STUDY OVERVIEW:
ELECTRICITY STORAGE SYSTEMS: APPLICATIONS AND BUSINESS CASES

CANADIAN ENERGY RESEARCH INSTITUTE

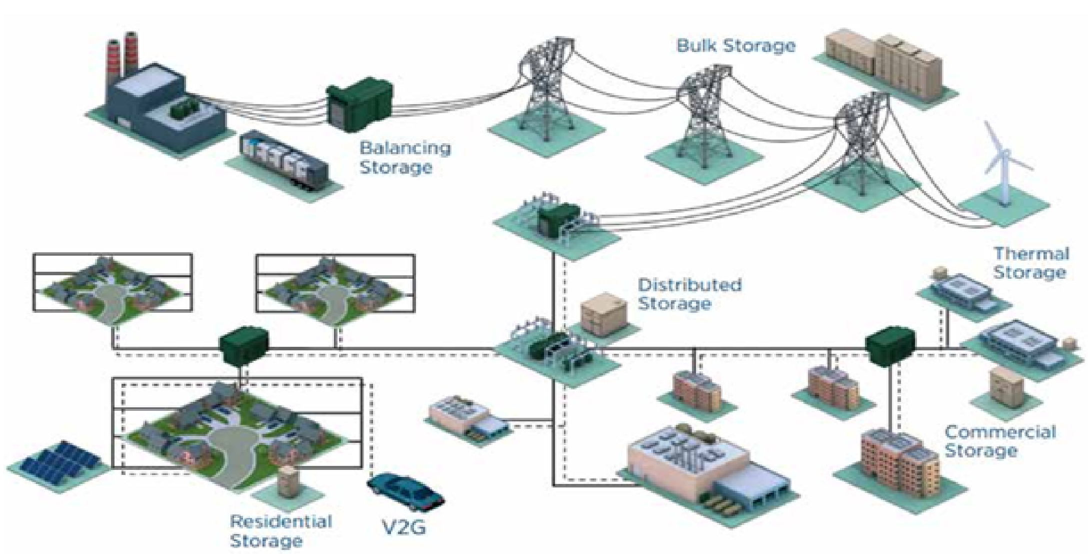
BACKGROUND AND STUDY SCOPE

Electricity storage systems (ESS) are gaining the attention of electric utility policy makers and system operators. Primary factors that have led to this renewed interest include increasing the share of variable renewable sources in the electricity generation mix, large capital costs of electricity grid infrastructure required to ensure system reliability, and high costs associated with managing peak electricity demands. The perceived benefits of ESS have led to new storage technology developments, demonstration projects, and research projects that quantify the benefits of ESS systems. This Canadian Energy Research Institute (CERI) study provides an assessment of three distinct value propositions for following electricity storage applications.

1) Electricity storage systems for behind-the-meter (BTM) applications: We assess the financial value of cases where commercial and institutional electricity consumers utilize on-site ESS to reduce overall electricity cost. Five types of facilities are assessed.
2) Electricity storage systems for bulk energy arbitrage: We assess the financial value of an electricity storage system that operates in energy arbitrage mode where electricity is purchased from an energy market in lower price periods and sold back when prices are high.
3) Electricity storage systems for renewable energy firming: We assess the economic cost of electricity supplied by a co-located wind, solar photovoltaic (PV), and an electricity storage system. An electricity storage system is used to firm up the variable output of wind and solar PV to supply dispatchable electricity.

These applications are assessed by considering current and future ESS capital costs. ESS technologies are currently going through a rapid development and adaptation phase. These trends could lead to reductions in future capital costs due to technology learning (i.e., the decline in technology costs due to technology maturity). We conducted a literature review of ESS technologies to obtain the required data and technology learning rates to estimate the future ESS capital costs. Lithium-ion (Li-ion) batteries, flow batteries, and hydrogen fuel cells are found to have the highest future cost reduction potential. All three application assessments are conducted for three future investment years (2020, 2030 and 2040) to gain insights into the impacts of changing ESS economics due to technology learning.

Figure 1.1: Locations and Applications of ESS



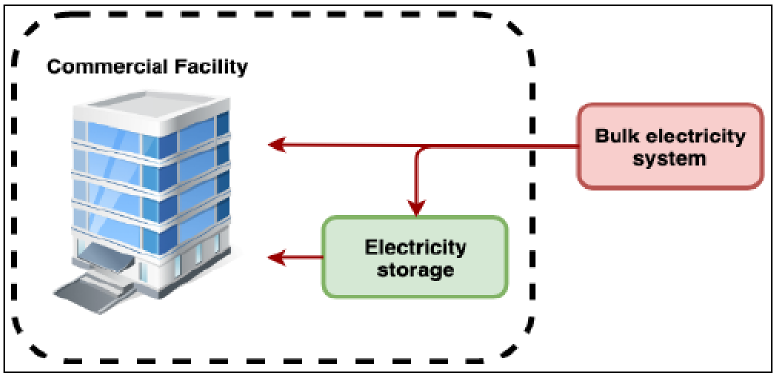
Two main energy storage application categories that are excluded in this analysis are ancillary services and transmission and distribution infrastructure services. Estimation of the value of energy storage under these application categories requires systems-level detailed modelling including simulations of generation, transmission, and distribution system operations. Such analysis is excluded from this analysis but reserved for future work.

