ISRI Circularity & Electrification Action Summit

Automakers and EV Recycling

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30 Second Snapshot:

- Automakers are increasingly striving toward vertical integration of supply chains—with battery manufacturing at the forefront.
- With surging demand for EV batteries, automakers are not only focusing on recyclability and reuse but are also committing to sustainably sourced critical minerals, and exploring new battery chemistries.
- The Department of Energy reports that lithium-ion battery recycling has a net cost, with transport accounting for half of the total cost. However, the global battery recycling sector is forecast to generate over $40 billion in revenue by 2040, underscoring the need for a coordinated domestic supply chain.
- U.S. and global automakers have committed to investing in new technologies, supporting battery recycling or reuse, and reducing virgin material use in their

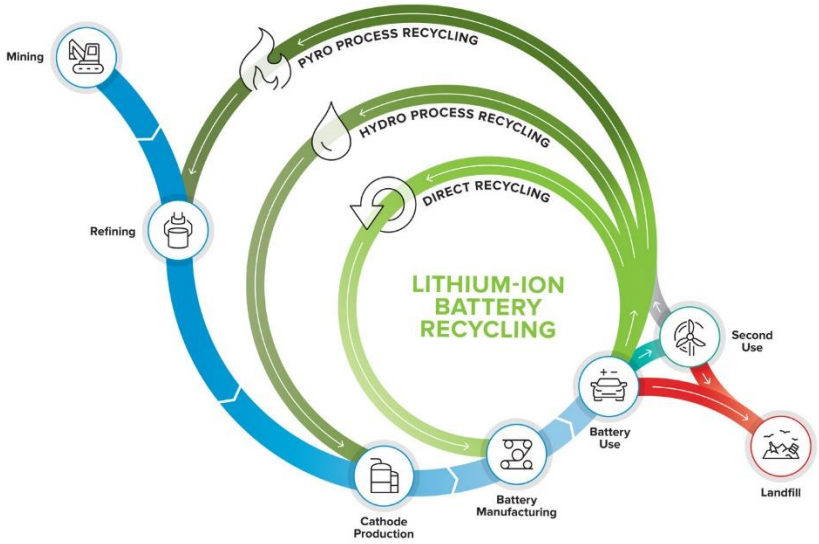
Introduction

The rise in electric vehicle (EV) adoption has been historic, with 670,000 EVs sold in the first half of 2023, compared to 306,000 sold in the first half of 2021. By 2030, Edison Electric Institute forecasts this momentum to yield 5.6 million annual EV sales in the United States, which is under President Biden's target of 50 percent EV sales by the same year, or about eight million vehicles. To power these vehicles, the U.S. Department of Energy (DOE) estimates that the global demand for lithium-ion batteries will grow by a factor of 5 to 10 over the next 10 years. Given this demand and the increasing prices of critical minerals powering these batteries, automakers are heavily investing in supplies of minerals and materials for their batteries to ensure that they are as cost-effective as possible. As EVs mature, automakers must confront the growing influx of EVs—and their components—nearing end-of-life. This brief unpacks how automakers are planning to support EV circularity—from batteries to vehicle bodies—and the challenges this comprehensive approach presents.

The Lifecycle of EV Batteries

Understanding how automakers view the lifecycle management of EV batteries is important to anticipate the opportunities and challenges that lay ahead. A majority of EV batteries go through four phases in their lifecycle: extraction and manufacturing, initial battery use, second use deployment where applicable and recycling, and/or landfill.[1] Automakers are becoming more active in each stage to influence the sustainability of, and overall investment in, EVs. To better visualize this lifecycle, see Figure 1.

Figure 1: Lifecycle of an EV Battery



This figure traces the lifecycle of an EV battery: mineral extraction and initial use (blue), second life application (light blue), recycling of materials for use in additional batteries (green). Batteries whose materials cannot be recycled are removed from the lifecycle (red). Second use application includes projects such as "improving grid performance via energy storage, charging EVs at stationary sites, etc."

Source: Argonne National Laboratory

Battery Demand Expected to Skyrocket

As time goes on, automakers are adding EVs to their portfolios with greater battery range. In 2020, General Motors (GM) announced it would launch over 30 new EVs globally through 2025, with vehicles reaching 450 miles on a single charge using batteries from Ultium Cells, GM's joint venture with LG Chem. U.S. DOE estimates 320 gigawatt-hours, the

[1] Not every battery chemistry may be cost-effective to recycle or deploy for second use. For instance, lithium iron phosphate (LFP) batteries are less expensive to create due to smaller amounts of critical minerals in their construction, but have less energy density than batteries with more critical mineral composition such as nickel manganese cobalt (NMC).

equivalent of one hour of power from 790 million solar panels, will be needed to meet U.S. passenger vehicle demand in 2028.

