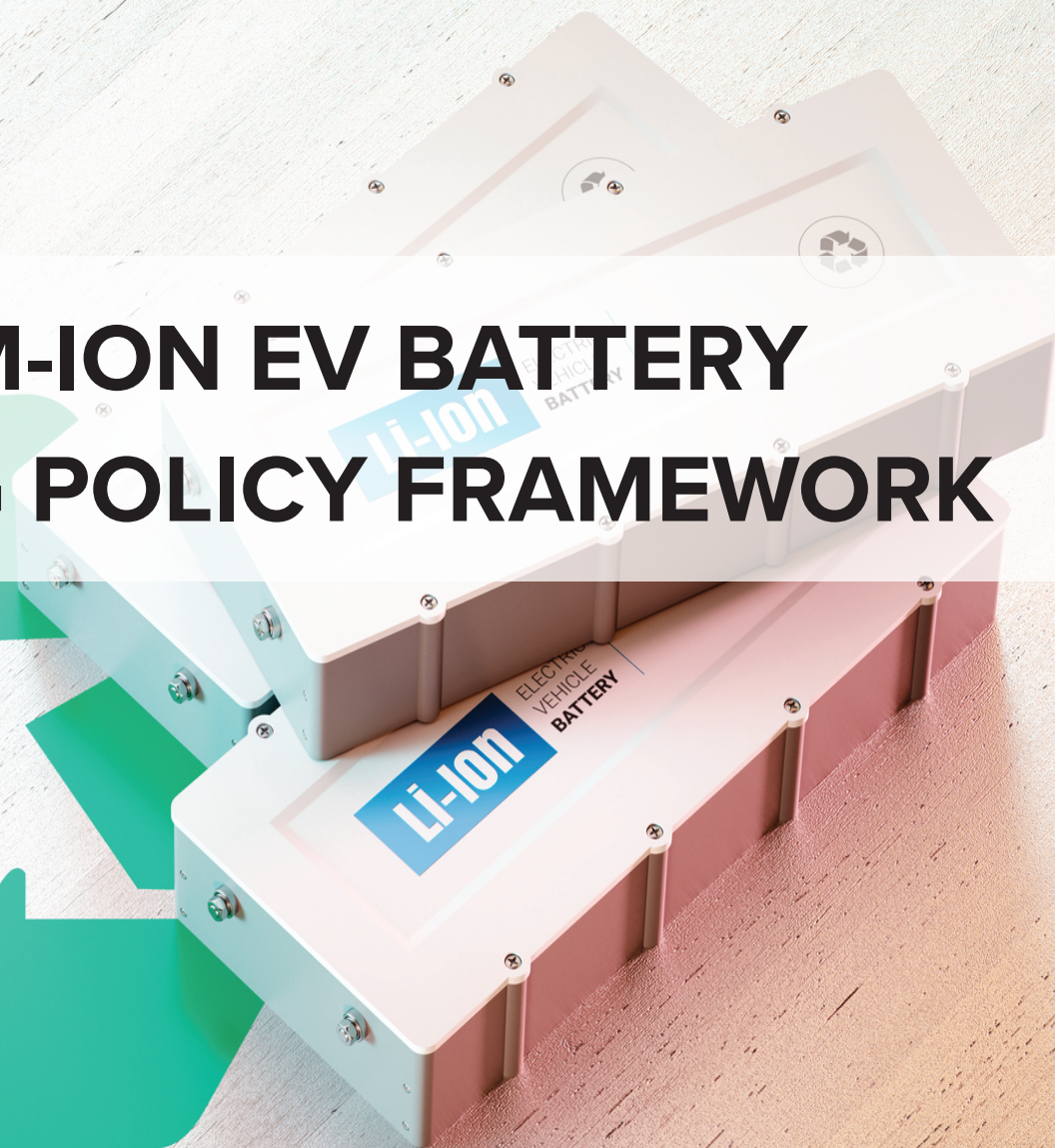




ALLIANCE
FOR AUTOMOTIVE
INNOVATION



LITHIUM-ION EV BATTERY RECYCLING POLICY FRAMEWORK



EXECUTIVE SUMMARY

Opportunity

The shift to an all-electric vehicle future will result in a significant rise in demand for EV batteries. Many of the materials needed to build EV batteries aren't yet produced domestically. A domestic circular economy, including battery recycling, offers an opportunity to reduce U.S. reliance on other nations for critical minerals used in EV batteries, while bolstering national energy security.

