Lithium-ion Car Battery Recycling Advisory Group

DRAFT Report

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Abbreviations

Abbreviation	Term
BEV	battery electric vehicle
BMS	battery management system
CARB	California Air Resources Board
CCR	California Code of Regulations
CFR	Code of Federal Regulations
CPUC	California Public Utilities Commission
DOD	depth of discharge
DRC	Democratic Republic of Congo
E-waste	electronic waste
EV	electric vehicle
g	gram
GWh	gigawatt-hour
IEEE	Institute of Electrical and Electronics Engineers
IRMA	Initiative for Responsible Mining
kg	kilogram
kWh	kilowatt-hour
LFP	lithium Iron phosphate
LIB	lithium-ion battery
LMO	lithium manganese oxide
LMO/LTO	lithium manganese with titanate oxide anode
Mt	million metric tons
MWh	megawatt-hour
NCA	lithium nickel cobalt aluminum oxide

Abbreviation	Term
NFPA	National Fire Protection Association
NMC	lithium nickel manganese cobalt oxide
OEM	original equipment manufacturer
OSHA	occupational Safety and Health Administration
RCRA	Resource Conservation and Recovery Act
SGIP	Self-Generation Incentive Program
SOH	state of health
t	metric ton
UL	Underwriters Laboratories

1. Introduction and Overview

1.1 Advisory Group Mandate

The 2017, California legislature passed Assembly Bill 2832 which mandates the creation of a Lithium-ion Car Battery Recycling Advisory Group.[1] The group is tasked with developing policy recommendations aimed at ensuring that as close to 100 percent as possible of lithium-ion batteries in the state are reused or recycled, as specified in the bill text:

"(c) On or before April 1, 2022, the Lithium-Ion Car Battery Recycling Advisory Group shall submit policy recommendations to the Legislature, in compliance with Section 9795 of the Government Code, aimed at ensuring that as close to 100 percent as possible of lithium-ion vehicle batteries in the state are reused or recycled at end-of-life in a safe and cost-effective manner. The policy recommendations shall reflect entire life cycle considerations for lithium-ion vehicle batteries, including, but not limited to,

- Opportunities and barriers to the reuse of those batteries as energy storage systems after they are removed from the vehicle,
- Best management considerations for those batteries at end-of-life, and
- The overall effect of different management practices on the environment.

In developing the policy recommendations, the advisory group shall consider both in-state and out-of-state options for the recycling of lithium-ion vehicle batteries."

The advisory group first convened on November 18, 2019, and consisted of representatives from the following organizations:

- Alliance of Automotive Innovation
- California Department of Toxic Substances Control (DTSC)
- California Energy Commission (CEC)
- California Environmental Protection Agency (CalEPA)
- California New Car Dealers Association
- Californians Against Waste
- Central Contra Costa Sanitary District
- Department of Resources Recycling and Recovery (CalRecycle)
- Earthworks
- Ford Motor Company
- Honda Trading America
- Kinsbursky Brothers International (KBI)
- Occupational Knowledge International
- PBRA - The Rechargeable Battery Association
- SA Recycling
- Southern California Association of Governments
- Surplus Service

- Sustainable Energy Solutions
- Tesla
- Umicore USA

2. Background

2.1 Electric vehicle (EV) Adoption and Battery Technologies

As the market for battery electric vehicles (EVs) has developed, battery design and performance have evolved. US EV sales show a shift towards significantly higher capacity batteries with longer vehicle ranges. The combination of a ramp-up in the deployment of BEVs and the increased size of BEV battery systems have dramatically increased the capacity of batteries on the road today (Figure 1). Over 60 GWh of LIBs have been deployed in US light-duty BEVs since 2010[2], which represents enough energy storage to meet California's peak electricity load for one hour.[3] Global manufacturing capacity for LIBs is expected to reach 250 GWh by 2020, and annual production could surpass that of lead-acid batteries (~500 GWh/year) by the year 2040.[4]

PLACEHOLDER FOR GRAPHIC IN DEVELOPMENT

Figure 1. Quarterly Electric Vehicle Sales by Cathode Chemistry and Cumulative Deployments of Electric Vehicle Batteries

LIBs designed to power the drive motor of a vehicle are often referred to as traction batteries. Most batteries consist of five key components: cathode, anode, separator, electrolyte, and cell container. For a LIB, the anode is typically made from graphite, the anode current collector is copper, and the cathode current collector is aluminum. The separator and cell container are made of different plastics. The cathode is made of a lithium metal oxide, combined with a transition metal, typically nickel, cobalt, iron, or manganese.

Different LIBs are distinguished by the metals that make up their cathode chemistry; for example, a battery using a nickel-cobalt-manganese cathode is referred to as an NMC battery.

The majority of early EV batteries were either NCA type (nickel-cobalt-aluminum, used by Tesla/Panasonic) or LMO (lithium manganese oxide, used in early Nissan Leafs). Moving forward, NMC batteries are widely expected to occupy a growing share of the EV battery market and may become the dominant chemistry after 2030.[4] Using different metals changes characteristics such as the energy density, power density, cycle life, safety and cost of batteries.[5] The choice of chemistry also affects the choice of battery management systems, cooling systems, and other components.

There are a variety of chemical formulations within different cathode compounds with important implications for material demand. For example, in an NMC battery, the ratio of nickel and manganese to cobalt can vary from a ratio of 1:1 to 8:1. These variations are communicated via a number following the battery chemistry: for example, "NMC 622" refers to a LIB with 60% nickel, 20% manganese, and 20% cobalt in the cathode.

2.2 Critical Materials for Batteries

LIBs use materials the US Department of Energy regards as critical because of the high risk of supply shortage and their necessity in the clean energy transition. The Biden administration recently released a report listing lithium, cobalt, nickel, and copper as essential critical minerals for LIBs .[6,7] Lithium and cobalt are highly concentrated geographically and generally considered to present the greatest supply risk, although lithium is mainly constrained by short-term production capacity rather than the quantity of global reserves. Nickel has a more stable supply chain than lithium and cobalt, although due to the increasing use of the high purity class 1 nickel, there are expected shortages in the next 5 to 7 years. These supply shortages are a product of underdeveloped production and processing to support upcoming demand, and the high import reliance of the US.[7]

Recycling of LIBs could play a substantial role in displacing primary material production for critical materials in the future.[8] This section describes some of the resource issues for key battery cathode materials and the potential for recycled materials.

2.3 Overview of EV LIB End-of-Life Management

2.3.1 Reverse Logistics

Before reuse or recycling is possible, LIBs must be removed from the vehicle, potentially stored until there are enough batteries for a cost-effective shipment, and transported to the appropriate facility. These steps are critical to effectively manage batteries, and there is a complex network of actors involved in safely getting the battery from its point of retirement to its next life cycle phase, whether that is reuse or recycling. The EV and/or battery may follow one of several pathways depending on whether the vehicle is purchased or leased, and the reasons for retirement.

PLACEHOLDER FOR GRAPHIC IN DEVELOPMENT

Figure 2: Potential pathways for retired EVs and EV batteries

Within dealership network

Leased vehicles or batteries that are under warranty are expected to return to the dealership where they were purchased. For leased vehicles where the vehicle is intact and the battery has a good state of health (SOH), the returned vehicle may be sold as a used car at the same dealership or sent to a wholesale auction to be purchased and sold by another dealer. If the vehicle is damaged but the battery pack is in good condition, it may be refurbished and reused directly in another vehicle as a replacement. If the battery is not suitable for reuse in a vehicle, it is assumed that the OEM will collect and ship the batteries to a repurposer or recycler (or coordinate the collection and shipment through a third party), although in practice this may not yet occur at most dealerships.

Outside dealership network

There is a high degree of uncertainty surrounding cases where the EV is privately owned since it is a relatively unregulated environment and these batteries have not yet been retired at large volumes. If the battery reaches EOL before the vehicle, it may be taken to a private repair shop that will need specialized personnel to remove and replace the battery. If the vehicle reaches EOL due to a collision, it will become the property of the insurance company to be sold at an insurance auction. In California, Copart and IAA are the largest auctions of this type. The auctions are physical locations, but the bidding process occurs online. Licensed dismantlers acquire most of their inventory this way, but any interested party can bid on and purchase a vehicle as well. Assuming the EV is purchased by a licensed dismantler, they could then sell the battery to a repair shop, another dismantler, or an individual customer. If the battery cannot be reused in another vehicle, it should be sent to a certified repurposer, recycler, or sorting facility.

Finally, if there is very little value left in the vehicle it could be sent to a metal scrap recycler, in which case the recycler would ultimately be responsible for sending the battery to a sorting, repurposing, or recycling facility.

Existing infrastructure

The dealership, repair, dismantling, and scrap metal recycling industries are well-established, with facilities throughout California. However, the facilities for collecting, sorting, and potentially disassembling (from pack to module) large format LIBs (such as those that will be removed from EVs) are largely hypothetical. The largest known facility within California is KBI's xEV strategies location in Brea, CA.

