NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Secondary Use of PHEV and EV Batteries – Opportunities & Challenges

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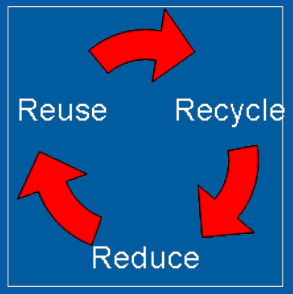

Funded by Energy Storage R&D (David Howell),
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Background – Battery Secondary Use

- It is a common belief that batteries in PHEVs and EVs expect to reach the end of their useful life when their capacity, energy, and/or power capabilities drop by 20% to 30%.
  - The reason is to have a vehicle that performs roughly the same at the beginning and end of the life of the battery.
- At the end-of-life, the "retired" PHEV or EV battery may still have reasonable energy capabilities for other applications such as stationary use.
- Secondary use of EVs (mostly NiMH) batteries was briefly studied in the past, but no implementation occurred
  - 1997 ANL study sponsored by USABC
  - 2002 Sentech study sponsored by SNL/DOE
  - "Electric Vehicle Battery 2nd Use Study" by Southern California Edison
- Due in part to the limited market of PHEV/EVs at the time, no second use programs have been implemented yet
  - 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

New Interest in Battery Secondary Use

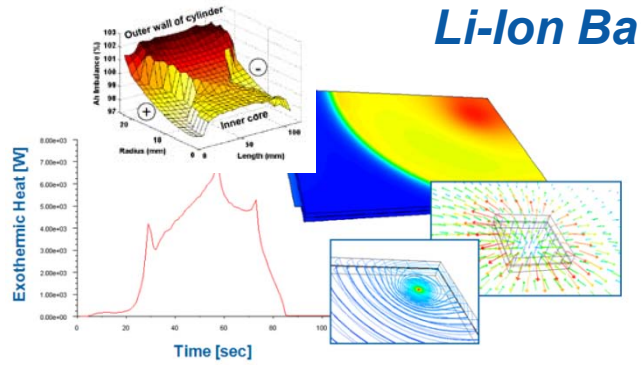
- New opportunities and dynamics for secondary use of "retired" electric drive vehicle batteries
  - Recent strong interest in PHEVs and EVs for reducing emissions, energy security, peak oil, and high price of oil.
  - Improved performance and life Li-Ion batteries, but still with high cost
  - Growing use of renewable solar and wind electricity; increased market penetration may benefit from energy storage
  - New trends in utility peak load reduction, energy efficiency, and load management
  - Smart grid, grid stabilization, low-energy buildings, and utility reliability has the need for energy storage such as batteries
  - Large investment in battery manufacturing for green economy
  - Reducing the initial cost of batteries by the value obtained in second use applications.