Challenge

Developing robust recycling and secondary use policies that aid in creating sustainable supply chains for battery manufacturers and ensure that batteries do not become landfill waste at end-of-life.

Solution

A core exchange with complete vehicle backstop policy would help address the challenge by assigning responsibility for EVs and EV batteries reaching their end-of-life throughout the vehicle lifecycle.

1. For EVs still in service and the battery within warranty: The EV manufacturer would be responsible for ensuring that the battery is properly reused, repurposed, or recycled.
2. For EVs still in service and the battery outside of warranty: If a battery pack, module, or cell is replaced before the vehicle reaches end-of-life, a core exchange program detailed by the EV battery supplier would be used for the replacement battery (or any module or cell). The entity removing the battery would be responsible for ensuring the used battery (or module or cell) is transferred to a qualified facility to be properly refurbished, repurposed, or recycled. A core exchange program, with proper transaction record-keeping, would be used by the entity selling the replacement battery to track that the used battery has been properly refurbished, repurposed, or recycled.
3. For EVs that have reached end-of-life:
 - a. A dismantler who takes ownership of an end-of-life vehicle would be responsible for ensuring the battery is properly reused, repurposed, refurbished, or recycled. If an EV battery is directly reused in another vehicle with no alterations, the process for EVs still in service would apply, and the used battery would become the responsibility and liability of the dismantler. If the used battery is refurbished or repurposed, the responsibility and liability would transfer to the refurbisher or repurposer, who would provide information on the battery attesting to such.
 - b. If an end-of-life EV with an OEM-certified battery¹ is not acquired and has not had parts removed² by a licensed dismantler,³ the vehicle manufacturer would be responsible to accept the vehicle and ensure that it is properly dismantled and the lithium-ion battery is properly reused, refurbished, or recycled.

¹ An OEM-certified battery is a battery that is part of the original vehicle as produced by the OEM, or sold by an OEM, or remanufactured to OEM specifications and approved by the OEM.

² OEM or representative verifying or confirming that parts have not been removed after transfer to dismantler.

³ Licensed dismantler refers to a dismantler who meets all state and/or federal regulatory and permitting requirements, has appropriate amount of liability insurance, and is authorized to handle EV batteries.

Background

The auto industry is committed to working toward a net-zero carbon transportation future that includes a shift to electric vehicles (EVs). In 2021, EV sales were 4.4 percent of light-duty vehicle sales in the U.S., up from 2 percent in 2020. Additionally, for the months of October – December 2021, EVs represented 6 percent of overall light-duty vehicle sales, the highest for any quarter to date and a 1.1 percentage point increase over the third quarter.⁴