Export

The United States is the third largest exporter of used vehicles after the European Union (EU) and Japan, exporting approximately 2.6 million vehicles between 2015-2018. This means that significant changes in the vehicle fleet of the United States (U.S.) will have also have implications for importing countries, particularly as vehicles become electrified. While exporting used vehicles in good condition could improve access to affordable zero-emissions vehicles, it will also shift the burden of battery disposal to the importing countries who may not have the infrastructure to recycle them safely. In addition, if batteries are exported the U.S. will lose control of the strategic materials that could be recovered through recycling.

2.4 Battery Reuse, Repurposing, and Remanufacturing

Given the large capacity and high performance of modern vehicle batteries, retired batteries could still offer significant value in lower-power, secondary applications (e.g., battery storage for electricity grid applications). A growing body of research has examined the economic feasibility and environmental impacts of second-life applications.[9–13]

Second-life EV batteries have generated excitement among investors, who see an opportunity to generate more profit via a second revenue stream, and environmentalists who imagine second-life batteries reducing the demand for new stationary energy storage batteries and making BEVs more affordable.[14] Since second-life batteries are a relatively new phenomenon, data about their performance is uncertain, but it is estimated that battery life can be extended by 10 years under favorable conditions.[15]

As specified by the U.S. Advanced Battery Consortium standards, an EV battery reaches the end of its usable life when its current cell capacity or power density is less than 80% of the rated capacity due to the demanding performance required to discharge rapidly as vehicles accelerate, and in order to maintain an acceptable range. [16] In reality, battery retirement will be determined by consumer preferences and the remaining capacity may be higher or lower than 80%. Many of these batteries will still be suitable for less intensive purposes, such as storing energy from solar panels to be used in off-grid or peak demand-shaving applications. Examples include Nissan subsidiary 4REnergy's repurposing of Nissan Leaf batteries into electricity storage units for a solar plant; Fiat's transition of their electric 500e model batteries to solar storage for an e-waste recycler firm called IT Asset Partners;[17] and B2U's repurposing of retired Nissan Leaf batteries without reconfiguration for solar storage to produce electricity and grid services products.[18]

Despite a growing number of companies in the repurposing space, the industry faces a number of barriers. In a qualitative analysis examining four case studies, researchers identified four primary barriers to second-life applications for retired vehicle batteries: customer bias due to safety and reliability concerns; the falling price of new batteries; the lack of standardization in design and changing battery chemistry; and a lack of transparency in battery pricing.[19] Most major solar and storage developers require a minimum warranty of 10 years for any battery system, so ensuring reliable performance is key. The lack of standardization is a challenge because BEV batteries are made by different manufacturers with variations in construction and chemistry. The chemistry is often unlabeled and may be unknown by the third-party refurbisher, which makes the testing and reassembly more complicated and expensive.

Figure 3: 300 kWh repurposed storage system at the UC Davis Robert Mondavi Institute Winery (Photo credit: M. Slattery)

Concerns about reliability primarily stem from the uneven degradation of battery cells over time. As an example, UC Davis Professor Dr. Jae Wan Park has conducted two demonstrations of this technology, one at the Robert Mondavi Institute Winery (Figure 3), and another in an off-grid PV charging system for EVs. In the off-grid charging system, the remaining capacity of cells ranged from 60-90% of their initial capacity.[16,20] Testing the charge capacity of individual cells, reconfiguring them into consistent packs, and installing a battery management system (BMS) that can monitor their safety and reliability are some of the key costs that will determine the success of this technology compared to new batteries.

In addition to the technical challenges illustrated above, there are political and economic issues that have yet to be resolved. One is a question of liability; if batteries are to be used in a second-life application, will the vehicle OEM retain responsibility for disposal and any safety hazards? Another issue is cost-competitiveness. The total cost of a second-life system must be lower than the cost of new batteries, which is rapidly declining. Furthermore, second-life batteries are currently ineligible for California's Self-Generation Incentive Program (SGIP), a funding mechanism for distributed energy investments, making it difficult for second-life systems to compete with new battery storage.[21]

Policy tools to support a domestic recycling industry could have the effect of simultaneously making recycling and reuse processes simpler and more feasible. Specifically, adopting more standardized battery designs that are easy to disassemble will make recycling easier and potentially lower the cost of refurbishing the battery to be used as grid storage.

2.4.1 Recycling Pathways

By reducing demand for raw materials, recycling avoids some negative environmental impacts from mining and could grow a domestic supply chain for key battery materials if it takes place domestically. This section describes processes and pathways for recovering recyclable materials from lithium electric vehicles batteries.

To recycle an EV battery, the first step is physical separation, which separates the anode and cathode from the casing materials, current collector foils (copper), and separators. The physical separation is typically done through mechanical crushing and then the filtering of powders from coarser materials. The cathode and anode materials are recovered as “black mass,” and can be further refined using hydrometallurgy or a pyrometallurgy-hydrometallurgy combination to recover individual materials. [22]***Mechanical Pre-Treatment:*** After packs are discharged and dismantled, batteries are mechanically shredded. Materials are sorted into plastic fluff, metal-enriched liquid, and metal solids. After sorting, most copper, aluminum, and steel casings are recovered. The remaining material is often referred to as ‘black mass’ and has relatively high concentrations of nickel, cobalt, lithium, and manganese. From there, materials may be recovered through secondary hydrometallurgical processes. ***Pyrometallurgical Recycling:*** In pyrometallurgical recycling, modules are smelted in a high-temperature furnace (~1500°C) to produce a concentrated alloy containing cobalt, nickel, and copper. These metals can then be extracted using a hydrometallurgical process. The lithium and manganese end up in a slag that can be directly used in the construction industry or processed further to recover lithium (Dunn et al. 2015, Umicore, n.d.).

Hydrometallurgical Recycling: Hydrometallurgical recycling is a chemical process involving leaching, removal of impurities, and separation. Leaching may be followed by solvent extraction and/or chemical precipitation to recover lithium, nickel, manganese, and cobalt.

Direct Cathode Recycling**:** Any combination of the processes described above where cathode materials are recovered in a suitable condition to be directly used in battery production, without breaking them down into individual material elements. The ReCell Center at Argonne National Laboratory is leading research and development in this area.[23]

The recovered materials can be used in either a ***closed-loop*** *or* ***open-loop*** *recycling system.* In closed-loop recycling, material recovered during recycling is used to manufacture the same product. For LIB cathode recycling to be closed-loop, the constituent material must be refined, then resynthesized into a new cathode compound. Synthesis of the cathode active material is a critical step in the manufacturing process and the synthesized cathode active material is often the highest cost input to cell production. Open-Loop recycling means recovered materials are used as inputs in a different product system. For example, recovered aluminum or steel alloys may be remelted to form different alloys for use in other industries [24]

2.4.2 Industry Landscape

The existing LIB recycling industry has developed around recycling consumer electronics, with the majority taking place in China, followed by South Korea.[25] Pilot and commercial facilities are operational to a smaller extent in Europe, North America, and Canada, although many are in the pilot stage and/or do not operate at full throughput capacity.[26] The US only has hydrometallurgical facilities operational totaling a yearly capacity of 27,600 metric tons; Li-Cycle corporation has a facility in Rochester, N.Y., Retriev technologies has a facility in Lancaster, OH, and Redwood Materials has a facility in Carson City, Nevada. In addition, there are four facilities under-development in Arizona, Nevada, Massachusetts and Alabama totaling a yearly capacity of 43,100 metric tons. US EV retirement between 2025 and 2028 is forecasted to surpass the combined capacity of 70,700 tons per year,[8] indicating a need for additional capacity needed to support national recycling of LIBs .

2.5 Regulatory Landscape for EV EOL Management

A complex set of regulations and standards cover the logistics, reuse, and recycling of LIBs. This section seeks to identify and clarify the applicable regulations and the end-of-life phase that they apply to. This knowledge is important to the discussion of barriers and opportunities presented in the next section, as well as inform the policy recommendations.

The U.S. lags behind other countries and regions that are leaders in EV adoption in the extent and complexity of policy and attendant regulation targeting end-of-life EV LIBs.[27] China and the EU, the two other largest adopters of EVs, both have policies in place or coming online that attempt to enhance the circularity of battery materials and bring or retain LIB supply chains within their respective regions, with recycling of end-of-life EV LIBs playing a role in both. Despite the common goal in both regions, and policies that attempt to consider life cycle and supply chain issues, the policies and directives take on very different forms given the distinctive governmental and political structures in each region. In contrast, the U.S. and California regulate activities that are relevant to end-of-life batteries, but do not have holistic, overarching policies for LIBs or even LIB end-of-life. Table 1 describes regulations relevant to LIB end-of-life in California.

Table 1: Regulations relevant to the proper disposal of LIBs within California. These regulations are parsed by the regulated activity. Please note many regulations apply to more than one activity and are therefore listed more than once.