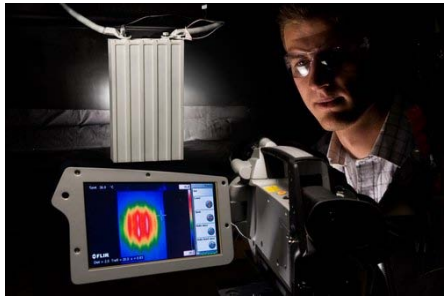
Current Second Use Activities

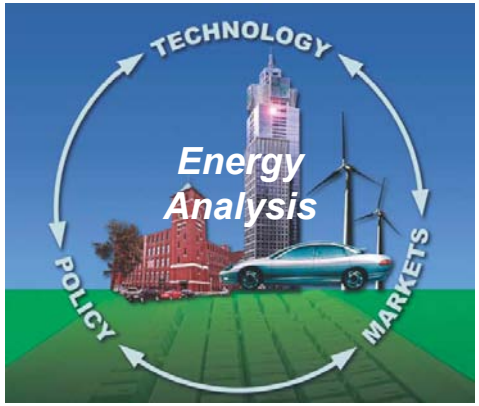
- **AEP & EPRI**… considering a Community Energy Storage (CES) appliance, which they've stated is *"the ideal secondary market we have been seeking for used PHEV batteries"*
- **UC Davis**… with funding from CEC has released an RFP titled "*Second Life Applications and Value of Traction Lithium Batteries"* to investigate profitable second use strategies and develop a Home Energy Storage Appliance (HESA)
  - The California Center for Sustainable Energy and its partners were selected for an Award
- **UC Berkeley/CEC**… investigated strategies to overcome the battery cost of plug-in vehicles by the value of integrating post-vehicle battery to grid
- **Rochester Institute of Technology**… funded by NYSERDA to investigate the second use of lithium ion batteries
- **Nissan**… has partnered with Sumitomo to initiate a business plan centered on recovering and reselling used automotive batteries
- **Enerdel** … is working with Itochu to develop energy storage systems for apartment buildings to *"help develop a secondary market"* for used batteries
- **Better Place**… is *"evaluating … second life applications for used batteries"* in partnership with Renault-Nissan
- **NREL**… funded by DOE to investigate the potential and value of PHEV/EV battery in second use and obtain data on performance of used batteries

NREL: Uniquely Positioned to Investigate Second Use

Li-Ion Batteries



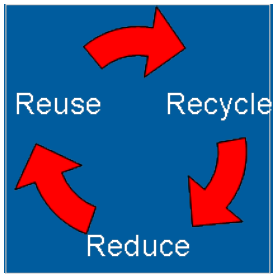




NREL Battery Secondary Use Project

Objective

- Evaluate the merits and value of end of vehicle life batteries for use in other applications – address challenges



Potential Benefits

- Reducing the (first) cost of batteries for PHEV and EV applications
- Reducing the cost and environmental impacts of recycling and disposal of batteries before their “true” end of life.
- Providing advanced inexpensive batteries for nonvehicle applications such as renewable electricity and home use

Approach

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

Phase 1: Assess the Merit
Some Second Use Applications

- Grid-Based Stationary
  - Energy Time Shifting
  - Renewables Firming
  - Service Reliability / Quality
  - Home Energy Appliance

- Off-Grid Stationary
  - Backup Power
  - Remote Installations

- Mobile
  - Commercial Idle Off
  - Utility & Rec. Vehicles
  - Public Transportation