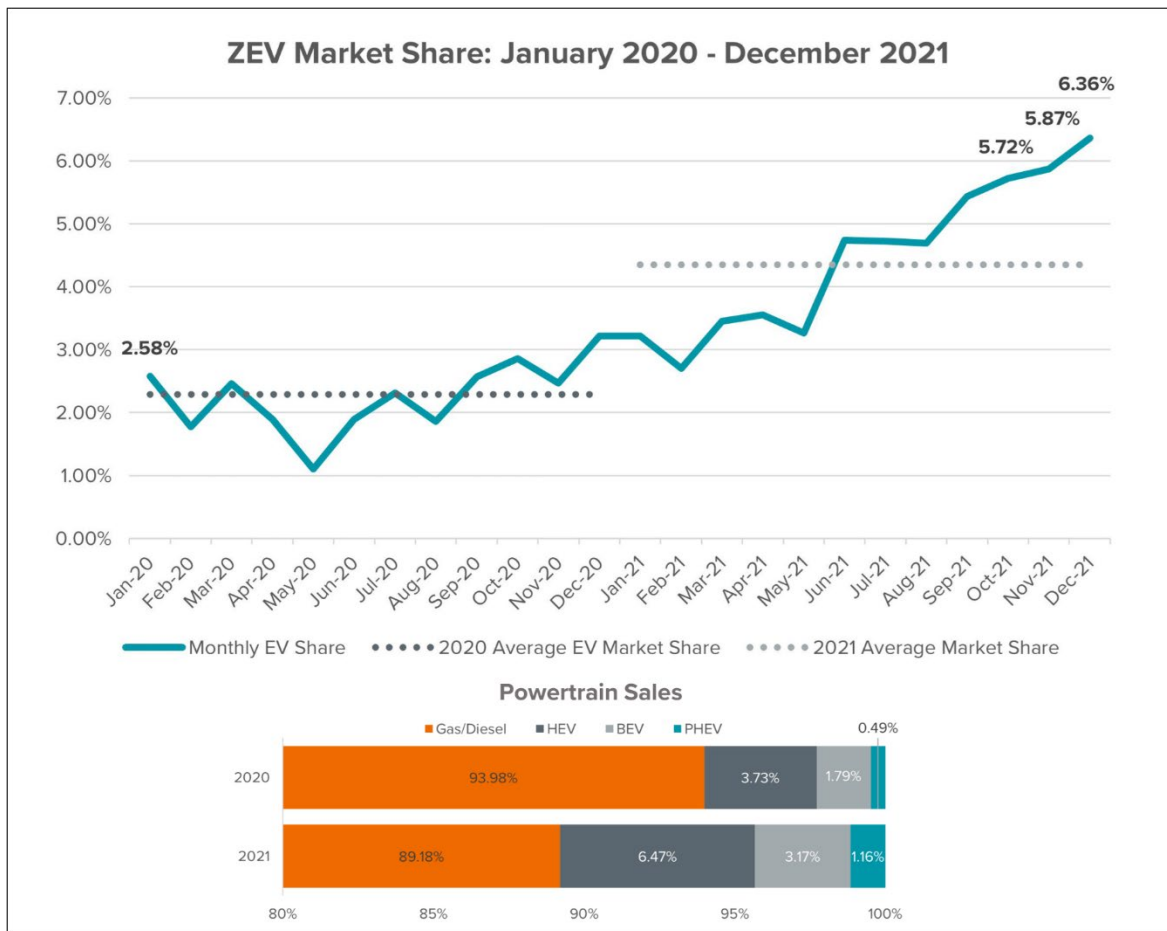


Figure 1: Click the Image to view data or visit: [bit.ly/GetConnected2021Q4](https://www.autosinnovate.org/posts/papers-reports/Get%20Connected%20EV%20Quarterly%20Report%20Q4.pdf)

Automakers are planning to invest over \$515 billion in electrification through 2030, and IHS Markit predicts there will be 130 EV models available in the United States by 2026.⁵ Additionally, individual automakers have announced plans to phase out internal combustion engine vehicles and move to a fully electrified fleet. This dramatic shift will result in a significant rise in demand for EV batteries.

⁴ <https://www.autosinnovate.org/posts/papers-reports/Get%20Connected%20EV%20Quarterly%20Report%20Q4.pdf>

⁵ Stephanie Brinkley, IHS Markit Forecasts EV Sales to Reach US Market Share of 7.6% in 2026, IHS Markit, <https://ihsmarkit.com/research-analysis/--ihm-markit-forecasts-ev-sales-us.html> (May 28, 2019).



EV Battery Supply Chain

The United States does not have significant reserves of some EV battery materials and currently depends on imports from other nations for most raw materials. EV battery recycling offers an opportunity to reduce U.S. reliance on foreign nations for critical minerals used in EV batteries while improving national energy security. In fact, vehicle manufacturers are already working with recyclers in the U.S. and North America to recycle their manufacturing and service battery scrap to provide an alternative and sustainable source of battery raw material. Although battery scrap from manufacturing and service is expected to represent a majority of the recyclable volumes prior to 2030, end-of-life EVs will contribute to a growing opportunity as EV adoption increases. In addition, vehicle manufacturers are collaborating with supply chain partners to establish pathways for recycled material reuse that are compatible with unique supply chains and future battery designs.