To navigate rising critical mineral costs and accelerate their EV sales, automakers are making strategic decisions between different battery chemistries. In 2022, nickel-manganese-cobalt (NMC) had 60 percent market share globally, lithium-iron-phosphate (LFP) was at 30 percent, and nickel-cobalt-aluminum (NCA) was at 8 percent. Tesla began using LFP batteries for all their standard range vehicles globally in late 2021. Rivian and Ford have also chosen LFP batteries for some vehicle models to boost profitability. Other chemistries like sodium-ion (Na-ion) and solid-state batteries are still largely being tested but offer potential cost advantages and reduced reliance on critical minerals. Chinese automaker JAC (backed by Volkswagen) is currently experimenting with Na-ion powered batteries, while Stellantis and Toyota are planning on producing solid state batteries by 2026 and 2027, respectively.

Extraction, Manufacturing, & Recycling of Batteries

Given their central role in current and future business development, U.S. automakers are strategically investing to ensure a consistent and ethically sourced supply of minerals and materials for their EV models, prioritizing both sustainability and proximity in sourcing decisions. GM, for instance, has a $650 million equity investment in securing lithium from the Thacker Pass Mine in Nevada, the largest known source of lithium in the United States. Additionally, automakers are incorporating refinement plants into their supply chains; Tesla broke ground in May 2023 on a lithium refinery in Texas that may produce enough lithium to power one million EVs annually by 2025.

After a 10 to 20 years, an EV's battery is no longer expected to be suitable to power a vehicle and will need to be replaced. A used lithium battery—absent any defects—can still be repurposed for other applications, such as backup power for the electrical grid. Major automakers like Nissan and Audi have begun to refurbish battery packs for use in transportation applications. Looking ahead, automakers are amplifying their investments to obtain recycled batteries, anticipating the gradual increase of these batteries reaching the end of their lifespan in the future. As the use of EVs grows, so does an increased emphasis by automakers on circularity. For its part, U.S. DOE aims to recycle 90 percent of batteries from consumer electronics, EVs, and grid-storage devices by 2030.

Materials Recycling & Integrating Circularity

While automakers focus on battery circularity, efforts to enhance the sustainability of their vehicles are ongoing. Recent sustainability reports from automakers emphasize using recycled materials as an input to vehicle manufacturing (e.g., Ford aspires to use only recycled or renewable content in vehicle plastics), as well as second-use or recycling of vehicle components at end of life. Automakers do not distinguish between EVs and non-

EVs when discussing vehicle component recycling or second-life applications. According to the Atlas EV Hub, more than 90 percent of cumulative U.S. EV sales (2011 to Q3 2023) come from seven automakers: Tesla (45.6 percent), GM (8.2 percent), Hyundai (6.5 percent), Ford (6.2 percent), Toyota (5.8 percent), Stellantis (5.5 percent), BMW (5.4 percent), Volkswagen (4.7 percent), Volvo (2.4 percent), and Mercedes-Benz (1.4 percent). For a more thorough breakdown of each automaker's commitments to recycling, see Table 1.

Regardless of whether they go onto second-life applications or not, all batteries eventually make their way to either a landfill or a recycling facility. Recycling batteries into components and minerals decreases the need for new raw materials to be mined, lowering the environmental, social, and potentially economic impact of the battery lifecycle.

The University of Technology Sydney estimated that more than 90 percent of minerals like cobalt, nickel, copper, and aluminum from lithium-ion batteries are recyclable. The U.S. DOE currently estimates recycling batteries is a net cost, however, with transport making up half of the total.

Table 1: Many EV Automakers are leaning into Sustainability across the Value Chain

Automaker	Battery Recycling	Metals Recycling	Plastics Recycling	Other Recycling
BMW	Requires cell manufacturers to partially source minerals from secondary (i.e., recycled) sources.	Uses up to 25% of recycled steel in vehicle manufacturing. Aims to increase to 50% by 2030.	Use of fishing nets, PET bottles, and natural fibers (e.g., hemp, kenaf, flax) in vehicle parts.	Up to 10,000 vehicles a year are processed at BMW's Recycling and Dismantling Centre in Unterschleißheim near Munich.
Ford	Using end-of-life vehicles as a supply chain. Commitment to increasing battery recycling. Partnering with Everledger for Battery Passport.	Recycles up to 20 million pounds of aluminum monthly at certain facilities. Largest automotive aluminum recycler globally. Closed-loop recycling system in place for aluminum scrap. 75% of metals recycled in average vehicle (includes non-EVs)	Aim for 20% recycled and renewable plastics in new vehicles by 2025 (certain regions). 17% of plastics recycled in average vehicle (includes non-EVs).	85% overall (includes non-EVs). 4% of liquids.
General Motors	Joint venture with Lithion for a recycling plant to open in 2023, processing 7,500 metric tons of li-ion batteries annually. Collaboration with Cirba Solutions for component and battery recycling.	Agreement with U.S. Steel for providing steel that has 75% fewer emissions. Developing new alloys that allow increased recycled content.	Collaborating on chemical recycling of automotive shredder residue to recycle plastics from EOL vehicles. 24 million pounds of plastics recycled from vehicles (includes non-EVs).	Sold 750,000 units of remanufactured parts (9 million since 2013; includes non-EVs). 100% recyclable packaging by 2030.

