Repurposing Electric Vehicle Batteries for Energy Storage to Support the Smart Grid

Sean B. Walker* Steven B. Young**
Michael Fowler*

*Chemical Engineering Department, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada
**School of Environment, Enterprise and Development, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada
The increasing popularity of electric, hybrid electric vehicles, and plug-in hybrid electric vehicles (EVs, HEVs and PHEVs) is changing the automotive industry and creating a new stream of automotive waste: used EV batteries. Given that they still have approximately 80% of their power capacity after automotive use, it may be feasible to repurpose EV batteries for use in energy storage and peak-shifting. Such repurposed batteries could be employed in a single home, an office building, a factory or a power plant. The integration of these energy storage systems into commercial and domestic applications would help support the efficient operation of the Smart Grid.

An energy storage system of properly configured repurposed Li-ion batteries provides potential cost savings for business and homeowners by shifting electricity purchases to off-peak times. For utilities, such a system can support an integrated system of renewable energy and help regulate demand. At the same time, it can provide environmental benefits, e.g., improved use of renewables and increasing the lifespan of Li-ion batteries. Our research program considers the capacity, degradation and overall performance of repurposed EV batteries, in addition to the development of business and policy strategies for their use in Canada.

Previous vehicle-to-grid (V2G) models [1]-[3] consider using a battery while it is still in the vehicle to return energy to the grid and suggest that PEVs may profitably provide power to the grid/home when vehicles are parked and connected to an electrical outlet [4]-[6]. In these studies, the economic potential of V2G from PEVs is typically considered to provide power for base load and peak load, as well as electric grid services known as ancillary services, considering energy storage of renewable energy sources. However V2G requires complex power electronics and control systems. Most importantly while the battery pack is in the automotive application it is a 'high value' asset and cycling the battery will degrade its performance and shorten its useful life in the vehicle. Alternatively, in a repurposed remanufactured battery system, storage could be online 24 hours a day to provide energy and storage for the Smart Grid, an advantage over V2G, where power from EVs can be accessed only when attached to the grid for charging. Whereas V2G conceives vehicles attached usually during times of lower energy demand, repurposed batteries can function for peak shifting, that is, contribute to the grid times of peak cost and demand.

Similarly the use of new batteries for load shifting has been studied in a number of demonstration projects [7]-[9]. However, the high cost of new Li-ion battery packs makes this option restrictive. Repurposed packs will be available at low cost, making the potential battery energy storage option economical. Incentives may be initially necessary to encourage users of reused battery systems, but are a positive policy measure because of potential environmental benefits. To encourage homeowners to use repurposed EV battery storage systems, decreases in energy transfer fees and a higher payment for feeding into the electrical grid might be considered. Commercial companies have an added incentive for storing power purchased off-peak, because they can benefit directly from unregulated energy prices. Also, note that with energy storage onsite there is a more effective use of the electrical transmission assets which are congested in some zones at peak hours, and there would be less loss of energy through the transmission system.

The benefits of the use of re-purposed packs include cost savings for the end user, more effective use of the transmission grid, emission reductions and integration of renewable power. Because the user can purchase energy during off-peak times, they can take advantage of variable pricing to reduce energy costs. Additionally, using repurposed-packs for energy storage allows for more efficient use of the energy grid by providing constant energy reserves and storage for meeting changes in supply and demand. This can cause a reduction in emissions, for example in Ontario by allowing energy generated using base load nuclear power to be stored and then used instead of coal or natural gas when demand peaks. Finally, using repurposed energy packs for energy storage and peak-shifting makes it easier to integrate intermittent renewable energy such as wind and solar by helping match supply with demand.

A further potential advantage of using repurposed packs is to keep battery packs in service longer, thus making more effective use of the original materials and manufacturing. The effective useful lifespan of 8 years in an EV battery pack is extended by a decade when repurposed for stationary use. Repurposed batteries add a separate life cycle to the manufactured battery and battery management system. When used outside of an EV, batteries have the potential to provide a safe, stable source of energy. Because the battery is first used only to power the EV, the battery is cycled as designed, and performs at optimal efficiency while in the vehicle, increasing
the battery lifespan. Then, the battery is reconfigured to work as a stationary system, repurposed to operate efficiently in a stationary setting. In Figure 1, the process life cycle of repurposing EV batteries for use in stationary settings is shown. Because EV batteries contain a very significant environmental and energy investment in materials and manufacture, it is important to consider the added value provided by extended use in a second life.

Challenges facing the use of repurposed battery packs include energy losses due to ‘round-trip’ charge efficiency fade, narrow price differentials across times of day in some jurisdictions, the reliability of reused packs and assurance of safety. A key concern with using repurposed batteries for load shifting is that a portion of energy is lost each time a pack is charged and discharged. As a packs ages, the amount of energy lost to heat increases; this is called charge efficiency fade.

For automotive manufacturers, charge efficiency fade has not been a significant concern as in EV operation the total capacity and thus vehicle range are the most important parameters. However, when the packs are being used to store and shift electrical energy, this charge and discharge efficiency critically determines whether energy storage will be cost-effective. Additionally, as energy prices vary geographically and by time of day, the usefulness of repurposed packs for energy storage also varies. There is scant information about the performance of EV battery packs at the end of their life in vehicles. This means that the reliability and future performance of the repurposed packs is also very uncertain.