View the full study at https://ceri.ca/studies

STUDY FINDINGS

Using ESS in commercial and industrial BTM applications has significantly increased over the past years, primarily because these customers usually pay facility demand charges (sometimes amounting to 50% of the total utility bill) according to the peak demands recorded during their billing periods. These customers can reduce their demand charges by shifting a fraction of the demand from on-peak to off-peak periods using ESS. The financial value of ESS in BTM applications depends primarily on the load profile of the facility and then on the utility rate structure applicable to that jurisdiction.

Figure 3.1: Behind-the-Meter ESS Applications for Electricity Bill Management



Noticeable storage cost reductions during the past few years have also promoted this trend and are expected to continue decreasing in most of the ESS technologies. In this study, we employed the peak-shaving technique to reduce the monthly peak demands of commercial and industrial BTM customers to examine how economic it is to use ESS for these applications. Under current rate structures, the utilization of ESS for BTM applications for electricity bill management in the studied provinces (Alberta, Saskatchewan, British Columbia, Ontario, and New Brunswick) starts to be profitable (with an internal rate of return ranging from 7% to 20%) from 2025 onwards. The profitability depends on the amount of peak demand shaving achievable by integrating ESS and the utility rate structure.

For a given facility, the shape of the electricity demand profile and the utility rate structure are the primary factors controlling the amount of peak demand reduction achievable by ESS. Generally, the wider the difference between energy and peak demand charges the more profitable the ESS project would be. Also, a flat load profile, with a small window between the minimum and maximum monthly loads, will likely result in a less profitable scenario for the implementation of ESS in BTM applications. In the near term, Li-ion batteries are the most competitive technology option primarily because of their fast response times, widespread commercial availability, and relatively longer life compared to other competing technologies such as the Lead-acid family of batteries.

Due to the limitations of the jurisdictional scope and unavailability of future electricity price data at this point, we are unable to make definitive conclusions about the financial value of ESS for bulk energy arbitrage applications. We can, however, point out the following observations that could be considered for future studies to gain more complete insights.

STUDY FINDINGS

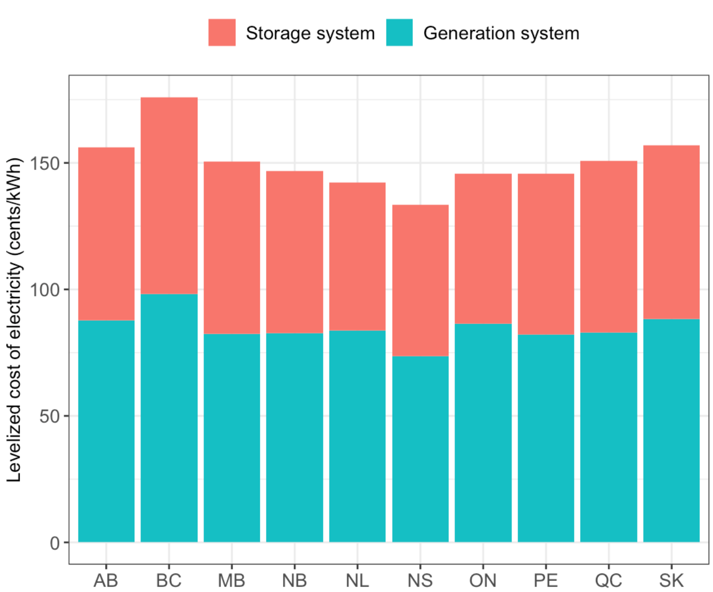
Table 5.2: Capital and Operating Costs of ESS Technologies Over the Analysis Period

ESS Technology	Investment Year	Capital Cost (power, $/kW)	Capital Cost (energy, $/kWh)	Fixed OM Cost ($/kW)	Variable OM Cost ($/MWh)	Round-trip Efficiency	Maximum Storage Hours	Cycle Life	Replacement Interval (cycles)
Li-Ion	2020	621	734	13	3.9	86%	6	3250	3250
	2030	339	401	13	3.9	86%	6	3250	3250
	2040	246	291	13	3.9	86%	6	3250	3250
Flow	2020	561	515	16	1.3	73%	10	8272	8272
	2030	314	288	16	1.3	73%	10	8272	8272
	2040	238	218	16	1.3	73%	10	8272	8272
Hydrogen fuel cell	2020	5873	32	60	0	40%	168	20000	6400
	2030	3735	21	60	0	40%	168	20000	6400
	2040	2804	15	60	0	40%	168	20000	6400

Notes: All costs are in 2018 Canadian dollars. A project life of 25 years is assumed for the analysis. Capital costs include the value of replacement costs where applicable. In this application, it is assumed that the storage units go through a single charge/discharge cycle per day on average. Main data source used is Schmidt et al. (2019).