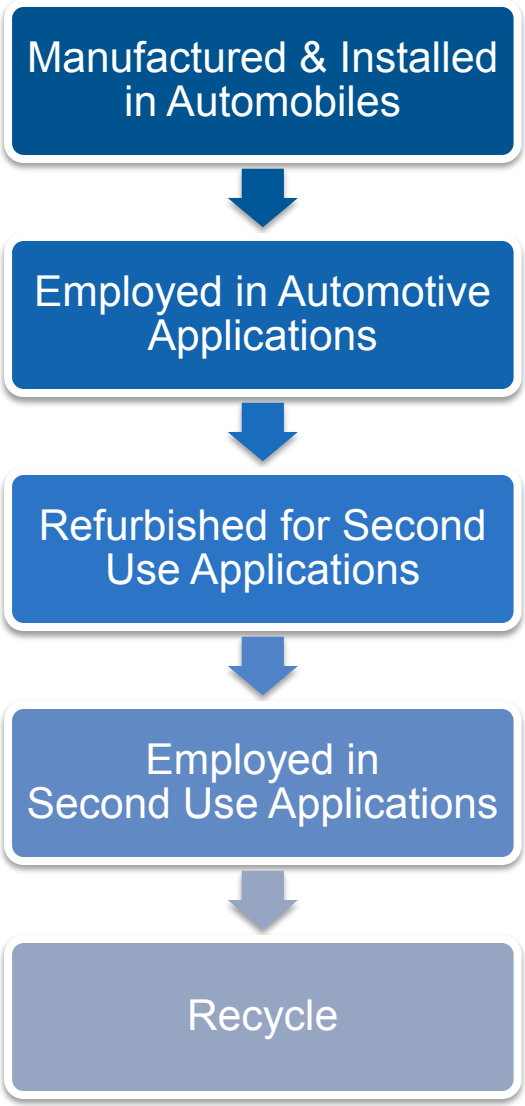
Phase 1: Assess the Merit

Application Identification

- All applications are considered, but high-value / high-impact ones are most desirable
- Accurate use profiles and economic data are needed
- Application value and impact will be estimated before progressing to a detailed investigation
- For each application, consider…
  - How does a battery retired from automotive service perform when subjected to the second use profile?
  - What are the projected revenues and costs?
  - What are the safety concerns and liabilities?
  - How do the performance, life, and cost of a second use battery compare with those of competing technologies?
  - What are the regulatory issues or other barriers specific to this application?
  - Is the scale of this application well suited to the expected availability of retired PHEV/EV batteries?

Phase 1: 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
- In this segment, the use strategy of the battery is optimized via the developed tools and practical considerations



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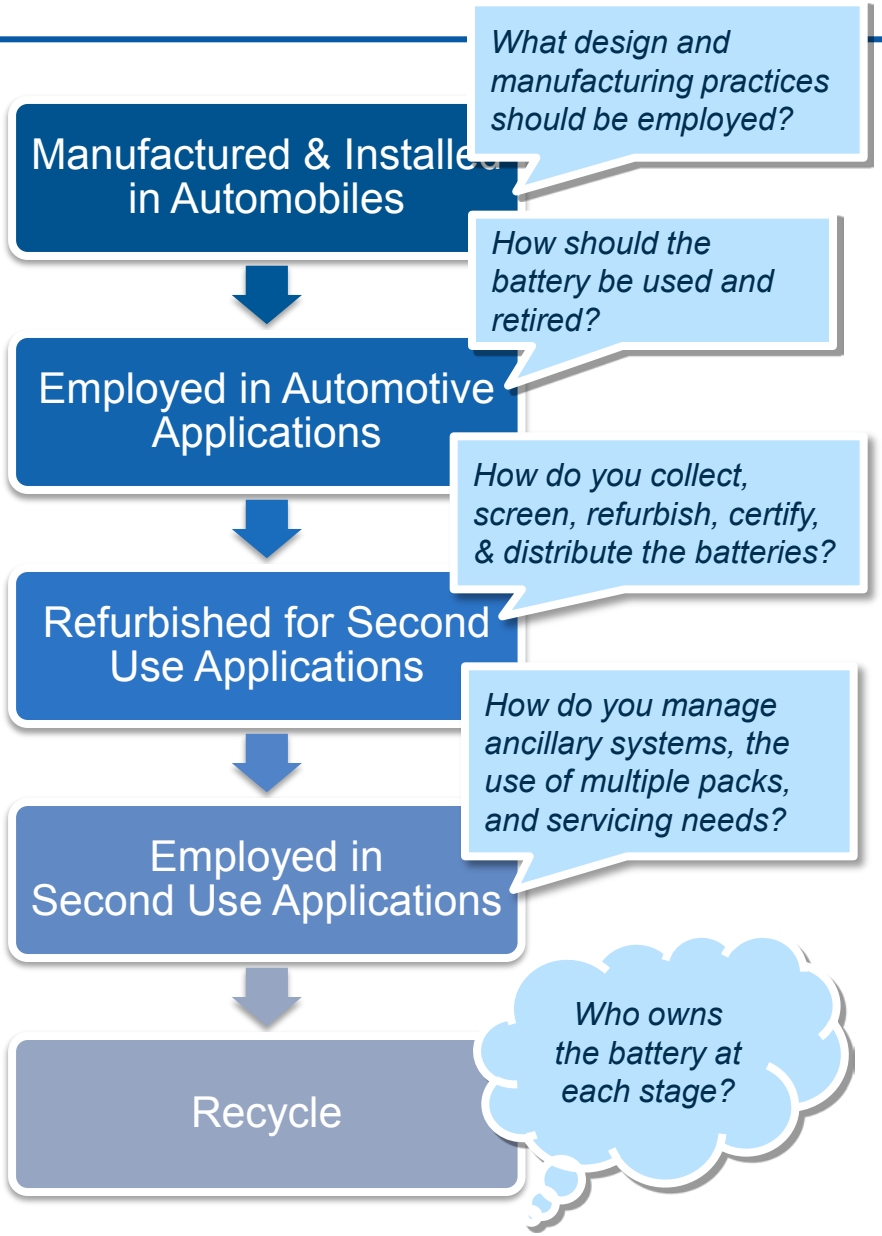
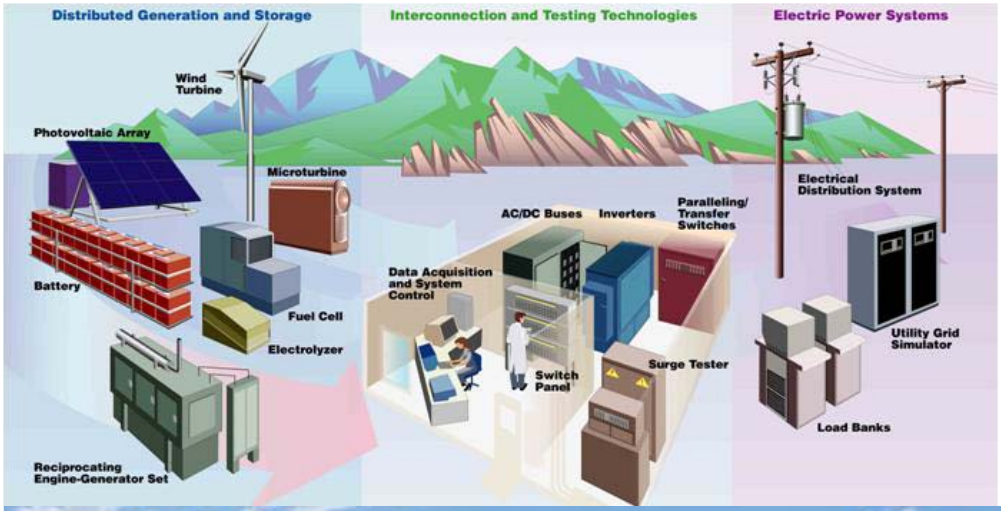


