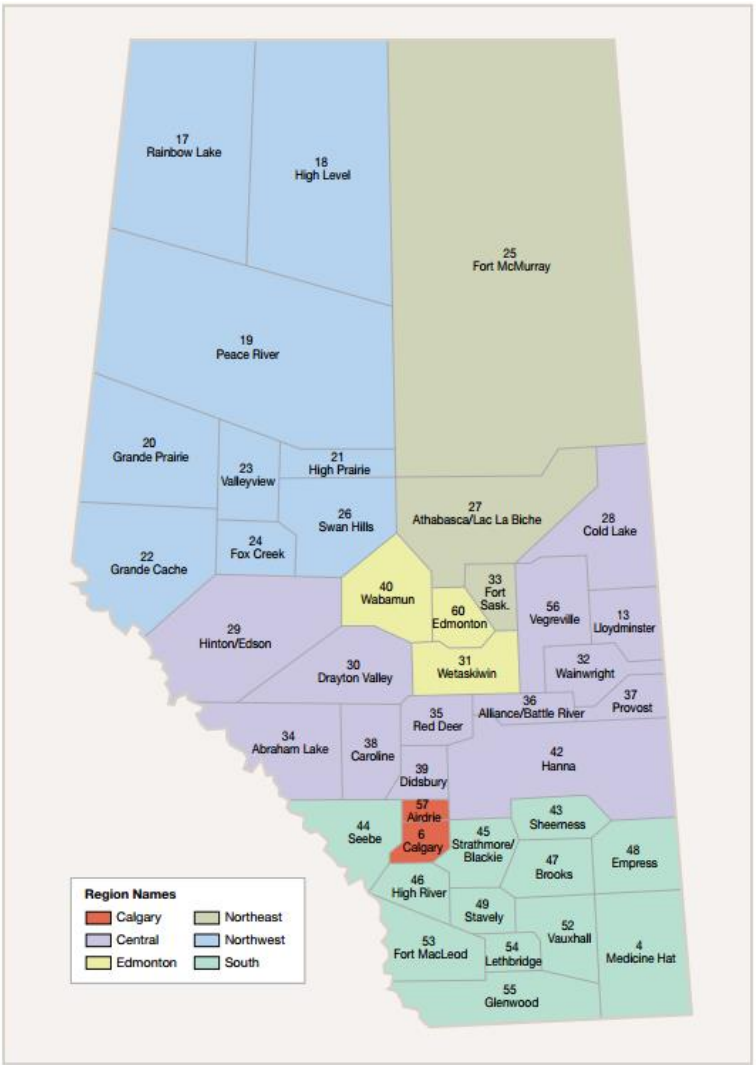
[5] AESO: Energy Storage Initiative Issue Identification Paper
[6] AESO: Energy Storage Work Group – Terms of Reference
[7] AESO: Energy Storage Integration – Discussion Paper
[8] AESO: Energy Storage Integration – Recommendation Paper
[9] AESO: Energy Storage Integration – Recommendation Paper

At a national level, the National Research Council of Canada has launched an "Energy Storage for Grid Security and Modernization" program and is conducting analysis on the benefits of deploying energy storage across the country. When released, Alberta should consider NRC's recommendations.[10]

RECOMMENDATIONS TO UNLOCK THE BENEFITS OF ENERGY STORAGE

Moving forward, the ASA looks forward to engaging in action-oriented discussions with the AESO to explore how storage can offer value to Alberta's grid and its customers through the benefits of grid balancing, T&D deferrals, and emissions reductions.[11] Realizing the multiple value streams of storage could prove to be a benefit to the Alberta electric system. Energy storage should be part of ongoing system planning conversations, along with incumbent technologies, to enable Alberta's energy transition to the grid of the future.

Figure 3: Alberta Transmission System Planning Regions[12]

