

## **PHEV/EV Li-Ion Battery Second-Use Project**

Manufactured &

nstalled in Automobile

Employed in

Automotive Application

Refurbished & Installed in

Employed In Second
Use Application

Recycled

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## 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 in-
- crease 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-lon 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



## Can Second Use

Justification

Premise:

The maximum salvage

value of a used hatten

will be less than a new

battery of equal capability

orecast future EV/PHEV

battery cost

Calculate Max

alvage Value of Used

Battery Based on State

of Health, New Batter

Cost, and "Refurbish

ment" Costs

Calculate the maximum

Initial purchase discou from the net present value of the battery's max salvage value

## Significantly Impact **Battery Prices?** 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/vr by 2015 and stabilize, falling in

### cost to ~\$560/kWh Variables

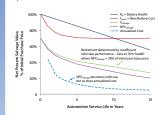
- Con = future cost of a new battery
- r = discount rate = 2.5%  $K_b$  = battery health factor =
- K = refurbishment cost factor = 15%/vr
- $K_{ij}$  = used product discount factor = 15%/vr
- $V_{\text{salvage}} = \text{battery salvage value}$ at retirement

 $NPV_{salvage}$  = 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<sub>salvage</sub> = V<sub>salvage</sub> \* (1-r)<sup>n</sup>

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



## DOE - NREL's Second Use Project

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

Battery manufactured

Design standards?

Optimizing Use Strategies

· For a given second use application,

· Changing these variables can have

value and general feasibility

a significant impact on total lifetime

Technical and economic performance

use strategies for each application

must be considered together to optimize

there can be many different ways to

& installed in auto

implement it



Regular performance checks to

Decision to remove/replace

battery in auto based on..

In-car performance?

Second use value?

Replacement cost?

support retirement election

How frequent?

· Automated in-situ?

What data/metrics?

Auto use continues

with new battery. .

Battery shipped and

installed for second use

Regulatory Issues?

Safety concerns?

Distribution mechanism?

Regular performance checks

to support retirement election

How frequent?

Servicing

Automated in-situ?

What data/metrics?

## 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
- 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

Who owns

the battery at

each stage?

· Safety concerns?

Replacement cost?

second use of traction batteries

Develop design and manufacture

facilitate their reuse

other applications

standards for PHEV/EV batteries that

Provide validated tools and data to industry

Propose regulatory changes to encourage

the reuse of retired traction batteries in

· Recycled value?

# · Mass produced cell and pack designs are required

Acquire Aged Li-Ion Batteries

Prefer field-tested batteries from (pre) production

Accelerated aging via lab testing is also an option.

but may not ensure correlation with actual field use



## Decision to retire/replace battery based on. · Continued second use value? \_\_\_\_ Second use service continues with battery replacement Battery recycled What is the hattery's total lifetime value?

Facilitating Implementation NREL's Distributed Energy Resources Test Facility could serve · Disseminate study findings to inform the as a venue for this phase market of the potential profitability of the

#### 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
- · Lab testing for precise control of conditions
- · Field testing for final demonstration

## **Objectives and Approach**

## What's Next

· The best use strategy will maximize the battery's total life-

be well matched in scale to EV/PHEV battery availability

time value, have a high feasibility of implementation, and

- 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
- · A workshop to solicit industry feedback on the entirety of the process is also being planned

## Acknowledgements

Retired auto battery

· Collection mechanism

· How to reconfigure?

· How to certify?

'refurbished

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