Phase 2: Verify Performance
Conduct Long-Term Testing

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



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

Phase 3: Facilitate Implementation of Second Use Projects

- **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

Planned Work – Battery Second Use

- NREL is currently seeking partners to investigate the reuse of retired PHEV/EV traction batteries to reduce vehicle cost and emissions as well as our dependence on foreign oil.
- A Request for Proposal (RFP) was issued in April 2010 seeking a subcontractor to accomplish the aspects of this effort.
  - You can find RFP No. RCI-0-40458 at www.nrel.gov/business_opportunities - current solicitations.
  - Proposals are due near the end of May 2010 (extended to early June 2010).
  - If you have questions regarding the RFP, please contact Kathee Roque at Kathee.Roque@nrel.gov.
- A workshop to solicit industry feedback on the entire process is also being planned.
- Aged batteries will be tested in 2-3 suitable second-use applications.
- Hope to answer the questions, “Do PHEV/EV batteries have any value for other application? What are the barriers?”

Concluding Remarks

- Secondary Use of PHEV and EV Batteries
  - DOE is supporting efforts to evaluate the second use of retired lithium ion batteries to identify if second use batteries could reduce the initial cost of PHEV and EV batteries.
  - NREL is involved technically and will collaborate with partners.
    - NREL has issued an RFP for collaboration