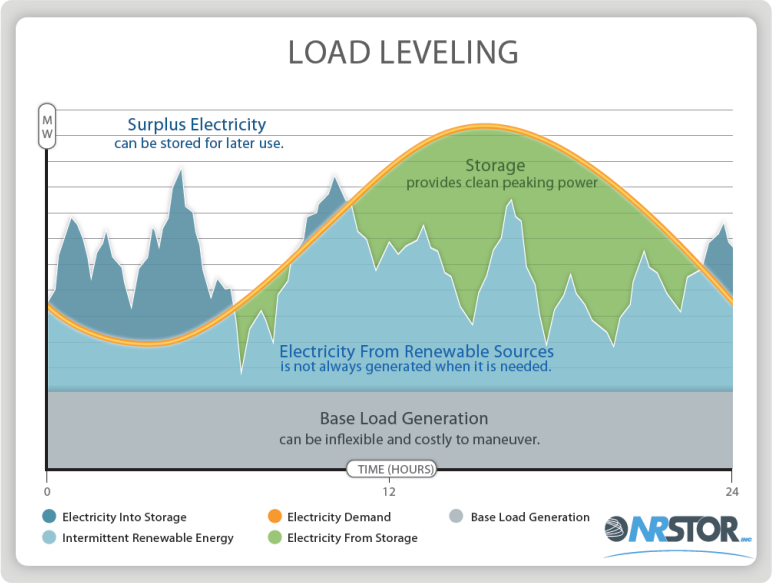


[10] NRC: Energy Storage for Grid Security and Modernization program
[11] RMI – Economics of Battery Storage
[12] AESO 24-Month Outlook

GRID BALANCING SERVICES FROM GRID-CONNECTED STORAGE

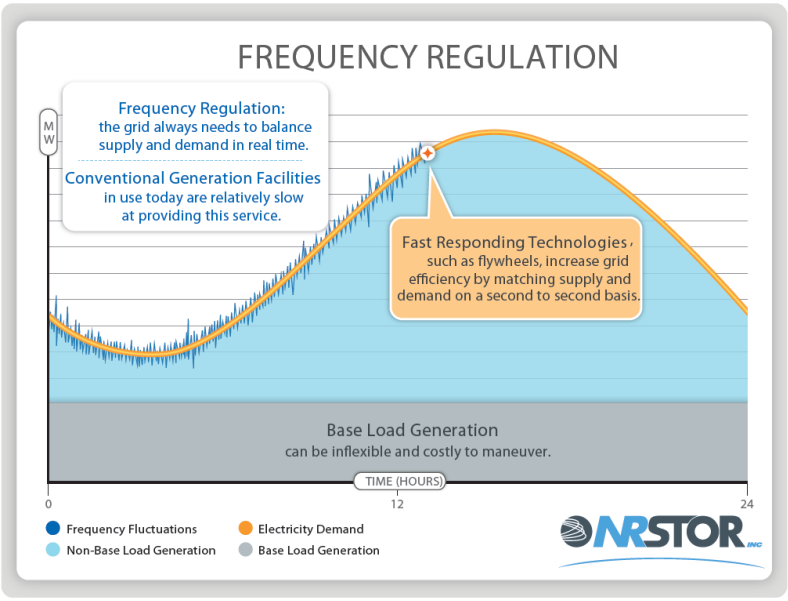
At the system operator level, a key application of energy storage for Alberta will be supporting the integration of renewable energy. Long duration energy storage in particular can take in excess generation from renewables when it is not required by loads, and store it until that power is required during peak load times. In other words, it can increase the load requirement in times of surplus and provide supplement generation when renewable generation drops off, resulting a more stable power market.

Figure 4: Load Levelling Services Provided by Energy Storage



Short duration energy storage can also provide many benefits to improve system stability as Alberta retires its coal generation. Short duration storage can act quickly to balance supply and demand as operating reserves. Storage can also assist the AESO with frequency regulation, voltage support, and black start; all services that coal generation currently provides to the grid.

Figure 5: Frequency Regulation Services Provided by Energy Storage



To allow grid-connected storage to be successfully deployed, the ASA proposes the following:

RECOMMENDATION 1

The ASA will work with the AESO and regulators to identify services and applications where energy storage can offer benefits to Alberta's electric grid. As part of this collaboration, we recommend conducting a Needs Identification Process to determine what services (existing or new) are required to help maintain a reliable electric grid going forward.

RECOMMENDATION 2

The ASA and AESO should conduct an assessment regarding whether assets solely providing system stability services should be exempt from certain investment prohibitive tariffs. For example, a standard Transmission Service rate for grid-connected storage offering only Operating Reserves (OR) would avoid "double charging" such assets under existing regulations and tariffs.

RECOMMENDATION 3

Energy storage should be allowed to participate in the energy and ancillary services markets, via small revisions to the AESO market rules, as any other capable technology that satisfies appropriate technical requirements. This rule development should be accelerated to allow energy storage inclusion in the Alberta market.