Regulated activity	**Relevant regulations**
Dismantling	*Facility licensing requirements:* California Vehicle Code Division 5 *Storage fire codes:* NFPA 855, Chapter 14
Transportation	*Hazardous Material transportation*: 49 CFR §173.185 (special consideration for damaged batteries)
Storage	*Storage fire codes:* NFPA 855, Chapter 14 Universal waste laws: 40 CFR §273.15 *CA Universal Waste Laws*: Chapters 12-16 title 22 of CCR
Disassembly	*High voltage equipment and personnel safety references:* NFPA 70B/E; IEEE C2 and IEEE 3007.3; OSHA 29 CFR 1926 and 1910 Storage fire codes: NFPA 855, Chapter 14 Universal waste laws: 40 CFR §273.15 *CA Universal Waste Laws*: Chapters 12-16 title 22 of CCR
Energy Storage System (ESS) Installation	*Interconnection:* CPUC Rule 21, CAISO/FERC Tariffs *Electrical storage requirements:* California Fire Code 1206; NFP 855; International Fire Code
Hazardous Waste Treatment	*Universal waste laws:* 40 CFR §273**,** Subpart E Permitting requirements: 40 CFR §§124 and 270 Standards for hazardous waste treatment, storage, and disposal facilities: 40 CFR parts 264, 265, 266, 268, 270, and 124 Notification requirement: section 3010 of RCRA. *CA Universal Waste Laws*: Chapters 12-16 title 22 of CCR *CA specific*: Health and safety division 20 chapter 6.5
Export	UN, EPA

2.5.1 Facility licensing requirements: California Vehicle Code Division 5

Any entity in California that participates in the vehicle afterlife market must comply with the *Occupational licensing and business regulations* under Division 5 of the California Vehicle Code. The following chapters are likely to apply to facilities that handle end-of-life LIBs, or are likely to do so in the future:

- Chapter 3: Auto Dismantlers
- Chapter 4: Manufacturers, Transporters, Dealers, and Salesmen

In addition, California Vehicle Code §220 and §221 are relevant as they are used to determine if a business location is considered an auto dismantler and therefore subject to licensing requirements. Of note is that according to CA Vehicle Code §11500, it is unlawful for any person to act as an automobile dismantler without having an established place of business, meeting specified requirements, and having a current, valid license or temporary permit issued by the DMV.

2.5.2 Storage fire codes*:* NFPA 855, Chapters 14 and 12 of the California Fire Code.

Used batteries must be stored in compliance with local fire codes, many of which are based on Chapter 14 of NFPA 855 and the International Fire Code. NFPA 855 states that collected batteries must be stored so that the terminals are protected either through battery design or protective packaging to prevent short circuits (14.3.1.2). It also includes requirements for indoor and outdoor storage, including but not limited to the following:

- For indoor storage (14.4)
    - Requires a fire prevention and mitigation plan to be submitted to the authorities having jurisdiction (AHJ) for approval
    - Requires that the room be protected by a radiant-energy detection system
    - Requires that the building be provided with an automatic fire suppression system
    - Requires that the storage space be protected by a water spray automatic suppression system
    - Requires the installation of explosion protection
- For outdoor storage (14.5)
    - Individual pile sizes are limited to 200 sq ft in an area separated from other piles by 10 ft

Storage regulations will be relevant to all entities that store batteries onsite, which is likely to include dealerships, auto recyclers, repair shops, repurposers, and recyclers. Both the International Fire Code and NFPA 855 are currently being adapted.[28]

Second-life or repurposed energy storage systems will also need to comply with Chapter 12 of the California Fire Code. Section 1206 addresses electrical energy storage systems, including: permits, construction documents, hazard mitigation analysis, seismic and structural design, vehicle impact protection (i.e. forklifts), combustible storage, testing, maintenance and repair, location and construction, maximum allowable quantities, storage batteries and equipment, fire extinguishing and detection systems, specific battery-type requirements.

*2.5.3 Universal waste laws: T*itle 40 of CFR in part 273

The federal Universal Waste regulations were adopted in 1995 (FR Doc. 95-11143) and are found in Title 40 of CFR in part 273. The U.S. EPA considers batteries (including LIBs) to be a universal waste, as defined in § 273.9. The applicability of the Universal Waste regulations (found in § 273.2 (b)(3)) is due to the battery[1] exhibiting hazardous waste characteristics[2]. While lithium-ion batteries contain less toxic metals (e.g., no lead or cadmium) than other types of batteries (e.g., lead acid batteries), they can be a safety hazard as they may contain flammable electrolytes and may be considered a hazardous waste under § 261.21(a)(2). The benefit of defining the batteries as universal waste is a more streamlined and less complex collection process at the end-of-life to increase their proper disposal by the public. The federal regulations require state standards to be either the same or more stringent. The California specific universal waste laws are found in chapters 12-16 title 22 of CCR and reflect similar requirements.

2.5.4 Hazardous waste: 40 CFR parts 264, 265, 266, 268, 270, and 124 and Resource Conservation and Recovery Act (RCRA) section 3010

The transportation and storage of lithium-ion batteries are covered under the universal waste laws, as discussed above, although the recycling of lithium-ion batteries is considered a hazardous waste treatment. The *Universal waste laws* in 40 CFR §273, Subpart E states the destination facilities are required to follow the hazardous waste treatment regulations and destination facilities are defined as "a facility that treats, disposes of, or recycles universal waste", therefore it covers the recycling of the batteries. The *Standards for hazardous waste treatment, storage, and disposal facilities* are under 40 CFR parts 264, 265, 266, 268, 270, and 124. These standards cover the permitting and siting of facilities and the emission and waste disposal standards.

RCRA section 3010 requires any person that generates, transports, or recycles regulated waste to notify the EPA and have an operating permit. California is an authorized state to provide permits, and the DTSC within the CALEPA is therefore responsible for reviewing applications. Part A of the permitting process outlined in 40 CFR §270.13 requires form 8700-23 which provides basic information of the facility. Part B is outlined in 40 CFR §§270.14 through 270.27 and is much more comprehensive, requiring an ongoing review by DTSC that takes an estimated 2 years to complete. The California H*azardous Waste Control* guidelines applicable to LIB end-of-life in California are found in Chapter 6.5 of Division 20 of the California Health and Safety Code. *Battery Management is* under Article 10.9 and deems the Federal Mercury-Containing and Rechargeable Battery Management Act (P.L. 104-142) as the law of the state.

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[1] Battery is defined in §273.9

[2] Hazardous waste characteristics are found in § 261 Subpart C

2.5.5 Hazardous Material transportation: 49 CFR §173.185 (special consideration for damaged batteries)

Lithium-ion batteries are regulated by the Department of Transportation (DOT) as a Class 9 (“Miscellaneous”) hazardous material. Shipping requirements for Lithium-ion batteries that are transported via rail or road are specified under CFR §173.185. Paragraph (b)(1) states that “Lithium cells or batteries, including lithium cells or batteries packed with, or contained in, equipment, must be packaged in a manner to prevent:

(i) Short circuits;

(ii) Damage caused by movement or placement within the package; and

(iii) Accidental activation of the equipment.”

The following paragraphs could apply to retired electric vehicle batteries:

- (b)(5): Specifies packing requirements for batteries larger than 12kg and impact-resistant outer casing
- (d): Lithium cells or batteries shipped for disposal or recycling are excepted from certain shipping and packaging requirements
- (f) Damaged, defective, or recalled cells or batteries are subject to more stringent packaging requirements and must be shipped in a UN-certified container

Batteries are typically shipped through established third-party logistics companies who are certified in hazardous material transportation. Nonetheless, the party who ships the battery is responsible for ensuring that it is packaged safely and demonstrating compliance with DOT regulations, so knowledge of transportation regulations and safety protocol will be necessary for dismantlers, disassemblers, and repurposers.

2.5.6 Interconnection: CPUC Rule 21, CAISO/FERC Tariffs

State, federal and local interconnection regulations will apply to any batteries used in grid-tied applications. In California, the regulations that interconnected battery storage must follow depend on the application of the system (Table 2).

Table 2: Battery storage interconnected to the electricity grid within California must comply with the following tariffs.[29]

Application/connection level	Corresponding Tariff
Net-energy metering/ non-export facility	CPUC Rule 21
Participating in wholesale market, connecting to distribution system	FERC-jurisdictional Wholesale Distribution Access Tariff

Participating in wholesale market, connecting to transmission system	CAISO Tariff

Interconnection requirements for net-metering facilities are established by the CPUC under Rule 21. CPUC Rule 21 contains provisions governing, among other bureaucratic procedures:

- Provisions specific to net energy metered facilities
- Technical operating parameters
- Certification and testing criteria
- Technical requirements for inverters

Each Investor-Owned Utility (IOU) is responsible for the administration of Rule 21 in its service territory. The procedures outlined in the IOU Tariffs rely heavily on UL 1741 and IEEE 929 as well as the testing described in *May 1999 New York State Public Service Commission's Interconnection Requirements* (page 222). Obtaining UL certification, while technically a voluntary standard, is therefore mandatory in practice for grid-connected systems and will require resources that could pose a burden for smaller companies.

3. Report development process

The advisory group met quarterly and was supported by researchers at the University of California, Davis (UC Davis). The first 14 months of the project was dedicated to knowledge-building. The advisory group met quarterly and the researchers along with invited speakers from academia, industry, and government agencies, presented background information on the LIB technology and market; environmental, health and safety impacts, current and potential reverse logistics (including dismantling), reuse, and recycling systems; relevant certifications, regulations and standards in the U.S. and California; and worldwide EV battery policies and initiatives.

