



Electric Vehicle (EV) Battery Management Study

Final Report to the Legislature

Pursuant to Engrossed Second Substitute
Senate Bill 5144 (2023)

By

Peak Sustainability Group

For the

Solid Waste Management Program

Washington State Department of Ecology

Olympia, Washington

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Peak Sustainability Group Bellingham, WA
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Executive Summary

In 2023, the Washington State Legislature passed a bill creating a comprehensive battery stewardship program. Part of the bill required the Washington State Department of Ecology to research the management of electric vehicle batteries and provide the Legislature a preliminary report in November 2023 and a final report in April 2024.

The preliminary report focused on the findings of research, examples from other jurisdictions, and identified areas for further inquiry. The preliminary report also summarized initial stakeholder input. This final report incorporates information on additional engagement efforts that happened in January 2024 to develop recommendations and identify priorities for further action.

The Electric Vehicle (EV) Battery Management Study Final Report to the Legislature reiterates research findings and examples from other jurisdictions, and identifies remaining questions related to EV battery management. The report addresses critical questions related to end-of-life pathways for EV batteries, volume projections of end-of-life EV batteries, relevant regulations, economic implications, and considerations pertaining to battery chemistry. These findings are summarized into emerging themes. Research was conducted through a combination of literature reviews, case studies, and stakeholder engagement efforts, including interviews, webinars, and an online survey.

In the first six months of 2023, 18% of vehicles sold in Washington state were EVs, making Washington state one of the leaders in EV adoption in the U.S. As existing EVs age, the number of EV batteries reaching end-of-life will increase in Washington. This final report shares findings regarding the various pathways EV batteries take when they no longer function within a vehicle and discusses the factors that determine what happens to EV batteries.

This final report identifies three immediate priorities for Washington state.

1. **Provide training, education, and resources to first responders, second responders, and automotive recyclers.** This report recommends creating a clearing house that can assess, consolidate, and distill existing resources and information for dissemination to relevant stakeholders.
2. **Determine who should have financial responsibility and liability for EV batteries.** Emerging policy solutions from other states include an extended producer responsibility (EPR) scheme and a core exchange program with producer take back.
3. **Form a Washington State EV Battery Management Task Force (Task Force) with a broad set of stakeholders to address mid- and long-term policy needs.** This report includes an expanded list of potential stakeholders that could make up the Task Force, as suggested by participants in this study effort. The Task Force could provide balanced engagement on policies to address financial responsibility and liability. Finally, the proposed Task Force could help Washington continue to adapt to a rapidly evolving EV battery landscape.

The growing market share of EVs will require a system of management that fosters innovation, moves forward state climate change goals, promotes responsible product stewardship, and supports safety for communities and the environment.

Introduction

Legislative directive

In 2023, the Legislature adopted [Engrossed Second Substitute Senate Bill 5144](#)³ (ESSB 5144) to provide for responsible environmental management of batteries and support a battery stewardship program. Section 17 of the bill (excerpted below) directed the Washington State Department of Ecology (Ecology) to research the management of electric vehicle (EV) batteries, conduct stakeholder engagement, and provide recommendations for EV battery management via a preliminary legislative report in November 2023 and a final report in April 2024.

*NEW SECTION. **Sec. 17. DEPARTMENT OF ECOLOGY RECOMMENDATIONS FOR MANAGEMENT OF ELECTRIC VEHICLE BATTERIES.***

(1) By November 30, 2023, the department of ecology must submit a report to the appropriate committees of the legislature on preliminary policy recommendations for the collection and management of electric vehicle batteries. By April 30, 2024, the department of ecology must report to the appropriate committees of the legislature on final policy recommendations for the collection and management of electric vehicle batteries.

(2) In developing the recommendations under subsection (1) of this section, the department of ecology must:

(a) Solicit input from representatives of automotive wrecking and salvage yards, solid waste collection and processing companies, local governments, environmental organizations, electric vehicle manufacturers, and any other interested parties; and

(b) Examine best practices in other states and jurisdictions.

Ecology hired a lead consultant and two supporting consultant groups to conduct EV battery research and stakeholder engagement, as well as develop policy recommendations for the Legislature’s consideration. The lead consulting group is Peak Sustainability Group, with GDS and Stikeen Strategies working as sub-consultants. All together, these three consultant groups will be referred to as “the consultant team.” This final legislative report summarizes their research findings and policy recommendations for EV battery management.

Terms used in this report

The following provides context for terms used in this report.

“Electric vehicle (EV)”

In this report, an EV is defined as a vehicle that can be powered by an electric motor that draws electricity from a battery and is capable of being charged from an external source.⁴ An EV

³ [https://lawfilesext.leg.wa.gov/biennium/2023-24/Pdf/Bills/Session Laws/Senate/5144-.pdf?q=20231003145449](https://lawfilesext.leg.wa.gov/biennium/2023-24/Pdf/Bills/Session%20Laws/Senate/5144-.pdf?q=20231003145449).

⁴ <https://afdc.energy.gov/laws/12660#:~:text=An%20EV%20is%20defined%20as,charged%20from%20an%20external%20source.>

includes both a vehicle that can be powered only by an electric motor that draws electricity from a battery (all-electric vehicle) and a vehicle that can be powered by an electric motor that draws electricity from a battery and by an internal combustion engine (plug-in hybrid electric vehicle – PHEV). For the purposes of this report, ‘vehicle’ is limited to a means of transportation on roads.

“End-of-life (EOL)”

When referring to EV batteries in this report, the term “end-of-life” is defined as the moment when a battery reaches the end of its usefulness and/or lifespan, as originally manufactured, in an EV.

Many other technical terms are used in this report, some of which may be new to reviewers. Key definitions associated with this report are found in Appendix A, and acronyms are listed in Appendix B.

EV battery supply chain and lifecycle

The supply chain and lifecycle of EV batteries is important to understand because decisions made at various points in that cycle affect the management of EV batteries at their end-of-life. A high-level overview of the life cycle of EV batteries includes the following steps:

Step one: product design

EV batteries are designed for use in an electric vehicle, usually for a specific make and model of car. This design process can affect the following steps depending on battery chemistry, other constituent materials, and the manufacturing process.

Step two: mining for a battery’s active materials

An EV battery’s constituent active materials (materials used for the exchange of ions to discharge and charge the battery) are first mined. Different battery chemistries have differing active materials including lithium, cobalt, nickel, iron, graphite, and more. Each of these minerals are mined in different regions across the world. As an alternative to mining for these materials, there is a growing interest in recovering materials from used batteries and recycling them for reuse in battery manufacturing.

Step three: material processing and refining

After mining or recovering the needed materials, an EV battery’s constituent materials are processed and refined. Much of this processing occurred in China until the federal government passed the Inflation Reduction Act (IRA). The IRA provides investment and growth in the U.S. battery market.

Step four: product manufacturing

An EV battery’s constituent materials are manufactured into the final functioning battery that is ready to be put to its intended use powering an electric vehicle.

Step five: product installation and use

Auto manufacturers install EV batteries into electric vehicles before the electric vehicle is put on the market and sold to a driver. The EV lives out its first life on the road, powering the vehicle as intended. EV batteries may require periodic maintenance and service by dealerships during the warranty period and may involve private or do-it-yourself repair after the warranty expires.

Step six: battery removal

A battery's first life ends when it is removed from its original EV for any reason, including removal when the battery no longer functions as intended in the EV vehicle, or damage from a collision, fire, or flood. Training and special equipment is required for the removal of an EV battery, as they can weigh over 1000 pounds. Steps six through eight are considered an EV battery's 'end-of-life' for the purposes of this study and report.

Step seven: end of first life battery repair, resale, reuse, repurposing, possible storage, and stockpiling

After a battery is removed from the original vehicle, it may be transported to a subsequent owner, or it may be stored or stockpiled before a second life. Resale after repair (if necessary) can lead to reuse in other EVs, EV conversions, and/or repurposing in non-EV applications, such as grid storage systems⁵.

Step eight: recycling, disposal, and abandonment

Ultimately, an EV battery is recycled, or in some cases disposed of or abandoned.

Evolution of EVs and EV batteries

It is helpful to understand the evolution of EVs and EV batteries to underpin the information in this report. This section provides a brief overview of the history of EVs and EV batteries up to this point.

A brief history of EVs

Electric vehicles date back to the 1830s, with the introduction of rechargeable batteries in the 1850s. Except for a brief experiment with EVs in the 1990's, commercially available EVs have not been part of the automobile marketplace until relatively recently. With the growing understanding of climate change and the recognition that EVs are cost effective alternatives to cars with internal combustion motors, EV sales are rapidly expanding in many parts of the country. Washington state is one of the leaders in EV adoption.

Battery technology has evolved rapidly since 2010 with different battery chemistries and formats. High-capacity manufacturing has boosted battery availability. Battery chemistries are evolving as well, resulting in batteries that contain less materials like cobalt and nickel that are problematic to secure and process. Both of these factors are reducing costs, which is key to ramping up EV production.

Commercial car companies are investing billions of dollars in U.S. production sites following the federal investment in EV batteries from the Inflation Reduction Act (IRA). The IRA prioritizes U.S. production of batteries. It also prioritizes mineral sourcing and processing from allied countries. Production of batteries in the U.S. is highly dependent on sources of recycled materials. Battery recycling companies operating in the U.S. currently receive the bulk of their recycled materials from battery original equipment manufacture's (OEM's) scrap.

⁵ U.S. Department of Energy: Battery Storage: <https://www.energy.gov/eere/vehicles/battery-policies-and-incentives-search>.

EV Battery Management Study Overview

As directed by Section 17 of [Engrossed Second Substitute Bill 5144](#)⁶ (E2SSB 5144) and Ecology, the consultant team focused the EV Battery Management Study (the Study) on:

- Gathering information about current EV battery management practices in Washington and other jurisdictions.
- Engaging with stakeholders (i.e., automotive recyclers, solid waste companies, battery recyclers, local governments, environmental organizations, electric vehicle manufacturers, and others) to gather further information on the management of EV batteries in Washington.
- Developing policy recommendations on EV battery management for the Washington State Legislature.

These tasks informed this final report to the Legislature, which covers the Study process, current findings, emerging themes, key knowledge gaps, and policy recommendations regarding EV battery management in Washington state.

Key questions

The consultant team was asked to conduct a literature review and engage with stakeholders to answer the following key questions about EV battery management in Washington state and other jurisdictions.

Volume and projections

- What is the estimated volume of EV batteries currently being collected in Washington?
- What is the ten-year projection for EV batteries requiring end-of-life management?

Regulations

- What regulations govern the collection, transportation, storage, processing, and recycling of EV batteries in Washington state?

Common post-first-life and end-of-life pathways

- What second-life use-cases exist for EV batteries?
- What are the common pathways for EV batteries at their end-of-life?
- What happens to EV batteries after they are collected?
- Where are EV batteries stored or stockpiled once they are removed from vehicles?
- At what facilities might EV battery storage occur?

⁶ [https://lawfilesexternal.wa.gov/biennium/2023-24/Pdf/Bills/Session Laws/Senate/5144- S2.SL.pdf?q=20230525111908](https://lawfilesexternal.wa.gov/biennium/2023-24/Pdf/Bills/Session%20Laws/Senate/5144-S2.SL.pdf?q=20230525111908).

Economics of battery management

- What is the financial landscape surrounding EV batteries?
- Are there existing programs that provide funding or incentives for EV battery management?

Battery chemistry and value

- What characteristics and values are associated with the most common EV battery chemistries?

Literature review methodology

The literature review conducted by the consultant team played a critical role in answering the key questions stated in the section above. The literature review process and steps included:

- Searching existing articles, academic research papers, industry reports, governmental publications, online databases, and business websites to gather information on the current system for collecting and managing EV batteries. The search included, but was not limited to, regulations, policies, and guidelines that apply throughout the battery lifecycle. The consultant team tried to be as comprehensive as possible to ensure that all relevant studies, published and unpublished, are included in the review.
- Screening the sources (literature, papers, reports, and publications) to determine their relevance to the key questions. The researchers devised a set of guidelines to include or exclude certain sources to avoid biases.
- Extracting applicable information from each source and determining its relevance to the key questions.
- Synthesizing information by summarizing, organizing, and comparing details across various sources.

The consultant team leveraged industry connections to conduct a comprehensive and exhaustive literature review on the current system for collecting and managing EV batteries. Case studies from other states, jurisdictions, and industry leaders were collected and analyzed to identify successful EV battery collection and management best practices, approaches, policies, infrastructure, and programs. The literature review findings were used to describe current knowledge of key activities and outcomes related to EV battery management.

Stakeholder process and participation

The consultant team solicited input from representatives of automotive wrecking and salvage yards, solid waste collection and processing companies, local governments, environmental organizations, electric vehicle manufacturers, and any other interested parties. The consultant team engaged stakeholders throughout the Study using the methods outlined on the following page.

Project web page

Ecology created a [EV Battery Management Study](#)⁷ webpage for information and stakeholder engagement opportunities related to the Study. The webpage provides an overview of the Study, along with dates, details, links, and contact information for stakeholder engagement opportunities.

Stakeholder outreach

The consultant team sent email invitations to representatives of over one hundred potentially interested stakeholder groups and organizations to invite them to participate in interviews, a survey, and two webinars. The invitation also encouraged contacts to invite any other interested parties into the Study process.

Participating stakeholders

The consultant team obtained input from a variety of potentially interested parties, including:

- Representatives from the auto recycling and metal recycling sectors
- State government staff in energy policy, hazardous waste, and economic development
- Washington city and county representatives, including those focused on solid waste management
- Companies that directly recycle EV batteries or collect and transport them for recycling
- Companies that recycle non-EV batteries
- Washington state first responders and their representatives
- Representatives for EV automakers
- Battery original equipment manufacturers (OEMs)
- Participants in the EV battery reuse market
- EV policy advocacy organizations
- Environmental advocacy organizations

Interviews

The consultant team conducted interviews that informed the literature review, answered key questions, and identified knowledge gaps related to EV battery management. Example interview questions can be found in Appendix G.

Webinars

The consultant team conducted two webinars to gather stakeholder input and fill key gaps in the research. One webinar was held on Tuesday, September 26, 2023, to gather information from participants holding key knowledge on the collection, management, and transportation of EV batteries. Attendees were asked questions related to the collection and management of EV batteries and had the opportunity to share their perspectives.

A second webinar was held on Thursday, September 28, 2023, for stakeholders impacted by an EV battery management system or were interested in sharing their priority outcomes of an EV battery

⁷ <https://ecology.wa.gov/waste-toxics/reducing-recycling-waste/our-recycling-programs/battery-stewardship>.

management system. Attendees were asked questions related to their knowledge and priorities for the collection and management of EV batteries in Washington state.

See Appendix D for webinar meeting summaries.

Policy Advisory Group

In January 2024, the consultant team invited representatives from 14 stakeholder organizations to attend two Policy Advisory Group (Group) meetings to inform the policy recommendations included in this final report. The first Group meeting was held on Thursday, January 4, 2024, and focused on identifying and developing key immediate policy priorities, including stakeholders to be included on an EV battery management task force and education and training for first responders, second responders, and auto recyclers. The Group also ranked and gave feedback on mid- and long-term policy priorities at the state and federal levels. A brief survey was sent out to the Group after the first meeting to ensure that all perspectives were gathered on policy priorities and inform the content of the second meeting.

Another Group meeting was held on January 31, 2024, which focused on clarifying potential immediate policy priorities with mixed support and discussing financial responsibility of EV batteries after their first life. Current bills and policies in other jurisdictions with broad support were also identified. These conversations helped clarify the recommendations presented in this report. After the second meeting, participants were given ten days to follow up with feedback, other considerations, and clarifications on the meeting notes, which were sent out to the Group.

See Appendix E for detailed summaries of the Policy Advisory Group meetings.

Survey

The consultant team designed and administered a survey to gather information to answer key questions on EV battery management and feedback on potential policies in Washington state. The deadline to provide input for inclusion in the final legislative report was January 31, 2024.

See Appendix F for a summary of survey results and Appendix H for example survey questions.

Email list

Ecology created an email list for the EV Battery Management Study and the greater implementation of the battery stewardship law. To receive updates on the battery stewardship program, [please sign up for our email list](#).⁸

⁸ https://public.govdelivery.com/accounts/WAECY/subscriber/new?topic_id=WAECY_303.

Findings: Literature Review

This section presents the results of the consultant team’s comprehensive literature review on the current system for collecting and managing EV batteries. The findings below provide information on the key questions laid out in the EV Battery Management Study Overview section earlier in this report. Each section addresses a theme related to EV battery management and provides a summary of key takeaways, an overview of findings to date, and remaining knowledge gaps.

Volume and projections

This section of the literature review provides preliminary findings on the current volume of EV batteries reaching end-of-life (EOL), as well as projections for the future. Factors that contribute to EOL EV battery projections are also discussed. Existing knowledge gaps are covered at the end of the section. This section is guided by the following questions:

- What is the estimated volume of EV batteries currently being collected in Washington?
- What is the ten-year projection for EV batteries requiring EOL management?

Key takeaways

- As of July 2023, there are 104,050 all-electric vehicles registered within Washington.
- The volume of EVs is increasing exponentially in WA.
- Currently, most EV batteries are under warranty in their original vehicle.
- Knowledge gaps make it difficult to estimate the number of EOL EV batteries currently collected in Washington and, therefore, it is challenging to project what that number will be in 10 years.
- Batteries may be reused or repurposed for 15-18 years after their use in their original vehicle, which could delay when they need to be recycled or disposed.
- Industry is investing in domestic recycling sites to manage projected future increases in EOL EV batteries, based on the growing market share of EVs and the demand for materials to create new batteries.

Findings to date

There are multiple factors to consider when estimating the number and type of EV batteries that are being recycled or disposed of in Washington state now and in the next ten years. The unknowns in some of these factors make volume estimates difficult. The following factors that influence volume estimates are discussed:

- The current number of EVs in Washington state.

- Projected EV sales volumes in Washington state.
- The length of time that EV batteries remain in the original vehicle.
- EV battery second and third life.

The number of EVs in Washington state

The Washington Department of Licensing⁹ tracks the number of EVs registered in Washington state. As of July 2023, there are 104,050 all-electric vehicles registered within Washington. The majority of EVs on the road will continue to be newer vehicles until the market reaches maturity. Using this number and EV sales forecasts, it is possible to estimate the number of future EVs in Washington. Figure 1¹⁰ below shows that of all EVs on the road in Washington, the greatest number are from model years 2021, 2022, and 2023, illustrating that most EVs on the road are newer vehicles.

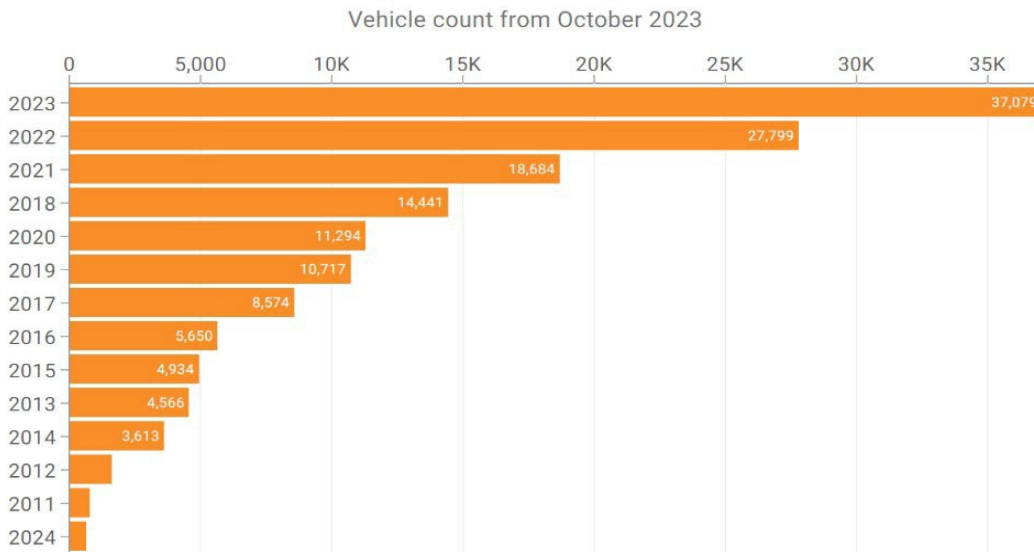


Figure 1. Washington EV population by model year.