EV Battery End-of-Life Options

The three pathways to responsibly dispose of EV batteries at end-of-life include: reuse/remanufacturing, repurposing (i.e., secondary use), and recycling. While each of these pathways offers opportunities for EV batteries to provide additional value, the primary factors influencing a particular selection include: the ease of part disassembly and part recovery, value to a secondary market for repurposing, the inherent recyclability of the constitutive materials, processes costs, and market demand.

Remanufacturing refers to the process of refurbishing battery modules or packs to as good or better quality and performance levels through the replacement of worn or deteriorated components and re-certifying them to OEM specifications. Therefore, remanufacturing represents the highest value for recovering used EV batteries: it reduces manufacturing costs, energy demand, and the need for natural resources.

Repurposing refers to the process of refurbishing EV battery components or packs to fulfill a different use from what was originally intended (i.e., secondary use). The potentially lower costs, fitting form factors and expected retained energy of second-life EV batteries have made them good candidates for stationary energy storage use cases, such as utility reserve energy capacity and renewable power storage. Therefore, repurposing EV batteries would offer advantages in supporting national energy security and our transition to clean energy. However, significant challenges (e.g., cost-efficient processes for collection, sorting, testing, repackaging and certifying of the repurposed packs to meet the required performance in a changing technology landscape) are yet to be solved to fully realize this opportunity. Moreover, while demand for second-life batteries could grow similarly to the projected growth of the stationary energy storage market, it will soon be comparatively smaller than the expected volumes of EV batteries that will be reaching end-of-life.



Recycling here refers to the process of treating EV batteries in such a way as to recover the maximum amount of their constitutive raw materials for reuse in identical or alternative industries. Various processes are employed for EV battery recycling (e.g., pyrometallurgical, hydrometallurgical, and hydro-pyrometallurgical) and often dictate the quality, quantity, and environmental impact of the recovered materials for further use. Similar to remanufacturing and repurposing, recycling also relies on appropriate methods for collection, transport, disassembly, testing, depowering, and shredding of the input battery material for further processing. Recycling will be the ultimate step in the life of all batteries. While ‘true’ end-of-life EV batteries are not expected to require recycling at high scale until later in the decade, domestic manufacturing of battery components (from cells to pack) will create early opportunities to support the development and scaling of recycling processes that will ensure recovery of the critical raw materials required in the manufacture of domestic EV batteries. In addition to reducing reliance on natural resources and ensuring ethical and equitable sourcing of raw materials, optimum recycling processes will offer strategic opportunities to reduce U.S. reliance on foreign nations for critical minerals used in EV batteries.

These three pathways all can provide benefits and should be considered on a case-by-case basis, but this paper is focused on EV battery recycling.

Challenges Associated With Positive Value Recycling

Transportation

The transportation of lithium-ion batteries to recycling and refurbishment centers continues to be one of the most expensive parts of facilitating the full battery lifecycle; methods and programs to reduce costs and mitigate inefficiencies, particularly during the early years of development, should be explored. Transportation and logistics costs can account for over half of the cost of recycling an EV battery.⁶ Lithium-ion batteries are classified as Class 9 hazardous materials, thereby requiring special handling when not installed in a vehicle, significantly driving up the costs of packaging, logistics and transportation of batteries, and directly impacting the economics of battery recycling and reuse. We recommend that the U.S. Department of Transportation re-evaluate existing regulations to make sure that they are appropriate for safety and not overly burdensome.

Sorting Based on Chemistry

To provide recyclers with easily identifiable battery chemistry information, vehicle manufacturers and battery recyclers have been working together on the development of industry standards, namely SAE J2984 *Identification of Transportation Battery Systems for Recycling Recommended Practice*. These types of standards identify chemistry and appropriate recycling streams for the various batteries and provide a template for vehicle manufacturers to disclose necessary information to the vehicle dismantler and EV battery recycler. Under these standards, vehicle manufacturers will ensure a label is on the battery pack that will provide pertinent information.

⁶ Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth: 100-Day Reviews Under Executive Order 14017, The White House (June 2021) at 94, <https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf>.

Impacts of a Closed-Loop Domestic Economy

Domestic EV battery manufacturing is in its infancy but is expected to grow in the near-term, making it even more imperative to initiate a domestic closed-loop economy. A domestic closed-loop economy will decrease reliance on mined materials, reliance on foreign economies, environmental impacts, transportation of goods, and the overall cost of the vehicle due to access to raw materials.

To maximize the creation of U.S. recycling jobs, and to secure domestic sources of battery materials, it will be important that recycling capacity keeps up with the growing demand for both recycling services and battery materials for U.S. cell manufacturers. If locally recycled materials are used, it will further encourage domestic cell manufacturing and the associated supply chain. The federal government has an opportunity to stimulate investment in domestic EV battery recycling and battery cell manufacturing, and in turn create domestic jobs. Given aggressive investments by other countries in their battery ecosystems, being slow to act will widen the gap and further challenge the prospects for a domestic U.S. supply chain.

EV battery manufacturing in the United States is expected to grow over the next decade and beyond. Domestic EV battery manufacturing will create scrap battery materials that will serve as an input to battery recyclers as the market continues to grow. And in parallel, battery recyclers will serve as input back into the manufacturing stream, creating a domestic circular economy. As EV battery manufacturing grows in the U.S., so too will relationships between recyclers and manufacturers, of both vehicles and batteries. Several strategic partnerships have already been announced and, as more EV battery manufacturing facilities come online, there will likely be more.

Core Exchange With Complete Vehicle Backstop

Policy

Under such a policy, for EVs still in service, if a battery (or any module or cell) is replaced before the vehicle reaches end-of-life, a core exchange program as detailed by the EV battery supplier or vehicle manufacturer would be used for the replacement battery (or any module or cell). The entity removing the battery would be responsible for ensuring that the battery (or module or cell) is transferred to a qualified facility to be properly refurbished, repurposed, or recycled.

For EVs that have reached end-of-life, a dismantler who removes the lithium-ion battery from the vehicle would be responsible for ensuring the battery is properly reused, refurbished, or recycled. In circumstances where an end-of-life EV is unwanted, and no parts are removed (i.e., a “complete vehicle”) by a licensed dismantler, the vehicle manufacturer would be responsible for accepting the vehicle and ensuring that it is properly dismantled and the lithium-ion battery is properly reused, refurbished, or recycled.



Advantages

A core exchange with complete vehicle backstop (“policy”) addresses the challenge of capturing close to 100 percent of end-of-life EV batteries without hindering innovation, and while allowing the EV battery recycling and reuse markets to grow. Traditional extended producer responsibility schemes are appropriate for negative value recycling products, limited secondary life opportunities, and/or natural resource-intensive recycling technologies. The domestic EV battery supply chain is quickly adapting to market dynamics due to the positive value of recovered materials, secondary life market opportunities, and awareness and demand for a domestic supply chain.

The policy has several advantages over traditional extended producer responsibility or environmental handling fee programs:

- Ensures EV batteries are properly reused, refurbished, or recycled throughout their lifecycle in the vehicle
- Does not increase the cost of EVs for consumers
- Ensures licensed dismantlers are not omitted from the market at end-of-life
 - If the complete vehicle is a positive business case, licensed dismantlers will continue to acquire end-of-life EVs
 - If/When the battery becomes positive value at end-of-life, it does not take away this opportunity for dismantlers
- Encourages auto manufacturers to continue to design for recycling and reuse
- Does not discourage innovation amongst recyclers
- Encourages dismantlers to become licensed
- Complete vehicle is easier and less expensive to transport than an EV lithium-ion battery.

The policy provides a safeguard to capture outlier EV batteries and, importantly, during unforeseen market fluctuations.