In January 2021, the report development process began, divided into four phases:

- Phase 1 (January 2021-March 2021): Identify barriers, opportunities, and existing landscape
- Phase 2 (April 2021-July 2021): Identify potential policy options
- Phase 3 (August 2021-December 2021): Incorporate feedback and create rough draft
- Phase 4 (January 2022-March 2021): Finalize report with recommendations

To address the scope of topics relevant to developing the advisory group recommendation, members were divided into three subcommittees, logistics, reuse, and recycling, based on self-selection. Table 3 reports the membership on each subcommittee.

Table 3: The three subcommittees (logistics, reuse, recycling) and the affiliation of each member.

Subcommittee Name and Member Affiliation
Logistics
1. Alliance for Automotive Innovation 2. California New Car Dealers Association 3. Earthworks 4. Tesla Inc. 5. The Rechargeable Battery Association 6. Umicore USA
Reuse
1. CA & NV IBEW-NECA Labor Management Cooperation Committee 2. California Energy Commission 3. Central Contra Costa Sanitary District 4. KBI Recycling 5. Southern California Association of Governments 6. Surplus Service 7. Tesla Inc. 8. The Rechargeable Battery Association
Recycling
1. Californians Against Waste 2. CalRecycle 3. Department of Toxic Substances Control 4. Ford Motor Co. 5. Honda Trading America 6. Occupational Knowledge International 7. SA Recycling LLC 8. Tesla Inc.

During phase 1 (January 2021-March 2021) the existing landscape (i.e. current conditions) for each subcommittee was defined, and barriers and opportunities for safe, effective, and economically efficient logistics, reuse or recycling were developed. Outcomes were reported back to the entire advisory group during the March meeting of 2021.

During phase 2 (April 2021-July 2021) potential policy options we identified and barriers and opportunities elaborated. Updates to the Advisory Group were provided at the May and July 2021 meetings on policy options and barriers and opportunities.

During Phase 3 (August 2021-December 2021) the Advisory Group had to develop the final report and recommendations. The outcomes of subcommittee recommendations and group discussions were incorporated into draft report documents, and policy options proposed by the subcommittees, and which were in many cases elaborated on or altered during Advisory Group meetings, were turned into a survey to aid in the process of prioritizing or eliminating policy options. Survey results can be found in table A1 and A2 of the appendix.

3.1 Decision Making process for selecting recommended policy options

THE FOLLOWING TEXT IS A PLACEHOLDER. FOR THE PURPOSES OF DEVELOPING A DRAFT REPORT, A DECISION PROCESS WAS DEVELOPED FOR DETERMINING RECOMMENDED POLICIES BASED ON SURVEY OUTCOMES (SEE TABLES 1 AND 2 OF THE APPENDIX). THE INTENT IS TO PROVIDE THE ADVISORY GROUP WITH AN *EXAMPLE* OF HOW WE CAN PRIORITIZE POLICY OPTIONS FOR DISCUSSION AND GUIDE DECISION-MAKING ON DETERMINING WHICH POLICIES ARE RECOMMENDED. THE INTENTION IS FOR THIS TO BE CHANGED TO REFLECT THE WISHES OF THE ADVISORY BOARD. WE WILL HAVE TIME AT THE OCT 22, 2021 MEETING TO DISCUSS THIS.

Survey outcomes were used to identify possible recommended policies for discussion, identify policies not recommended, and identify policies which were neither opposed nor supported.

The following logic tree was used to assess policy options and assign them to groups designated as either not recommended policies (those with strong opposition), policies with neither strong support nor strong opposition, policies with modest support worthy of further evaluation, and policies recommended policies (those with majority support). Figure 3 describes the logic tree applied to the survey responses (survey results can be found in table A1 and A2 of the appendix).

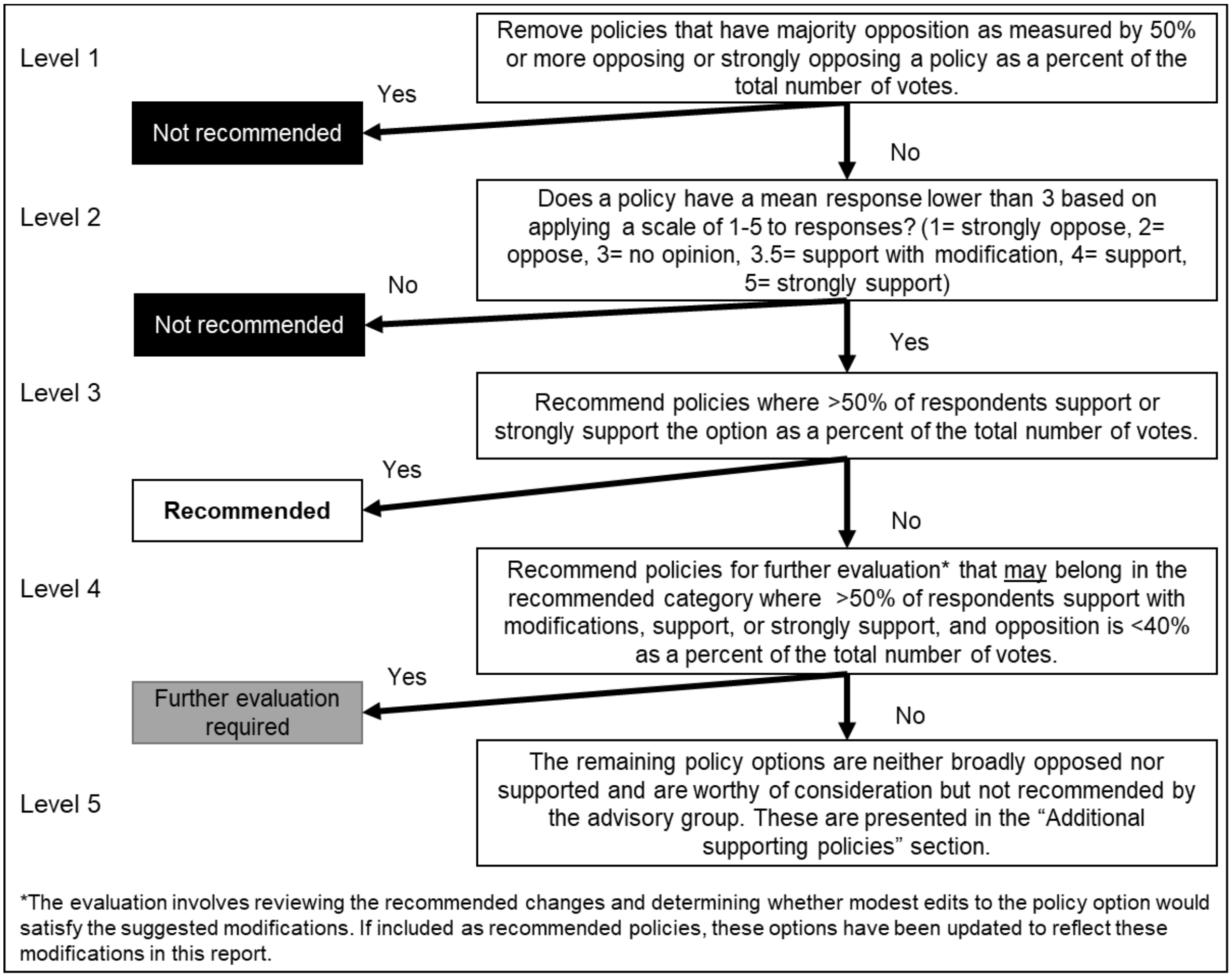

Figure 3. Logic tree for prioritizing or eliminating policy options.

End placeholder text

4 Subcommittee Outcomes: Barriers and Opportunities

4.1 Logistics

The scope of the logistics committee includes activities that facilitate both reuse and recycling, acknowledging that batteries must first be safely collected and transported to realize the benefits of either process. The activities that fall under the scope of logistics include removal of the battery from the vehicle (referred to as dismantling), testing to determine appropriate next use, collection and sorting, transportation, and tracking.

4.1.1 Barriers to safe and efficient logistics

The barriers to safe and efficient logistics emerge from the structure of the current vehicle afterlife market, fire and other safety risks from LIBs, current regulations, a lack of information on battery history and current condition, and a shortfall in capacity for handling anticipated flows of retired EV LIBs. The following sections further explore these barriers.

Capturing out-of-warranty batteries

Many of the barriers identified stem from the decentralized and unregulated nature of the vehicle afterlife market in the United States. Retired EVs may end up being handled by several different parties who have unequal access to the resources and information necessary to manage end-of-life batteries properly. One of the concerns mentioned by participants was that once vehicles and/or batteries are out of warranty, it is difficult to track them or control what happens. Given the market-driven nature of the vehicle afterlife industry, returning EOL batteries to a domestic reuse or recycling system essentially relies on there being some financial incentive or benefit for doing so to whoever is handling the battery.

Safety

EV batteries are significantly higher voltage than car batteries have been in the past and pose a threat of electrocution if mishandled. Whoever removes the battery from the vehicle must take certain safety precautions, particularly if the battery is physically damaged. For example, the battery must be drained and disconnected before performing any work on the vehicle or battery. Facilities should also be equipped with appropriate personal protective equipment (PPE), including but not limited to rubber gloves and boots, high voltage-safe tools, matting, and a safety rescue hook. The other key safety issue is fire. In the event of a fire, EV batteries may reach temperatures up to 1000 C due to thermal runaway. Facilities can mitigate fire damage by keeping a fire safety blanket onsite and dismantling and storing EVs in an isolated area.