Projected EV sales volumes in Washington state

Figure 2¹¹ shows the predicted exponential growth of EV sales globally. The market share of EVs is increasing in Washington and across the country. In the first half of 2023, EVs were 18% of new car sales in Washington. Large OEMs are investing in EVs to offer mainstream consumers a wide array of EV choices. Shifts in the auto market contribute to the growth seen in the EV market share, but there is a large amount of uncertainty. The draft Washington State Transportation Electrification Strategy projects that by 2035, the number of plug-in EVs in Washington state could range from 1.8 million to 3.8 million EVs.¹²

⁹ <https://data.wa.gov/Transportation/Electric-Vehicle-Population-Data/f6w7-q2d2>.

¹⁰ <https://data.wa.gov/d/f6w7-q2d2/visualization>.

¹¹ IEA, <https://rmi.org/insight/x-change-cars>.

¹² Draft Washington State Transportation Electrification Strategy, pg. 55.

<https://deptofcommerce.app.box.com/s/1ydxw10qsnygn3gosz5en75zxsj6ps05>

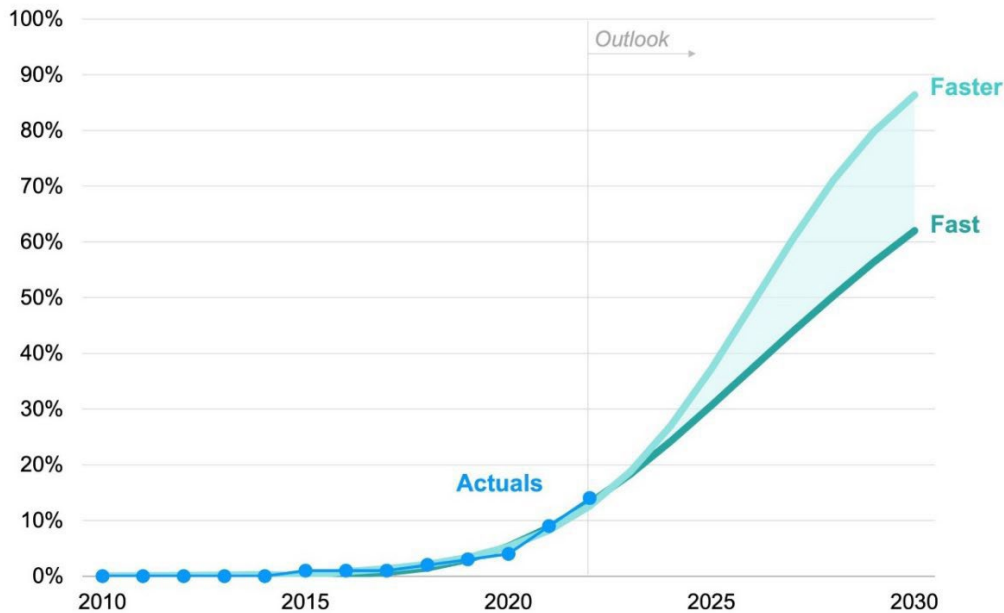


Figure 2. Rocky Mountain Institute’s global EV sales projections.

The length of time that EV batteries remain in the original vehicle

It is difficult to know when the projected number of EV batteries in Washington will require end-of-life management because there is uncertainty about how long EV batteries typically remain in their original vehicle. Figure 3¹³ show that on average, EV batteries are covered under warranty 8-10 years, but that they may remain in the original vehicle much longer. It is also difficult to know how long an EV battery may continue to be used in its second or third life.

Global EV battery data indicates that EV batteries last on average 15-18 years before vehicle end-of-life, with many batteries lasting up to 21 years in the original vehicle.¹⁴ OEMs and companies that specialize in refurbishing batteries are extending the life of battery packs. Battery technology has advanced over the last decade to extend battery life. For example, modern lithium iron phosphate (LFP) batteries, which may replace lithium-ion technologies, may last up to twenty years.

Incidents such as collisions, fires, or floods may shorten the time that an EV battery remains in the original vehicle. In cases where the battery is damaged in the incident, the battery may be recycled or disposed. The consultant team researched the rate of EV incidents in Washington, but the number is unknown.

¹³ Call2Recycle. <https://www.call2recycle.org/>.

¹⁴ Circular Energy Storage – at 7:18 of the video, Hans Eric Melin, November 4, 2021, <https://youtu.be/czwuxBnPIGY>.

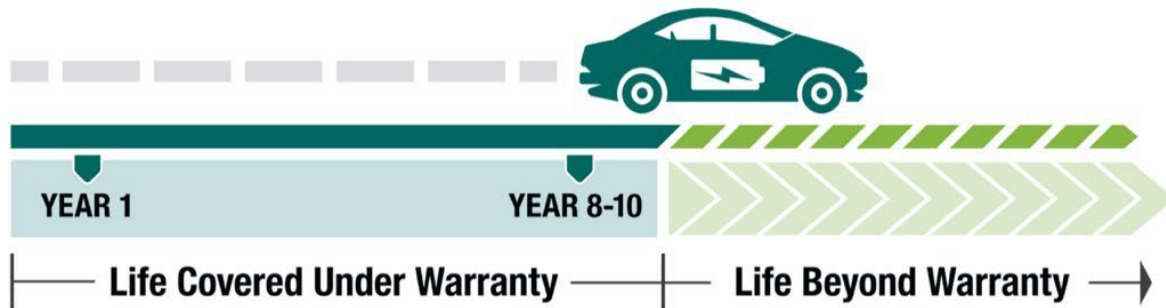


Figure 3. Full first life of an EV Battery generally lasts beyond warranty.

EV battery second and third life

After use in the original vehicle, EV batteries may have a second, and, in some cases, a third life. The market for battery reuse includes reuse in other vehicles, repurposed for use in boats and RVs, or used as stationary grid storage. The number of EV batteries being reused and repurposed is difficult to estimate because these pathways occur in a distributed system that involves many stakeholders.

There is a do-it-yourself (DIY) community within Washington state that reuses EV batteries for EV conversions and other purposes. In EV conversions, an internal combustion engine (ICE) vehicle is modified to become an electric vehicle. The DIY community purchases EV batteries from insurance auctions either within Washington state or from auction sites in other regions of the United States. These batteries are generally being auctioned while still part of a vehicle, and in cases where they are purchased from other regions in the United States, they are shipped to Washington state. The Seattle EV Association (SEVA)¹⁵ is an example of an organization that has connections to the DIY community within Washington state. The number of EV batteries in Washington state used by the DIY community is unknown.

Several companies are developing energy storage systems using post-first life EV batteries. The state of California offers incentives to this emerging industry via the California Energy Commission (CEC). EV batteries used for energy storage systems may have a second or third life that lasts 5-20 years. While the number of batteries entering second and third life is not known, there is demand for these batteries. Figure 4¹⁶ shows how EV battery packs can be repurposed for grid energy storage.

¹⁵ Seattle EV Association (SEVA), <https://www.seattleeva.org/wp/>.

¹⁶ <https://www.b2uco.com/technology>.



Figure 4. B2U’s UL certified EV Pack Storage (EPS) System enables the use of EV battery packs without reconfiguration in large scale energy storage.

Nationally, the amount of EV batteries entering the recycling market is expected to exceed recycling capacity around 2044 (Figure 5¹⁷). The volume of lithium-ion batteries (LIBs) entering and exiting Washington’s salvage, recycling, and reuse sector is increasing every year. There is active debate about when or if the EV battery reuse and repurposing market will reach saturation. The capacity of this market adds another unknown in understanding when EV batteries will need to be recycled or disposed. If the market continues to expand, most EV batteries may have an extended life prior to being recycled or disposed. The projections of when there will be a significant volume end-of-life batteries to manage in Washington will be influenced by this market.

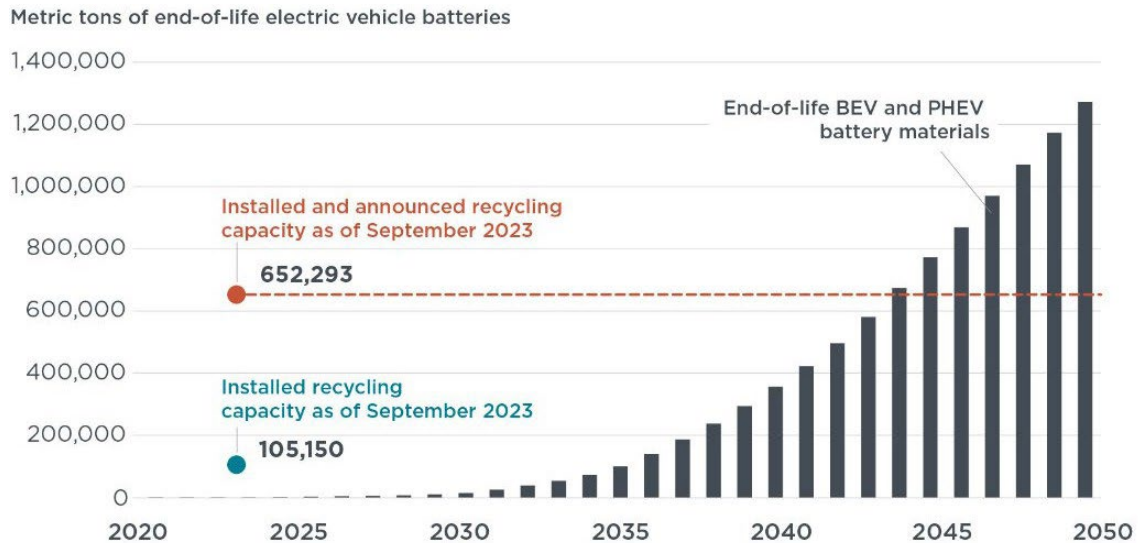


Figure 5. Recycling capacity versus projected end-of-life EV battery materials in the U.S.

¹⁷ <https://theicct.org/us-ev-battery-recycling-end-of-life-batteries-sept23/>.

Knowledge gaps

- What is the estimated volume of EV batteries currently being collected in Washington?
- What is the ten-year projection for EV batteries requiring end-of-life management?
- What is the number of EV batteries reaching end-of-life due to vehicle incidents?
- What volume of EV batteries have a second and third life in Washington state?
- How long do second and third lives for EV batteries typically last?
- What is the capacity of the reuse and repurposing market in Washington state?

Regulations

This section of the literature review provides information on current regulations that apply to end-of-life EV batteries and related processes. The storage, management, and transportation of EV batteries in Washington is controlled by a system of state and federal laws and regulations. State and federal regulatory mechanisms are summarized, highlighting some challenges with the current management system. Existing knowledge gaps are covered at the end of the section. This section is guided by the following question.

- What regulations govern the collection, transportation, storage, processing, and recycling of EV batteries in Washington state?

Key takeaways

- EV batteries are regulated by a combination of state and federal transportation regulations, fire codes, and waste regulations.
- An EV battery removed from the original vehicle in Washington may be classified as a “product” if it will be directly reused as-is (no processing before reuse). Otherwise, the battery is a waste that must be designated in accordance with Chapter 173-303 Washington Administrative Code (WAC).
- Reused “product” batteries are not regulated under Chapter 173-303 WAC unless the reused battery is determined to be waste.
- Waste EV batteries are regulated in Washington as universal waste and may be managed under the dangerous waste regulations. Washington’s universal waste regulations are broader in scope than the federal Resource Conservation and Recovery Act (RCRA) regulations because some batteries may designate as state-only dangerous waste. This means some battery chemistries will be subject to regulation in Washington, but not hazardous waste at the federal level.

Findings to date

The State of Washington regulates the transport, storage, and disposal of batteries through a combination of transportation regulations, fire codes, building codes, and waste regulations. State and federal regulations also address all batteries as waste material. However, the regulations do not specifically, address lithium-ion EV batteries.

A summary table of state and federal regulations pertaining to the management of EV batteries is provided in Appendix C. The sections below discuss the state and federal regulations influencing the management of EV batteries.

Federal regulation of batteries as universal waste

The U.S. Environmental Protection Agency (EPA) allows all batteries destined for recycling to be managed as universal waste, as defined in 40 C.F.R. part 273. The EPA determined that most lithium-ion batteries (LIBs) on the market today are likely to be hazardous waste when they are disposed due to their ignitability and reactivity characteristics. Although EV batteries meet the regulatory definition of hazardous waste, most businesses will likely manage them under a “streamlined” set of universal waste rules.

The U.S. EPA also states that an EV battery can be evaluated and determined to be a product, rather than waste if there is a “reasonable expectation of reuse”¹⁸ when evaluated by an electronic waste reverse logistics provider. The requirements for handlers of universal waste allow certain management activities, such as sorting and mixing batteries. The disassembly of a battery pack into individual modules or cells with no damage done to the cell casing does not make a battery damaged or defective.

On October 23, 2023, [EPA announced a new rulemaking](#)¹⁹ effort to improve the recycling and management of lithium batteries, including lithium-ion batteries. EPA is developing a proposed rule to add specific universal waste standards for lithium batteries, which may impact EV battery management.

Federal regulations pertaining to the transportation of batteries

Transportation of EV LIBs is regulated by the U.S. Department of Transportation (DOT) as a Class 9 (“Miscellaneous”) hazardous material. The packaging and shipping of LIBs must meet specific requirements. Lithium cells or batteries, including those packed with or contained in equipment, must be packaged in a manner to prevent short circuits, damage caused by shifting or placement within the package, and accidental activation of the equipment. The shipping and packing requirements are more stringent for damaged batteries than those that are still functional. Auto sellers, scrap processors, dismantlers, and disassemblers are responsible for ensuring that the transportation and shipping of EV batteries follows DOT regulations.

Transportation of used or scrap vehicles

The Washington Motor Vehicle law requires any entity handling or transporting used or scrap vehicles to comply with Title 46 of the Revised Code of Washington (RCW). Motor vehicle transporters, hulk haulers, scrap processors, and vehicle wreckers operating in Washington state must maintain a valid license.

Washington State Fire Code

The 2021 Washington State Fire Code addresses the hazards associated with the use of lithium-ion and lithium-metal batteries. Retired batteries must be stored in compliance with the Washington

¹⁸ <https://www.epa.gov/hw/lithium-ion-battery-recycling-frequently-asked-questions>

¹⁹ <https://www.epa.gov/hw/improving-recycling-and-management-renewable-energy-wastes-universal-waste-regulations-solar>

state fire codes. New code language adopted from the 2024 International Fire Code (IFC), regulates the storage of LIBs. The fire codes include guidelines for permitting, fire safety plans, indoor and outdoor storage, construction requirements, fire protection systems, explosion control, and reduced requirements for the storage of partially charged batteries. In addition, the National Fire Protection Association provides standards that define the requirements for operation, maintenance, and decommissioning of stationary energy storage systems, which are a possible post-first life application of EV batteries.

Washington state dangerous waste regulations

Ecology sets forth the Dangerous Waste Regulations in Chapter 173-303 WAC. EV batteries removed from vehicles and reused as products aren't solid waste and therefore aren't dangerous waste. Once a person determines an EV battery no longer serves its intended purpose and it will be discarded (or recycled), the EV battery is a spent material²⁰ and a solid waste²¹. Additional information about how batteries can be managed under Chapter 173-303 WAC is available on Ecology's website²².

Most battery chemistries, including LIBs, meet the definition of dangerous waste (e.g. reactive, ignitable, and/or state-only solid corrosive and toxic). In most cases, spent EV batteries may be managed under Washington's universal waste regulations. These regulations do not address EV batteries specifically, but EV batteries meet the definition of a battery.

Washington's universal waste regulations are broader in scope than the federal Resource Conservation and Recovery Act (RCRA) universal waste regulations in 40 CFR 273. As a result, some batteries may designate as state-only dangerous waste, due to toxicity criteria, or as corrosive solids. This means some battery chemistries will be subject to regulation in Washington that are not regulated as hazardous waste at the federal level.

Businesses must evaluate batteries and determine whether to manage the battery as fully regulated dangerous waste or under the streamlined universal waste regulations. Most EV batteries are managed as universal waste. Universal waste handlers²³ must properly contain batteries that show signs of damage and must contain any releases. Handlers must determine whether any material resulting from a release is dangerous waste, and if so, must manage the released material in compliance with all applicable requirements. Strict storage time limits, disposal, and shipping requirements apply to management of batteries designated as dangerous waste.

Insights into the application of Washington state regulations and codes

Interviews, survey results, and webinars with EV battery stakeholders suggest that training is needed to clarify and provide guidance on Washington state's dangerous waste regulations. Confusion exists on how to identify a damaged EV battery and how to comply with U.S. DOT shipping regulations. Stakeholders also emphasized the need for guidance, resources, and funding to train first responders

²⁰ As defined in WAC 173-303-040

²¹ WAC 173-303-016

²² <https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Dangerous-waste-guidance/Common-dangerous-waste/Batteries>

²³ As defined in WAC 173-303-040

on EV battery assessment, collection, transport, and disposal at the scene of an accident or following an incident (fire, flood, etc.).

Knowledge gaps

- How can damage to end-of-life EV batteries be assessed to classify a given EV battery as ‘waste’ or a ‘product’?
- What are the characteristics that indicate that a battery is no longer able to serve its intended purpose and is therefore designated as waste?
- To what degree do the existing regulations impact the feasibility of the reuse, repurposing, and recycling of EV batteries?
- How might the existing regulations prevent or promote the abandonment of an end-of-life EV LIB?
- How might battery chemistry influence the demand for revised policies that redefine a ‘battery’ and specify regulations and guidelines unique to specific battery chemistries?

Common post-first-life applications and end-of-life pathways

This section of the literature review provides preliminary findings on the current management of EV batteries reaching end-of-life in Washington state, as well as applications for post first life EV batteries. Factors that contribute to these end-of-life pathways are also discussed. Existing knowledge gaps are covered at the end of the section. This section is guided by the following questions:

- What second-life use-cases exist for EV batteries?
- What are the common pathways for EV batteries at their end-of-life?
- What happens to EV batteries after they are collected?
- Where are EV batteries stored or stockpiled once they are removed from vehicles?
- At what facilities might storage occur?

Key takeaways

- There are two major pathways for EV batteries at their end-of-life which are determined by whether the battery is managed by the original equipment manufacturer (OEM) network and what initiates the end-of- life.
- Most EV batteries are currently under warranty, and OEMs are responsible for their proper recycling, reuse, and repurposing.
- The demand for EV battery reuse and repurposing exceeds supply, which means that a strong market exists for EV batteries that are out-of-warranty and EVs that are damaged through collision, flood, fire, and other incidents.
- EV batteries cannot be removed easily by non-skilled labor or abandoned easily due to their size and weight.

- Maintaining economic viability for the auto recycling industry is important because safe dismantling of internal combustion engine (ICE) vehicles and their hazardous components or materials at end-of-life needs to continue for decades. This industry can serve an important role as EVs reach end-of-life in larger numbers in Washington state.
- Changes in policies, regulations, battery chemistry mix, cost of transportation, cost of recycling, and market value of critical minerals could at any time create a situation where EV batteries reach a negative value. Abandonment could become more common.

Findings to date

As Washington begins to have more EV batteries reaching the end of their first life, multiple entities will be involved in moving batteries into their next life cycle stage. According to the National Renewable Energy Laboratory, a new EV battery's life cycle is 12-15 years. The same battery's reuse lifetime ranges from 5-30 years depending on how it is used.²⁴ This section first describes common pathways for EV batteries at their end-of-life, which includes information on the second-life use-cases and what happens once EV batteries are collected. This is followed by a discussion of transportation and storage, which affect all pathways.

Pathways

Many factors determine the future of used EV batteries within and beyond Washington state. This report describes two major pathways that are defined by who manages the battery: the dealership and vehicle OEM network, or the vehicle or battery owner. There are four broad categories of events that initiate an EV battery's entry into the two major pathways, which are described below. After discussing each path and the entry ways to these paths, battery cessation is discussed. For the purposes of this report, battery cessation is when a battery's pathway ends in recycling, disposal, or abandonment.