TRANSMISSION & DISTRIBUTION SERVICES FROM STRATEGICALLY SITED STORAGE

Storage can also be thought of as "energy in time" because storage can hold energy and release it when it is needed. By siting energy storage assets in appropriate locations, the use of storage can eliminate or defer the need to invest in new transmission and distribution assets. In locations where transmission demand is greater than capacity, because of a growing peak load or surplus generation, storage can be used as an alternative to building out a new distribution line or transmission line, relieving the system of congestion.

In the next four years the Alberta Electricity System Operator (AESO) is anticipating a need for 17 new transmission projects, costing approximately $2.5 billion. Even under a low growth scenario, the AESO estimates 11 projects will be required before 2020 at a cost of $800 million.[13] Harnessing the benefits of energy storage should be considered as an alternative to traditional transmission investments.

[13] AESO 2015 Long-term Transmission Plan

Figure 6: Asset Deferral Services Provided by Energy Storage

RECOMMENDATION 4

During system planning, the AESO should give due consideration to other assets (such as energy storage) that can alleviate system burden as an alternative to "wires" solutions for transmission upgrades.

"STACKED" SERVICES FROM BEHIND-THE-METER STORAGE

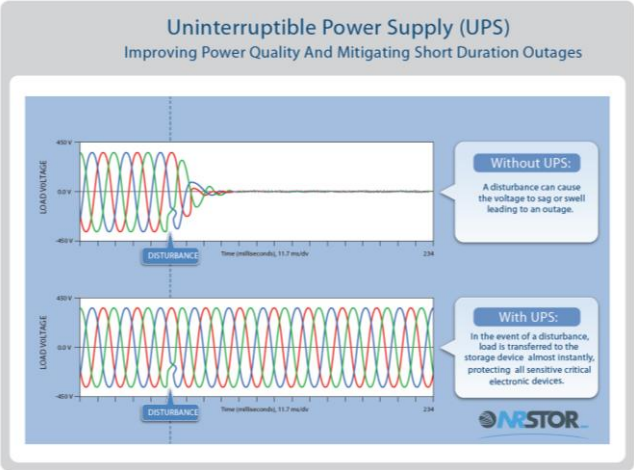
Residential Storage

Energy storage placed behind-the-meter can provide myriad benefits directly to consumers of all sizes. Residential energy storage is a key application. Homeowners and small businesses can utilize energy storage to manage their energy usage and optimize their energy costs. For consumers who own their own solar generation, storage can also allow them to increase their self-consumption and reduce their dependence on the grid.

Commercial and Industrial Storage

Energy storage can provide commercial and industrial customers with a source of reliable backup power. Storage providing uninterruptible power supply services can improve the quality of power used. It can also allow customers to manage their electricity bills by optimizing their consumption based on market pricing, for those customers that don't have fixed rates, and significantly reduce peak loads and demand charges. At the same time, behind-the-meter storage is technically capable of bidding into operating reserve markets to offer benefits to the grid and offer another revenue stream to the customer.

Figure 7: UPS Services Provided by Energy Storage



However, it should be noted that the grid-scale benefits of storage cannot currently be recognized by all behind-the-meter storage projects; only projects with a range of over 5MW, 10 MW, and 15MW can participate in the Supplemental, Spinning and Regulating Reserves Ancillary Service markets, respectively. Currently, large customers that are interested in installed behind-the-meter energy storage must undergo a long process to connect their storage assets to the grid. Streamlining this process would reduce the regulatory barriers to energy storage deployment.

RECOMMENDATION 5

The ASA can help the appropriate regulators (AESO, AUC) to develop a straightforward and transparent process to expedite behind-the-meter energy storage interconnections (for both residential and industrial customers).

ENVIRONMENTAL AND EMISSIONS REDUCTION SERVICES FROM ENERGY STORAGE

Energy storage is an enabler of carbon emission reductions. By enabling electricity to be stored, emissions-free renewable generation can be stored during off-peak hours and deployed during on-peak hours. These environmental benefits should be quantified to further incentivize the deployment of energy storage.

Remote Communities

According to the Government of Canada, Alberta is home to at least two off-grid communities, using approximately 1.45 MW of diesel power generation to serve 533 people.[14] Energy storage can enable micro-grid solutions, and can unlock the environmental benefits resulting from reduced dependence on diesel fuel.

RECOMMENDATION 6

The Alberta Department of Energy should continue to allocate funds from its carbon emissions levies to accelerate the deployment of technologies offering greenhouse gas emissions reduction benefits. Funding energy storage projects is an important means of enabling the integration of more renewable energy.