The necessity for specialized dismantling creates an opportunity to create skilled jobs within the state of California. To prevent harm and take advantage of the opportunities presented by the EV transition, resources such as information, training, and safety equipment must be widely accessible to anyone who may be in the position to disassemble an EV.

Storage

Because of the safety hazards described above, whoever handles an end-of-life battery must follow certain storage and transport protocols. As noted in the Relevant Regulations section, storage requirements are defined by the local fire code and include minimum space requirements and fire suppression capabilities. Storing batteries onsite may present a burden and liability, particularly for smaller facilities that do not have sufficient space to hold batteries for extended periods. This was mentioned as a concern for both auto dismantlers and dealerships. Dealership representatives voiced concern about becoming long-term storage sites for batteries, particularly since most EV sales and ultimately returns will take place at dealerships in denser urban areas, where space is scarce and valuable. Meanwhile, dismantlers are concerned about the safety threat posed to their facility and personnel.

While dealerships have connections to the OEM and their collection network, dismantlers may not have information about where to send batteries. According to an invited speaker from the

Auto Recyclers Association, many are currently accumulating them onsite in the absence of a clear directive.

Transportation

As noted in the regulatory landscape section, the party handling the battery must also comply with hazardous materials shipping protocol as specified by DOT, which increases the cost of transportation. Furthermore, damaged batteries are subject to more stringent transport requirements, as specified by paragraph (f) in the DOT Code of Federal Regulations (CFR) §173.185. Specifically, they must be shipped in a United Nations-certified container, which are custom-ordered from dangerous goods manufacturers at great expense. Estimates of the cost of transportation vary widely but are estimated on average to contribute 40-60% of the overall cost of recycling.[30]

Unlicensed dismantling

According to CA Vehicle Code §11500, it is unlawful for any person to act as an automobile dismantler without having an established place of business, meeting specified requirements, and having a current, valid license or temporary permit issued by the DMV. Licensed dismantlers process an estimated 840,000 of approximately 1.2 million vehicles that reach EOL in California each year. However, an ongoing concern is the rise of unlicensed dismantling in the state, which is problematic because unlicensed dismantlers do not take the same precautions when disposing of hazardous materials and fluids. Unlicensed dismantlers acquire most of their vehicles through auto auctions and dismantle them in various locations, including repair shops, remote areas, parking lots, industrial lots, and residences.

Unlicensed dismantling is particularly undesirable for EVs given the hazards posed by large-format Lithium batteries when handled incorrectly. In addition, it further complicates the EOL chain of custody and may make it more challenging to capture retired batteries for reuse and recycling. Participants representing the dismantling industry identified this issue and are concerned that any added burden imposed on licensed dismantlers will push more vehicles into the unregulated grey market, where it is cheaper to operate.

Infrastructure and capacity gaps

Since EVs are not currently being retired at a large scale, California does not currently have the needed capacity in terms of trained personnel to handle high voltage batteries. Participants also identified a lack of infrastructure for battery disassembly from pack to module.

Regulatory barriers

Participants identified several areas where clarity on existing regulations is desired and discussed the need for alignment between federal and state regulations. Clear instructions on navigating hazardous materials transportation and hazardous waste regulations such as packaging, safety, and storage requirements were recommended. Participants also mentioned a need for solutions to minimize the cost of compliance, especially for smaller operations.

Universal waste classification

Lithium batteries are classified by DTSC as a universal waste. However, a key point of discussion was defining at what point they become classified as waste, which will affect what activities may be classified as hazardous waste treatment and who may be considered a generator, handler, or treatment facility. This is an issue that affects all subcommittees.

Lack of regulations defining producer responsibility

At present, it is unclear who will coordinate and pay for the collection, transportation, and processing of retired batteries. In the absence of extended producer responsibility for end-of-life batteries (or some alternative mechanism), the system is reliant on the profitability of reuse and/or recycling to incentivize collection.

Information needs

To facilitate an optimal EOL pathway, the parties involved must have access to information about the battery and knowledge of how to handle it safely.

Condition of battery:

Information about the condition of the battery is necessary to enable the party handling the battery to determine the next appropriate use for the battery and how to ship it there. Specifically, knowing the state of health (SOH) is necessary to determine whether the battery is most suitable for reuse in a vehicle, repurposing for stationary storage, or recycling. In addition, information about the battery's history and whether it had been in an accident would alert the handler to the potential of physical damage so they could take the needed precautions.

Battery chemistry:

Knowledge about battery chemistry is most important for recyclers because sorting before recycling makes the material recovery process more efficient. However, this information would also be valuable to the party handling the battery for negotiation purposes, as recyclers may be willing to pay for higher-cobalt chemistries or at least cover the cost of transportation.

Information about how to safely handle batteries

Participants pointed out that OEMs provide training for dealers about how to handle their batteries and vehicles. It was recommended that this sort of information be made accessible and distributed to independent dismantlers, repair shops, and first responders. In addition, it was recommended that agencies provide clear, detailed guidelines on OSHA, storage, and shipping requirements, and make funding available to support videos and other training materials. Currently, information on handling EVs and hybrids is available from the Auto Recyclers Association and Salvage Wire, a consultancy based in the United Kingdom, and the Department of Transportation.[31]

4.1.2 Opportunities

Opportunities mostly reflect the potential benefits to reducing end-of-life management costs and improving safety, both of which would improve conditions for robust reuse and recycling systems.

Reduced cost and environmental impact of transportation

Addressing the barriers listed above would make the reverse logistics process more efficient by avoiding unnecessary transportation since improved information along the chain of custody would allow relevant stakeholders to send batteries directly to the most appropriate destination. Another strategy to reduce the cost of transportation could be facilitating a collection system with strategic infrastructure that enables batteries to be regionally accumulated prior to transport to make the shipment more cost-effective. In addition to making the process more economical, reducing the distance traveled also reduces the overall environmental impact of recycling. Finally, the cost of transportation can be reduced by identifying strategies that ease the cost of regulatory compliance without sacrificing the need for safety.

Increased recycling rates

Improving the collection rate and reducing the cost of transportation would increase the recycling rate for Lithium-ion batteries, which would make the industry more economical by increasing throughput. In turn, this would allow California and the United States to realize the environmental, economic, and social benefits of recovering critical materials from EVs. Participants also pointed out that creating a successful collection program could provide a framework to encourage the recycling of other products such as computers, outdoor power equipment, and solar panels.

Improved conditions for reuse and repurposing

Reducing the cost of transportation and improving the possibilities for testing and tracking would also support the reuse industry by making it easier to determine which batteries are best suited for reuse. In addition, better information about battery storage would increase safety and avoid unnecessary degradation, which will also support reuse.

Benefits to dismantling industry

In the near term, establishing a robust network and facilitating access to information will provide a solution for people and companies who do not know what to do with stranded battery packs. As more battery packs come offline, the demand for collection and dismantling will create skilled job opportunities within California.

Improved Safety

Better information on proper handling, storage, and shipping protocol will promote safety for all parties involved in end-of-life management. Access to knowledge about the battery's condition will also alert the party handling the battery about the need to follow extra precautions or use specialized packaging.

4.2 Reuse

Reuse and repurposing are terms often used interchangeably. Here each has a particular meaning; reuse refers to the use of a used LIB in an EV (i.e. after removal from a vehicle and any needed repair, refurbishment, or remanufacturing), and repurposing refers to the use of a used LIB in another application (i.e., an application other than as a traction battery in an EV). While the subcommittee was titled "Reuse," its mandate included both reuse and repurposing, though as evident in the discussion that follows, the subcommittee mostly focused on repurposing.

Reuse and repurposing of electric vehicle batteries face a number of barriers as well as opportunities and benefits that can be grouped into larger themes. Identified barriers include cost, allocation of responsibility, lack of information and data, battery design, and lack of volume for a sustained business plan. Identified opportunities and benefits include reduced environmental impacts relative to alternatives, economic opportunities and benefits, provision of energy storage services, and others such as improved traceability, and reduced incentives for planned obsolescence. The following text describes the barriers and opportunities for reuse and repurposing in greater detail.

4.2.1 Barriers

Cost

For used batteries to be competitively priced against new batteries they must be offered at a discount, which is difficult to achieve given the falling costs of new batteries. New EV LIB battery pack costs fell by an average 87% between 2010 and 2019.[32]

The main costs of repurposing come from acquiring batteries, testing to determine state of health, and reconfiguring and equipping batteries with a battery management system (BMS), thermal management, and other required hardware and software. In addition, battery storage systems must meet certain standards, either because they are mandated by law or expected by the market. The cost of obtaining the necessary certification presents a significant burden for repurposers, who are typically smaller startup companies and do not have the same resources to draw from as, for example, OEMs. In addition, the cost of storing batteries onsite, permitting, and complying with the regulations are a strain on the companies, and the added lack of clarity about the regulatory compliance that is, or will be, required may dissuade actors from the market.