- Pathway 1: Dealership and OEM Network
- Pathway 2: Outside of Dealership and OEM Network

The two pathways share steps, split, and converge (Figure 6). The information presented here is a simplification and differences exist between OEMs. A battery that is out-of-warranty can enter either of the major pathways. Export outside the U.S. is an exit from the major pathways and is not considered part of battery cessation in this report.

²⁴ Kelleher Environmental, Gracestone Inc, & Millette Environmental. (2019). Research study on reuse and recycling of batteries employed in electric vehicles: The technical, environmental, economic, energy, and cost implications of reusing and recycling EV batteries. September 2019. <https://www.api.org>.

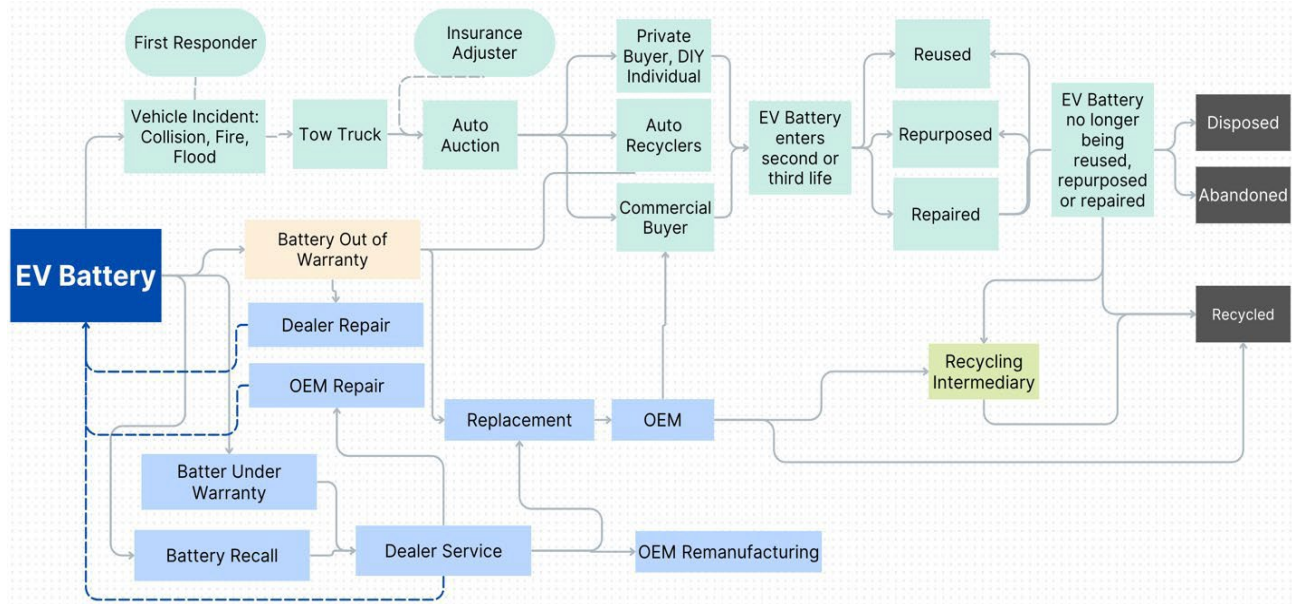


Figure 6. Overview of potential end-of-life pathways for EV batteries.

Pathway 1. Dealership and OEM network

Vehicle manufacturers are responsible for EV batteries under warranty. Warranty regulations and programs require vehicle manufacturers to properly reuse, repurpose, or recycle an end-of-life EV battery that is under warranty and removed from a car. In some instances, the dealership or OEM network will accept out-of-warranty batteries.

OEM warranty and redeployment of used LIBs

Federal regulation in the U.S. mandates that electric car batteries be covered by warranty for a minimum of eight years and 100,000 miles. “Some automakers only cover (warranty) an EV’s battery pack against a complete failure, while automakers like Tesla, Nissan and Volkswagen will honor the warranty if the capacity percentage drops below a specified threshold, typically 60-70 percent, during the warranty period.”²⁵ The benchmark for state of health proposed by the California Air Resources Board is 80% when compared to the battery’s original capacity. These warranted batteries generally get returned to the OEM via a dealership or service center.

A dealership or OEM service center may be able to repair a battery under warranty. When the EV battery is not repaired, the battery is generally replaced with a new battery. Auto dealers work closely with their respective OEMs to return EV batteries if there is an issue with the battery that requires it to be removed. Batteries spend minimal time at an OEM service center or dealership before transport back to the OEM. Some dealerships wait to remove a battery from a vehicle until the replacement arrives from the OEM.

²⁵ Nicholas, D. (2023.) EV battery warranties and exclusions. GreenCars. June 2023.

<https://www.greencars.com/greencars-101/ev-battery-warranties-and-exclusions#:~:text=EV%20Battery%20Warranties%3A%20Manufacturer%20Coverage,a%20minimum%20of%20eight%20years.>

When the EV battery is returned to the OEM, it may be remanufactured, recycled, or sold where it may enter second-life use-cases. Remanufacturing is when entities replace EV battery parts, such as modules or cells, and the remanufactured battery can be put back in a vehicle. These processes may be carried out by a company other than the OEM.

Spiers New Technologies remanufactures, repurposes, and recycles battery packs for approximately 65% of the non-Tesla OEMs including Ford, GM, Nissan, Porsche, Toyota, VW, and Volvo. “As many as 2,000 battery packs are shipped monthly into the company’s Oklahoma City facility, where they are assessed and rehabilitated or put to a new purpose.” Additional facilities exist in Los Angeles and Detroit, but not Washington state. According to the owner, Dirk Spiers, “80-90% can be refurbished and returned to a vehicle, 5-10% will be recycled, and the remaining batteries [are] repurposed.”²⁶ These percentages may vary depending on each manufacturer’s procedures and practices for rehabilitation.

Recalls by OEMs

Recurrent Auto estimates the EV battery failure rate is approximately 1.5%. Recalled batteries are returned to the OEM for repair or recycling.

Out-of-warranty repairs and service by dealers, OEMs

Most EV batteries currently in cars are under warranty. Dealers may service a battery in an out-of-warranty vehicle. While this is not a major pathway, the number of out-of-warranty batteries will increase over time. Tesla has the largest population of out-of-warranty vehicles and offers replacement batteries for owners who are not satisfied with an out-of-warranty vehicle’s range. When an EV battery is out-of-warranty, the owner generally must pay out of pocket for a battery replacement.

Pathway 2. Outside the OEM network

An EV battery that is outside the OEM network can take many paths. These batteries exit the OEM network when there is a vehicle incident or the battery is out-of-warranty.

Vehicle incidents resulting in auto auction

EV batteries enter the marketplace when there has been an incident such as a collision, flood damage, fire damage, or other events triggering insurance claims. Initial interviews suggest that the EV battery is often undamaged, and the health of the battery determines its value. The value of the battery is a major factor in determining the path it takes.

In the event of a collision, a vehicle’s ownership is often transferred to an insurance company and resold via insurance auctions across the country. These damaged vehicles are purchased by a wide array of buyers including auto recyclers, commercial businesses built around consumer or fleet EV conversions, repurposing businesses creating grid storage solutions, and a large DIY community. In rare but documented instances, buyers remove good batteries from vehicles and replace them with an inferior battery before resale of the vehicle at auction.

Auction purchases may arrive in Washington from across the United States, shipped to the buyer for around \$1,000-2,000. Washington EVs sold at auctions may also leave the state and be dispersed

²⁶ *Where do EV batteries go when they die?* <https://www.youtube.com/watch?v=HlurjZsWJoc>.

across the U.S. The number of batteries entering and leaving the state through auctions is unknown. Auctions may also be a means through which EVs and the batteries in them are exported out of the U.S.

Auto recycling companies, also referred to as dismantlers and salvage yards, commonly purchase EVs from insurance auctions. Vehicles purchased at auction are transported to the auto recycling facility, which dismantles the vehicle to resell parts before crushing and selling the vehicle shell for scrap.

Dismantlers purchase damaged EVs when the price point allows for a slight profit from the recollection, removal, and resale of a used EV battery and other EV parts. The EV battery is the most valuable part of the EV due to current economic conditions. Unless the whole vehicle is being resold, batteries are often removed from an EV for resale. EV batteries often weigh around 1,000 pounds or more for in pickup trucks and SUVs. An automotive lift is required to remove a battery. Special training and tools help keep workers safe as they remove the battery. Learning to safely work on high voltage systems (400 and 800 volts) may be a new skill for some auto recyclers.

Interviewees stated that it is common for auto recyclers in Washington to immediately isolate a battery if it is determined to be damaged. Often a third-party carrier will come to the facility to package and transport a battery to an appropriate recycler. Auto recyclers shared that this process is expensive.

Several stakeholders shared that it is important to maintain economic viability of auto recyclers as the market transitions to EVs. Auto recyclers currently support the safe dismantling of vehicles with internal combustion engines (ICE vehicles). They will have an important role when more EVs reach end-of-life in Washington state.

With a wide range of buyers, EV batteries are dispersed into multiple marketplaces for reuse and repurposing. Types of repurposing include energy storage systems supplying backup power for renewable energy generation and back-up storage for buildings, DIY repurposing for home backup power, RVs, boats, or other applications. Several individuals and entities in Washington are converting ICE vehicles to electric vehicles, while B2U Storage Solutions is using repurposed Nissan LEAF batteries to store energy collected from its 1 MW solar farm located in Lancaster, California.

The demand for EV batteries for reuse or repurposing exceeds the supply, which means that the value of the battery exceeds the cost of transportation. A twelve-year-old Tesla Model S 85kWh battery may sell for \$15,000 to \$25,000 in an auction, according to interviews and online auction sites. This same 1,200-pound battery may sell to a battery recycler for only \$240 to \$1,200, because recyclers only pay for the value of the battery's materials, not its function of storing and discharging energy. While no publicly accessible data exists for the composition of buyers, it seems likely that not many batteries are currently reaching recycling through this pathway based on the economics.

The market dynamics are unlikely to shift until there is a larger volume of end-of-life batteries to increase supply. There are different perspectives on the potential size of the reuse and repurposing industry. Some believe that it will saturate and that end-of-life batteries will be recycled rather than having a second life, while others think that the second-life use-cases will continue to grow.

Out-of-warranty batteries or non-insured batteries

When EV batteries are out-of-warranty, independent repair shops or individuals engaged in DIY repair may service them after diagnostic testing. In cases where the battery is not repaired for use in its original vehicle, the batteries may be sold to private or commercial businesses for reuse or repurposing.

Battery cessation: recycling, disposal, or abandonment

Battery cessation occurs when an EV battery exits or bypasses second- or third- life. When this happens, a battery's pathway is usually to be recycled, disposed of, or abandoned.

Approximately 98% of critical minerals in EV batteries are recoverable through recycling. Recycling centers are being built around North America to support the battery supply chain and vehicle manufacturing. In certain cases, OEMs have relationships with recyclers or recycling intermediaries that allow them to manage EV batteries for which they are responsible. A discussion of the economic drivers and incentives is included under the Economics of Battery Management section of this report, beginning on page 30.

Initial stakeholder interviews suggest that abandonment and disposal of EV batteries is not common. This is due to the high value of second-life batteries and the fact that most EV batteries are still under warranty.

The lack of knowledge regarding where to send batteries and/or the perception that handling costs are too high may result in the disposal or abandonment of EV batteries. Smaller organizations outside OEM networks may not always know which organizations to work with to properly recycle EV batteries in a cost-efficient way. Increasing the awareness of networks and solutions for stranded batteries could support smaller operators. Changes in policies, regulations, battery chemistry mix, cost of transportation, cost of recycling, and market value of critical minerals at any time could create a situation where EV batteries reach a negative value. If EV batteries reach a negative value, then abandonment could become more common.

Considerations for all pathways

Transportation

Transportation can make up roughly half of all recycling costs. Transportation methods of EVs and EV batteries vary depending on the pathway and even within pathways. OEMs may employ their own specific battery transportation procedures and processes while following the same regulations. Transportation costs will continue to be a driver of determining what happens to an EV battery, and changes in transportation regulation have the potential to increase or decrease the number of batteries being reused, recycled, or repurposed.

The transportation of EV batteries in the U.S. is regulated at the federal level. Stakeholders stressed the importance of a nationwide solution that helps address the high cost of transportation. The number of batteries with the potential to become stranded will be dependent on future technology developments and the commodities market.

At the state level, some jurisdictions are considering ways to allow collection sites to facilitate transportation, infrastructure development, and strategies to reduce the cost of transporting

batteries. If successful, these efforts will increase the number of batteries being reused, repurposed, or recycled.

Storage considerations

The method of storage of undamaged batteries after they have been removed from vehicles depends on the entity removing the battery and which pathway the battery is following. Batteries may be removed from an EV by a dismantler, exporter, EV conversion business, individual, auto repair shop, rebuilder, scrapper, or others. Initial stakeholder engagement suggests that focusing on long-term infrastructure needs and building knowledge of existing networks for recycling, reuse, and repurposing will reduce the likelihood of batteries being stockpiled or stored for extended periods of time.

If batteries are damaged, more stringent regulations apply to their storage as well as transportation. These batteries have the potential to burden auto recyclers. First responders may have to manage damaged EV batteries when responding to an incident, and there is broad interest in supporting them with training.

Knowledge gaps

- What methods do auto recyclers use to detect damage?
- Is there a common set of best practices for damage detection?
- Do best practices exist for handling high voltage systems in EVs while dismantling them?
- If there is a set of common best practices for handling damaged batteries? Does this extend to facilities of different scales?
- What policies, training, and education can support first responders in Washington state?
- What battery information and diagnostic instruments do first responders need at the scene of a vehicular accident to assess if a battery is damaged, if special precautions are needed, and where the vehicle should be towed?
- What is needed to improve workforce safety of EV lithium-ion battery handlers?
- How can the number of salvaged EVs and EV batteries from auto auctions be tracked to project the future volumes of batteries reaching ultimate end-of-life and recycling?
- What tools can be used to provide EV battery sellers, buyers, re-users, re-purposers, and recyclers access to battery information?
- What market conditions will drive the stockpiling and abandonment of out-of-warranty EV batteries?

Economics of battery management

This section of the literature review provides preliminary findings on the economics of EV battery management in Washington state. Factors that contribute to these economic considerations are also discussed. Understanding the economic dynamics of recycling lithium-ion batteries (LIBs) is critical, with profitability influenced by factors such as transport costs, battery chemistry, and recycling methods. Additionally, the challenges associated with the increasing volume of end-of-life LIBs

highlight the importance of efficient collection networks, financial responsibility frameworks, and state and federal incentives. Existing knowledge gaps are covered at the end of the section. This section is guided by the following questions:

- What is the financial landscape surrounding EV batteries?
- Are there existing programs that provide funding or incentives for EV battery management?

Key takeaways

- The value of an EV battery changes over time, depending on its condition and the market value of its materials. EV batteries with over 70% capacity have the highest resale value.
- Battery production costs are decreasing due to economies of scale.
- Recycling LIBs can be economically viable, and profitability depends on factors like transport costs, battery chemistry, pack design, and recycling methods.
- Collection and transportation costs vary based on whether the battery is damaged, distance to a recycling facility, and the volume of batteries shipped.
- OEMs and vehicle owners are the main responsible parties for proper EV battery disposal, depending on the warranty status of the battery.
- Cost and logistical barriers to EV battery management in Washington state are high in part because much of the domestic battery industry is located in the southern U.S.
- There are several existing financial incentive programs related to the Inflation Reduction Act and Infrastructure Investment and Jobs Act that can support industries involved in end-of-life EV battery use and management to reduce the costs of battery disposal.

Findings to date

The value of an EV battery changes over time, depending on factors like its condition and the market value of its materials. These materials, ranked by value, include cobalt, nickel, copper, and lithium. When reselling, EV batteries with over 70% capacity have the highest value. Table 1 summarizes the value of new or nearly new EV batteries.

Table 1. EV battery replacement costs.

Battery Type	Battery Capacity	New/Like New Battery	\$/kWh	Data Source:
Tesla S	100 kWh	\$12,000-\$15,000 ¹	\$153	Find My Electric
Tesla 3	75 kWh	\$13,500	\$137	J.D. Power, Recurrent Auto
Chevy Bolt	66 kWh	\$16,000	\$250	Recurrent Auto
Nissan Leaf	40 kWh	\$4,500	\$187	Recurrent Auto

Source: <https://www.findmyelectric.com/blog/tesla-battery-replacement-cost-explained/>

Battery production costs are decreasing, with the average price dropping from \$137/kWh in December 2020 to a projected \$62/kWh by 2030.²⁷ This reduction is due to economies of scale, and further decreases may require technological advancements like solid-state batteries.

The second-life use of EV batteries is a growing industry, driven by demand for EV conversions and stationary energy storage. Auto recyclers face competition at auctions, especially in Washington where active EV associations, like the Seattle EV Association, contribute to innovation. There's potential for economic benefits in repurposing batteries for non-automotive uses, such as energy storage. Collaboration with research institutions and business incentives may promote innovative technology and commercial ventures, extending the life of batteries and managing recycling costs.

It is important to note that there are different pricing metrics for EV batteries depending on industry segment. Currently, the common metrics employed are \$/kWh and \$/pound. Through much of an EV battery's life, from production to post-first-life, it is priced in \$/kWh according to its energy capacity. However, recyclers often pay for end-of-life (EOL) batteries in \$/pound. It is possible to convert between these two values if the battery's energy density is known.

Recycling lithium-ion batteries (LIBs)

Research suggests that recycling LIBs can be economically viable, with costs ranging from -21.43 to +21.91 \$/kWh.²⁸ Profitability depends on factors like transport costs, wages, battery chemistry, pack design, and recycling method. Recycling of EV batteries in the U.S. is expected to be profitable at around 7-8000 tons per year.²⁹

Without appropriate networks and solutions, EV batteries may end up stranded. Changes in policies, regulations, battery chemistry, transport costs, recycling costs, and market value of minerals could lead to situations where EV batteries have a negative recycling value.

Transporting LIBs

The volume of LIBs entering and exiting Washington's reuse, salvage, and recycling sectors increases every year. The costs associated with recycling include the collection and transportation of the battery, dismantling and disassembly, and the recycling process itself.³⁰ Collection and transportation costs vary based on whether the battery is damaged, distance to a recycling facility, and the volume of batteries shipped.

Transporting individual batteries to a recycling center can be an intensive cost component if higher volumes of batteries cannot be consolidated and shipped at the same time to increase cost efficiency. Additional costs are associated with transporting damaged batteries because they have an increased risk of fire and, as a result, require extra precautions to ship. This includes additional packaging that must be custom-made and comply with U.S. DOT standards.

²⁷ <https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/>

²⁸ "Financial viability of electric vehicle lithium-ion battery recycling", Lander et al, iScience Volume 24, Issue 7, 23 July 2021, 102787

²⁹ <https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/>

³⁰ Electric vehicle lithium-ion battery recycled content standards for the US – targets, costs, and environmental impacts; Dunn et al, Resources, Conservation and Recycling Volume 185, October 2022, 106488, October 2022.

Shipping costs can be decreased with an efficiently designed collection network that optimizes collection points and existing infrastructure, such as dismantlers and dealerships. Because of their access to vehicles coming off warranty, manufacturers are in a prime position to lead this centralized planning and ensure that operations are in place for all batteries to be recycled, which would likely lead to economic benefits from economies of scale.

Financial responsibility

The original equipment manufacturer (OEM) is generally responsible for end-of-life recycling if the battery pack is under warranty. For out-of-warranty batteries, vehicle owners typically bear the costs of disposal. Many stakeholders support a national solution, with some suggesting a system of Extended Producer Responsibility (EPR) to alert OEMs about battery issues throughout end-of-life to prevent stranded batteries. New Jersey and Hawaii are two states that have bills proposed for EPR of EV batteries. Some states, like California, have explored core exchange programs. See the Other Jurisdictions section on page 37 for more details.

Private partnerships

As Washington’s EV footprint expands, the process of shipping used LIBs out-of-state will increase in cost and become more logistically challenging given interstate transportation regulations and the sheer number of batteries being shipped in the future. Today, much of EV battery manufacturing and recycling is done in the so-called “battery belt” across the South. Therefore, the Washington state EV and EV battery system is geographically removed from many battery manufacturing and assembly firms, as well as remanufacturing, refurbishment, recycling, and related aftermarket industries. This exacerbates the cost and logistical barriers of reusing and recycling EV batteries in Washington state.

Considerations for addressing this issue may include incentivizing efficient recycling hubs and other private partnerships in the EV battery industry. Attracting these firms to the region could reduce transportation challenges and support the regional economy. At the same time, discussions about creating regional infrastructure will need to take into consideration possible community and environmental impacts of future EV battery-related industrial activities in the region. These concerns will need to be factored into the overall economic benefits analysis.

Cost share opportunities and initiatives

The anticipated growth in the number of EVs operating in Washington has the potential for both positive and negative economic impacts, some of which could be substantial.

Local businesses centered around internal combustion and hybrid vehicle service, maintenance, and repair already exist in limited numbers. However, businesses focused on servicing EVs are limited. As the need grows to support out-of-warranty EVs, it is anticipated that the demand for such services in Washington state will grow substantially. These businesses will eventually create jobs, enhance the tax base, and support local economies.

Various forms of support will likely be needed to ensure the long-term viability of this industry segment, including access to vocational training around battery service, clear communication from state and local authorities concerning battery end-of-life processes, as well as the potential for start-up funding for new ventures in underserved communities or in parts of the state where EV

penetration is currently low but anticipated to rise. Many incentive mechanisms may support this growth including grants and low-interest EV business incentive loans.

State initiatives and federal funding opportunities

There are several applicable statewide initiatives that support the growth of the battery industry through the transportation and electricity sectors, in addition to promoting environmentally responsible battery disposal. One example is this Study and the directive to review pertinent issues for managing EV batteries. Other mandates include the state's initiative to increase purchases of environmentally preferable products, reduce greenhouse gas emissions, and reduce energy use.

There are several existing financial incentive programs that can support industries involved in end-of-life EV battery use and management to reduce the costs of battery disposal. Applicable incentives are primarily through the Inflation Reduction Act (IRA) and Infrastructure Investment and Jobs Act (IIJA). Regardless of their origin, battery materials recovered in domestic recycling and are used in a qualified project count as "domestic content" in the manufacturing of new batteries. The IRA provides a 30% Investment Tax Credit (ITC) for new recycling facility construction and may offer a 10% bonus for zero emissions energy projects that utilize domestic content. IRA Direct Pay enables public entities to construct facilities that may qualify for federal tax credits. The Federal Direct Pay options directly enable public entities to take on responsibility, and potential revenue, of battery recycling centers. IIJA provides grants to entities constructing qualified projects. The ITC concept can also be extended through partnership with private entities to construct and operate a recycling center dedicated to meeting state mandates.

Knowledge gaps

- What is the profitability associated with recycling different EV battery chemistries?
- Which recycling methods appear to have the most favorable economics?
- Economically viable EV lithium-ion battery recycling is increasing. What are the routes to profitability in Washington state? What industry segments need further development?
- What are the implications, positive and negative impacts, of assigning responsibility of EV management to EV owners in Washington state?
- What barriers exist as the industry continues to establish and refine the ecosystem supporting EV battery collection, transportation, and reverse logistics in Washington state (i.e., acquisition, management, and transport of used EV batteries)?
- How might shipping and packaging regulations be modified, based on battery chemistry, to relieve the cost burden of transportation and promote an increase in recycling?
- At what price point are incentives needed to prevent the stockpiling and abandonment of end-of-life EV batteries?
- What market conditions drive the stockpiling and abandonment of out-of-warranty LIBs?

Battery chemistry and value

This section of the literature review covers battery chemistry considerations and the associated value of EV batteries. Remaining knowledge gaps are covered at the end of the section. This section is guided by the following question:

- What characteristics and values are associated with the most common EV battery chemistries?

Key takeaways

- Today's EV batteries are predominantly lithium-ion and there are two main categories of lithium-ion EV battery chemistries – nickel-based chemistries and lithium iron phosphate (LFP).
- Cobalt and nickel are the two most valuable materials in lithium-ion batteries. Both materials are only used in nickel-based battery chemistries.
- Battery value varies over time, depending on fluctuating commodity markets for battery materials.
- Many EV batteries currently reaching end-of-life in Washington and around the country contain high amounts of cobalt and nickel.
- The rate of return for recycling lithium iron phosphate (LFP) batteries, which lack cobalt and nickel, is lower. Profitability for LFP recycling depends on a high enough price of lithium in the spot market.
- The research indicates that recycling LFP is not currently profitable, therefore creating a disincentive to eventual recycling.
- LFP batteries have much longer lives than nickel-based chemistries. This means that they may be high-value candidates for repurposing after serving their first life in an EV, such as use in stationary storage applications, and may not be ready to be recycled for 20-30 years.

Findings to date

Background

The cost of battery manufacturing is now dominated by the cost of the constituent materials. Through much of the 2010s, the cost of EV battery production was dominated by the cost to assemble the battery. This switch has happened because battery manufacturing has now realized production cost reductions from economies of scale. Therefore, much of what determines the value of an EV battery is its chemistry.

While all EV batteries contain lithium in the electrolyte, battery chemistries are categorized by their cathode material. There are two main categories of lithium-ion EV battery chemistries – nickel-based chemistries and lithium iron phosphate (LFP). Nickel-based chemistries include nickel-cobalt-aluminum oxide (NCA) and nickel-cobalt-manganese (NCM), which both contain cobalt and nickel. While LFP batteries lack both cobalt and nickel, they contain copper foils in the anode and lithium in the electrolyte. EV batteries hold value across several areas of the battery cell, including the materials within the cathode, electrolyte, and anode.

Because all EV battery chemistries contain lithium, they all rely, to some extent, on the lithium commodity market to determine their value. Commodity markets are famously volatile, and the lithium market is no exception. Lithium commodity prices experienced a 15-fold price spike during the pandemic and have since returned to 2017 levels after this spike.³¹ Cobalt, nickel, and copper market prices also fluctuate based on market dynamics.^{32 33 34} Spot market price volatility can be exaggerated by small changes in real world conditions. For any commodity, and especially battery materials, a price spike causes a surge in investment to fill this need, which often leads to short term oversupply and price drops.

Nickel-based battery chemistries

While nickel-based chemistries contain lithium, they also contain two materials – cobalt and nickel – that are much more valuable than lithium and thus, play a larger role in determining battery value. Cobalt is the costliest material used in EV batteries, which makes it most valuable for EV battery recyclers. Nickel is the second most valuable material to recyclers. Many EV batteries currently reaching end-of-life in Washington and around the country contain high amounts of cobalt and nickel.

These two minerals have been instrumental in EV success, allowing batteries to be smaller while enabling EVs to go further. However, due to high costs and environmental and societal concerns associated with cobalt mining, auto and battery OEMs have steadily been reducing the percentage of cobalt in their nickel-based chemistries.^{35 36}

Lithium iron phosphate (LFP) batteries

Because cost is a main driver of battery evolution, lithium iron phosphate (LFP) batteries – which do not contain expensive cobalt or nickel – are rapidly gaining market share for standard range vehicle offerings from most manufacturers. Additionally, LFP batteries have a lighter and simpler battery thermal management system, which greatly reduces risk of thermal runaway and fire. LFP batteries can also endure three to five times more charge/discharge cycles than nickel-based chemistries.

While they are less expensive to manufacture, the rate of return for recycling LFP batteries is lower than nickel-based chemistries because they lack valuable cobalt and nickel. Therefore, the profitability of recycling LFP batteries depends on the prices of lithium and copper in the spot market. While LFP batteries represent a miniscule fraction of batteries currently reaching end-of-life, they will eventually make up a significant proportion of end-of-life batteries. The research indicates that recycling LFP is not currently profitable, therefore creating a disincentive to eventual recycling.

Potential mechanisms to ensure that LFP batteries are not stranded at end-of-life because of low commodity prices may be important to consider. Fortunately, LFP batteries have far longer lives than nickel-based chemistries, so there is time to identify solutions. LFP batteries may be high-value candidates for repurposed EV batteries in stationary storage applications after serving their first life

³¹ <https://tradingeconomics.com/commodity/lithium>.

³² <https://tradingeconomics.com/commodity/cobalt>

³³ <https://tradingeconomics.com/commodity/nickel>

³⁴ <https://tradingeconomics.com/commodity/copper>

³⁵ <https://www.energy.gov/eere/vehicles/articles/reducing-reliance-cobalt-lithium-ion-batteries>

³⁶ <https://www.autonews.com/manufacturing/can-ev-battery-makers-move-away-cobalt>

in an EV. This could translate into a 20-30+ year lag before today's new LFP batteries are ready for recycling.

Evolving battery landscape

As battery recyclers respond to the influx of different end-of-life batteries, they are paying attention to future battery designs and chemistries. As more EVs retire and technology changes, stakeholders will likely prioritize recycling batteries of higher material value and a shorter transportation distance to the recycling center.

Knowledge gaps

- What is the tipping point or price at which LFP batteries become economic to recycle?
- What policies or solutions may support recycling battery chemistries that do not contain valuable minerals?

Other Jurisdictions

The consultant team identified relevant case studies that may inform considerations for EV battery management in Washington state. These case studies focused on California and Colorado, as both states have released reports on EV battery management in the last two years. Relevant takeaways and recommendations from each report are detailed in this section. Two recent bills for EV battery management are also mentioned at the end of this section.

Key Takeaways

- Manufacturers are required to properly reuse, repurpose, recycle, and manage the EV batteries under warranty.
- Out-of-warranty batteries are difficult to track and there are discussions in other jurisdictions attempting to define who is responsible for out-of-warranty EV batteries.
- Most EV batteries are still under warranty and in their original vehicle.
- California and Colorado are discussing different infrastructure needs to build collection and transportation networks to prepare for when there is a larger volume of end-of-life EV batteries.
- California is investing in research and development around EV battery uses during second life, and Colorado's research team recommended investments in research and development. Both are incentivizing businesses associated with EV battery end-of-life management or are considering investments.
- Due to the rapidly evolving nature of EV Battery management, new policy approaches continue to evolve in multiple jurisdictions, including New Jersey, Hawaii, and Quebec.

California

California Environmental Protection Agency (CalEPA) identified potential policies to address the management of lithium-ion EV batteries (LIBs) by forming the Lithium-ion Car Battery Recycling Advisory Group (Advisory Group). The Advisory Group spent three years developing policy

recommendations after hearing from 26 experts representing industry, academia, and government agencies. Their findings and policy recommendations can be found in the [Lithium-ion Car Battery Recycling Advisory Group Final Report](#).³⁷

Findings from California and policy proposals

There are existing warranty regulations and programs that require vehicle manufacturers to properly reuse, repurpose, or recycle EV batteries that are under warranty. Out-of-warranty LIBs were identified as a challenge in California, as there is no method to track them. As a result, the volume of out-of-warranty batteries or their locations is unclear. The authors state that “retired EVs may end up being handled by several different parties who have unequal access to the resources and information necessary to manage EOL batteries properly.”

Two major policies were proposed by the Advisory Group to complement the existing management of EOL batteries that are under warranty: 1) core exchange with vehicle backstop, and 2) producer take-back.

The core exchange with vehicle backstop policy aims to recapture out-of-warranty LIBs using a similar process that the state uses for lead-acid batteries. A core charge is a form of deposit made when a new battery is purchased. When the battery is returned, the deposit is refunded.

The core exchange with vehicle backstop policy and producer take-back policy defines responsibility for the return of the EV battery based on two scenarios. In the first scenario, the battery reaches end-of-life before the vehicle reaches end-of-life. The entity removing the EOL battery would hold responsibility for its proper reuse, repurposing, or recycling. The entity selling an EV battery would use a core exchange program to track that the used battery was properly managed.

In the second scenario, the EV reaches end-of-life before the EV battery and goes to a dismantler. The dismantler who has ownership of the end-of-life vehicle has responsibility for the EV battery and is responsible for ensuring the battery is properly reused, repurposed, refurbished, or recycled. If the battery goes to a separate entity for refurbishing or repurposing, the responsibility goes to the new entity.

The proposed producer take-back policy applies to situations where an EV reaches end-of-life and doesn't go to a dismantler. In this case, the vehicle manufacturer is responsible for the proper management of the vehicle and the battery.

Defining ownership responsibility for EV EOL management was suggested to create environmental responsibility across the lifespan of an EV battery. Additional policy needs related to the EV battery management regulatory landscape include:

- Reducing transportation costs
- Supporting transportation research
- Developing strategic collection and sorting infrastructure
- Clarifying the existing universal waste regulations
- Accessing battery information, including chemistry and OEM

³⁷ https://calepa.ca.gov/wp-content/uploads/sites/6/2022/05/2022_AB-2832_Lithium-Ion-Car-Battery-Recycling-Advisory-Goup-Final-Report.pdf

Considerations for Washington state

There are important differences between Washington state and California. The California Energy Commission (CEC), a state agency, is funding efforts to repurpose used EV batteries into grid storage. Grid stability is a major challenge in California. There is a pressing need to add more stationary storage to the grid that can be provided with the addition of repurposed batteries. As a result, California has several facilities and demonstration sites that use repurposed EV batteries for grid storage.

California has strict laws regarding vehicle dismantling and seeks to penalize dismantling outside of the state regulated system. Some stakeholders in Washington are concerned that California's approach applied in Washington would stifle innovation in the nascent reuse and repurposing industry. The policy options generated by the California Advisory Board reflect the composition of its membership. Washington state may want to consider different policy options as input is gathered from priority stakeholders.

Colorado

In 2020, the Colorado Department of Public Health and Environment tasked Colorado State University with reporting the status of EV battery recycling and reuse in Colorado.

Researchers analyzed the environmental, economic, and human health impacts associated with EV battery recycling and end-of-life. Stakeholder interviews and a review of the scientific and trade literature yielded insights into potential technological, regulatory, commercial, and educational initiatives that can prepare Colorado for growth in electrified transportation. A major recommendation from the report was to form a study team to develop in-depth policy recommendations and strategies. Findings and policy options from this process can be found in the [Colorado EV Battery Recycling Study](#).³⁸

Findings from Colorado and policy proposals

The researchers from Colorado found that most lithium-ion EV batteries in the state are under warranty and in their original vehicle. The researchers did not find evidence of storage or stockpiling in Colorado. Disposal, remanufacturing, recycling, materials recovery, and second-life activities were found to be occurring out of Colorado, or at small or non-commercial scales within the state. Similar to findings in California, the researchers found that there were knowledge gaps for what happens to out-of-warranty batteries.

The researchers suggest options for value-adding initiatives that may support the new EV post first life energy economy. Recommendations include:

- Fund businesses that support second life use, recycling, logistics of EV batteries in state through investment credits and grants for EV battery research and development
- Encourage utilities to invest in and use passive energy storage systems
- Develop a recycling hub to create efficient and cost-effective management of EV batteries in the state. A recycling hub would simplify transportation and reduce its costs

³⁸ Colorado State University. (2021). Colorado EV battery recycling study. https://www.researchgate.net/publication/354131908_Final_report_Colorado_EV_battery_recycling_study.

- Establish collection centers similar to what exists for the electronics industry
- Clarify and harmonize regulations for handling, processing, disposal, and transportation of batteries
- Resolve battery ownership in scenarios when it is unclear to reduce potential harm to the environment
- Promote transparency and standardization for battery recycling and automotive recyclers and dismantlers
- Create a statewide education program for sharing basic knowledge and facts about battery safety, management, and end-of-life (EOL) scenarios
- Promote consumer engagement through battery rebates, returnable deposits, recycling stipends
- Develop an exchange program for out-of-warranty batteries to encourage consumers to return their EOL batteries for new or refurbished EV batteries to increase the number of EOL batteries that have a second life

Considerations for Washington state

The findings from Colorado reinforce what was reported in California. Both reports emphasize the need for investing in infrastructure to collect and transport EV batteries efficiently. Neither state has a way to effectively track out-of-warranty batteries or batteries going to second- and third life. Future research and policy development from these two states and others may provide additional insights and ideas for Washington to consider.

Emerging policies in other jurisdictions

Due to the rapidly evolving nature of EV battery management, new policy approaches continue to evolve in multiple jurisdictions. New Jersey introduced and passed extended producer responsibility legislation ([Bill S3723, 2023](https://www.njleg.state.nj.us/bill-search/2022/S3723)³⁹) that will use a two-year regulatory process to further engage stakeholders and develop definitions. Hawaii introduced similar legislation ([Bill SB 2311, 2024](https://www.capitol.hawaii.gov/session/measure_indiv.aspx?billtype=SB&billnumber=2311&year=2024)⁴⁰) that includes more detailed definitions. Finally, outside of the United States, Quebec has also launched an industry-funded [EV Battery Recovery program](https://recuperationdesbatteriesve.ca/en/ev-battery-recovery-home/)⁴¹, developed by the Canadian Vehicle Manufacturer’s Association and Global Automakers of Canada in partnership with the Quebec government.

³⁹ <https://www.njleg.state.nj.us/bill-search/2022/S3723>

⁴⁰ https://www.capitol.hawaii.gov/session/measure_indiv.aspx?billtype=SB&billnumber=2311&year=2024

⁴¹ <https://recuperationdesbatteriesve.ca/en/ev-battery-recovery-home/>

Emerging Themes

The emerging themes discussed in this section are based on a literature review of EV battery management, stakeholder interviews, survey responses, and webinar discussions. Policy makers should consider these themes when evaluating policy options. Emerging themes include:

- The battery industry and regulatory landscape are co-evolving rapidly.
- Industry stakeholders are refining procedures to meet federal and state regulations.
- EV battery recycling is a nascent industry undergoing rapid change.
- Training related to best practices for EV battery incident response is needed to support first responders.
- Varying perspectives exist regarding responsibility for end-of-life batteries.
- Streamlined access to information on fire response, towing, storage, and auto recycling best practices is needed to support the safe collection and management of end-of-life batteries.
- Industry stakeholders are concerned that state-by-state laws and regulations are creating a patchwork of rules and codes that make recycling, reuse, and repurposing difficult or economically impractical.

There are mixed levels of agreement amongst stakeholders on various issues. For example, levels of agreement with the statement “an active market exists for batteries to be reused or repurposed” varied due to the different perspectives on the DIY reuse and repurposing community. A representative from the DIY community strongly supported the right to repair in a webinar discussing emerging themes and priorities. The DIY community member shared that the right to repair should extend to EV battery repair, reuse, and repurposing. Industry stakeholders expressed a preference that trained individuals manage EV battery repair and reuse due to safety concerns.

Recommendations

As directed by Ecology, the consultant team engaged a Policy Advisory Group with 18 stakeholders from 14 organizations that represented a wide range of interests regarding EV batteries and related policy needs. This group was a subset of the larger group of stakeholders that participated in interviews, webinars, or an online survey in the fall of 2023. Two Policy Advisory Group meetings were held in January 2024 to identify and define immediate policy needs for Washington state, as well as point to potential mid- and long-term policies needing further research and discussion. A survey was sent to the Policy Advisory Group between meetings to capture the range of perspectives on various policy priorities and identify which policies had apparent broad support and which had mixed consensus. The survey also asked for perspectives on who should bear financial responsibility for EV battery management. The two meetings and the survey informed the recommendations in this section. See Appendix E for Policy Advisory Group meeting summaries and questions from the Policy Advisory Survey.

Immediate policy needs were defined as those needing timely state action due to existing barriers, challenges, or risks. This report includes recommendations addressing immediate policy needs. Mid-term policy needs were defined as policies that should be addressed in two to five years after

additional stakeholder input. Long-term policy needs were defined as those with complexity requiring significant coordination, stakeholder input, or infrastructure development. This report groups policies that could be either mid- or long-term together since there was no clear consensus on which should fall into each category. The survey also asked whether policy priorities were better addressed at the state or federal level, or if stakeholders were simply opposed to the policy priority. The focus of this report is on state level policy priorities. Some policies may be appropriate for legislative action while others may be better addressed via state regulation or guidance.

Immediate policy needs for Washington state

The following recommendations were identified as immediate policy needs.

1. **Provide training, education, and resources to first responders, second responders, and automotive recyclers.** This report recommends creating a clearing house that can assess, consolidate, and distill existing resources and information for dissemination to relevant stakeholders.
2. **Determine who should have financial responsibility and liability for EV batteries.** Emerging policy solutions from other states include an extended producer responsibility (EPR) scheme and a core exchange program with producer take back.
3. **Form a Washington State EV Battery Management Task Force (Task Force) with a broad set of stakeholders to address mid- and long-term policy needs.** This report includes an expanded list of potential stakeholders that could make up the Task Force, as suggested by participants in this study effort. The Task Force could provide balanced engagement on policies to address financial responsibility and liability. Finally, the proposed Task Force could help Washington continue to adapt to a rapidly evolving EV battery landscape.

Education, resources, and training

There is broad consensus and support for certain educational and training needs, due to the varied technologies and rapidly evolving nature of the EV battery market. Information on proper management can differ between manufacturers, and a variety of organizations have developed training programs. As research and technology change, this information will also evolve. A variety of agencies within the state have jurisdiction over various stakeholders; therefore, there is a risk of duplicative efforts between agencies around education, resources, and training. Some stakeholders identified that it was challenging to find and filter information from different sources. Avoiding duplicative efforts and closing information gaps could be achieved by creating a clearing house. A clearing house will help consolidate and disseminate information on EV battery management best practices and avoid duplicative efforts between agencies. Providing emergency responders with training and education on how to safely handle EV batteries is a high priority and should be considered for immediate policy support by the legislature.

First responders

First responders include EMTs, fire fighters, and police officers who respond to vehicle incidents involving EVs. Stakeholders shared existing resources and identified additional needs. For example, General Motors (GM) is adapting existing trainings into an [online version](https://gmevfirstrespondertraining.com/)⁴², the National Fire

⁴² <https://gmevfirstrespondertraining.com/>

Protection Association (NFPA) has [guides](#)⁴³ and [training](#)⁴⁴ on EV response, and Tesla provides [guides for emergency responders](#)⁴⁵ for each of its vehicles. Assistance is needed to focus the information and resources into a product that includes key takeaways for first responders that they can apply in a variety of situations involving different electric vehicles and batteries. There needs to be a repository for sharing the new information and someone to coordinate this effort. This could be addressed by having a clearing house with associated staff.

Multiple methods exist to extinguish an EV battery fire, and more real-world testing is needed to define what works best. At the state level, there is a need for funding, equipment, a facility for testing and training, approval to do a large-scale burn, and assistance with clean-up and disposal. A facility dedicated to training first responders may be particularly important in preparing responders to manage risks associated with EV crashes and fires.

The urgency of addressing first responder needs is reflected by the introduction of SB 5812⁴⁶ in the 2024 legislative session. During a bill hearing, stakeholders identified needed support for first and second responders:

- Information and guidance for first responders and other crash scene workers about fire risks associated with lithium-ion battery fires in electric vehicles
- Vehicle-specific information in emergency response guides on how to:
 - Fight lithium-ion battery fires
 - Mitigate thermal runaway and the risk of lithium-ion battery reignition
 - Mitigate risks associated with stranded energy in lithium-ion batteries during emergency response and before a damaged electric vehicle is removed from the scene
 - Safely store an electric vehicle with a damaged lithium-ion battery
- Manufacturer emergency response guides modeled on ISO standard 17840⁴⁷ and Society of Automotive Engineers (SAE International) recommended practice J2990⁴⁸
- Continued research on ways to mitigate or deenergize stranded energy in high-voltage lithium-ion batteries
- Continued research on ways to reduce the hazards associated with thermal runaway resulting from high-speed, high-severity crashes

A clearing house can consolidate information being developed by multiple organizations and in multiple jurisdictions. A clearing house could also track who is conducting research, training, and

⁴³ [https://www.nfpa.org/education-and-research/emergency-response/emergency-response-guides#aq=%40culture%3D%22en%22&cq=%40taglistingpage%3D%3D\(%22EV%20Guides%22\)%20%20&numberOfResults=12&sortCriteria=%40title%20ascending](https://www.nfpa.org/education-and-research/emergency-response/emergency-response-guides#aq=%40culture%3D%22en%22&cq=%40taglistingpage%3D%3D(%22EV%20Guides%22)%20%20&numberOfResults=12&sortCriteria=%40title%20ascending)

⁴⁴ <https://www.nfpa.org/for-professionals/training-for-me/alternative-fuel-vehicles-training/electric-vehicles>

⁴⁵ <https://www.tesla.com/firstresponders>

⁴⁶ <https://app.leg.wa.gov/billsummary?BillNumber=5812&Initiative=false&Year=2023>

⁴⁷ <https://www.iso.org/standard/78461.html>

⁴⁸ https://www.sae.org/standards/content/j2990_201907/

best practices, as well as identify gaps in information. This approach will help the state avoid duplicative efforts in research, development, and training.

Second responders

Second responders involved in EV battery management include tow-truck drivers, clean-up crews, and other stakeholders supporting first responders at incidents. In certain cases, a second responder such as a tow-truck driver may be the first on scene. While certain information on managing EV batteries applies to both first and second responders, there are unique needs for different stakeholders. For instance, tow-truck drivers will need information about safe transport, as well as when to call for fire response.

Automotive recyclers

Automotive recyclers need education, training, and resources on how to safely dismantle vehicles, safely store batteries, and preserve the batteries for safe reuse. Automotive recyclers play a key role in ensuring EV batteries are successfully reused, recycled, or properly disposed. The Institute of Scrap Recycling Industries (ISRI) [provides curriculum](#)⁴⁹ focused on safe EV battery handling for recycling professionals. The Automotive Recyclers Association and its regional affiliate, Automotive Recyclers of Washington (AROW) provide additional resources for members. However, automotive recyclers who are not a part of AROW may be at a disadvantage in accessing key information. Automotive recyclers and others storing batteries need specific information on properly handling of damaged and defective batteries.

Education, resources, and training for auto recyclers is an immediate policy need due to the potential for EV batteries to get stranded in automotive yards. Automotive recyclers who are familiar with the markets for internal combustion engine (ICE) vehicles may not be as familiar with existing markets for recycled or reused EV batteries. Spreading information to help automotive recyclers connect with existing markets will help them adapt to increasing numbers of EVs, stay economically viable, and reduce the likelihood of abandoned batteries. A current example of information that would be helpful to automotive recyclers is information about Redwood Material's [dismantler portal](#)⁵⁰ that provides a quote for an EV battery and will organize transportation for the battery for dismantlers and salvagers. However, not all automotive recyclers in Washington are familiar with this service and others like it.

Financial responsibility and liability

Developing a policy that assigns financial responsibility for EV battery management is high priority that needs further discussion with stakeholders. Several new stakeholder groups were discovered through the study process and should be engaged more fully than the timeline of this study allowed. Certain stakeholders, such as consumers, the insurance industry, and others need greater representation to achieve balanced discussions on financial responsibility and liability. Stakeholder engagement could take place through the proposed Washington EV Battery Management Task Force or through a regulatory process like New Jersey.

While the stakeholder group did not reach consensus around financial responsibility or liability, there was support for policy directions being taken in other states, specifically New Jersey. In

⁴⁹ <https://www.isri.org/battery-safety-courses>

⁵⁰ <https://portal.redwoodmaterials.com/sell-my-battery/>

discussing who should have financial responsibility it is important to consider the state of Washington’s goals of broad EV adaptation and long-term financial stability of EV management programs. The pathways that EV batteries may take informs who might be responsible at different points in an EV battery’s life (See Figure 6. Overview of potential end-of-life pathways for EV batteries, on page 26). Most EV batteries today are under warranty, and EV original equipment manufacturer (OEM)s have clear financial responsibility for these batteries.

There is a need for determining financial responsibility when an EV battery is no longer under warranty, when there has been an EV incident, and/or when the battery exits its second or third life. The markets for reuse, repurposing, or recycling seem to be absorbing batteries that have a positive value. However, there is uncertainty in how markets will evolve over time. Assigning financial responsibility for batteries that no longer have a positive market value will reduce the chance batteries will be abandoned.

Whoever possesses the battery has de facto financial responsibility. This de facto responsibility tends to place the financial burden of neutral and negative value batteries on consumers and automotive recyclers. When financial responsibility for an EV battery is not clear, the de facto financial responsibility falls to the auto recycling industry. They in turn may have to charge consumers to get rid of the EV battery, discouraging proper disposal. If the car has been resold, consumers relying on used cars are those most likely to have to pay for disposal of EVs and EV batteries at end-of-life.

Two policy solutions are currently emerging at the state level in the United States. The first policy solution is California’s proposed core exchange program with producer take-back. The second policy solution is extended producer responsibility (EPR). EPR legislation has passed in New Jersey ([Bill S3723, 2023](#))⁵¹, and Hawaii has introduced similar legislation ([Bill SB 2311, 2024](#))⁵². Stakeholders in the policy advisory meetings were generally supportive of New Jersey’s approach.

The New Jersey legislation EPR model relies on battery management plans as an effective way to manage out-of-warranty, orphaned, or stranded batteries. A stakeholder shared that EPR policy should be written to provide flexibility so that direct partnerships can be made between OEMs, dismantlers, and consumers, allowing EV batteries to take the most efficient pathway at end-of-life.

EV manufacturers in the meetings expressed concerns about batteries that had been modified for repurposing (i.e. energy storage). In these cases, the battery is no longer what the manufacturer produced, and they may not have the information needed to manage the modified battery safely. There was support from multiple stakeholders for the idea that after an EV battery is removed from a vehicle for recycling, repurposing, or reuse by a party unrelated to the OEM, the OEM should no longer bear financial responsibility for the battery.

The valuation of end-of-life EV batteries has changed during the past five years from negative to positive. Further market changes are possible, and stakeholders emphasized the importance of flexible policies to adapt to further changes. The New Jersey policy provides a high level of flexibility and will rely on a two-year regulatory process to develop definitions and additional details. Though

⁵¹ <https://www.njleg.state.nj.us/bill-search/2022/S3723>

⁵² https://www.capitol.hawaii.gov/session/measure_indiv.aspx?billtype=SB&billnumber=2311&year=2024

not yet passed, the policy in Hawaii has more clarity on definitions. Stakeholders agreed that policies that keep EV batteries within the United States are preferable to exporting batteries.

Washington State EV Battery Management Task Force

This Study recommends that a Washington State EV Battery Management Task Force (Task Force) be formed to carry out a multi-year stakeholder engagement process that assesses medium and long-term policy needs. A clearer picture of the stakeholders involved when an EV battery is removed from its original vehicle emerged from research, and several groups have been under-engaged in policy discussions.

Many of the policy solutions discussed in this Study are complex and did not have clear consensus or support among participating stakeholders. The Task Force would provide a venue for more in-depth conversations and broader stakeholder engagement, particularly regarding community, environmental, and environmental justice interests. Additionally, due to the evolving nature of EVs and the EV battery industry, there will be a continued need for balanced voices, careful consideration, and flexibility in policies proposed and adopted to address EV battery management in Washington state.

Representatives from the following groups should be considered for inclusion on a Washington State EV Battery Task Force:

- Auto recyclers/salvage yards/licensed dismantlers
- Auto-auction houses
- Insurance industry
- Aviation
- EV battery recyclers
- Businesses engaged in EV battery reuse or re-purposing
- DIY Community
- Environmental groups
- Environmental justice groups
- EV and EV battery manufacturers
- EV dealerships and dealer repair shops
- EV owners/drivers
- Fire inspectors/investigators
- First responders (firefighters, law enforcement, EMS/Health)
- Local governments
- Maritime groups (Washington Department of Transportation - Ferries)
- Product stewardship non-governmental organizations

- Emergency responders
- Solid waste collection professionals
- Third party repair shops
- Towing and recovery industry
- Washington State Building Code Council
- Washington Department of Commerce
- Washington Department of Ecology
- Washington State Patrol

Mid-term and long-term policy needs for Washington state

The following policy priorities had mixed support from stakeholders responding to the policy survey, and in some cases, there was no clear consensus when the priorities need to be or can be addressed. We recommend that the proposed Washington State EV Battery Management Task Force further consider the following policies that:

- Advance reuse or repurposing of EV batteries
- Advance EV battery recycling
- Provide better access to information on battery health for reuse, resale, and repurposing
- Continue to reduce any environmental and community hazards posed by EV batteries
- Use permits or other tools to regulate the reuse and repurposing of EV batteries by individuals or businesses to support public safety
- Ensure used EV batteries can be used in existing and new grid-related incentive programs
- Provide access to diagnostic tools for entities who interact with used EV batteries or damaged electric vehicles
- Develop logistics systems for efficiently collecting and transporting EV batteries in state (i.e. hub and spoke model)
- Develop best practices for checking the health of the battery when entering its second or third life
- Develop a funding system to finance collection, recycling, and safety programs related to EV batteries
- Develop incentives or an exchange program to encourage consumers to turn in EV batteries

Even though there were only two meetings in January to discuss policy options, stakeholder discussions were robust. The stakeholder group discussed regulations for the do-it-yourself (DIY) community using EV batteries for energy storage, DIY EVs, and other purposes. A stakeholder from the fire response community shared concerns about not knowing how to appropriately manage household fires involving an energy wall. There was discussion about balancing safety and risk management with the right to repair. A stakeholder familiar with the DIY community shared in an

earlier interview that they felt the DIY community in Washington was a source of innovation and was concerned that the community may not be considered as a source of solutions and progress.

Multiple stakeholders also shared that they would like additional attention given to policies related to reuse. Original equipment manufacturers (OEMs) are incentivized through the federal Inflation Reduction Act (IRA) to use used EV batteries as a source for recycled materials. There needs to be discussion around when it is appropriate to recycle an EV battery versus putting it to use in a second or third life application.

Policy priorities that may be addressed outside Washington state government

A majority of stakeholders in the Policy Advisory Group either identified the following policies as being best addressed at the federal level or were opposed to the policy being addressed at all. We recommend that the proposed Washington EV Battery Task Force review the following policy priorities with a broader stakeholder group to confirm whether state or federal action is more appropriate:

- Develop a process standard for the disassembly, processing and recycling of lithium-ion batteries that can be verified by a third party to guarantee a minimum environmental standard
- Increase transparency and standardization within the EV and EV battery manufacturing communities
- Increase transparency and standardization within the battery recycling and automotive salvage/dismantling communities
- Increase transparency of the battery supply chain
- Create efficient and safe transportation regulations that apply to EV batteries
- Require or incentivize original equipment manufacturers to design EV batteries in a way that makes repurposing, reuse, and recycling less time and cost intensive
- Incentivize the development of a universal diagnostic system for EV battery health

It is worth noting that while some priorities had mixed consensus about who can best address them, there was consensus that efficient and safe transportation regulations that apply to EV batteries would be best addressed by federal government.

As battery technology and the EV market evolves, we recommend maintaining engagement with stakeholders involved with or impacted by EV battery management. Continuing to assess where there are state needs or policy gaps will be important, as will avoiding duplication of existing efforts or resources. The broad array of stakeholders also means that there will be a need for agencies such as the Departments of Ecology and Commerce to find opportunities for coordination with each other and local governments.

Conclusion

The Washington Electric Vehicle (EV) Battery Management Study used a combination of research, stakeholder engagement, interviews, and analysis of existing policies to better understand the current state of EV battery management in Washington state. EV technology is evolving and the market for EVs is increasing. Washington is one of the top five states in the country for the rate of EV adoption. While most EV batteries are under warranty, over time the number of batteries that enter second or third life will increase. There is an active market for second-life EV batteries for reuse, repurposing, and recycling, though the potential size of the market is debated. Effective EV battery management will need to adapt over time to changing markets and technology.

The study identifies key priorities, policy recommendations, and additional stakeholders to guide the state towards effective EV battery management. This final report recommends three actions to address immediate needs surrounding EV battery management.

1. **Provide training, education, and resources to first responders, second responders, and automotive recyclers.** This report recommends creating a clearing house that can assess, consolidate, and distill existing resources and information for dissemination to relevant stakeholders and help avoid duplicative efforts between agencies.
2. **Determine who should have financial responsibility and liability for EV batteries.** While other states have explored extended producer responsibility (EPR) and a core exchange program with producer take back, there was agreement that examining New Jersey's recent EPR law for EV batteries was a good place to start.
3. **Form a Washington State EV Battery Management Task Force (Task Force) with a broad set of stakeholders to address mid- and long-term policy needs.** The time frame of this study was too short to comprehensively delve into many aspects of EV battery management. The work this study started must continue. This report includes a comprehensive list of potential stakeholders based on a better understanding of EV battery end-of-life pathways and feedback from stakeholders participating in this study. The Task Force could provide balanced engagement on policies to address financial responsibility and liability.

The growing market share of EVs will require a system of management that fosters innovation, moves forward state climate goals, promotes responsible product stewardship, and supports safety for communities and the environment.

Appendix A. Key Definitions

Unless context indicates otherwise, the following terms have the meanings given below when used in this report.

Anode

A negative or reducing electrode⁵³ in a battery that releases electrons to the external circuit and oxidizes during the electrochemical reaction. For our common understanding, we can picture the negative terminal of a battery.

Auto recyclers/dismantlers

Companies that dismantle and recycle vehicles.

Battery cell

EV battery cells are the individual, basic units of a battery. Each cell functions to chemically store energy. A battery cell contains three major components, a cathode, anode, and electrolyte. The cell houses its components and electrochemical reaction within a casing. Cells may come in cylindrical, pouch or prismatic form factors.

Battery cessation

The end of a battery's lifespan resulting in disposal, recycling, or abandonment.

Battery chemistry

The battery's active materials or more specifically the materials used in the cathode, anode, and electrolyte. Shorthand generally refers to the battery's cathode materials. It is common to refer to LFP, NMC and NCA as the three most common EV battery chemistries.

Battery module

A unit that consists of a number of EV battery cells which are connected in series or parallel, forming units that produce the required voltage and energy capacity.

Battery pack

The complete enclosure that delivers power to an EV. It houses the collection of modules and cells. Modules are assembled into EV battery packs, also in series or parallel within a hard enclosure. They also contain other vital components, including software for monitoring (battery management system/ BMS) the pack and its thermal management.

Cathode

The positive or oxidizing electrode⁵⁴ in a battery that acquires electrons from the external circuit and is reduced during the electrochemical reaction. Also known as the positive terminal of a battery.

⁵³ <https://depts.washington.edu/matseed/batteries/MSE/components.html#:~:text=The%20Anode%20is%20the%20negative,reduced%20during%20the%20electrochemical%20reaction.>

⁵⁴ <https://depts.washington.edu/matseed/batteries/MSE/components.html#:~:text=The%20Anode%20is%20the%20negative,reduced%20during%20the%20electrochemical%20reaction.>

Electric vehicle (EV)

An EV is defined as a vehicle that can be powered by an electric motor that draws electricity from a battery and is capable of being charged from an external source.⁵⁵ An EV includes both a vehicle that can only be powered by an electric motor that draws electricity from a battery (all-electric vehicle) and a vehicle that can be powered by an electric motor that draws electricity from a battery and by an internal combustion engine (plug-in hybrid electric vehicle- PHEV). For the purposes of this report, 'vehicle' is limited to means of transportation on roads.

End-of-life (EOL)

The moment where a battery reaches the end of its usefulness and/or lifespan, as originally manufactured, in an EV.

Energy density

The amount of energy a battery contains compared to its weight or size.

Electrolyte

The battery component which allows ions (charge carrying particles) to pass easily between the anode and cathode. Liquid electrolytes in current EV batteries are lithium salts (lithium ions).

Kilowatt-hour (kWh)

Measure of a battery's energy capacity. 1 kWh is defined as the energy consumed at a power level of 1 kW for one hour. It is also the unit used to measure electricity consumed on an electric meter. Washington utility rates vary from \$0.03-0.15 /kWh, averaging 13 cents/kWh in September 2023, according to the Energy Information Administration.

Lithium-ion battery (LIB)

A type of rechargeable battery which uses the reversible reduction of lithium ions to store energy.

Lithium iron phosphate (LFP)

A chemical compound, LiFePO_4 , commonly called LFP. LFP batteries use lithium iron phosphate as the cathode material to store lithium ions. LFP batteries typically use graphite as the anode material. The chemical makeup of LFP batteries gives them a high current rating, good thermal stability, and a long lifecycle.

Lithium nickel-cobalt-aluminum oxide (NCA)

A highly thermally stable cathode material used in lithium-ion batteries.

Nickel-manganese-cobalt (NCM)

A cathode material used in batteries. While NCM is technically LNCMO, it is called NCM for convenience's sake and is created when nickel (Ni) and manganese (Mn) are mixed into lithium cobalt oxide (LCO). Depending on the percentage of these materials in the battery's cathode, different characteristics are achieved. NCM-811 refers to the nickel-rich layered cathode material, comprising 80% nickel, 10% cobalt, and 10% manganese.

Post-first-life application

The use of an EOL battery which helps to extend its usable life before it is ultimately recycled or disposed of. Applications include:

⁵⁵ <https://afdc.energy.gov/laws/12660#:~:text=An%20EV%20is%20defined%20as,charged%20from%20an%20external%20source.>

- Reuse in another electric vehicle after the battery has been removed from the original vehicle.
- Reuse in electric vehicles after operators create a new battery from the packs and cells that have sufficient remaining capacity through a process known as refurbishment or remanufacturing.^{56, 39}
- Reuse in an EV conversion using previously used battery modules or battery pack(s).
- Repurposing an EV battery in an energy storage system.

Remanufacturing (Refurbishing)

A process of extensive refurbishing of used, but usually not defective, products to restore them to the quality standards of the product as if it were new. To this end, the product in most cases is partially or completely disassembled to inspect the components and/or sub- assemblies.

Repair

A process in which a battery is serviced.

Reuse

A process in which an EV battery is used in another EV after it is removed from the original vehicle.

Repurpose

Use of EV batteries in a non-EV context, i.e., batteries used for energy storage systems.

Vehicle dismantling

Removing vehicle parts, including the battery, and collecting them for reuse, repurposing, recycling, or sale.

Waste

A used or unused battery becomes a waste on the date the handler decides to discard it. Most batteries meet the definition of dangerous waste⁵⁷ (ignitable, reactive, and/or corrosive) but may be managed under the universal waste standards.⁵⁸ Waste generators are required to evaluate a battery to determine whether it meets criteria that qualifies it as dangerous waste or universal waste. Businesses may manage spent EV batteries as a universal waste.

⁵⁶ <https://www.api.org/~media/Files/Oil-andNaturalGas/Fuels/Kelleher%20Final%20EV%20Battery%20Reuse%20and%20Recycling%20Report%20to%20API%2018Sept2019%20edits%2018Dec2019.pdf>.

⁵⁷ WAC 173-303-040

⁵⁸ Standards for Universal Waste Management, WAC 173-303-573.

Appendix B. Acronyms

DDR

Refers to a damaged, defective, or recalled EV battery.

DIY

Do-it-yourself.

OEM

Original equipment manufacturer. Vehicle manufacturers or battery manufacturers.

EOL

End-of-life.

EPR

Extended producer responsibility.

EV

Electric vehicle.

ICE

Internal combustion engine.

IJA

Infrastructure Investment and Jobs Act.

IRA

Inflation Reduction Act.

ITC

Investment Tax Credit.

kWh

Kilowatt-hour. Measure of a battery's energy capacity.

LIB

Lithium-ion battery chemistry.

LFP

Lithium iron phosphate battery chemistry.

NCA

Lithium nickel-cobalt-aluminum oxide battery chemistry.

NCM

Nickel-manganese-cobalt battery chemistry.

SOH

EV battery state-of-health.

Appendix C. Applicable Codes, Laws, and Regulations

Regulations and standards govern the dismantling and disassembly of vehicles, as well as the management, transportation, and storage of LIBs within Washington state and the U.S. as detailed in Table 2.

Table 2. Regulations and codes relevant to EV battery management within Washington state.

EV LIB Management Activity	Relevant Regulations
Dismantling of a vehicle (Vehicle parts removed and collected, including the battery, and are discarded or recycled)	<p>Washington Facility Licensing Requirements: Washington Administrative Code (WAC)</p> <p>High voltage equipment and personnel safety references: NFPA 70B/E; IEEE C2 and IEEE 3007.3; OSHA 29 CFR 1926 and 1910</p> <p>Washington Fire and Building Codes and Standards: 2021 Washington State Fire Code, and amendments of Chapter 12 of the 2021 edition of the International Fire Code; 2023 edition of NFPA 855 for the Installation of Energy Storage Systems (extended)</p> <p>Washington State Dangerous Waste Regulation, Chapter 173-303 WAC; Standards for Universal Waste Management: WAC 173-303-573</p>
Shipping and Transport of an EV LIB	Hazardous Materials Regulations, U.S. DOT: 49 CFR §173.185
Storage of an EV LIB	<p>Washington Fire and Building Codes and Standards: 2021 Washington State Fire Code, and amendments of Chapter 12 of the 2021 edition of the International Fire Code; 2023 edition of NFPA 855 for the Installation of Energy Storage Systems (extended)</p> <p>Federal Universal Waste Regulations: 40 CFR §273.15</p> <p>Washington State Dangerous Waste Regulation, Chapter 173-303 WAC; Standards for Universal Waste Management: WAC 173-303-573</p>

EV LIB Management Activity	Relevant Regulations
<p>Disassembly (Vehicle parts removed and collected, including the battery, and reused or remanufactured)</p> <p><i>*Under Washington Standards for Universal Waste Management, batteries that no longer serve their intended purpose are considered waste.</i></p>	<p>Washington Facility Licensing Requirements: Washington Administrative Code (WAC), Title 46.</p> <p>High voltage equipment and personnel safety references: NFPA 70B/E; IEEE C2 and IEEE 3007.3; OSHA 29 CFR 1926 and 1910</p> <p>Washington Fire and Building Codes and Standards: 2021 Washington State Fire Code, and amendments of Chapter 12 of the 2021 edition of the International Fire Code; 2023 edition of NFPA 855 for the Installation of Energy Storage Systems (extended)</p> <p>Repurposed Batteries (designated as waste): Washington State Dangerous Waste Regulation, Chapter 173-303 WAC; Standards for Universal Waste Management: WAC 173-303-573</p>
<p>Energy Storage System (ESS) Installation</p>	<p>Washington Electrical Storage Requirements: 2021 Washington State Fire Code, and amendments of Chapter 12 of the 2021 edition of the International Fire Code; 2023 edition of NFPA 855 for the Installation of Energy Storage Systems (extended)</p>
<p>Hazardous Waste Handling, Treatment, Storage, and Disposal</p>	<p>Federal Universal Waste Regulations, Standards for Destination Facilities: 40 CFR §273, Subpart E</p> <p>Permitting requirements: 40 CFR §124 and 40 CFR §270</p> <p>Standards for hazardous waste treatment, storage, and disposal facilities: 40 CFR Parts 124, 264, 265, 266, 268, and 270</p> <p>Notification requirement: Section 3010 of Subtitle C of the Resource Conservation and Recovery Act (RCRA)</p> <p>Washington State Dangerous Waste Regulation, Chapter 173-303 WAC</p>

Appendix D. Webinar Meeting Summaries

Fact-finding webinar - September 26, 2023

The early portion of the fact-finding webinar was spent providing an overview of the EV Battery Collection and Management Study process. Representatives from the Washington State Department of Ecology clarified that this process is not currently informing any legislation or rules but is focused on gathering information on current practices and perspectives of those in the EV battery management space.

A representative from a vehicle dealership described in depth the procedure at their location for determining battery end-of-life, removing the battery from the vehicle, storing it briefly, and packaging it appropriately to transport it to another branch of the company. This company's policy is to replace the whole battery unit, and send the old battery back to the OEM, rather than replace specific damaged cells within the battery. The battery's safety plug is pulled to make its connectors dead, but the dealership lacked equipment to discharge the battery cells prior to transport. The representative explained that even if there is residual energy in the battery, if the connectors are dead, the voltage cannot reach the car and it is safe for first responders or vehicle technicians to work around. The removed battery is repackaged in the protective shell that the replacement battery arrived in. The representative explained that there is significant documentation in the transportation process, and that drivers of trucks carrying EV batteries are provided with emergency safety information.

A representative from a different automaker shared that they follow similar procedures to what the first representative shared, but that they can replace individual damaged battery cells, rather than replacing the whole battery module or pack.

One of the automaker representatives reported that three used hybrid vehicle batteries were abandoned on their dealership lot, and the dealership had to pay for their end-of-life.

A conversation about emergency response to battery fires took place. A representative from an automaker voiced that special equipment and chemicals were required to put out lithium battery fires, and that water cannot be used. A representative from a local fire department countered that statement, by informing the group that emergency services have no special chemicals to extinguish EV battery fires, and instead uses tens of thousands of gallons of water, as recommended by the National Fire Protection Association (NFPA). Another emergency management professional followed that up by stating that local fire services are moving to a stance of non-intervention, and letting EV battery fires burn out, while keeping the fire contained. A large battery recycler stated that they had the chemical agent F500 onsite to extinguish battery fires.

Interested parties webinar - September 28, 2023

The interested parties webinar sparked a lively conversation around several poll questions (see Figure 7), which gauged attendees' perspectives on several emerging themes from research.

Emerging Themes

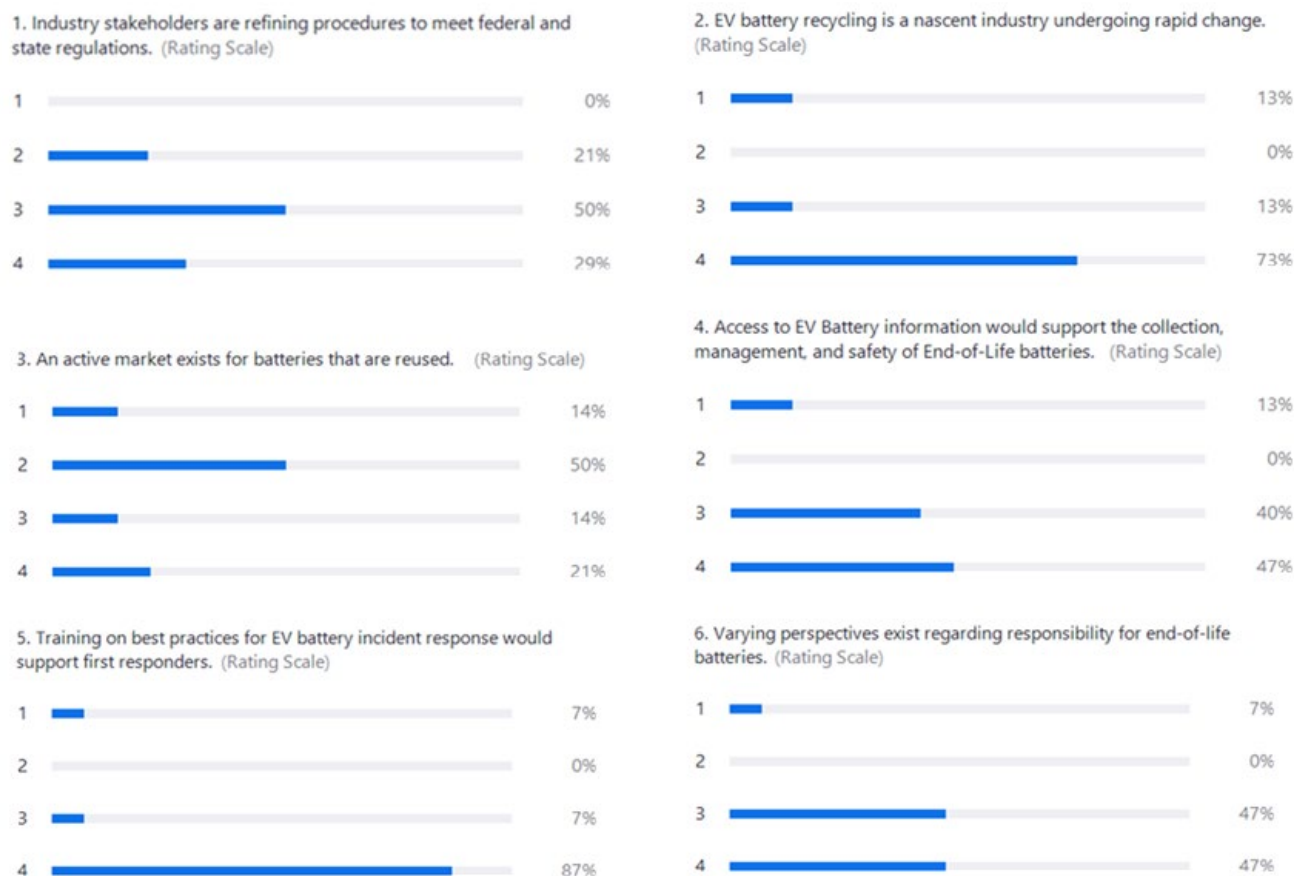


Figure 7. Poll responses to emerging themes.

The poll asked respondents to rate statements on a scale from 1-4 with the higher number translating to higher support (1- strongly disagree, 2 – disagree, 3 – agree, 4- strongly agree). Poll responses showed majority strong agreement with the statement “training on best practices for EV battery incident response would support first responders.” Webinar attendees also strongly agreed with the statement “EV battery recycling is a nascent industry undergoing rapid change.” Most respondents also agreed or strongly agreed that access to EV Battery information would support the collection, management, and safety of EV batteries, and that varying perspectives exist regarding responsibility for end-of-life batteries. A more mixed response was received to the statement “An active market exists for batteries to be reused.” Conversations around that question revealed that there was uneven awareness among webinar attendees of the extent of the reuse market. Some webinar attendees in the emergency management sector expressed concern with the safety of EV battery reuse. Respondents recognized that there are individuals and businesses reusing batteries safely and meeting regulatory requirements. Multiple respondents pointed out that many lithium-ion battery fires are coming not from EV batteries, but smaller batteries, like those in micro-mobility devices.

The interested parties webinar also highlighted that while large vehicle OEMs have well-defined procedures and connections for sending used EV batteries for recycling or remanufacturing, smaller entities do not. One attendee recalled local officials being at a loss for how to deal with an EV battery abandoned in a parking lot. Other more sporadic receivers of EV batteries, like small businesses, (e.g., independent auto repair shops or EV conversion participants) solid waste companies, and the emergency response community, have less awareness of or connections with entities that will collect and recycle the batteries at a reasonable cost.

The respondents in the interested parties webinar were able to highlight areas of a flowchart of EV battery end-of-life pathways, that they felt they understood well, or had questions on. The most questions were marked on what happens when an EV battery goes through a collision, fire, or flood, when an EV battery goes to an auto auction, and when an EV battery goes to DIY reuse, DIY dismantling, disposal, or abandonment. The most well understood pathways were when a battery was within or outside of warranty and goes to a dealership for repair or remanufacturing.

Appendix E. Policy Advisory Group Meeting Summaries

Policy Advisory Group Meeting #1 – January 4, 2024

The first Policy Advisory Group meeting began with an overview of the group's purpose of informing the recommended immediate-, mid-, and long-term policy needs for EV battery management in Washington to be included in the final Washington EV Battery Management Study Report. One key recommendation identified was the need to create an EV Battery Task Force to guide further consideration of the mid-term and long-term policy recommendations over the next several years. The Policy Advisory Group was presented with a list of potential stakeholders to be included on such a Task Force and asked to fill any identified gaps to ensure all relevant parties are represented in this Task Force.

The group then moved into a discussion of immediate policy needs. Representatives from emergency response community identified the need for a central repository of best practices for fire response, towing, storage, and auto recycling when dealing with damaged EV batteries. Attendees noted that there is some information available on the subject, but best practices are frequently changing and scattered across different sources. The group determined that centralized information on EV battery management best practices would also help address the issue of stranded batteries. Preliminary research found most batteries still falling under manufacturer warranty. While recyclers have reported different levels of value for batteries, there are battery recyclers finding positive value in orphaned batteries. As more EV batteries are no longer covered by warranty, or if battery values change, the potential for stranded or abandoned batteries could increase.

For mid-term policy priorities, the group discussed the current lack of permitting and codes specific to DIY reuse and repurposing of EV batteries and acknowledged the need for future permitting requirements to prevent dangerous home applications. Representatives from the battery recycling and vehicle manufacturing sectors shared that policies around universal battery diagnostic tools would likely not be effective as a mid-term priority because, though many entities are currently investing in diagnostic tools, the technical feasibility of wide-spread use of the tools is still ways off.

In the discussion of long-term policy priorities, meeting attendees from across sectors broadly supported recent examples of flexible EPR bills and programs, like those from New Jersey and Quebec.

Policy Advisory Group Meeting #2 – January 31, 2024

The second Policy Advisory Group meeting continued discussions of immediate-, mid-, and long-term policy priorities from the first meeting, informed by a policy advisory group survey that was sent out between the two meetings. The group reaffirmed support for education, training, and resources for first and second responders, as well as auto recyclers, and noted the need for training specifically related to safe handling and transportation of EV batteries.

The group then engaged in a conversation around financial responsibility for EV batteries. The group showed broad support for vehicle manufacturers' responsibility for an EV battery ending once the battery is removed from the vehicle for third party reuse, repurposing, or recycling. A representative from the battery recycling sector pointed out that without a clearly identified chain of financial

responsibility, de facto responsibility of negative-value EV batteries is placed on auto recyclers and consumers. The group discussed the need to engage the insurance industry in future conversations around financial responsibility. One attendee explained that normally, if the battery stays in the car in the event of a crash, the battery is considered part of the car and properly reusing or recycling it is a cost covered by insurance. However, there are instances in which insurance may not currently cover costs around end-of-life EV batteries. One example was of a crash in British Columbia, in which the battery was ejected from the EV, caught on fire, and was eventually covered with sand to smother the flames. This created costs for environmental remediation that insurance did not consider as covered costs. Because of this, the battery and sand remained in place at the crash site for months. In an example from Florida, EVs with saltwater damage from flooding were written off by insurance and sold at auction. Many of these batteries went overseas, but some were purchased by consumers in the US, where they later caught fire because of the saltwater damage, causing additional costs and putting lives at risk. The group raised concerns that changing what is covered by insurance for EVs could have cost impacts to consumers that could negatively impact adoption.

This example renewed discussion of the dangers posed by reused batteries that are not properly inspected. Multiple attendees voiced concern that without new rules around liability, a growing market of DIY battery reuse would mean growing potential for dangerous house and vehicle fires that could risk lives and impose costs on the public and the state. One representative from emergency management highlighted the additional dangers first responders face when approaching a structure fire if they are unaware it is caused by repurposed EV batteries. Another representative cautioned the group to also consider that restricting consumers' ability to alter and reuse their EV batteries would go against the right to repair movement, and that representing consumers' interests well should be a key consideration moving forward.

The group again showed broad support for a flexible EPR policy, like the approaches taken in New Jersey, Quebec, and recently proposed in Hawaii.

Policy Advisory Group Survey Questions

The following represents the survey sent to stakeholders participating in the policy advisory group.

This survey is to seek feedback from stakeholders invited to participate in a policy advisory group for the Washington EV Battery Management Study. The Washington State Department of Ecology is in the process of soliciting stakeholder input in the development of recommendations for the collection and management of Electric Vehicle (EV) batteries pursuant to Engrossed Second Substitute Bill 5144, Section 17. A preliminary report was submitted to the legislature on December 4, 2023, that recommended additional stakeholder input to develop policy recommendations for the final report. The final report will include recommendations on immediate policy needs. The report will recommend the formation of a Washington EV Battery Task Force to address mid- and long-term policy needs. A list of potential policy needs for a Washington EV Battery Task Force's consideration will be included in the final legislative report. The results of this survey will inform what immediate, mid-term, and long-term policy priorities are included in the final report. Your participation is appreciated.

Q1 Name (First, Last):

Q2 Name of Organization:

Q3 Please sort policy priorities into groups and rank them within each group, with the highest-ranking priority being the most important to address. Policy priorities can be sorted into immediate policy priorities for Washington state (a policy is urgently needed), mid-term policy priorities for Washington state (a policy is needed in 2-5 years), long-term policy priorities (a policy is needed with a timeframe greater than 5 years), and federal policy priorities. There is also a group for policy priorities that you oppose being pursued by either the Washington state or federal government. These do not need to be in a ranked order. The policy priorities listed focus on the underlying need as much as possible, and the strategy for how it would be achieved could be developed by a Washington EV Battery Task Force. An example is that there is a need to fund future programs that manage EV Batteries, but there are many strategies for how that could be done (i.e. a core exchange program, extended producer responsibility, etc.)