[14] Government of Canada: Status of Remote/Off-Grid Communities in Canada

CONCLUDING THOUGHTS

Energy storage can play an important role in optimizing and modernizing Alberta's electricity grid. With ambitious renewable energy targets and the maturation of energy storage technologies, Alberta is well positioned to benefit from the services that storage can deliver. The ASA encourages the province to innovate on its policies to align with the innovations that have occurred with technologies. Alberta can move quickly on developing language to recognize and consider storage as a part of the electricity system. Developing storage-specific transmission service rates, streamlining the storage interconnection process, and investing carbon pricing dollars into storage will accelerate the deployment of energy storage, allowing the province to benefit from a reliable and low carbon grid. The ASA and its member companies are eager to work with the province and with Alberta-based stakeholders to refine the case for storage and execute on these recommendations.

Questions on this paper can be directed towards:
Geoff Osborne, Associate, NRStor Inc. gosborne@nrstor.com
Shivani Chotalia, Analyst, NRStor Inc. schotalia@nrstor.com

APPENDIX 1: ENERGY STORAGE TECHNOLOGIES[15]

Many different storage technologies exist and can be applied for varying applications. These technologies are also in various stages of maturity; pumped hydro storage has been in use for decades, researchers continue to innovate on battery chemistries today, flywheels have reached a commercial scale, and compressed air represents a large opportunity for bulk storage. A few key energy storage technologies are highlighted below.

FLYWHEELS

A flywheel is a mechanical battery that stores kinetic energy in a rotating mass. When electricity demand is low, the flywheel uses power from the electrical grid to drive a motor that spins the flywheel at high speeds, allowing the flywheel to store excess energy from the grid. When demand is high, the flywheel's momentum causes the motor to act as a generator, which then slows down the flywheel, putting power back onto the grid.

SOLID STATE BATTERIES

A solid state battery has both solid electrodes and solid electrolytes. They are able to convert stored chemical energy into electrical energy. The electrolytes allow ions to move between the electrodes and terminals, allowing currents to flow from the battery to provide energy. Types of Solid State Batteries include:

- Electrochemical Capacitors
- Lithium Ion Batteries (LI-ION)
- Nickel Cadmium Batteries (NI-CD)
- Sodium Sulfur Batteries (NAS)

LEAD ACID BATTERIES

A lead acid battery is widely viewed as a mature technology and as inexpensive compared to newer technologies. Invented in 1859, lead acid batteries have a relatively high power to weight ratio and are common in motor vehicles. Large-format lead acid batteries are also widely used to storage electricity for backup applications such as in cell phone towers, high availability settings like hospitals, and stand-alone power systems.

FLOW BATTERIES[16]

A flow battery is a type of rechargeable battery using two chemical components dissolved in liquids contained within the system and most commonly separated by a membrane. The technology resembles both a fuel cell and a battery - where liquid energy sources are tapped to create electricity and are able to be recharged within the same system.

A major advantage of flow batteries is that they can be almost instantly recharged by replacing the electrolyte liquid, while simultaneously recovering the spent material for re-energization.

Different classes of flow cells have been developed, including redox, hybrid and membrane-less. The fundamental difference between conventional batteries and flow cells is that energy is stored as the electrode material in conventional batteries but as the electrolyte in flow cells.

[15] Energy Storage Ontario: Technologies
[16] Energy Storage Association: Flow Batteries

COMPRESSED AIR ENERGY STORAGE ("CAES")

Compressed Air Energy Storage uses electric motor driven compressors to compress air into underground, typically salt, caverns during periods of excess generation (e.g. all the wind generators are producing at maximum capacity) or low demand (e.g. at night time). Pressure in the caverns can be as high as 3000psi. When electricity demand is high, the pressurized air is heated and expanded in an expansion turbine which drives a generator for power production. For illustration purposes, a 160MW CAES facility with 60 hours of energy storage capacity could generate enough electricity to power the City of Red Deer at its peak demand load for a period of close to one week.

There are two compressed air energy storage projects currently operating in the world today, one at Huntdorf Germany and one at MacIntosh Alabama. There are a number of projects under development around the world including the Apex project in Texas (320MW) and the Pathfinder Project (3000MW) located in Utah.