The difficulty in competing with new batteries is exacerbated in California because second-life batteries are not eligible for incentive programs like the CPUC's Self-Generation Incentive Program (SGIP), which partially subsidizes the cost of new energy storage systems.

Allocation of responsibility

The lack of clarity within the industry regarding legal obligations and responsibilities for second-life batteries is a barrier to the development of start-ups and partnerships with OEMs. If a battery is repurposed by a third party and not the OEM, it is unclear if the OEM or the repurposer will be liable if there is an accident. The same may be true regarding responsibilities for final disposition of the battery (i.e., recycling), especially under regulatory schemes with some kind of extended producer responsibility. The same can be said for allocating benefits for the perceived social and environmental value of repurposing.

In the case that the OEM is not responsible, they may still be sensitive to negative press in the event of an accident and attendant reputational risks, which could dissuade their participation in arrangements that facilitate second-life uses. However, the current end- of-life process for an EV does not allocate responsibility of the battery to the OEM. Batteries only return to the OEM if they are returned due to warranty issues, or if the vehicle is retired within the warranty period.

Lack of information or data

Repurposing and reuse companies, including those that may refurbish, remanufacture or reconfigure LIBs retired from EVs prior to second-life usage, need access to information about the battery's state of health (SoH) to estimate the remaining lifespan and determine whether the battery is suitable for reuse or repurposing. Access to this information could also enable second-life companies to offer performance guarantees, which are especially important given that second-life batteries are competing with new batteries from established, larger manufacturers that provide such guarantees. Without access to manufacturers' BMS, determining the SOH requires an expensive and time-consuming testing process.

Since repurposers typically connect batteries of the same make and model in storage units, the sector would also benefit from increased access to identifying information about the battery type (i.e., chemistry, voltage, and rated capacity). Finally, transparent information about the battery history would alert anyone working on the battery to follow special safety protocols, for example if the vehicle it was removed from had been damaged or in an accident.

First-life battery design

The repurposing process can be done at the cell, module, or pack level. All of which require removing the pack from the EV, and in the case the pack is broken down to the cell level, disassembling the LIB pack. The lack of standardization between OEMs complicates the secondary market because the disassembly and dismantling process is different for each pack design. Since batteries are not designed to be disassembled, the process can be dangerous and costly.

Acquisition challenges

The current lack of supply of retired EV LIBs is a barrier to advancing the second-life industry. The quantity of EVs currently being retired is low compared to the amount that will retire in the next several decades. Furthermore, the supply of retired batteries will likely be dispersed between dealerships, auto dismantlers, insurance auctions, and scrap metal recycling facilities, complicating the reverse logistics process and acquisition routes for the second-life industry.

4.2.2 Opportunities and benefits

Environmental benefits

Harnessing the remaining usable capacity in retired electric vehicle batteries may displace demand for new battery products, which avoids the negative impacts associated with mining, refining, and manufacturing and reduces reliance on imported critical materials. Alternatively, deployment of repurposed batteries may expand the energy storage market, rather than simply displacing new battery production, in which case key environmental benefits may come from supporting storage needs on the grid required to accommodate the renewable energy transition.

Economic opportunities

A key economic benefit of reuse is the job creation that would accompany the development of a new industry, not just in the state but as part of a labor force that could spread across the country. The solar industry, where job creation helped fuel the industry, may provide a model for the nascent second-life battery industry.

Another economic benefit is the potential cost savings to the end-user of a second-life battery system, assuming reused or repurposed batteries can be delivered at a lower cost. More affordable energy storage also promotes equity by enabling households and communities who may not otherwise be able to afford energy storage to be more resilient in the face of natural disasters, for example by providing backup power during public safety power shutoff events.

Encourage transparency and coordination across the value chain

Participants identified an opportunity to set expectations and criteria about the traceability and capture of products before they are put onto the market, which would provide a positive example for other industries. Encouraging reuse and repurposing could also enable repairers to connect with OEMs, encouraging a feedback loop so OEMs know how to design for repair or repurposing, and design the market to avoid planned obsolescence. Finally, tracking product longevity and resale can be an incentive for brands to prove they are not planning for obsolescence

4.3 Recycling

The recycling subcommittee was formed to identify options to address barriers and incentivize recycling that minimizes environmental and economic cost while maximizing material recovery. The scope covered includes material recovery via recycling process.

The recycling of EV LIBs at end-of-life faces a number of barriers as well as opportunities and benefits that can be grouped into larger themes. Barriers include existing regulations, cost, industry development within the United States, and lack of information and data. Opportunities and benefits include reduced environmental and social impacts, economic opportunities and benefits, increased safety, and recycling industry growth. The following text outlines the barriers and opportunities in greater detail.

4.3.1 Barriers

Regulations

The regulatory environment within California, and at the national and international level, is a common barrier for the LIB recycling industry. There is a lack of clarity of regulations relevant to LIB recycling and a lack of alignment between regulations at state and national scales. Particular barriers in California include a lengthy permitting process for establishing a recycling facility within the state, which is a likely deterrent for industry. The DTSC, a key agency in permitting, has improved their processing to an average of two years, which is still a long and costly timeline for a business developer. There is also added uncertainty because there has not been a hazardous waste recycling facility sited within California in over 8 years, limiting the ability to infer from recent projects what the needs and timelines might be for new development.

This type of regulatory uncertainty makes investment in recycling infrastructure risky and deters industry from development within California. This risk is exacerbated by an unguaranteed stream of retired LIBs due to a lack of consolidated take-back, collection, or reverse logistics system within the state. While this report is California-specific, it is important to note that at the national scale there is currently no regulatory alignment of strategies for recovering critical materials within the US, which has been an additional barrier to the recycling of LIBs. This may change in the near future due to President Biden’s Executive Order on America’s Supply Chains and it is unclear if California is prepared to align with these strategies.[7]

Economics

For recycling to proliferate without government intervention it must be economically compelling. Currently, recycling of EV LIBs is understood to be unprofitable. Moreover, the value of recovered material is uncertain due to the continuous evolution of cathode chemistries, not to mention volatility in metal prices. A key evolution is reduced cobalt in cathode chemistries, due to the high price of cobalt and increasing concerns over human rights violations during its production. This reduction in cobalt reduces the value of the recovered material.

There are a handful of industrial scale LIB recycling plants globally, with the bulk of recycling taking place in Asia. The closest recycling facilities to California areRedwood Materials in Carson City, Nevada, and Retriev Technologies in Trail, British Columbia. Considering planned developments in North America by multiple companies including Li-Cycle, Redwood Materials, Lithion, and American Manganese, it seems some investors anticipate LIB recycling to be cost-effective in the near future. Data from industry makes could assist the government in understanding the economics of LIB recycling and inform necessary steps the government could take to support development of the recycling industry.

Supply of retired EOL LIBs

Another barrier to cost-effective recycling is the lack of a guaranteed stream of EOL LIBs due to both a relatively small volume of EV battery retirements at this time (though this will change in the coming years), and inadequate reverse logistics infrastructure. The responsible party for the cost of disposal of the EV at the EOL is currently the owner of the vehicle for batteries outside warranty. This does not encourage recycling, considering there is a significant cost to recycling of the battery and no easy and accessible reverse logistics process.

Both barriers (high cost and an unclear process for getting an LIB recycled) could result in the exporting of EVs or spent LIBs, therefore resulting in the loss of recoverable critical materials and potentially contributing to E-waste dumping and environmental injustices, which has been documented widely for other e-waste streams.

Industry development within the United States

Another barrier to the development of an industry within the U.S. is the lack of a LIB battery supply chain in North America that will purchase the recovered materials after recycling. While cells are manufactured within the U.S. (e.g., Panasonic for Tesla), the precursors to cell manufacturing such as cathode production are not located within the U.S. This means recovered material will be exported to produce cathode materials, which undermines the ultimate goal of increasing energy security by reducing dependency on other markets for clean energy technologies.

Lack of information or data

The lack of knowledge about the battery at its EOL is a barrier to recycling by increasing costs and safety risks. For recycling to be most efficient, cathode chemistry should be labelled, and disassemblers should have knowledge as to the safest way to remove the battery from the EV.

4.3.2 Opportunities

Reduced Environment & Social Impact

The recycling of LIBs will reduce environmental impacts by replacing primary materials with the recovered materials. This in turn, conserves resources and maximizes the use of existing materials already extracted. This reduced ore extraction minimizes environmental and social impacts, such as those that arise from cobalt mining in the Democratic Republic of Congo. These human rights abuses which stem from both improper protective gear for workers, among other unsafe working conditions, and the use of child labor. In addition, the mining of all these critical materials create health impacts on the local communities from which they are extracted and refined and strain them for resources, such as clean water. Locally, the recycling of LIBs will conserve landfill capacity and reduce the reliance on hazardous waste landfills. Proper management will also reduce the risk of fire or leaching of toxins that could occur if the battery is not stored or otherwise managed properly at EOL.

Economic opportunities

The development of a recycling industry within the nation presents an opportunity for the creation of jobs that require a skilled labor force. In addition, there is the economic opportunity of reducing reliance on overseas materials and the risk of supply disruption due to geopolitics. By recycling within the nation, the recovered materials can be used in the production of new batteries to support the clean energy transition, and reduce US vulnerability to price shocks. This national supply, along with increased economies of scale and technological improvements, has the potential to result in the decreased cost of batteries.

Recycling industry growth

As the recycling industry grows, it could potentially lead to the development of a national battery supply chain and an enhanced closed-loop model. A closed-loop LIB supply chain consists of used batteries sent to recycling to recover materials, which are then returned to the battery supply chain to manufacture cathodes, which are then used to manufacture batteries. Currently, there are no cathode manufacturers within the U.S., requiring recovered materials to be shipped internationally. The development of domestic recycling could encourage the development of these intermediary industries within the U.S. In addition, increased recycling will inevitably lead to technological innovation within the industry that could result in higher efficiencies, thus minimizing residual waste. A similar effect may be observable for economies of scale and economies of learning, which could result in an economically sustainable industry.

5. Policy Recommendations

TEXT WILL BE ADDED TO INTRODUCE THIS SECTION. THIS SECTION IS INTENDED TO BE REVISED BASED ON ADVISORY GROUP FEEDBACK. THE FOLLOWING POLICIES WERE SELECTED BASED ON THE DECISIONMAKING PROCESS OUTLINED IN SECTION 3.1.

IN THE OCTOBER 22 MEETING, THE ADVISORY GROUP WILL HAVE THE OPPORTUNITY TO APPROVE THIS METHOD OF SELECTING RECOMMENDED POLICIES OR CHOOSE AN ALTERNATIVE APPROACH. THE ADVISORY GROUP WILL ALSO HAVE THE OPPORTUNITY TO DISCUSS THE RECOMMENDED POLICY FOR DEFINING RESPONSIBILITY AND ADVOCATE FOR ANY POLICIES THEY BELIEVE SHOULD BE MODIFIED, REMOVED FROM, OR ADDED TO THE LIST OF RECOMMENDATIONS. A SECTION WILL BE ADDED TO REPRESENT DISSENTING VIEWS.

NOTE: IN THE FINAL REPORT, THE POLICY DEFINING EOL RESPONSIBILITY WILL BE PRESENTED FIRST, THEN FOLLOWED BY COMPLEMENTARY "SUPPORTING POLICIES" THAT ADDRESS MORE SPECIFIC BARRIERS. FOR THE PURPOSES OF THIS DRAFT, THE UC DAVIS TEAM IS PRESENTING THE "VEHICLE BACKSTOP" OPTION AS THE RECOMMENDED POLICY FOR DEFINING EOL RESPONSIBILITY BECAUSE IT RECEIVED THE LOWEST OPPOSITION (SEE TABLE 1 IN THE APPENDIX FOR SURVEY RESULTS).

5.1 Recommended Policy for defining responsibility for end-of-life management

At present, no party is required to coordinate and pay for the collection, transportation, and processing of retired out-of-warranty batteries, so the disposal route depends on the profitability of reuse and/or recycling. This could create "orphaned batteries" if individual consumers or small operations end up in possession of batteries they do not have the resources or motivation to dispose of properly. Without a mechanism to collect orphaned batteries, they may be unsafely accumulated, illegally abandoned, or exported.

The following policy options seek to prevent the loss of batteries through the routes described above, either by defining a responsible party (options 1, 2a, and 2b) or establishing a financing mechanism for responsible end-of-life management (options 3, 4, and 5):

1. Core exchange and vehicle backstop proposal
2. Producer take-back
    a. Companion legislation requiring return to the OEM
    b. No companion legislation
3. Environmental handling fee applied at time of purchase
4. Environmental handling fee gathered through vehicle registration fee
5. Hybrid environmental handling fee

The advisory group recommends the legislature enact [Option 1] to define responsibility for EOL management. This option is presented in detail below along with supporting and dissenting opinions from advisory group members. Options 2-5 are described in Section X ("Alternative options for defining responsibility").

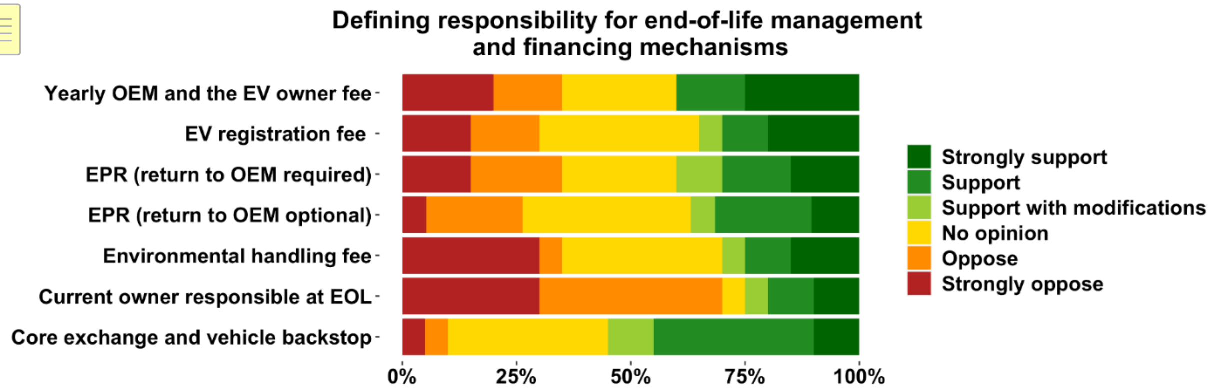

Figure 4: Survey results for defining responsibility for end-of-life management and financing mechanism. Full results can be found in tables A1 and A2 of the appendix.

[PLACEHOLDER] Recommendation: Core exchange and vehicle backstop proposal

The following option was originally proposed by the Alliance for Automotive Innovation (AAI) and endorsed by [x] out of 20 advisory group members:

"For EVs **still in service**, if a battery pack, module, or cell is replaced before the vehicle reaches EOL, a core exchange program as detailed by the EV battery supplier* or manufacturer shall be used for the replacement battery (or any module or cell). The entity removing the battery shall be responsible for ensuring the used battery (or module or cell) is properly reused, repurposed, refurbished, or recycled. The entity selling an EV battery shall use a core exchange** program to track that the used battery has been properly disposed of.

For EVs **reaching EOL,** a dismantler who takes ownership of an EOL vehicle is responsible for ensuring the battery is properly reused, repurposed, refurbished, or recycled. In circumstances where an EOL EV with an OEM certified battery is not acquired by a licensed dismantler, the vehicle manufacturer shall be responsible for ensuring that the vehicle is properly dismantled and the lithium-ion battery is properly reused, refurbished, or recycled.

*Supplier refers to the entity selling the battery, which could be a dismantler, repurposer, or manufacturer. For example, if a battery is repurposed for a stationary storage application, the responsibility for ensuring the battery is recycled transfers to the repurposer."

**Core exchange: In the auto parts industry, a "core" is used to encourage the return of old parts that can be remanufactured or recycled. Often, this takes the form of a core charge, where the customer pays a deposit when purchasing a new part. The deposit is then refunded when the part is returned. In the vehicle backstop policy proposal, the details of the core exchange program can be decided by the OEMs and may or may not involve an added charge. Two examples provided by AAI were 1) a case where the used battery is shipped to OEM part sales, and 2) where the battery is replaced by a repair shop with an existing recycling arrangement.

1. The battery is removed by a repair shop, who ships it to OEM part sales, battery aftermarket sales, or battery refurbisher. The OEM part sales, aftermarket sales, or refurbisher returns a replacement battery to the repair shop, and is then responsible for ensuring the used battery is properly recycled.
2. The OEM, battery aftermarket sales, or battery refurbisher requires proof that the repair shop removing the battery has properly recycled, refurbished, or put it into a non-vehicle secondary use market before providing a replacement battery

Considerations for implementation

- The legislature or responsible agency should revisit this policy periodically to assess its effectiveness in preventing abandoned and exported batteries and evaluate whether any changes are necessary.

Advantages:

- The “vehicle backstop” will address LIBs that could potentially become orphaned
- Does not add to purchasing cost of electric vehicle
- Encourages independent reuse and repurposing for batteries with available capacity
- Specifies transfer of responsibility for refurbished, reused, and repurposed batteries

Disadvantages:

- In some cases, a dismantler may remove a battery and sell it for reuse in another vehicle. If that dismantler is considered the supplier, it may be difficult to enforce the requirement that the supplier (i.e., dismantler) be responsible for ensuring proper reuse (etc.) or recycling of that battery when it reaches end-of-life.

Comments from advisory group for discussion:

“Support as part of a broader strategy that covers the rest of the batteries.”

“This only applies to a very narrow subset of batteries and should be combined with #1 above”

“Seems to be status quo as of now.”

“Although automotive dismantlers can develop know-how on refurbishing and recycling (by a sub-contractor), it is dangerous to rely 100% on these automotive dismantlers. Eventually, it should be the car OEM (Original Equipment Manufacturer) who should ensure that appropriate recycling technologies do exist. What will happen if automotive dismantlers refuse to take back some EV battery packs because there is not recycling technology available.”

