Abstract

Hybrid/Electric Vehicles (EV/HEVs) will represent 7% of the global vehicle market by 2020. 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, ², ³, ⁴, ⁵, ⁶, ⁷, ⁸

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 2019⁵, 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 public⁸, ¹⁰, ¹¹

Methodology

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

Motivation

Electrolyte in Regular Li-ion Batteries
Not Recoverable

Structural

Make Recycling Attractive to Consumers
Significantly More Affordable Li-ion
Increased Reliability & Decreased Electrical Costs
Satisfaction of Green Lifestyle

Group

Knowledgeable Industry to Provide Li-ion/HEV Services
Charging, Maintenance, Support

Personal

Regular Li-ion Batteries: Reactive to Li-ion Batteries

Battery Value from 80% Remaining Battery Capacity Lost

Green Battery Recycling Method

<table>
<thead>
<tr>
<th>Green Battery Recycling</th>
<th>Traditional Battery Recycling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most value recovered</td>
<td>10% value recovered</td>
</tr>
<tr>
<td>Environmentally friendly</td>
<td>Very energy intensive</td>
</tr>
<tr>
<td>No toxicity byproducts</td>
<td>Batteries must be incinerated</td>
</tr>
<tr>
<td>Creates new raw materials for batteries</td>
<td>Most valuable materials put into concrete</td>
</tr>
</tbody>
</table>

Green Battery Recycling vs. Traditional Battery Recycling

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 sources⁵, ⁶

Engineering Solution

Recycling System Design

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

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

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Notes: