Recharging the Future

Closing the Loop on the Lithium-ion Battery Lifecycle

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Abstract

Hybrid/Electric Vehicles (EV/HEVs) will represent 7% of the global vehicle market by 2050. Lithium-ion (Li-ion) batteries, half the car's cost, are safe while in use but hazardous when they enter traditional waste streams. By developing a closed loop recycling process, subsidies reduce consumer battery cost by 11%, and an energy storing electrical grid balances energy supply/demand, increases useful battery life by 100%, and increases grid efficiency. Green Battery Recycling technology recycles 90% of material value into new raw materials. Our closed loop process manages valuable hazardous materials responsibly, thereby decreasing cost, improving national security, and promoting environmental health.[1, 6, 11]

Goals

- **Understand Current Li-ion Battery Lifecycle:** economic analysis, recycling methods, challenges
- **Design Economical Closed Loop Recycling Program**

Challenge Addressed

- **Necessity for Closed Loop Recycling Process:** manage hazardous materials and recover valuable resources
- **Toxicity:** Li-ion batteries are less safe than public perceives
  - Safe when sealed and used properly but materials pose health and safety hazards in landfills and incinerators
- **Exponential Growth:** necessity for responsible management
- **Lack of Legislation:** mandate Li-ion battery recycling
- **Insufficient Traditional Recycling Method:** large value losses
- **Proactive Approach Proposed:** enact recycling program in time for projected first wave of retired batteries in 2019[6, 11]

Background

- **Li-ion Battery Technology:** Powering EV/HEVs
  - High performance, lightweight, in-vehicle safety, commonly used in consumer electronics
- **Traditional Lead-Acid Car Batteries:** 96% recycling rate
  - Material hazards well understood by the public[10, 11]

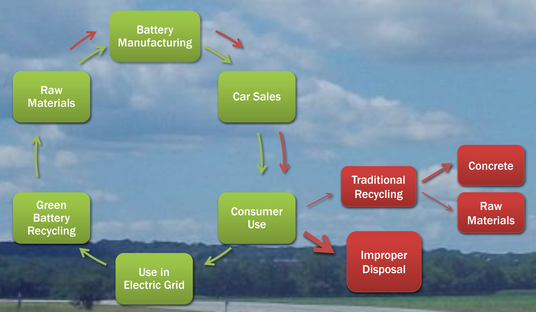
Methodology

A Socially Conscientious Method to Enact Closed Loop Li-ion Battery Recycling

	Motivation	Skills
Structural	**Enact Legislation to Regulate Li-ion Batteries:** Establish Li-ion Battery Tracking Program; Help Power Companies Integrate Batteries into the Electric Grid, Require Post-Use Recycling	**Work With Vehicle Dealers and Power Companies:** Register Batteries at Purchase; Collect Batteries after Vehicle Use for Use in Electrical Grid
Group	**Make Recycling Attractive to Consumers:** Subsidies Mean Affordable EV/HEVs; Increased Reliability & Decreased Electricity Costs; Satisfaction of Green Lifestyle	**Encourage Industry to Provide EV/HEV Services:** Charging, Maintenance, Support; Government Owned Vehicles
Personal	**Expand Vehicle Battery Legislation:** Regulate Li-ion as well as Lead-Acid Batteries; Subsidize Li-ion Batteries	**Make Recycling Practical for Consumers:** Easy Registration at Purchase; Easy Collection by Servicers During Battery Replacement

Recycling System Design

Comparison of Idealized (Green) and Current (Red) Lifecycles



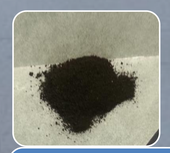
Green Battery Recycling	Traditional Battery Recycling
Most value recovered	10% value recovered
Little energy used	Very energy intensive
No toxic byproducts	Batteries must be incinerated
Creates new raw materials for batteries	Most valuable materials put into concrete

Green Battery Recycling Method

Batteries Are Shredded
- Must be discharged in advance to prevent fires
- Organic electrolytes are volatized and easily captured and neutralized

Iron is Separated with Magnet
- Iron is recovered at this point and is fully recyclable

Metals Dissolved into an Acidic Solution
- Plastics don't dissolve, instead float to top and are skimmed off
- Solution is warmed to 70^{0} C



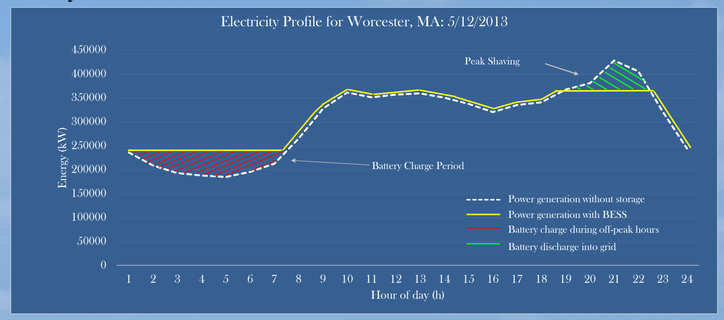
pH of Solution Increased
- Valuable materials precipitated and recovered: nickel, lithium, cadmium, manganese, & cobalt
- Solution becomes environmentally safe

1, 8, 9, 11

Engineering Solution

Battery Energy Storage System (BESS): second use batteries store energy in electric grid

- **Problem**
  - Average power generation > average demand
  - Battery value from 80% remaining battery capacity lost
- **Solution: "Peak Shaving"**
  - Store excess off-peak generated energy
  - Use stored energy during peak demand
- **Save Energy, Make Money**
  - Expensive peak generation unnecessary
  - Recovers the typically lost off-peak energy
  - Allows effective use of wind turbines and solar panels, cyclical renewable sources[5, 6]



Recommendations

Implementation of "A Socially Conscientious Method to Enact Closed Loop Li-ion Battery Recycling" would reduce upfront and maintenance cost of batteries by up to 11% by using Li-ion batteries in the electric grid and recycling them using Green Battery Recycling.[6]

Acknowledgements

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Notes: For MPI logo and original image of the CR3 logo used to make a copy in Adobe Illustrator, see 4. For background photo, see 7. The graphics were made by team members. The last two photos in the Green Battery Recycling Method graphic were taken by Katherine in the Electrochemistry Lab.