Group 1: Immediate Policy Priorities for Washington State

Group 2: Mid-term Policy Priorities for Washington State

Group 3: Long-term Policy Priorities for Washington State

Group 4: Federal Policy Priorities

Group 5: Opposed to Policy Priority Being Pursued by Washington State or Federal Government

Policy Priorities Discussed:

_____ Provide education, training, and resources for first and second responders.

_____ Provide education, training, and resources for auto recyclers and salvage yards.

_____ Identify who is responsible for EV batteries after a vehicle incident.

_____ Identify who is responsible for EV batteries when they are no longer under warranty.

_____ Develop training materials on safe and efficient transportation, handling, management, and collection.

_____ Access to diagnostic tools for entities who interact with used EV batteries or damaged electric vehicles.

_____ Access to information on battery health for reuse, resale, or repurposing.

_____ Reduction in environmental and community hazards posed by EV batteries.

_____ Develop logistics systems for efficiently collecting and transporting EV Batteries in state (i.e. hub and spoke model)

_____ Develop best practices for checking the health of the battery when entering its second or third life.

_____ Advance reuse or repurposing of EV batteries.

_____ Advance EV battery recycling.

_____ Develop a funding system (or fee) to finance collection, recycling, and safety programs related to EV batteries.

_____ Develop incentives or an exchange program to encourage consumers to turn in EV batteries.

_____ Use Extended Producer Responsibility as the mechanism to fund and manage EV Battery collection, recycling, and programs related to EV batteries.

_____ Use permits or other tools to regulate the reuse and repurposing of EV Batteries by individuals or businesses to support public safety.

_____ Develop a process standard for the disassembly, processing and recycling of lithium-ion batteries that can be verified by a third party to guarantee a minimum environmental standard.

_____ Clearly define responsibility for the financing of recycling EV batteries that cost more money to collect and recycle than the value of their materials.

_____ Access to battery information from the original equipment manufacturer (OEM).

_____ Access to battery chemistry information (i.e., marking or labeling).

_____ Increased transparency and standardization within the battery recycling and automotive salvage/dismantling communities.

_____ Increased transparency of the battery supply chain.

_____ Efficient and safe transportation regulations that apply to EV batteries.

_____ Require or incentivize original equipment manufacturers to design EV batteries in a way that makes repurposing, reuse, and recycling less time and cost intensive.

_____ Ensure eligibility of used EV batteries for use in existing and new grid-related incentive programs.

_____ Incentivize the development of a universal diagnostic system for EV battery health.

Q4 Please use this space for questions or comments on the potential policy priorities. This space can also be used if there is additional information you would like to share on your ranking and sorting.

Q5 Are there other immediate policy priorities that the state of Washington should address for EV battery management?

Q6 Are there other mid-term (2-5 years) policy priorities that the state of Washington should address for EV battery management?

Q7 Are there other long-term (greater than 5 years) policy priorities that the state of Washington should address for EV battery management?

Q8 A proposed recommendation for the final legislative report is to form an EV Battery Task Force to address mid- and long-term policies for Washington state. (Potential participants are listed in pdf of

the January 4th meeting presentation slide deck and in the meeting summary notes.) Who should be on the task force for it to have a balanced representation from different stakeholders?

Q9 Who should have financial responsibility for EV battery collection, management, and recycling?

Appendix F. Summary of Survey Results

The consultant team disseminated a survey to potential stakeholders to develop a more complete understanding of EV battery management in the State of Washington. The survey was also available on Ecology’s website through January 31, 2024. This survey is separate from the Policy Advisory Group Survey discussed in Appendix E, and rather was to tool to gather information. The survey asked stakeholders to share their knowledge of the opportunities and barriers for EV battery collection and management; gathers information on the current collection and management of EV batteries; and identifies potential priorities and policies on EV battery management to help inform policy recommendations. See Appendix H for example survey questions. The findings include responses from 113 multiple interest stakeholder groups (Figure 8). Only 24% of respondents completed the full survey (Figure 9), with many opting to only answer sections pertinent to their industry or on topics which they had information to share.

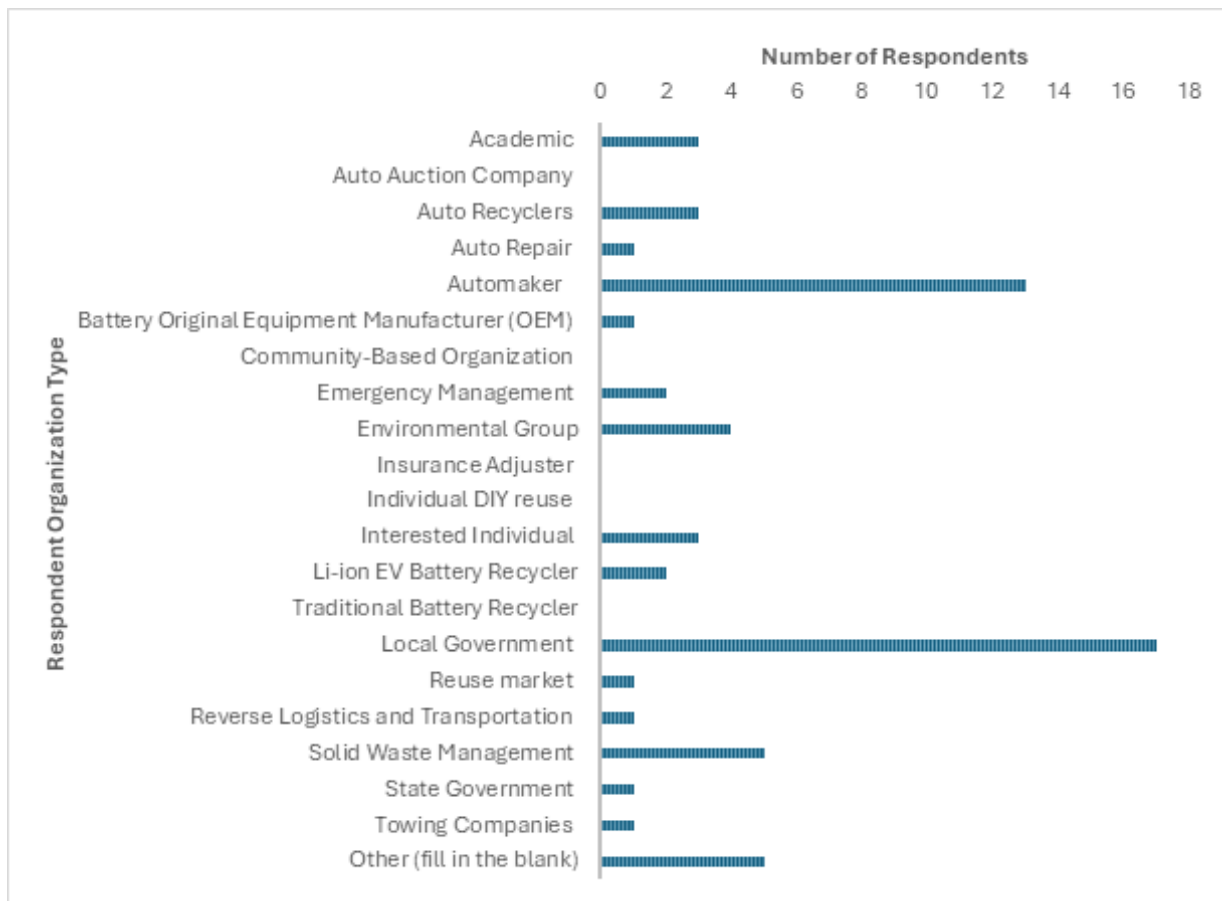


Figure 8. Survey respondents who initiated the survey.

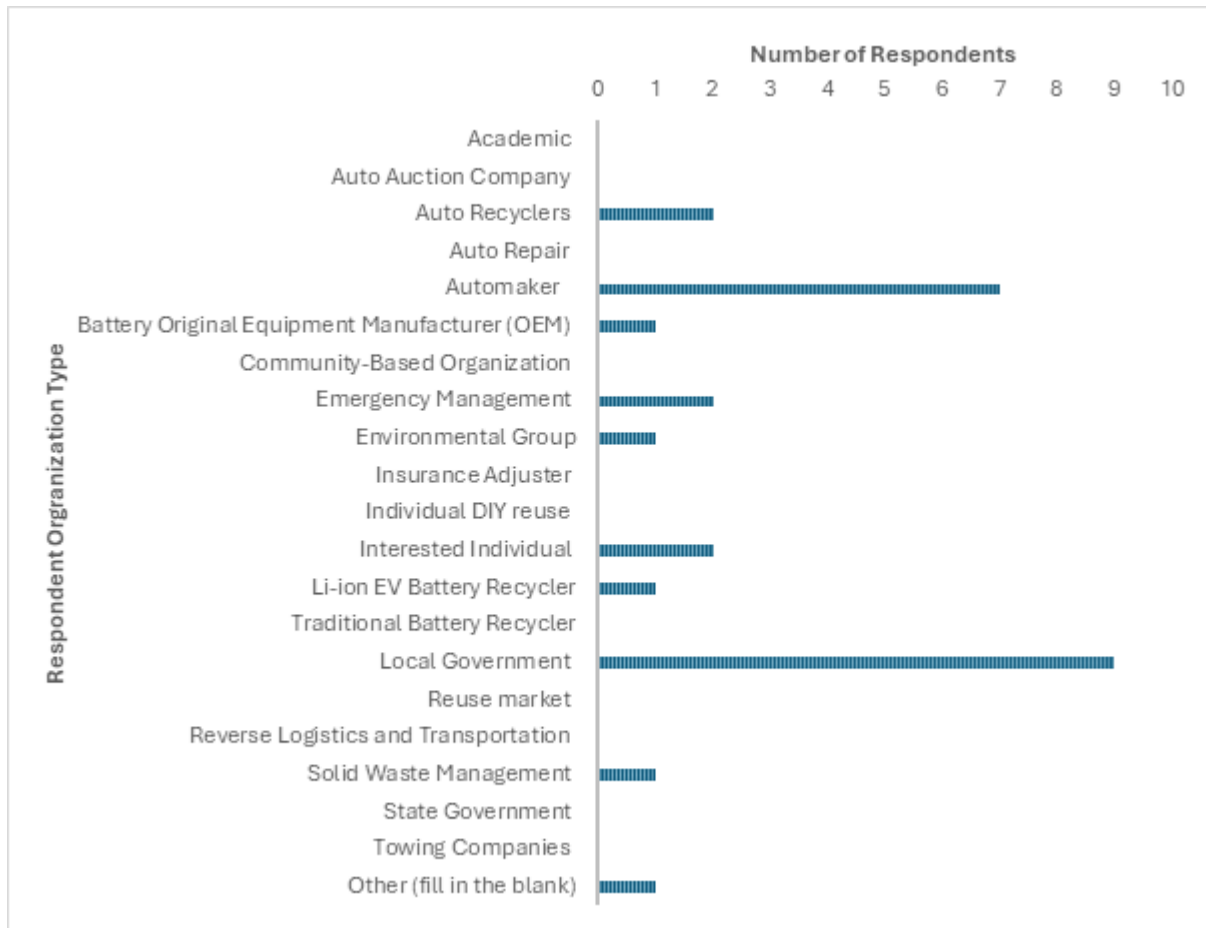


Figure 9. Survey respondents who completed the full survey.

Findings

With limited representation from certain interest groups, the research team urges readers to use caution when drawing conclusions from the data on what policies and priorities have broad support and or mixed support. The findings provide a stage to engage interested parties in future discussion.

Priorities

Stakeholders indicate *apparent support* for the following priorities.

- Access to battery information from the original equipment manufacturer (OEM).
- Access to battery chemistry information.
- Reduction in environmental and community hazards posed by EV batteries.
- Safe removal, handling, and transportation of EV batteries.
- Advancement of EV battery recycling industries.
- Streamlined and coordinated rules for within-state EV battery transportation.
- Clear battery ownership guidelines to remove ambiguity concerning environmental liability.
- Access to information about how to respond to EV battery fires.

- Training for emergency responders on how to fight EV battery fires.

Stakeholders indicate mixed support for the following priorities.

- Access to information on battery health for reuse, resale, or repurposing.
- Clearly defined responsibility for the payment of recycling EV batteries that cost more money to collect and recycle than the value of their materials.

Policies

Stakeholders hold limited opposition for the following policies.

- Support the enforcement of unlicensed dismantling laws to prevent environmental hazards and stranded batteries.
- Clarify and harmonize regulations that pertain to the transportation of batteries within Washington state.
- Require original equipment manufacturers (OEMs) to provide information on how to respond to fires due to EV batteries they manufacture.
- Develop training materials on safe and efficient transportation, handling, management, and collection.

Stakeholders indicate mixed support for the following policies.

- Require producer take-back with companion legislation requiring return of lithium-ion batteries to the original equipment manufacturer at end-of-life.
- Apply an environmental handling fee at the time of purchase to finance a collection, recycling, and safety program.
- Require recovery rates for specific critical materials in batteries such as cobalt, nickel, lithium, and copper.
- Require or incentivize original equipment manufacturers to design EV batteries in a way that makes repurposing, reuse, and recycling less time and cost intensive.
- Develop a process standard for the disassembly, processing and recycling of lithium-ion batteries that can be verified by a third party to guarantee a minimum environmental standard.
- Require recycled content standards for EV battery manufacturers.
- Apply a fee that is split between the EV owner and auto-manufacturer at the time of purchase to finance a collection, recycling, and safety programs.
- Assign a battery identification number (like a VIN for cars) to EV batteries.
- Incentivize the development of a universal diagnostic system for EV battery health.
- Create an online database for tracking and reporting lithium-ion batteries that are end-of-life (for the purposes of this survey, a battery is at the end-of-life when it is done with its original use in a vehicle).

- Require companies that are recycling batteries to report their total recovery rates, as well as the recovery rates of cobalt, lithium, manganese, and nickel.
- Encourage the insurance industry to provide coverage for out-of-warranty batteries and/or batteries refurbished for ongoing vehicle use.
- Ensure eligibility of used EV batteries for use in existing and new grid-related incentive programs.
- Establish battery rebates, returnable deposits, or recycling stipends to encourage consumers to recycle batteries.
- Develop an end-of warranty battery exchange program that would encourage consumers to turn in EV batteries for new or refurbished EV batteries.
- Develop strategic collection and sorting facilities in Washington state to reduce transportation costs.

Appendix G. Example Interview Questions

Below is an example set of interview questions that the consultant team used in industry stakeholder interviews.

General

1. What does your day-to-day involvement with EV batteries look like? How does your company/organization interact with EV batteries?
2. Roughly what volume of EV batteries is your industry currently interacting with at end-of-life?

End-of-life process

1. What are the common pathways for batteries at the end of their life in the original vehicle?
 - a. For an intact car with a battery at EOL?
 - b. For a wrecked car with a functioning battery?
 - c. What are relevant financial considerations for various end-of-life pathways?
2. At what point are batteries removed from vehicles?
 - a. What are the common methods of battery removal, and who carries out this process?
 - b. How much time/cost does it take to remove a battery pack?
 - c. Do you know of sites where battery packs are removed from vehicles?
3. Are there methods to tell if a battery is damaged? If so, please explain.
 - a. What information would be useful for salvage yards to flag if a battery is damaged?
 - b. What about its general state of health?
4. How is it determined whether a battery is worth reselling?
 - a. Who makes this determination?
 - b. Are there records of sales and buyers?
5. Who makes the determination of whether or not a battery is suitable for reuse?
 - a. When is this determination made?
 - b. How is this determination made?
 - c. What is the tipping point that determines that a battery has negative value?
6. Who sells EV batteries?
 - a. Where are they sold?
 - b. How much are they typically sold for? (a range is fine)
 - c. Who buys EV batteries?

- d. What are the financial motivations for buying used EV batteries?
7. At what point are batteries fully discharged for safe transport and storage or recycling?
8. Can you describe the process of how batteries are shipped when they leave your facility?
 - a. Can you describe the players involved in the shipping process?
 - b. Can you describe shipping methods used for batteries?
 - c. Who pays for the shipping?
 - d. What types of containers are used to ship batteries?
 - e. Do shippers assume responsibility for the safety of the batteries during shipping?
9. Where are EVs (and batteries) ending up?
 - a. Do they leave the state?
 - b. Do they leave the country?
10. What do you see as the biggest challenges to the end-of-life process for EV batteries?
11. What do you see as the biggest opportunities for the end-of-life process for EV batteries?

Storage and stockpiling

1. Where are EV batteries stored or stockpiled once they are removed from vehicles?
 - a. Are there specific facilities designated for their temporary storage?
 - b. What safety measures are in place?
 - c. Do you know of specific locations where batteries are stored or stockpiled?
2. Is there anything specific that concerns you about the storage and stockpiling of EV batteries?

Disposition pathways

1. What happens to EV batteries after they are collected?
 - a. Are they sold to a secondhand market?
 - b. Sold to battery recyclers?
 - c. Disposed of?
 - d. Other?
 - e. Do you have any insight as to roughly what percentage of EV batteries are reused after the original vehicle usage versus recycled?
2. Where and how do auto recyclers acquire EVs?
3. How do you handle batteries that are going to different disposition pathways?
4. What are the existing practices and infrastructure for each of these pathways?
5. Are there barriers or exceptions to recycling?

- a. How would you ease these barriers?
- b. What standardization can be applied to battery pack design to support efficient recycling?

Battery chemistry considerations

1. Are you able to differentiate between battery chemistries?
 - a. If yes, does this contribute to safety considerations?
 - b. If not, what would be helpful to help differentiate between chemistries?
2. Would you potentially be supportive of nuanced regulations to support the differing safety considerations of varying battery chemistries?
 - a. What about nuanced regulations to support the differing economic considerations of varying battery chemistries?
 - b. Are there existing regulations or incentives that best support recycling certain battery chemistries?

Regulatory framework

1. How do current regulations and guidelines regarding EVs, and EV batteries impact your industry segment?
 - a. What specific regulations apply to your industry segment?
 - b. Which are most burdensome?
 - c. Which are most supportive?
 - d. Do any of these regulations address environmental protection and public safety?
2. What regulations or guidance would be helpful for your industry to function most effectively to enable safe handling, storage, transportation and ultimately recycling of Li-ion batteries?
 - a. Are there existing regulations, policy proposals or guidelines in Washington that you would like to see changed?
3. Are there existing regulations, policy proposals, or guidelines from other states that you would like to see in WA?
 - a. Are there regulations, policy proposals, or guidelines from other states that you don't want to see in WA?

Conclusion

1. Please describe information gaps or education needs to help your industry segment.
 - a. Would it be useful to have more information about:
 - i. Safe handling and storage best practices?

- ii. Differences in battery chemistries and corresponding flammability if damaged?
2. Can you describe ways your industry can help fill information gaps that may exist to better inform stakeholders, policy makers and the public about how your industry functions and the important role it plays with EV batteries?
3. In an ideal world, what would you see as the best practices for your industry related to EV Battery end-of-life and recycling?
4. Are there any suggestions for best practices you would like to share with other stakeholders in the EV battery industry?

Appendix H. Example Survey Questions

Washington State Electric Vehicle Battery Management Survey

SECTION 1.

Below are questions about your involvement with electric vehicle (EV) batteries.

1. Please select what best describes your organization or involvement with EV batteries.

- Academic
- Auto Auction Company
- Auto Recyclers
- Auto Repair
- Automaker
- Battery Original Equipment Manufacturer (OEM)
- Community-Based Organization
- Emergency Management
- Environmental Group
- Insurance Adjuster
- Individual DIY reuse
- Interested Individual
- Li-ion EV Battery Recycler
- Traditional Battery Recycler
- Local Government
- Reuse market
- Reverse Logistics and Transportation
- Solid Waste Management
- State Government
- Towing Companies
- Other (fill in the blank) _____

2. Please describe your day-to-day involvement with EV batteries.

3. Please enter an estimate for the number of batteries your organization works with on an annual basis.

SECTION 2.

The regulatory landscape for the management of EV Batteries is evolving at both the state and federal levels. Regulations and laws may change based on federal level policy decisions. Below, questions invite stakeholders to provide input on codes, regulations, and policies. You may skip questions for which you do not have an answer or are unable to share an answer.

