

Battery Recycling Interaction with Washington

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ABSTRACT

As the market for plug-in hybrid and electric vehicles continues to grow, so too will the demand for advanced batteries using lithium-ion and other chemistries. The need to recycle advanced batteries will grow as well lest the batteries become a solid waste disposal problem. Currently, lithium recycling is an industry in its infancy, but one that will need to develop to meet expected growing demand. This considers policy issues that policymakers will need to address as the demand for advanced battery recycling emerges.

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INTRODUCTION

Significant advancements have taken place in the development of technology to recycle lithium-ion batteries. But, whether these advancements can become the foundation of a successful commercial industry comparable in scale to lead-acid battery recycling depends on four factors.

1. Success would be positively affected once the cost of recycled lithium is at least equal to the cost of "virgin" lithium. Presently, this is not the case. The cost of recycled lithium currently exceeds the cost of virgin lithium by an estimated 10 to 20 per cent. Technology advancements must occur for the cost of recycled lithium and other components in advanced batteries to at least equal the cost of virgin materials so that investors will have confidence that large-scale recycling can be profitable.
2. For a large-scale commercial lithium recycling industry to be successful, a large "pool" of batteries with a standardized design must exist so that lithium and other materials can be easily extracted and fed into the process. This likely will occur if sales of plug-in hybrid and electric vehicles utilizing lithium-ion batteries designed in a standardized manner reach expectations. This would result in a large "pool" of spent batteries eligible for recycling.
3. Even if a "pool" of spent batteries exists, a collection and delivery system must be in place so that recyclers have a sufficient volume of spent battery feedstock. Some states such as California, New York and Rhode Island are moving aggressively to establish such a collection and delivery system, but other states will have to be encouraged to do so as well.

4. Policies developed at the federal government level can have a profound effect, either positive or negative, on the success of any lithium recycling initiative. Two federal agencies, the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) play different, but equally vital, roles in the development of an industry to recycle advanced batteries used in hybrid, plug-in hybrid and electric vehicles. Both DOE and EPA have supporters and detractors in their work to foster a recycling industry for advanced batteries.

It is beyond dispute that lithium-ion and all other rechargeable batteries should be recycled rather than simply dumped in landfills. Ultimately, those public and private sector interests seeking to foster a successful lithium recycling industry hope that recycling lithium will achieve a performance rate equivalent to the two most successful recycling industries of all time, lead-acid batteries and vehicles.

Congress will continue to debate key issues affecting the ability of DOE and EPA to do their work. These issues include:

- Defining the missions of DOE and EPA in fostering advanced battery recycling.
- Evaluating relationships among federal, state and local governments.
- Setting funding levels for DOE and EPA to carry out their obligations.

I. THE DEPARTMENT OF ENERGY'S ROLE IN FOSTERING AN ADVANCED BATTERY RECYCLING INDUSTRY

For nearly 40 years, the U.S. federal government has actively pursued research and development of advanced batteries for use in hybrid, plug-in hybrid and electric vehicles. While this level of support has been stronger in some years than others, advanced battery research has nonetheless become an integral part of the government's effort to curb reliance on imported oil. However, research and development of advanced battery recycling has, until recent years, largely been an "after thought."

The government's commitment to advanced battery research was formalized in 1976 when Congress enacted the "Electric and Hybrid Vehicle Research, Development and Demonstration Act," which authorized the study of battery chemistries such as lead-acid, sodium sulfur and, ultimately, lithium [1].

The research and development since has experienced periods of ups and downs. In 1981, President Ronald Reagan cancelled the battery research program as he sought to dismantle DOE entirely. The Reagan proposal to dismantle DOE never moved through Congress and in later years, under Presidents George H.W. Bush and Bill Clinton, the battery R&D program regained strength. The Energy Policy Act of 1992 specifically directed DOE to reinvigorate the battery demonstration program.

With this renewed federal commitment, U.S. automakers formed the U.S. Council for Automotive Research (USCAR) and, within that new program, created the U.S. Advanced Battery Consortium (USABC) to focus on advanced battery development. The USCAR program received, and to this day continues to receive, support from DOE. The overarching goal of the federal government's program to develop advanced batteries has remained the same through the years: reduce the cost of hybrid vehicles to a level comparable to conventional vehicles using standard internal combustion engines.

In 2002, under President George W. Bush, the Partnership for a New Generation of Vehicles was restructured into what is now known as the FreedomCAR program in DOE. The battery research component of the revamped program was focused on nickel-metal hydride (NiMH) and lithium-ion chemistries. The program continues with the strong support of President Barack Obama.

Table 1 shows federal spending on battery and battery-related research and development since 2002.

Table 1. Annual Appropriations, in Millions of U.S. Dollars[2] Source: U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy (EERE).

Fiscal Year	Amount
2002	\$24.1
2003	21.6
2004	22.3
2005	22.5
2006	24.5
2007	40.9
2008	48.3
2009	69.4
2010	76.2

In 2009, in response to a sharp economic downturn, Congress enacted a massive economic stimulus bill that included \$1.5 billion for the development of a domestic battery supply chain, with part of that going toward a lithium recycling facility:

- \$28.4 million to develop lithium supplies;
- \$259 million to produce Li-ion cell components such as cathodes, anodes, separators, and electrolyte solution;
- \$735 million to make cells using diverse chemistries such as iron phosphate, nickel cobalt metal, and manganese spinel;
- \$462 million for pack assembly facilities; and
- \$9.5 million for a lithium recycling facility.

Ultimately, a successful commercial industry to recycle advanced batteries using lithium and other chemistries could be modeled on the established, highly-profitable lead-acid battery recycling industry (See Figure 1).

