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Remanufacturing, Repurposing, and Recycling of Post-Vehicle-Application Lithium-Ion Batteries

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The costs of recycling must be borne by remanufacturing and repurposing applications, which are profitable.

The growing use of lithium-ion batteries in vehicles is supporting electrification to meet the standards for increased average mileage and decreased greenhouse gas emissions. Thus, it is urgent to develop processes for remanufacturing, repurposing, and recycling post-vehicle-application lithium-ion batteries. This project involves enhancements to current remanufacturing technology, demonstration of repurposed post-vehicle-application lithium-ion batteries in a stationary energy storage system, and development of an effective recycling process for recovering aluminum and copper.

Study Methods

A fundamental question is what to do with post-vehicle-application lithium-ion batteries that have fallen below regulatory standards for use in on-road vehicles. Such a battery has additional economic value that can be reclaimed in any of three ways: 1) Remanufacturing for reuse in vehicles; 2) Repurposing by reengineering for an off-road, stationary storage application; and 3) Recycling by disassembling each cell in the battery and safely extracting the metals, chemicals and other byproducts. Progress has been made in developing each area.

A cost-benefit analysis was done independently for each of the three areas of post-vehicle-application processing. Costs included those for operations, transportation, material handling, infrastructure development, and facility development. Benefits included avoided costs for storing batteries and for producing new batteries, as well as sales of repurposed batteries and recovered materials in recycled batteries.

In addition, a forecasting model for the number of post-vehicle-application lithium-ion batteries helps ensure sufficient supply. The model considers multiple, wide-ranging vehicle demand forecasts, a probability distribution of vehicle application life, and a percent useable factor post-vehicle-application.

Findings

Proprietary processes for remanufacturing, including comprehensive battery testing, have been developed by industrial partner Sybesma's Electronics. These were enhanced to create a fail-safe environment through the design and construction of a fire-resistant workbench, which allows the operator to drop a battery into a container in case of an undesirable event. The wheeled container is safely transported to an appropriate location using an extended handle.

A stationary energy storage system using post-vehicle-application lithium-ion batteries has been demonstrated. Energy is extracted through a standard electric plug. Options for energy input include a standard charger and solar panels. Tests were conducted to show that charging and discharging could be effectively done. The energy storage system consists of two batteries known to have similar state-of-life characteristics.

Recycling process development focused on cleanly separating, and thus recovering, copper, aluminum and lithium iron phosphate. Laboratory-scale experiments were designed and conducted based on a review of previous studies concerning lithium cobalt oxide batteries, which identified acid leaching as the most popular method for extracting raw materials. Nitric acid for the lithium iron phosphate coated aluminum cathode and sulfuric acid for the carbon coated copper anode, both at relatively low concentrations, were used to separate the coatings from the foils. The experiments were conducted at various temperatures ranging from 33°C to 60°C. The material was exposed to the acid for either one or two minutes.

Layout of a Disassembled $LiFePO_4$ Cell with an Unopened Cell
Source: Authors' photo, 2013.

Policy Recommendations

1. Recycling in isolation is not profitable. The costs of recycling must be borne by remanufacturing and repurposing applications, which are profitable.
2. The growing number of post-vehicle-application lithium-ion batteries implies that provisioning for their processing must become an immediate priority.
3. Remanufacturing and repurposing extend the useful life of post-vehicle-application lithium-ion batteries consistent with the principles of sustainability and obtain additional economic benefit before battery recycling.

About the Authors

Charles R. Standridge is the Associate Dean of the Seymour and Esther Padnos College of Engineering and Computing at Grand Valley State University and the principal investigator for this project. Lindsay Corneal, Ph.D. is an Assistant Professor in the School of Engineering at Grand Valley State University. She led the repurposing demonstration and the recycling process development.

To Learn More

For more details about the study, download the full report at ***transweb.sjsu.edu/project/1137.html***

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