Automaker	Battery Recycling	Metals Recycling	Plastics Recycling	Other Recycling
Hyundai	Establishing battery circulation system for recycling and reuse. Task force formed in 2022 for battery life cycle investment.	100% of waste metals from vehicle manufacturing process are recycled.	Replacing non-metals, such as plastic and glass, with biomaterials, and recycled products (door trims in EV models from recycled bottles).	82% recycling rate for end-of-life vehicles (includes non-EVs).
Mercedes-Benz	73% of returnable high-voltage lithium-ion batteries are being routed to remanufacturing for reuse in vehicles or for second life in energy storages.	Use of up to 70% recycled steel and up to 100% recycled aluminum for vehicle manufacturing.	Use of PET bottles and other recycled plastics in vehicle fabrics.	95% of materials in all cars and vans of up to 3.5 t gross vehicle weight can be reused or recovered.
Stellantis	Recycled 1.7 million parts including batteries in 2022. 69.3% recycling rate for Li-ion batteries in 2021.	Not Specific	Use of recycled products such as PET bottles in interior of new vehicles (non-EV specific).	All vehicles in EU are 95% recoverable and 85% recyclable (non-EV specific). SUSTAINera program to implement recycling of components and parts.
Tesla	100% recycling of on-site generated manufacturing scrap. No batteries from factory go to landfill. Development of recycling technology for nickel and iron-based cathodes.	In-house aluminum alloy research to add recycled inputs in more applications	Not Specific	90% of manufacturing waste recycled.
Toyota	Aim for closed-loop battery recycling by 2026. Collaboration with Redwood Materials for	Not Specific	Use of bio-based plastics in seat cushions for certain EV models.	

Automaker	Battery Recycling	Metals Recycling	Plastics Recycling	Other Recycling
	battery recycling in North Carolina plant.			
Volkswagen AG	Salzgitter, Germany battery pilot plant aims to reach 90% battery recycling rate; future closed-loop system at all battery plants.	Created Aluminum Closed Loop Project in 2017 that has now been implemented at four vehicle plants across the European Union.	All EV models utilize sustainable material for ceiling headliners, door trims, and decorative inlays.	Operate six battery factories in EU by 2030, each with closed-loop recycling.
Volvo	Partnership with Redwood Materials for battery recycling plant in California.	Aims to use up to 40% of recycled aluminum and 25% of recycled steel in new vehicles by 2025.	Aims to use up to 25% of recycled or bio-based plastics in new vehicles by 2025.	84% of production materials are recycled.

Each automaker listed in this table addressed battery, metals, and plastics recycling in more detail than other vehicle parts in their respective sustainability reports. Entries marked as "Not Specific" indicate areas where the automaker has not provided explicit details such as timelines, percentages, or other performance metrics related to recycling and recovery in their most recent company Sustainability Report.

Source: 2022-2023 Sustainability Reports of various automakers.

Automakers may be able to draw on existing models and experience to facilitate recycling of lithium-ion batteries, establishing more cost-effective designs and processes. Lead acid batteries have a high rate of recycling (around 99 percent), which offers a glimpse into what may be possible. EV batteries can be integrated directly into the vehicle body, however, and it is unclear if battery technology will advance enough to make it feasible to standardize on form factor, battery chemistry, and other facets that would make it possible to easily remove and recycle a vehicle's battery.

To deploy EVs at scale in the United States, automakers are leaning into cost-effective strategies like vertically integrating supply chains and strategically locating plants near both suppliers and recycling firms. For example, General Motors' Ultium Cells mega-factory, located in Warren, Ohio and co-located with Li-Cycle's recycling facility, will directly process scrap from the automaker's facility.

Similarly, reusing critical minerals from batteries already in the ecosystem can provide a more cost-effective way to scale up development and deployment of EVs for automakers, relative to sourcing new minerals. Toyota and Redwood Materials partnered in 2022 to create a sustainable, closed-loop battery ecosystem for the automaker's electric powertrains. This system will comprise both preemptive battery health screening and the collection of used batteries for recycling and reintroduction into Toyota's battery supply chain. Redwood has similar agreements in place with automakers Ford and Volvo, as well as battery maker Panasonic.

Opportunities & Challenges for EV Recycling

The EV battery recycling industry is still emerging with only five percent of lithium-ion batteries recycled in the United States in 2022. Despite challenges—including the costly transport of hazardous materials, inconsistent battery labeling, and the low value of some minerals, the sector holds considerable potential. McKinsey forecasts the global battery recycling sector to produce over $40 billion in revenue by 2040, highlighting the urgency for a domestic, coordinated supply chain.

Automakers are increasingly striving toward vertical integration of supply chains—with battery manufacturing at the forefront. This move to vertical integration can improve cost-effectiveness of EV manufacturing and give automakers greater certainty and control over the sustainability of EVs. This trend is a significant departure from the current landscape for vehicle and battery recycling and has major implications for the recycling sector. Automakers are grappling with ethical sourcing, maintaining quality control, and adapting manufacturing practices to accommodate for greater integration of recycled materials. Navigating this burgeoning landscape will require refinement of recycling technologies, working with regulatory bodies, and ensuring a steady stream of quality recycled materials. Crucially, it necessitates coordination with existing recycling industries as automakers approach the sector from a different angle.