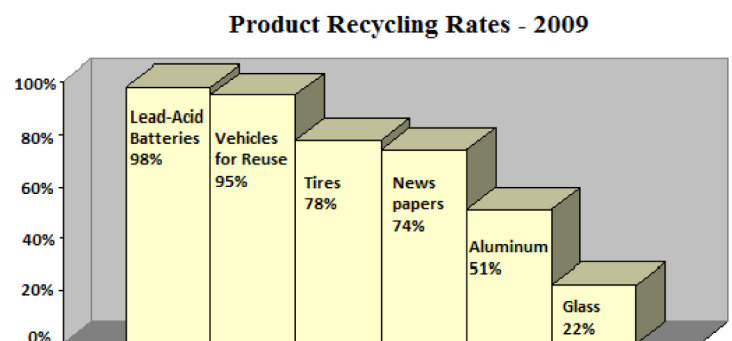


Figure 1. Source: Battery Council International & Automotive Recyclers Association[3]

More than 100 million 12-volt lead-acid batteries used in automobiles are recycled each year in the U.S., making them the most recycled consumer product in the world [4]. The price of recycling is rolled-into the price of the original battery. No other battery chemistry can make that claim. In addition, the price of recycled lead is lower than the price of

virgin lead mined from the ground. Lead-acid battery recycling has been in operation for many years - long before the U.S. Congress enacted its first solid waste disposal law in 1976 - and its success has enabled lead, an otherwise highly toxic substance, to continue its role as a resource for low cost batteries that are essential for mobile and stationary requirements.

The vehicle recycling industry's record has been no less impressive, with an estimated 10 million vehicles per year in North America being recycled, resulting in an estimated annual turnover of \$22 billion, according to the Automotive Recyclers Association, a trade group organized in 1943 [5].

In fact, the lead-acid battery and vehicle recycling industries can be regarded as "templates" for the growing "life-cycle sustainable development" and "product stewardship" movements that are gaining prominence in North America and around the world.

Because advanced batteries utilizing lithium, cobalt, nickel, cadmium and other substances have the potential to achieve greater energy densities than lead-acid, the need for the recycling of those products is no less compelling. Simply disposing advanced batteries that contain any of these substances in landfills can result in considerable harm to ground water and the air.

Lithium-ion batteries have become commonplace in portable consumer electronics and a number of recycling companies have been in business for several years. However, the recycling companies continue to face the challenge of developing processes to accommodate a wide variety of feedstock types on a large scale. That problem would be positively addressed by the growth in sales of hybrid vehicles utilizing lithium in battery systems designed on a standardized basis and fed into a recycling process that could yield an end product competitively priced with virgin materials. How soon that sales increase can take place remains an open question. A consensus exists that the current cost of advanced batteries used in plug-in hybrid and all electric vehicles is too high and must come down if plug-in and electric vehicles that use lithium batteries are to capture a significant market share. While automakers prefer not to say specifically how much batteries cost, some analysts estimate they add as much as \$16,000 to the cost of a car and comprise more than one-third the cost of the car itself. Economies of scale and research breakthroughs could drive these costs down. It is these vehicles that are expected to provide one of the strongest platforms for the development and growth of a lithium-ion battery recycling industry. One optimistic assessment of how hybrid, plug-in hybrid and electric vehicles might sell in future years is illustrated in [Figure 2](#).

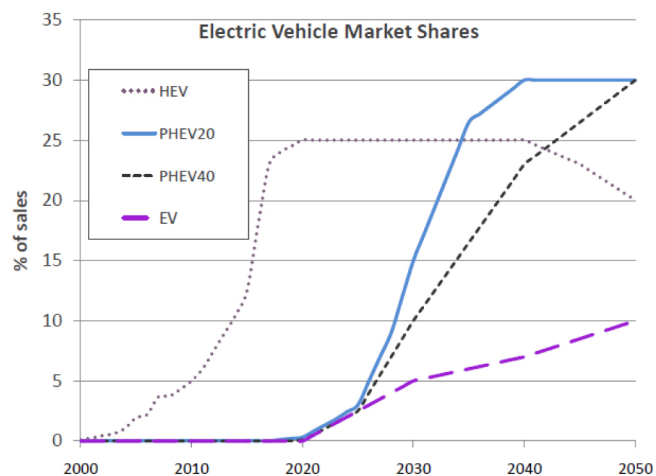


Figure 2. "Multi-Path Transportation Futures Study,"
US Department of Energy, March 2007[6]

Whether the recycling of advanced batteries using lithium and other chemistries can achieve a level of scale comparable to lead-acid battery recycling, however, depends not only on an increase in battery "feedstock," but also on the development of processes that would result in the price of recycled materials being at least equal to the cost of virgin materials. With the support of the DOE's Vehicle Technologies Program, Argonne National Laboratory has undertaken an evaluation of various recycling technologies [7].

Three approaches to the recycling of advanced lithium batteries are:

- 1). Pyrometallurgy, a very well established process using high temperatures to downgrade material to a metallic state for sale as base metals.
- 2). Hydrometallurgy, another well established process using aqueous chemicals to solubilize material for precipitation or electrowinning in further processes.
- 3). Direct recycling, an emerging technology in which specific unit operations are utilized to separate different materials into concentrates that may be directly put back into battery production.

A successful advanced battery recycling industry would, according to a 2010 study by Argonne, minimize the demand for virgin lithium in providing materials for advanced battery production (See [Figure 3](#)).

DOE, therefore, can be expected to have an important role not only in the development of an advanced lithium battery industry, but also in fostering a recycling industry. A well-structured lithium recycling industry, therefore, not only will provide the battery manufacturing industry with a low-cost material resource, but also serve environmental protection needs.