Recharging the Future

Closing the Loop on the Lithium-ion Battery Lifecycle

Team Members: Abhinav Adhikari (Chemical Engineering), Norbert Hugger (Physics), Hannah Sattler (Mechanical Engineering), Katherine Tattersall (Mathematical Sciences)

Advisors: Eric Gratz, Professor Diran Apelian (Mechanical Engineering)

Abstract

Hybrid/Electric Vehicles (EV/HEVs) will represent 7% of the global vehicle market by 2030. 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 20196, 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: 90% recycling rate
  - Material hazards well understood by the public10, 11

Methodology

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

Motivation

- Enact Legislation to Regulate Li-ion Batteries: Establish Li-ion Battery Tracking Program
- Help Power Companies Integrate Batteries into the Electric Grid: Require Proof of Recycling

Skills

- Work With Vehicle Dealers and Power Companies: Require Batteries for Use in Electric Vehicles
- Collect Batteries after Vehicle Use for Use in Electrical Applications

Group

- Make Recycling Attractive to Consumers: Wholesale, Mass-Affordable EV/HEVs
  - Increased Reliability & Decreased Electricity Costs: Satisfaction of Green Lifestyle
- Enact Legislation to Provide EV/HEV Services: Charging, Maintenance, Support Environment Owned Vehicles

Personal

- Expand Vehicle Battery Legislation: Regular Li-ion as well as Lead-Acid Batteries Subsidize Li-ion Batteries
- Make Recycling Practical for Consumers: Ease Registration at Purchase
  - Easy Charging, Maintenance, Support

Method of Green Battery Recycling

1. Batteries are shredded.
   - Must be discharged at Electrochemistry Lab.
2. Iron is separated from Magnets.
   - Iron is recycled at Michigan Steel Industries.
3. Metal is dissolved into Acidic Solution.
   - Phosphorus and other byproducts are dissolved in these processes.
4. Phosphorus is leached, resulting in Acidic Solution.
5. pH of Solution increases.
   - Phosphorous is precipitated and recovered.
   - Nickel, Cadmium, and other metals and byproducts are precipitated and recovered.

Method of Traditional Battery Recycling

1. Batteries are shredded.
   - Must be discharged at Electrochemistry Lab.
2. Iron is separated from Magnets.
   - Iron is recycled at Michigan Steel Industries.
3. Metal is dissolved into Acidic Solution.
   - Phosphorus and other byproducts are dissolved in these processes.
4. Phosphorus is leached, resulting in Acidic Solution.
5. pH of Solution increases.
   - Phosphorous is precipitated and recovered.
   - Nickel, Cadmium, and other metals and byproducts are precipitated and recovered.

Recycling System Design

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

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
  - Recover the typically lost off-peak energy
  - Allows effective use of wind turbines and solar panels, cyclical renewable sources5, 6

Recommendations

Implementation of “A Socially Conscionous 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

We would like to thank Eric Gratz (right) for guiding our project, the Electrochemistry Lab at WPI for sharing the Green Battery Recycling Technology with us, and Martin Burt, founder of Fundacion Paraguaya for introducing us to Influencer Theory.2