Use of ESS for bulk energy arbitrage is found to be not financially attractive under the assumed conditions. The analysis considered three ESS technologies along with their current and future capital costs. The financial value of the electricity arbitrage operation is estimated using electricity prices observed in the Alberta electric energy market over the last four years. None of the conditions we assessed yield favourable financial value for the storage technologies assessed. This is due to two factors. One is the higher capital cost of storage. The other is the lower spread between peak electricity prices and off-peak prices. Standalone bulk energy arbitrage is profitable if the difference between the purchase price and selling price of electricity is sufficient to cover the investment cost and operating expenses. Prices observed in Alberta are not volatile enough to consistently produce wider price spreads to produce favourable conditions for bulk energy arbitrage using ESS. The financial value of ESS in bulk energy arbitrage mode of operation can improve if ESS can tap into multiple revenue streams. These multiple revenue streams could be revenues earnable through the provision of other power system services such as capacity services and ancillary services.

Figure 5.5: Lowest LCOE Reported in Each Province in 2030 and Cost Contribution of the Main System Components



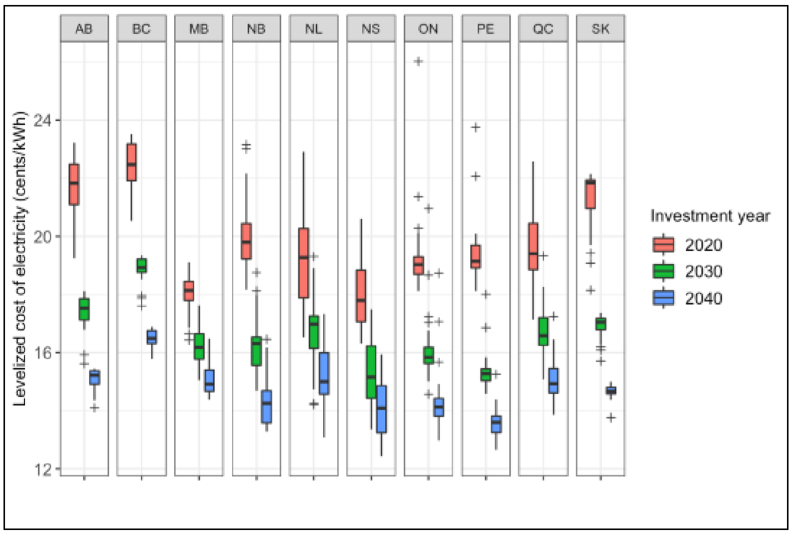
Economics of renewable energy firming by ESS was assessed by considering wind and solar resource availability in 250 locations in 10 Canadian provinces. At each location, we simulate the operation of a solar photovoltaic (PV), wind, and ESS-based integrated electricity supply system that has similar availability as a conventional generating unit. A linear optimization model is developed to determine the optimal system design and to estimate the levelized cost of electricity (LCOE).

STUDY OVERVIEW:
ELECTRICITY STORAGE SYSTEMS: APPLICATIONS AND BUSINESS CASES

STUDY FINDINGS

Electricity supplied by the simulated renewable energy system is emissions free and therefore has the ability to supply zero greenhouse gas (GHG) emissive electricity at a similar level of reliability as a conventional generating unit. The estimated LCOE values of 250 integrated electricity supply systems were simulated. Depending on the province, the minimum reported LCOE is in the range of 16-21 cents/kWh in the investment year 2020, which corresponds to near term conditions. However, as storage and renewable generation technologies mature, and capital costs decline due to technology learning, the LCOE declines by about 15-22% by 2030 and by 22-32% by 2040. The lowest LCOE values are observed in Atlantic Canada, Ontario, and Manitoba.

Figure 5.4: Distribution of LCOE Values by Province and Investment Year (25 locations per province)



In all provinces, the estimated LCOE values are currently higher than conventional generation technologies such as natural gas combined cycle (NGCC) units. By 2030-2040, variable renewables and storage combined systems are competitive against other zero GHG emissive dispatchable technologies such as nuclear power, large hydro, and coal/natural gas-fired units with carbon capture and storage.

Integrated electricity supply systems, in general, require two types of storage systems to provide energy arbitrage in two-time scales. Intra-day energy time-shifting can be provided at the lowest cost by battery systems such as Li-ion and flow batteries. Inter-day and inter-week energy time-shifting can be economically provided by hydrogen fuel cells. Expected cost declines of hydrogen fuel cells make them competitive for long-duration storage applications.

Utilities in many jurisdictions – including Canada – have already developed or are currently in the process of developing grid-scale demonstration projects of co-located ESS and variable renewable power generating units. As renewables become a larger part of the grid, system stability considerations may require they include inherent firming and coupling with ESS to provide a plausible technical solution. Our analysis shows that, regardless of the jurisdiction, storage systems account for 50% of the cost of electricity supplied by ESS and renewables combined generation system. Both decline in cost through commercial-scale project implementation and improvement in storage system efficiency through research and development and could potentially reduce the overall cost.