Necessary Safety Net Legislation and Regulation

To ensure that a core exchange with complete vehicle backstop policy is successful, legislation and/or regulation should be considered to:

- Make auto manufacturers responsible during the lithium-ion battery warranty period to ensure end-of-life EV batteries are properly transferred to a qualified facility to be refurbished, repurposed, or recycled.
- Through a core exchange process for replacement batteries, require all vehicle repair parties (dealerships, independent repair shops, collision shops) to ensure end-of-life or replaced EV batteries are transferred to a qualified facility to be properly refurbished, repurposed, or recycled. Require proper record-keeping for service-battery providers.

- Require vehicle auction houses (including insurance auctions) to sell end-of-life EVs only to licensed dismantlers or to transfer the complete vehicle to the auto manufacturer through the *back-stop*. Require auction houses to keep proper records showing that end-of-life vehicles are going to licensed dismantlers or vehicle manufacturers through the complete vehicle backstop.
- Enact licensing processes at the state level for dismantlers, and enforce licensing requirements.
- Require dismantlers that remove EV batteries to ensure all end-of-life EV batteries are properly transferred to a qualified facility to be refurbished, repurposed, or recycled; rules could allow for dismantlers to become a licensed battery shredding operation.
- Establish an auto manufacturer complete vehicle backstop. Any EV containing an OEM lithium-ion battery that is not acquired by a licensed dismantler would be the responsibility of the auto manufacturer to dismantle and to ensure the battery is properly reused, repurposed, or recycled.
- Make proper recycling of batteries repurposed outside of the vehicle the responsibility and liability of the entity repurposing the battery unless otherwise stated in a contract.
- Require standardized labeling of EV batteries per SAE J2984. Additionally, make entities repurposing an EV battery responsible for re-labelling the battery per SAE J2984.
- Apply penalties to stakeholders for non-performance.



Appendix
Policy Framework: EV Battery End-of-Life Responsibility

State of Vehicle	State of Battery	Warranty Status	Responsible Party
In-Service	Damaged or otherwise needs to be replaced	In warranty	Vehicle manufacturer would be responsible for ensuring EV battery is properly reused, refurbished, or recycled
In-Service	Damaged or otherwise needs to be replaced	Outside of warranty	- Dealerships, independent repair shops, collision shops, entity removing the battery, etc. would be responsible for ensuring the battery is transferred to a qualified facility to be properly reused, refurbished, or recycled. - Record-keeping for a core exchange would be required for each battery pack, module, or cell replaced. A clear, identifiable, and traceable serial number would be required on the replacement part.
End-of-Life	N/A (dismantler or vehicle manufacturer will determine state of battery)	Outside of warranty	- A dismantler who removes the lithium-ion battery from the vehicle would be responsible for ensuring the battery is transferred to a qualified facility to be properly reused, refurbished, or recycled. - In circumstances where an EOL EV is unwanted, and no parts are removed (i.e. a “complete vehicle”) by a licensed dismantler, the vehicle manufacturer would be responsible for ensuring that the vehicle is properly dismantled and the lithium-ion battery is properly reused, refurbished, or recycled.
EV Battery Secondary Use			Non-vehicle secondary use owner would be responsible for ensuring the battery is properly recycled, unless stated otherwise in a contract.



Appendix

Core Exchange Example

(<https://www.napaonline.com/en/what-is-a-core>)

What is a Core?

- Certain types of auto parts can be recycled or, more specifically, remanufactured for future sale. These parts have a core price that is used as a form of deposit on the portion of the part that can be remanufactured and that is designed to encourage return of the old part. The “core,” simply put, is your old part. Returning cores can save you money on replacement parts.
- Parts that may have a core price include brake shoes, brake master cylinders, water pumps, starters, alternators, and air conditioning compressors.

Core Charges and Core Prices

- The sale of a remanufactured part involves the price of the part itself, as well as an additional core charge to encourage the return of the old part for remanufacturing purposes. The core charge, sometimes called a core price, is a form of deposit you pay until returning your old part. If you don't have the core at the time of purchase, you must pay the core charge. That charge is refunded to you when you return the core.