A key issue facing the use of Li-ion batteries for energy storage is the risk of fire and explosion, so standards will have to be developed. Additionally, recent well-publicized fires in Tesla vehicles and the new Airbus Dreamliner, have brought to the forefront the risk of using Li-ion devices. In large stationary applications which call for greater numbers of battery packs, this risk could be of concern.

Continued research is needed into the technical performance of repurposed EV batteries, in addition to the development of policy strategies for their use in Canada. Future research will develop analytical models using IESO cost data to determine the feasibility of repurposed batteries to provide energy storage and for businesses that purchase unregulated energy.

Most pressingly, analyses of how batteries degrade during their life in EVs are needed to gain a clearer picture of the condition of batteries before they are used to support the Smart Grid. This would allow for better prediction of the performance and lifespan of the repurposed units in repurposed applications. Further, business models must be developed to determine how businesses and residential users can effectively obtain used EV battery systems, and to evaluate how repurposed power products may be marketed in Canada. Finally, there is a need to develop a sound policy strategy in Canada that encourages consumers to purchase the storage units to reduce their energy costs to support the Smart Grid.

Figure 1. Existing (left) and proposed extended (right) life cycles of EV battery packs [10]

References
Sean B. Walker is a postdoctoral fellow in the Department of Chemical Engineering at the University of Waterloo. Dr. Walker’s primary research interest is in the integration of sustainable energy generation and storage technologies with the existing energy transmission infrastructure. This research has included investigations into the financial and technological performance of using EV batteries for residential energy storage and the investigation of power-to-gas as an energy storage technology. His research often includes examining potential policy solutions to improve the efficiency of Canada’s energy systems.

Energy Storage: Industrial-Sized

Power reliability is a concern for all industries. But consider the implications for Canada’s refineries: An interruption or voltage reduction lasting a mere blink of an eye can be enough to trip sensitive equipment leading to a plant outage. Processing stops, feedstocks must be flared resulting in increased emissions, and even the best designed and maintained plants risk safety or more serious environmental incidents. The bill can be $Millions per event.

New technologies such as large-scale battery banks or flywheels may provide the resilience needed by refineries and other large industries. Storage facilities that can meet a large load (20+MW) for a short period of time could sustain a plant during a transitory interruption, or supply essential equipment for a longer period so a plant can shut down in a safe, managed way, avoiding excess flaring caused by an emergency shutdown. Sufficient storage capacity could even aid in creating a local micro-grid island containing local generation and storage, capable of supporting the area during a major outage like the 2003 wide-scale blackout.

Much of the initial concept testing for this kind of large-scale storage has been in aid of the grid. Demand for power varies widely both seasonally and on a daily basis, and generation always has to match demand. In Ontario, the Independent Electricity System Operator (IESO) sends dispatch instructions to large generators every five minutes, and provides fine adjustments every two seconds. However even the best generators are slow to respond; conventional physical equipment just cannot increase output that quickly. Fortunately, demonstration projects with new storage technologies are starting to show promise as economic alternatives in delivering the fast adjustments required to constantly balance the system.

Commercial application of industry-sized storage will require multi-party cooperation, given the needed capacity and the potential for upstream impacts. A conference held in Nov., 2013, in Sarnia, Ontario, brought together key players to facilitate discussion of the potential benefit to local industry. Titled “Grid Resiliency Through Energy Storage in SW Ontario,” presenters included: suppliers of the new technology; representatives from local industry; the province’s grid provider, Hydro One; IESO; and, Bluewater Power, the Local Distribution Company (LDC). Keynote and panel speakers provided details of the capabilities of the different technologies and of the needs of industry and the LDC, providing each side with an overview of the potential opportunities and generating further discussion.

Peter Smith is an Energy Consultant living in Sarnia, Ontario. He has 40 years of experience in the energy industry, including the design, construction, commissioning and operation of nuclear, coal fired, gas and oil fired power plants. He spent 14 years managing the commercial operations of 14 power plants in Eastern Canada, including relationship management, economic operation, commercial and government contract negotiations. Prior to this he spent 14 years in a number of roles related to energy purchasing, conservation and management for a large chemical plant in Sarnia. He has experience in purchasing and selling natural gas, thermal energy and electricity.

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Since much of this technology has been developed or refined in Ontario, and the suppliers are based in Ontario, it would be fitting to see Ontario benefit from the development of a full-scale project in the province. The Sarnia area contains a unique mixture of electricity generation, large industrial loads, and engineering/technical experience and knowledge. With a broad industrial base of energy companies, it provides an ideal location for the practical application of these technologies. However, emerging technologies such as this often need financial support from the government in order to become established and reach economic maturity. As the conference attendees heard, the government is presently supporting some demonstration projects and further support will probably be needed to develop an industrial application in Sarnia. A committee under the auspices of the Sarnia Lambton Economic Partnership has commissioned a study of the available technologies to determine which may offer the best fit for a demonstration project in this unique area. The committee continues to pursue every opportunity.

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