Alberta is well suited to develop CAES projects because:

1) There are a number of salt formations that can be economically developed for CAES projects and salt cavern development is well understood with numerous salt caverns having been developed for a variety of hydrocarbon and waste storage solutions;
2) For conventional CAES technology, much of the equipment used for storage and generation is well understood and often utilized in the various oil and gas applications. In other words there is a great deal of readily available know how in Alberta that can be utilized to develop CAES projects in Alberta.

PUMPED HYDRO

Pumped Hydro is a type of energy storage used by power systems for load balancing. Pumped hydro storage facilities work by storing energy as water, pumped from lower reservoirs to higher reservoirs. When electricity demand is high, power is generated by releasing the stored water through turbines, similar to conventional hydropower stations. When electricity demand is low, the excess generation capacity is used to pump water into the upper reservoir. Pumped Hydro works both as a turbine and a generator. Differing from conventional hydroelectric stations, pumped hydro storage stations are a net consumer of electricity as a result of the hydraulic and electrical losses incurred in the cycle of pumping from the lower to upper reservoirs.

ELECTRIC VEHICLES

Electric vehicles - and their batteries - can be considered as both controllable load during periods of lower demand and, with the appropriate technologies, a source of supply during times of higher demand. With amendments to the Micro-Generation Regulation, customers could supply the grid or use the electricity to meet their own energy needs through smart electric vehicle charging stations.

THERMAL ENERGY

Not all stored energy necessarily comes directly back to the power grid as electricity. Off-peak energy can be stored as thermal energy, which can then be used to supply heating and/or hot water needs, reducing electricity consumption during on-peak periods. Increasingly, solar thermal systems are being used around the world to supplement or replace the electrical energy drawn from the grid for such uses. Ice Storage Systems do just the opposite where off-peak energy is used to make large blocks of ice to help cool buildings during peak hours. Other more sophisticated, high-temperature thermal storage systems can also be used to generate steam for electricity production to supply back to the grid.

FUEL PRODUCTION

Electricity can be used as an input in the production of other types of fuels such as hydrogen and biofuels, which can also act as an energy storage medium. These fuels can then be used to generate electricity to send back into the grid at optimum times – or for other non-electrical energy needs. Off-peak electricity can also be used for compressing natural gas – an emerging need in the transportation sector.

APPENDIX 2: BACKGROUND & OUTLOOK ON THE ALBERTA ELECTRICAL MARKET

ALBERTA REGULATORY BODIES

The electricity system in Alberta is governed by multiple regulatory bodies including:

The Alberta Electricity System Operator (AESO)

The AESO is an independent not-for-profit entity responsible for the safe, reliable and economic planning and operation of the provincial transmission system. The AESO operates the wholesale market, and is responsible for planning, developing, and providing customer access to the transmission system.

The Alberta Utilities Commission (AUC)

The AUC is a government body responsible for regulating electricity generation and transmission by setting rates, as well as for project approvals from the start to the decommissioning of projects.

The Market Surveillance Administrator (MSA)

The MSA's mandate includes surveillance, investigation, and enforcement in order to ensure the fair, efficient and openly competitive electricity market in Alberta.

ALBERTA MARKET AND ELECTRICITY SYSTEM[17]

Alberta's deregulated electricity market structure is unique in North America. Rather than having the electricity rates set by a central regulator, an economic merit order system is used to find the equilibrium price balancing supply and demand. In addition to the energy price, separate tariffs are imposed on load customers to recover the costs of transmission and ancillary services.

Generation and Market Pricing

The deregulated market encourages price competition among electricity generators. Alberta follows an "energy-only" model, meaning that generators are paid based only on the energy that they actually produce rather than based on their capacity of how much they are capable of producing. Energy prices are set based on real-time supply and demand. Generators provide offers to the Alberta Electricity System Operator (AESO) for the quantity of megawatts they propose to sell and at what price. These offers are entered seven days ahead of the delivery hour and generators can change the price up to two hours before. The pricing must fall within the range of $0/MWh to $999.99/MWh.

To dispatch the electricity, the AESO creates a merit order by sorting the offers from the lowest to the highest price. The AESO will then dispatch the electricity starting with the lowest price offers moving up towards the higher priced offers until all electricity required to meet the demand has been dispatched. The price of the last offer that is dispatched represents the equilibrium price where supply meets demand, and is set as the system marginal price (SMP).

The SMP is continuously set on a minute-to-minute basis, and the average of the 60 SMPs calculated in one hour represents the pool price.

