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PHEV/EV Li-Ion Battery Second-Use Project

Jeremy Neubauer, Ahmad Pesaran – National Renewable Energy Laboratory • AABC 2010

Motivation

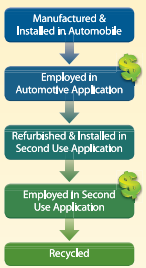
Plug-in Hybrid Electric Vehicles (PHEVs) and full Electric Vehicles (EVs) have massive potential to reduce US dependence on foreign oil and emissions

Battery costs need to be reduced by ~50% to make PHEVs cost competitive with conventional vehicles, which is seen as the major inhibitor to electric vehicle uptake

One option to reduce initial cost: reuse the battery in a second application following its retirement from automotive service and offer a cost credit for its residual value

Battery Reuse Strategies

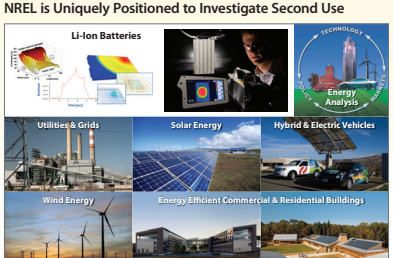
- PHEV/EV batteries degraded to 70-80% of original power/capacity are insufficient for automotive use
- These "retired" batteries may still be highly capable and could be reused in other applications
- "Second use" applications could significantly increase the total lifetime value of the battery, and thus reduce its cost to the automotive user



Second Use History

- Second use of automotive traction batteries was studied in the late 90's / early 00's. Results showed promise, but due to the limited market of PHEV/EVs, no second use programs were implemented
- New opportunities and dynamics for second use of PHEV/EV batteries are driven by the growing PHEV/EV market, advances in long life Li-ion batteries, and the perceived benefits of grid-integrated energy storage
- However, many of the hurdles identified in the original studies still pose questions today:
  - Sensitivity to uncertain degradation rates in second use
  - High cost of battery refurbishment and integration
  - Low cost of alternative energy storage solutions
  - Lack of market mechanisms and presence of regulation
  - Perception of used batteries

NREL is Uniquely Positioned to Investigate Second Use



Justification

Can Second Use Significantly Impact Battery Prices?

Premise:
The maximum salvage value of a used battery will be less than a new battery of equal capability

Assumptions:

- Profitable and willing second use applications are available
- Primary competitor for used EV/PHEV batteries are new EV/PHEV batteries
- EV/PHEV battery pack production will grow to 400k/yr by 2015 and stabilize, falling in cost to ~$560/kWh

Forecast future EV/PHEV battery cost

Calculate Max Salvage Value of Used Battery Based on State of Health, New Battery Cost, and "Refurbishment" Costs

Calculate the maximum Initial purchase discount from the net present value of the battery's max salvage value

Variables

C_{new} = future cost of a new battery

r = discount rate = 2.5%

K_h = battery health factor = 3%/yr

K_r = refurbishment cost factor = 15%/yr

K_u = used product discount factor = 15%/yr

$V_{salvage}$ = battery salvage value at retirement

$NPV_{salvage}$ = net present value $V_{salvage}$ with discount rate r over years in service n

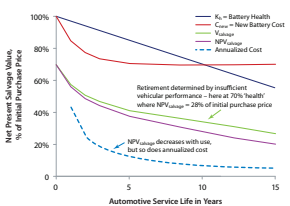
Equations

$V_{salvage} = (1 - K_r - K_u) * (K_h * C_{new})$

$NPV_{salvage} = V_{salvage} * (1-r)^n$

Result

Second Use may reduce initial cost to the consumer by up to 28%



Objectives and Approach

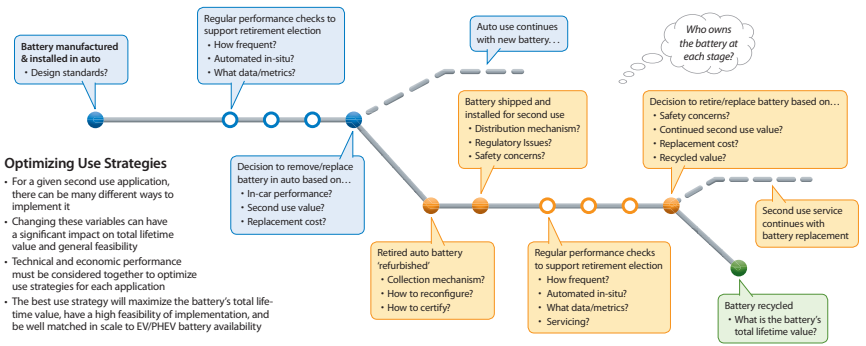
DOE - NREL's Second Use Project

Objective: Identify, assess, and verify profitable applications for the second use of PHEV/EV Li-Ion traction batteries to reduce the cost and accelerate adoption of PHEV/EVs

Phase 1: Assess Merit → **Phase 2:** Verify Perfomance → **Phase 3:** Facilitate Implementation

Application Identification

- All applications are considered, but high value/ high impact ones are most desirable
- Detailed and accurate electrical profiles, environmental conditions, and economic data are needed
- Application value and impact will be estimated before progressing to a detailed investigation
- Grid applications from the consumer to power plant level, as well as secondary mobile applications may prove valuable

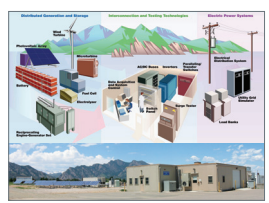


Optimizing Use Strategies

- For a given second use application, there can be many different ways to implement it
- Changing these variables can have a significant impact on total lifetime value and general feasibility
- Technical and economic performance must be considered together to optimize use strategies for each application
- The best use strategy will maximize the battery's total life-time value, have a high feasibility of implementation, and be well matched in scale to EV/PHEV battery availability

Acquire Aged Li-Ion Batteries

- Prefer field-tested batteries from (pre) production PHEV/EVs
- Accelerated aging via lab testing is also an option, but may not ensure correlation with actual field use
- Mass produced cell and pack designs are required



NREL's Distributed Energy Resources Test Facility could serve as a venue for this phase

Conduct Long-Term Testing

- Subject the aged batteries to the expected use profile and conditions of the second use application to verify performance/ degradation predictions and lifetime valuations
- Lab testing for precise control of conditions
- Field testing for final demonstration

What's Next

- NREL is currently seeking partners to investigate the reuse of retired PHEV/EV traction batteries to reduce vehicle cost, and ultimately emissions and dependence on foreign oil as well
- A request for proposal (RFP) was issued in April 2010 seeking subcontractors to support all aspects of this effort
- A workshop to solicit industry feedback on the entirety of the process is also being planned

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Technical questions regarding Battery Second Use should be directed to Jeremy Neubauer at 303-275-3084 or *jeremy.neubauer@nrel.gov*

Facilitating Implementation

- Disseminate study findings to inform the market of the potential profitability of the second use of traction batteries
- Provide validated tools and data to industry
- Develop design and manufacture standards for PHEV/EV batteries that facilitate their reuse
- Propose regulatory changes to encourage the reuse of retired traction batteries in other applications

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