1. **What codes, regulations, and policies are you aware of that apply to your EV (and EV battery) practices or are of interest to you?**
2. **What changes to the existing codes, regulations, and policies would you suggest? Please list or describe the code along with the desired revision(s).**
3. **Are there additional codes, regulations, and policies that you feel are important to EV battery management in Washington state and are worth considering?**
4. **What information would help people in your industry, sector, or community to better access or understand codes, regulations, and policies?**

SECTION 3.

The Department of Ecology has been tasked to develop recommendations for EV battery management in Washington with the help of stakeholders. EV battery management programs and potential policies could take many forms and have different goals. Please indicate your support for the following possible priorities or policies of an EV battery management program. Some of the items listed may or may not fall under the jurisdiction of Washington state. We list them here to capture the broader interests and needs of stakeholders.

[We would like to thank California EPA's Lithium-Ion Car Battery Recycling Advisory Group (2022 Final Report) and Colorado State University's Thomas H. Bradley and Timothy C. Coburn (2021 Colorado EV battery recycling study) for their efforts designing policies which informed the options in this section of the survey. A number of potential priorities and policies listed in this section were adapted or came directly from these reports.]

1. **Please indicate your level of support for the following priorities from Strongly Oppose to Strongly Support.**
 - a. Access to battery information from the original equipment manufacturer (OEM).
 - b. Access to battery chemistry information.
 - c. Access to information on battery health for reuse, resale, or repurposing.
 - d. Increased transparency and standardization within the battery recycling and automotive salvage/dismantling communities.
 - e. Increased transparency of the battery supply chain.
 - f. Streamlined and coordinated rules for within-state EV battery transportation.
 - g. Development of an exchange program for li-ion EV batteries (cores) similar to the program for lead acid batteries.
 - h. Advancement of EV battery reuse or repurposing industries.
 - i. Advancement of EV battery recycling industries.

- j. Safe removal, handling, and transportation of EV batteries.
- k. Reduction in environmental and community hazards posed by EV batteries.
- l. Increased efficiency in the removal, handling, and transportation of EV batteries.
- m. Reduced cost of locating EV battery processing facilities in Washington from increased ease of permitting.
- n. Access to diagnostic tools for entities who interact with used EV batteries or damaged electric vehicles.
- o. Clear battery ownership guidelines to remove ambiguity concerning environmental liability.
- p. Clearly defined responsibility for EV battery end-of-life processes including reuse, refurbishment, and repurposing.
- q. Clearly defined responsibility for the payment of recycling EV batteries that cost more money to collect and recycle than the value of their materials.
- r. Access to information about how to respond to EV battery fires.
- s. Training for emergency responders on how to fight EV battery fires.

2. Are there other priorities that Washington state should consider for EV battery collection and management?

3. Please share your level of support for the following possible policy options from Strongly Oppose to Strongly Support.

- a. Require a digital identifier on every EV battery to access information about the battery.
- b. Require a physical written label on every EV battery with information about the battery.
- c. Assign a battery identification number (similar to a VIN for cars) to EV batteries.
- d. Incentivize the development of a universal diagnostic system for EV battery health.
- e. Create an online database for tracking and reporting lithium-ion batteries that are end-of-life (for the purposes of this survey, a battery is at the end-of-life when it is done with its original use in a vehicle).
- f. Require companies that are recycling batteries to report their total recovery rates, as well as the recovery rates of cobalt, lithium, manganese, and nickel.
- g. Require pre-approval from interested parties to bid on EVs at auctions to enable tracking of EV batteries purchased at auctions.
- h. Incentivize EV battery research and development, including businesses that focus on reusing and repurposing EV batteries.
- i. Encourage the insurance industry to provide coverage for out-of-warranty batteries and/or batteries refurbished for ongoing vehicle use.
- j. Ensure eligibility of used EV batteries for use in existing and new grid-related incentive programs.

- k. Modify Washington State Dangerous Waste Regulations to have EV batteries only be considered waste after it has been shown that they cannot be recycled, to make it easier for the materials such as lithium, cobalt, and other critical materials to be reused.
- l. Provide EV battery recycling incentive packages such as tax breaks or grants.
- m. Establish battery rebates, returnable deposits, or recycling stipends to encourage consumers to recycle batteries.
- n. Develop an end-of warranty battery exchange program that would encourage consumers to turn in EV batteries for new or refurbished EV batteries.
- o. Support the enforcement of unlicensed dismantling laws to prevent environmental hazards and stranded batteries.
- p. Develop training materials on safe and efficient transportation, handling, management, and collection.
- q. Support transportation research for safe and efficient removal, handling, and transportation of EV batteries.
- r. Develop strategic collection and sorting facilities in Washington state to reduce transportation costs.
- s. Clarify and harmonize regulations that pertain to the transportation of batteries within Washington state.
- t. Require producer take-back with companion legislation requiring return of lithium-ion batteries to the original equipment manufacturer at end-of-life.
- u. Apply an environmental handling fee at the time of purchase to finance a collection, recycling, and safety program.
- v. Apply a fee that is split between the EV owner and auto-manufacturer at the time of purchase to finance a collection, recycling, and safety programs.
- w. Provide financial incentives in the form of tax breaks or incentives to facilities who disassemble EV batteries.
- x. Require recovery rates for specific critical materials in batteries such as cobalt, nickel, lithium, and copper.
- y. Require or incentivize original equipment manufacturers to design EV batteries in a way that makes repurposing, reuse, and recycling less time and cost intensive.
- z. Develop a process standard for the disassembly, processing and recycling of lithium-ion batteries that can be verified by a third party to guarantee a minimum environmental standard.
- aa. Require recycled content standards for EV battery manufacturers.
- bb. Require original equipment manufacturers (OEMs) to provide information on how to respond to fires due to EV batteries they manufacture.

- cc. Fund the development of protocols and training for the emergency response community to respond to EV battery fires.

4. What other policy options should Washington state consider?

5. Please select all of the following content areas that you have knowledge in, or would like to provide input on:

Your answer to this question will determine which of the remaining sections of the survey you will answer. You may always select a section now and skip questions later if they are not relevant to you.

We invite you to help us build a more complete understanding of EV battery management that will be shared with you and the general public. The information you share will help inform future policy recommendations.

- EV battery removal
- EV battery testing and repair
- EV battery storage and stockpiling
- EV battery resale
- EV battery reuse
- EV battery recycling
- EV battery disposal or abandonment
- EV battery chemistry considerations
- Community interests in EV battery management
- Environmental and Environmental Justice interests in EV battery management

Note: The sections for each content area often use similar, although not identical questions.

SECTION 4.

Below are questions about what happens to EV batteries at their end-of-life. For the purposes of this survey, a battery is at the end-of-life when it is done with its original use in a vehicle. You may skip questions for which you do not have an answer or are unable to share an answer.

1. What are the common pathways for EV batteries at the end of their life in their original vehicle? Please select all that apply:

- I don't know
- Repair
- Storage or Stockpiling
- Resale
- Reuse
- Recycling
- Disposal or Abandonment
- Other (fill in the blank) _____

2. What factors determine the pathway an EV battery takes? (Choose all that apply)

- I don't know
- Economics/price
- Battery chemistry
- Logistics
- Battery health or condition
- Regulations
- Other (fill in the blank) _____

3. Please share any additional information you have on what determines which pathway an EV battery takes.

4. What methods are there for determining if an EV battery is damaged?

5. Are people in your industry, sector, or community able to determine a battery's health?

- Yes
- No

6. What methods are there for determining an EV battery's health?

If your organization or industry uses a diagnostic tool, then please share any information that you can about it.

7. How does battery health contribute to safety considerations for your industry, sector, or community?

8. What would be helpful to better identify the health of an EV battery? Why is an EV battery typically removed from a vehicle?

- Battery's state of health (SOH) is less than the warranted percentage
- Battery is damaged
- Vehicle is damaged
- Other (fill in the blank)

9. What are best practices for battery removal? Where do batteries go after removal?

10. What amount of EV batteries do you estimate are being reused annually?

Please include a **number** (e.g. "1,500"), **units** (e.g. "batteries", "tons of batteries", or "MWh batteries"), and **scale** (e.g. "at my recycling facility," "in Washington state", or "in the U.S.")

11. What industries, organizations, and/or individuals are reusing EV batteries? What are the supply sources for reused batteries?

SECTION 5.

Below are questions about the process of removing EV batteries from EVs. You may skip questions for which you do not have an answer or are unable to share an answer.

1. In your line of work, who removes EV batteries from the original vehicle? Please select all that apply.

- I don't know
- Trained EV repair mechanics
- Any mechanic
- Anyone
- Auto dealer
- Auction house
- Salvage or towing yard
- Other (fill in the blank)

SECTION 6.

Below are questions about the reuse and repurposing of EV batteries after they are separated from their original vehicle. Reuse is defined here for the purpose of this survey as individuals or organizations taking an EV battery that is no longer in its original vehicle and using it in another vehicle, a stationary energy storage system, or for another purpose. Reuse can include the process of refurbishing the battery for another purpose outside of the original vehicle. You may skip questions for which you do not have an answer or are unable to share an answer.

- 1. How are EV batteries being reused?**
- 2. What are the existing practices for reuse? (e.g. procedures for safe handling, safe operation in new use, battery diagnostics and health, etc.)**
- 3. What do you think would be the best practices for reusing EV batteries?**
- 4. What are barriers to best practices for reusing EV batteries?**
- 5. What concerns do you have about the reuse of EV batteries?**

SECTION 7.

Below are questions about the recycling of EV batteries. The first 8 questions will ask about the battery recycling process, while the remaining 5 questions will ask about transportation and reverse logistics for EV battery recycling. You may skip questions for which you do not have an answer or are unable to share an answer.

- 1. What amount of EV batteries do you estimate are being recycled annually?**

Please include a **number** (e.g. "1,500"), **units** (e.g. "batteries", "tons of batteries", or "MWh batteries"), and **scale** (e.g. "at my recycling facility," "in Washington state", or "in the U.S.")

2. What are the existing practices for recycling EV batteries?
3. What do you think would be the best practices for recycling EV batteries?
4. What are barriers to best practices for recycling EV batteries?
5. What concerns do you have about the recycling of EV batteries?
6. What are the sources of revenue resulting from recycling EV batteries?
7. What, if any, are the near- to medium-term barriers to making EV battery recycling economical?
8. Where are EV batteries currently recycled?

(Recycling describes the processing of EV batteries for materials. The collection of EV batteries is not considered recycling). **Please select all that apply.**

- I don't know
- Within Washington state
- Within the United States
- Outside of the United States
- Other (fill in blank) _____

9. What are the supply sources for EV battery recyclers? (e.g. auto recyclers, vehicle auctions, third party battery collectors, etc.)
10. What is the process for transporting sourced EV batteries to recycling locations?
11. How must EV batteries be prepared for transportation to recycling locations?
12. What are the costs of transporting EV batteries to recycling locations, and who pays them?
13. What happens to EV batteries with materials valued less than it costs to transport and recycle them?

SECTION 8.

Below are questions about the chemistry of EV batteries. You may skip questions for which you do not have an answer or are unable to share an answer.

1. Are people in your industry, sector, or community able to differentiate between battery chemistries?
 - Yes
 - No

2. How do they differentiate between battery chemistries?
3. What would be helpful to better identify the battery chemistry of an EV battery? Please be as specific as possible.
4. How does battery chemistry contribute to safety considerations for your industry, sector, or community?
5. How do differing battery chemistries affect where batteries go at their end-of-life?
6. How does battery chemistry influence the value of a battery for your industry, sector, or community?

SECTION 9.

Below are questions about your community's interests in the management and collection of EV batteries. You may skip questions for which you do not have an answer or are unable to share an answer.

1. What are your community's interests for EV battery management and collection?
2. What do your community think would be the best practices for the collection and management of EV batteries?
3. What does your community think are barriers to best practices for the collection and management of EV batteries?
4. What concerns does your community have about the collection and management of EV batteries?

SECTION 10.

Below are questions about environmental and environmental justice concerns with the management and collection of EV batteries. You may skip questions for which you do not have an answer or are unable to share an answer.

1. What environmental and environmental justice concerns do you have with EV battery management and collection?
2. What do you think would be the best practices for the collection and management of EV batteries?
3. What are barriers to best practices for the collection and management of EV batteries?
4. What are opportunities to support environmental and environmental justice interests through EV battery management and collection?

CLOSING

1. Is there anything else you would like to share with us?
2. Would you like to be added to a mailing list to receive updates on webinars, legislative reports, and other engagement opportunities related to this study?

- Yes
- No

3. Would you be comfortable with us reaching out to you for follow-up on any answers provided?

- Yes
- No

4. Please provide your name and an email address here if you are willing to be contacted for follow-up on any answers provided:

If you provide contact information, then our consultants will separate your survey responses from your email address before sharing the survey results with the Department of Ecology. Your individual answers to survey questions will be kept strictly confidential.

Name _____

Email Address _____

Appendix I. Impacts of the Inflation Reduction Act (IRA) requirements

Impacts of the Inflation Reduction Act (IRA) requirements for domestic products in the tax credit structure for renewable energy are discussed below. The IRA works in conjunction with other incentives, namely the Infrastructure and Jobs Act of 2021 and incentives available within the State of Washington.

Infrastructure Investment and Jobs Act overview

Passed in November 2021, the Infrastructure Investment and Jobs Act (IIJA) provides funding for the programs and initiatives listed below, which are designed to address the issues identified in this report.

- Battery and Critical Minerals Mining and Recycling Grant Program (\$125 million)
- Earth Mapping Resources Initiative (\$320 million)
- U.S. Geological Survey’s Energy and Minerals Research Facility (\$167 million)
- Rare Earth Elements Demonstration Facility Program (\$140 million)
- Battery Materials Processing and Battery Manufacturing Recycling (\$2.8 billion)
- Electric Drive Vehicle Battery Recycling and second Life Apps Program (\$200 million)
- Advanced Energy Manufacturing and Recycling Grant Program (\$750 million)
- Future of Industry Program and Industrial Research and Assessment Centers (\$550 million)

Inflation Reduction Act overview

The Inflation Reduction Act (IRA) of 2022 impacts the techno-economics for many energy resources, offering funding, programs, and incentives designed to decelerate energy related emissions. Most provisions of the IRA became effective January 1, 2023, with varying degrees of benefits based on the applicant’s ability to meet eligibility requirements.

Taking advantage of IRA incentives, such as tax credits, can create value by leveraging existing zero-emission assets or investments in new technologies. The primary mechanisms that utilities can take advantage of is Investment Tax Credits (ITC) and Production Tax Credits (PTC), which currently provide significant tax rebates on the cost of solar PV, energy storage, hydrogen power systems, microgrid equipment systems, as well as nuclear.

The ITC can help leverage new clean energy investments while the PTC offers benefits for the production of zero-emission energy. The IRA establishes a means for the Tax Code for zero-emission technologies to receive a PTC for manufacturing based on a variety of eligibility factors.

IRA EV benefits

The IRA has many direct benefits to the EV supply chain, manufacturing, and recycling, industrial decarbonization, critical materials processing, refining, and recycling, incentivizing domestic production, and improves supply chains. Figure 10⁵⁹ illustrates the number of battery or EV manufacturing project announced since the IRA passed. Programs related to EVs include:

- Extends and expands the Qualifying Advanced Energy Project Credit (\$10 billion)
- Establishes the Advanced Manufacturing Production Tax Credit (\$30.62 billion)
- Enhances use of Defense Production Act of 1950 (\$500 million)
- Expands the Advanced Technology Vehicles Manufacturing (ATVM) Direct Loan Program (\$3 billion)
- Creates the Domestic Manufacturing Conversion Grants (\$2 billion) and the Clean Heavy-Duty Vehicle Program (\$1 billion)
- Encourages people to buy EVs through the Clean Vehicle Tax Credit, which provides consumers up to \$7,500 if they buy a new qualified plug-in EV or fuel cell electric vehicle.
- Aims to strengthen domestic EV supply chains by requiring critical minerals be extracted or processed in the United States or a Free Trade Agreement country, or recycled in North America, with final assembly in North America.

Zero-emission technology

The term ‘zero-emission technology’ means any technology that produces zero emissions of any air pollutant that is listed pursuant to section 108(a) of the Clean Air Act (or any precursor to such an air pollutant); and any greenhouse gas. The term ‘qualified project’ includes any project, activity, or technology that— (A) reduces or avoids greenhouse gas emissions and other forms of air pollution in partnership with, and by leveraging investment from, the private sector; or (B) assists communities in the efforts of those communities to reduce or avoid greenhouse gas emissions and other forms of air pollution.

IRA domestic content provision

The IRA treats recycled battery materials as locally "urban mined," or materials recovered from scrap rather than obtained from mining. That has encouraged U.S. companies to move faster on recycling efforts than their counterparts in the European Union, which has focused instead on mandates, including minimum amounts of recycled materials in future EV batteries.

The IRA includes a clause that automatically qualifies EV battery materials recycled in the U.S. as American-made for subsidies, regardless of their origin. This clause is important because it qualifies automakers using U.S.-recycled battery materials for EV production incentives.

⁵⁹ <https://www.canarymedia.com/articles/clean-energy-manufacturing/the-south-is-building-the-most-vibrant-ev-and-battery-hub-in-the-us>.

Boosting responsible domestic production would require leveraging the latest science not only in material extraction but also in developing substitutes and fostering recycling, reuse, and remanufacturing.

Direct Pay option

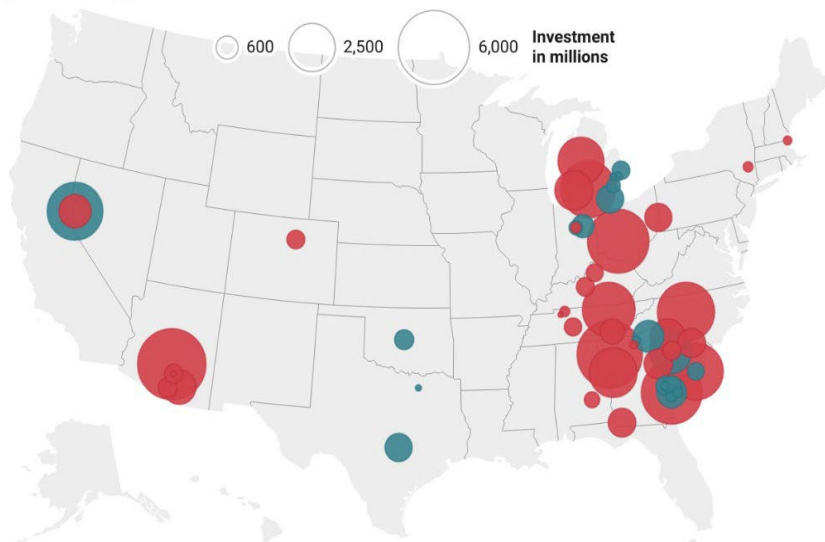
The concept of Direct Pay originated as part of the 2010 Domestic Manufacturing and Energy Job Act and is utilized in the more recent IRA. The basic mechanism of Direct Pay is that it allows a taxpayer to treat tax credits that they have earned as an overpayment of taxes, allowing the taxpayer to utilize the tax refund mechanism in the tax code to receive a direct payment of cash from the Treasury Department in lieu of monetizing the tax credit through another means. In other words, utilities who are not seeking a profit and therefore do not have a tax burden, can still take advantage of this direct pay option. This opens the door for public entities (municipalities, etc.) to take advantage of tax credits available for qualified projects.

IRA qualifying recycling projects

A qualifying recycling project re-equips, expands, or establishes an industrial or a manufacturing facility to produce or recycle specified advanced energy property (defined in Notice 2023-18⁶⁰). The technology should target an industrial or manufacturing facility to reduce greenhouse gas emissions by at least 20%. Eligible projects for investment tax credits⁶¹ include clean energy and grid manufacturing and recycling projects; industrial greenhouse gas emission reduction projects; and critical material processing, recycling, and refining projects.

New planned factories or expansions unveiled from August 2022 to May 2023

■ Batteries ■ Electric vehicles



Map: Canary Media

Figure 10. Battery and EV manufacturing projects announced since IRA passage.

⁶⁰ Internal Revenue Bulletin: 2023-10 | Internal Revenue Service (irs.gov).

⁶¹ Advanced Energy Project Credit – 26 U.S. Code § 48C.