The low marginal production costs of renewable energy create a tendency for renewable energy prices to trend downwards. This can lead to electricity prices that are uneconomic for all generators lasting for

[17] AESO: Guide to Understanding Alberta's Electricity Market

extended periods of time. With very low prices caused by renewable generators, remaining generators will have a tendency to submit higher merit order prices in order to recoup their required revenues during the remaining periods. Introducing energy storage to the system can reduce price volatility by creating a price floor for generators. Storage increases market liquidity, allowing market participants to better establish forward prices and hence assist hedging efforts. Overall, storage is demonstrably beneficial for planning for consumers, generators, and the system as a whole, and can minimize system costs.

Transmission

Alberta's transmission system is an important part of the power grid including ~26,000 km of transmission lines. The transmission system connects ~235 generating units and 170 market participants to the market. Transmission is designated as a monopoly service in Alberta with the AESO being responsible for long term planning. The AESO directly assigns transmission development and operation to transmission facility owners based on their service territory, with the exception of specific projects for which a competitive process is used.

The AESO's aim is to maintain market efficiencies with an uncongested transmission system. The AESO conducts long-term planning to ensure that transmission is sufficient to support the electricity market. Every two years, at minimum, the AESO issues a Long-Term Transmission Plan outlining their most recent forecasts for loads, generation, and the overall electricity system.

Ancillary Services[18]

Ancillary services include all services required to maintain the functions of the electricity system at acceptable levels of voltage and frequency. In Alberta, the AESO is the sole purchaser of ancillary services, which are procured through a separate market operated on an independent third party platform. Costs for ancillary services are recovered through the AESO tariff on load customers as part of transmission costs. The four key ancillary services are:

1. Operating Reserves
    a. Regulating Reserves – respond to instantaneous differences between supply and demand by adjusting generator output
    b. Contingency Reserves – respond to unexpected systems events
        i. Spinning Reserves – provide an immediate response of reserve power
        ii. Supplemental Reserves – supply of reserve power or reduced load within 10 minutes
2. Transmission Must-Run – requires generators to remain online and operating at a specified output level in order to compensate for insufficient transmission infrastructure
3. Load Shed Services – control systems allowing the AESO to instantly trip off demand of large electricity consumers during unexpected system events
4. Black Start Services – generators that are able to start their services with no outside source of power, and can be used to re-energize the transmission system in the event of a system-wide blackout

Operating reserves are purchased by the AESO each day through an online exchange, and the other three ancillary services are acquired through contracts with both generators and loads. In order to offer operating reserves, a generator or load must meet the requirements outlined in *Table 1*.[19]

[18] AESO: Ancillary Services Participant Manual
[19] AITF: Techno-economics of Energy Storage

Table 1: Operating Reserve Requirements[20]

	Regulating Resource (RR)	Spinning Resource (SR)	Supplemental-Resource	Supplemental-Generation
Minimum Capacity	15 MW of Regulating Range	10 MW	5 MW	5MW
Minimum Ramp Rate	1/10 of the Maximum Regulating Range per minute			
Minimum Continuous Operation	60 minutes at any point in the Regulating Range A regulating resource has to be able to produce any Real Power with the Regulating Range without manual intervention by the resource operator.	60 minutes - following an AS Directive within a dead band equal to the greater of +/- 5 per cent of the AS Directive or 1 MW	60 minutes	60 minutes - following the first 10 minutes of an AS Directive, must be able to maintain Real Power output for the duration of the AS Directive at the greater of 95 per cent of the AS Directive or within 1 MW of the AS Directive volume
AS Dispatch Response Time	15 minutes	15 minutes	15 minutes	15 minutes
Control Signal/ Directive Response Time	40 seconds to "short ramp" control signals 28 seconds for Real Power	10 minutes	10 minutes - the volume of Real Power shall be reduced to; at minimum 100 per cent, and at maximum 110 per cent of the AS Directive volume	10 minutes - the volume of Real Power shall be changed to; at minimum 100 per cent, and at maximum 110 per cent of the AS Directive volume

[20] ibid

CLIMATE CHANGE POLICY AND IMPLEMENTATION[21]

On November 22, 2015, Alberta announced its new Climate Leadership Plan signaling a shift in the electricity markets and how the generation breakdown will be structured. The plan focuses on four key actions:

Phase-out Coal, Phase-in Renewables

By 2030, Alberta plans to have phased out all 18 of its coal-fired generating plants representing more than 6200 MW of installed capacity. Approximately two thirds of the generating capacity that is removed is planned to be replaced by renewable energy, and the other one third by natural gas. To achieve these targets, the Alberta government has stated that it will offer incentives for renewable generation and that it expects renewable generation to account for 30% of the province's energy generation by 2030.

