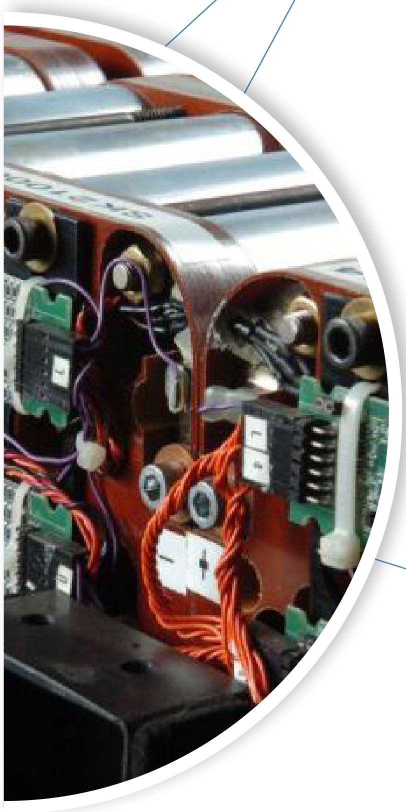
Energy and Materials Issues That Affect Electric Vehicle Batteries



Advances in electric vehicles and their batteries have caused a shift in predominant battery chemistry. Hybrid vehicles generally use Ni-MH batteries, while PHEVs and BEVs use Li-ion batteries because of their higher energy density and other advantageous properties. The Ni-MH batteries are generally recycled by smelting, which recovers the nickel (and iron) for use in the manufacturing of stainless steel. The economic incentive for recycling is the recovery of the nickel. The rare earths (MH) go to the slag, which is used as aggregate in roadbeds (replacing gravel, a very low-valued material), but one company is starting to recover them from the slag by leaching. Rare earths can also be recovered by leaching processes on the spent battery (without smelting). Argonne has published several papers on Ni-MH batteries.

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Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

Potential benefits of battery recycling:

- Any potential hazards from disposal are avoided.
- Recycled materials may be less expensive to produce than virgin materials.
- Reliance on imports can be reduced or eliminated.
- Demand for scarce resources is reduced.
- Even with rapid growth in the demand for lithium, the United States could be self-sufficient in lithium with recycling.
- Energy use and environmental impacts of producing recycled products are almost always less than those of producing new products from raw materials in the ground.

Most of Argonne's work focuses on Li-ion batteries for PHEVs and BEVs. These have not yet become mass-market vehicles, and so very few end-of-life batteries have become available for 2nd use or recycling, although work is under way to ensure that viable options are available. Lithium metal oxides are used as the cathode in these batteries; the metal is cobalt, nickel, manganese, combinations of these, or phosphorus and iron. Copper, aluminum, and steel are also components of the cell structure. No rare earth elements are used. Battery attributes vary with cathode material, and no single winner has emerged.

When a battery's performance declines below acceptable levels for vehicular use, it may still be suitable for second use in utility storage, but eventually performance will be too poor for that use as well, and the battery will require disposition. Note that some batteries might be used directly by utilities. Although battery disposal could result in negative environmental effects, the battery contains valuable and recyclable materials (including the battery housing and electrical connections), the recovery of which will be economical.

Argonne uses detailed process analysis (pioneered in the 1970s at Argonne and elsewhere) to develop a life-cycle inventory (LCI) of all of the inputs and outputs at every stage of the battery's life cycle, from raw materials extraction to final disposition after use. Conversion of the inventory into a full life-cycle analysis that estimates health and environmental impacts is very uncertain and can be done numerous ways. Argonne simply compares energy use and emissions among processes to inform researchers and policy-makers about the implications of different decisions.

As a result of Argonne's LCI of Li-ion battery production and recycling, key conclusions can be made.

- **First**, the energy use and emissions — especially those of CO_2 and SO_x — resulting from all of the available recycling processes are lower for than those from the production of batteries from raw materials.
- **Second**, energy savings increase as more materials are recovered — and increase even more the closer they come to a final usable form in which they can be recovered.
- **Third**, recovery of high-value products depends on an ability to identify batteries that come back for recycling so that clean streams of single chemistry can be fed into appropriate recycling processes. An SAE committee is developing labeling standards to enable identification and separation. Technology for producing useful products beyond basic elements from mixed streams is not available.

Depending, however, on the cathode composition and the recycling process chosen, the value of the cell materials recovered will differ. Most of the lithium-ion batteries available for recycling today contain cathodes that are primarily cobalt oxides, and the recovery of elemental cobalt drives the process economics. Recovering the lithium and aluminum from slag is not economical. Nickel is less valuable than cobalt, and the other metals are even less valuable, and so batteries with lower cobalt content — such as most of those now being built for vehicles — are less attractive for recycling by current methods. Newer recycling processes are under development by Onto/RSR and Toxco/Kinsbursky to recover not the basic elements, but active cathode materials (including the lithium they contain) that could be reused in batteries and are much more valuable than their constituent elements. The quality of the recovered materials must be assured, and their formulation must still be useful, even if the leading edge of battery chemistry has advanced.

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