A New Carbon Price

Alberta plans to implement a carbon price across all sectors covering 78% to 90% of provincial emissions. Carbon pricing is expected to help fund efforts to reduce greenhouse gas emissions, research and innovation, green infrastructure, development of renewable energy projects, and an offset of potential cost increases for low- to mid-income Albertans.

Capping Oil Sands Emissions

Alberta plans to legislate an overall maximum GHG emissions limit of 100 Mt per year on the oil sands. The limit is expected to provide room for growth and development of the resource sector while incenting technological progress and emissions reducing innovations.

Methane Emissions Reduction

Alberta has set a target of reducing methane emissions by 45% by 2025. Methane emissions from the oil sands made up 70% of provincial methane emissions, and 25% of all oil and gas emissions in 2013. Alberta's plan is to apply new emissions standards into the planning stage for new facilities, as well as a Joint Initiative on Methane Reduction and Verification for new and existing facilities.

[21] Climate Leadership Plan

APPENDIX 3: BEST PRACTICES IN OTHER NORTH AMERICAN JURISDICTIONS

Other jurisdictions in North America have recognized the value that storage can bring to their grids and have been developing supportive regulations.

In the North-eastern USA PJM developed multiple storage pilot projects using technologies such as batteries (64 MW in 2011) and flywheels (20 MW in 2013). Through these projects, PJM has introduced market rules deploying a new regulation signal and a new regulation performance market incentive to support fast-responding, limited-duration energy storage projects.[22]

In New York, the NYISO has developed regulations supporting the uptake of distributed energy storage resources. The NYISO allows storage to participate in day-ahead and real-time wholesale markets, and has implemented rules allowing storage to deliver frequency regulation services.[23]

In Texas, ERCOT has piloted a Fast Responding Regulation Service for facilities that can respond within 60 cycles of a trigger[24] and found that use of faster-responding regulation service has the potential to increase reliability at a lower cost than conventional service.

California has successfully incentivized long duration energy storage through procurement processes. The California Public Utilities Commission mandated the state's three largest utilities to procure 1.3 GW of energy storage by 2020. California also introduced a Self-Generation Program, offering credits for on-site generation combined with energy storage. In 2013 the program's budget was $77 million, divided among the state's utilities.[25]

Ontario, similar to California, has successfully deployed storage on its grid through procurement processes for energy storage assets. Ontario has launched 2 procurements involving storage: a 10MW RFP for alternative sources of regulation service in 2012, and secondly a two-phase competitive procurement process for ~50 MW of storage as outlined in Ontario's 2013 Long Term Energy Plan. The province is now in the process of developing these projects.[26]

The Midcontinent Independent System Operator (MISO), operating markets in 15 Midwestern states and Manitoba, is also investigating ways of growing storage in its market. The current MISO system allows energy storage to participate in frequency regulation markets but prevents them from participating in other ancillary services markets such as spinning and supplemental reserves. As the MISO restructures their tariffs Alberta should take note of their strategy and its effect on the storage market.[27]

[22] PJM: Energy Storage
[23] GTM: 3 States Driving Energy Storage for Utilities and Customers
[24] ERCOT: Fast Responding Regulation Service
[25] ibid
[26] IESO: Energy Storage
[27] Utility Dive: How MISO is Reforming Market Rules to Spur Storage Deployment

APPENDIX 4: FURTHER READING

The following documents provide a more detailed understanding of the Alberta Electricity System, and the value of integrating Energy Storage:

- The AESO Long-term Transmission Plan
- The AESO 24-Month Reliability Outlook (2014-2015)
- The Alberta Climate Leadership Report
- The U.S. Department of Energy Electricity Storage Handbook
- The Rocky Mountain Institute's The Economics of Battery Energy Storage
- Techno-economics of Energy Storage – Comparison of battery, compressed air and power to gas energy storage technologies in the Alberta context
- U.S. Energy Storage Monitor: 2015 Year in Review
- IESO Report: Energy Storage
- AESO Comparison between Electricity Storage and Existing Alberta Sire Dispatch Profiles
- AESO Modelling Dispatch Operations of Energy Storage Facilities in the Alberta Wholesale Electricity Market