“Workable, but 'do the right thing' decision making is widely diffused”

“OEMs like Tesla already have a core exchange program in place for batteries in need of repair or refurbishment. This service should be viewed as a complementary to EOL recycling, especially for batteries that can be refurbished. Battery pack life extension is the superior option to recycling for both environmental and business reasons. This is why before decommissioning and recycling a Page 5 of 32 consumer battery pack, Tesla does everything it can to extend the useful life of each battery pack, including sending out over-the-air software updates to Tesla vehicles to improve battery efficiency when our engineers find new ways to do so. Vehicle dismantlers may choose to manage EOL batteries with or without the rest of the vehicle. Regardless, Tesla believes suppliers/manufacturers should be responsible for the proper reuse, repurposing, refurbishment or recycling of the battery packs they deployed on the market, if and when those batteries are offered back to the suppliers/manufacturers. Suppliers/manufacturers should include battery refurbishers and repurposers to ensure a clear transfer of responsibility for re-manufactured and re-purposed battery products."

5.2 Recommended supporting policies

The advisory group recommends the following policies to address specific barriers to reuse and recycling and ensure that reuse and recycling processes are safe and environmentally responsible. **The policy options are not mutually exclusive** and should be considered complementary to the proposed policy defining responsibility for end-of-life management.

Table 4. Recommended Policies

Category	Policy	Purpose
Access to battery information	Physical labeling requirement	Facilitate sorting to improve process efficiency; enable easy identification of battery OEM
	Digital identifier	Identify LIB chemistry at end-of-life; identify responsible party for safe disposal; improve safety during disassembly
	Universal diagnostic system	Reduce cost of testing; enable performance guarantees for reused and repurposed batteries
Support repurposing, reuse, and recycling industry development	Recycling incentive packages	Mitigate upfront capital costs; encourage recycling within California
	Disassembly incentive packages	Encourage disassembly within California
	DTSC permit timeline*	Reduce cost of locating processing facilities within California
	Expand eligibility for battery storage systems*	Enable cost-competitiveness with new batteries
Circular economy and quality recycling	Minimum material recovery targets	Ensure recovery of strategic materials
	Design for repurposing, reuse, and recycling	Reduce reuse and recycling costs
	Third-party verification*	Ensure batteries are recycled sustainably
Safe and efficient reverse logistics	Support enforcement of unlicensed dismantling laws	Prevent leakage from unlicensed dismantling
	Develop training materials	Improve safety and workforce capacity
	Support transportation research	Reduce transportation cost
	Develop strategic collection and sorting infrastructure	Reduce transportation cost
	Universal waste regulations*	Reduce transportation cost and administrative burden

*Denotes policies that receive majority support with minor modifications

5.2.1 Access to battery information

Lack of access to information about battery packs was identified as a barrier by all subcommittees. The party removing the battery needs information about the condition to determine the next suitable use and whether any extra precautions are necessary during shipping and handling. In addition, the reuse, repurposing, or remanufacturing company needs information about the battery's SOH to ensure quality and provide performance guarantees, and recyclers need to know the chemistry to sort batteries and process them at maximum efficiency. The following policies are recommended by the advisory group to increase access to information:

Physical labeling requirement[3]

Require original equipment manufacturers (OEM) to attach a physical label containing information about the battery in symbol or text form to the pack in a visible and legible manner. The label(s) should be located such that they are visible during maintenance, replacement and after being removed from the vehicle. The advisory group recommends the following information be included in the label[4]:

- Auto manufacturer's name
- Battery manufacturer's name
- Main cathode chemistry (e.g. NMC)
- System voltage (e.g. 28.8V)
- Capacity (e.g. 50 kWh)

The California Air Resource Board (CARB) is developing a labeling requirement as part of their proposed Advanced Clean Cars II regulation. The information required includes the manufacturer name, cathode chemistry, voltage, performance/capacity, product alert statements/hazards, composition/process related information, and electronic information exchange/digital identifier. Advisory group members recommend that labeling requirements align with forthcoming CARB requirements, as well as the Society for Automotive Engineers standard for EV batteries (SAE2936).

Additional suggestions from AG:

- "There are some concerns over who would be responsible for this labeling process. We would want specific language prohibiting manufacturers from delegating this labeling process to the dealers, as has been done with Proposition 65 labeling requirements."

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[3] This policy has been modified from its original version to suggest alignment with CARB ACCII and SAE following comments from advisory group members

[4] This list differs, and includes less information, than the proposal developed by CARB.

Advantages

- The label allows recyclers to easily sort LIBs by cathode chemistry, which maximizes process efficiency and material recovery rates.
- Easy identification of the battery OEM and chemistry will streamline the repurposing process since stationary repurposed systems must be built using the same type of battery.
- Because some cathode chemistries have more material recovery value than others, information about battery chemistry will enable the party handling the battery to negotiate the cost paid to or by recyclers.

Disadvantages

- If only the main cathode chemistry is listed and not the full stoichiometry of the cathode (e.g., NMC 622), it may not be enough to identify the value of materials within the battery.
- The cathode chemistry may be proprietary information to the battery manufacturer.

Electronic information exchange (i.e. QR code with online database)

An electronic information exchange should be enabled by a digital identifier, such as a QR or barcode, applied as a physical label on the battery pack. This digital identifier will direct to an online database.

The advisory group recommends the following information to be included in the online database:

- Main cathode chemistry (e.g. NMC)
- Capacity (e.g. 100 kWh)
- System voltage (e.g. 28.8V)
- Instructions for disassembly
- OEM contact information to request safe disposal of the battery

Advantages

- Providing easily accessible disassembly instructions can increase safety at battery end-of-life
- Easily accessible OEM contact information can expedite the recovery of LIBs at their end-of-life, which would prevent orphaned batteries and increase recycling rates.
- The information shared on this platform has the potential to expand past the advisory group recommendations.

Disadvantages

- May not be enough information to maximize reuse, repurposing, and recycling

Universal diagnostic system[5]

In addition to information about the contents of the battery pack, it has been suggested that enabling third-party access to SOH would facilitate repurposing and reuse by reducing the time required for testing. The advisory group recommends a Universal Diagnostic System (UDS) be installed on the battery that would enable non-OEM actors to access relevant data about the condition and/or history of the battery *after it has been removed* from the vehicle. The UDS would be analogous to the Onboard Diagnostics II (OBD2) systems in vehicles where engine and other vehicle system information (and particularly faults or failures) is reported. OBD2 is required for all light-duty vehicles built after 1996.

The California Air Resources Board is currently drafting a standardized battery SOH proposal as part of the Advanced Clean Cars II regulation. CARB's proposal requires the OEM to calculate a SOH of battery with a minimum accuracy (+/- 5%) based on the remaining amount of 'Usable Battery Energy' as measured by SAE J1634 lab test methods. The SOH must be readable by driver without a tool and normalized so that 100% equals new on all cars. The proposal also requires OEMs to define and disclose the SOH value that qualifies for warranty repair.

The CARB proposal is distinct from this proposal for a UDS because the UDS would function even after a battery is removed from a vehicle; however, coordination and alignment with CARB where possible is recommended by several members to avoid overlapping regulation.

Advantages

- Enables informed decisions about reusing, repairing, and recycling, which ultimately reduces the overall costs.
- Increased information on the use and state of health can enable maximum use and value out of the battery packs through repurposing and reuse.
- Enables more locations to diagnose and work on batteries, which would lower cost to consumers.

Disadvantages

- Could require special LIB design for vehicles sold in California and result in increased costs
- Intellectual property concerns for OEM's algorithm and software
- Easily accessible information on state of health could encourage unlicensed repurposing

5.2.2 Support repurposing, reuse, and recycling industry development

The high upfront cost and lack of large-scale battery retirement contribute to the unfavorable economics of reuse and repurposing. Furthermore, it is preferable for disassembly, reuse, and recycling to take place within California to create skilled jobs and guarantee the processes meet the state's high environmental standards; however, these standards may also add cost, making

[5] This policy has been modified from its original version to include more information about CARB's ACC II SOH proposal

it difficult to compete with other jurisdictions. The following policies are recommended by the advisory group to mitigate these barriers and encourage industry development within California

Economic incentive package provided to lithium-ion battery recyclers within California

The State should provide financial incentives in the forms of tax breaks or grants to hazardous waste processors that recycle lithium-ion batteries to mitigate upfront costs and encourage industry development within California.

Advantages

- Subsidizing upfront costs will make California-based recycling competitive with other states
- Recycling within California will ensure compliance with high environmental standards and reduce the transportation distance at the end-of-life

Disadvantages

- Does not ensure the long-term economics are profitable
- Could lead to overbuilding recycling capacity or inefficient siting
- The public may be skeptical about recycling as a hazardous waste processing industry

Economic incentive package to encourage disassembly within California

Provide financial incentives in the forms of tax breaks or grants to facilities who disassemble battery packs to encourage industry development within California.

Advantages

- A disassembly industry will create skilled jobs in California

Disadvantages

- Concern that bad actors could take advantage of financial incentives, leading to abandoned sites
- Encourages disassembly within California regardless of whether it is the optimal location

Establish a timeline for hazardous waste processing permit[6]

As part of the hazardous waste facility permitting process, a timeline shall be established during the initiation of the permitting process. Both DTSC and the permit applicant are expected to comply with this timeline and any and all milestones as described in SB 158. The successful completion of this process in a timely manner depends on the applicant providing adequate

[6] This policy option has been modified from its original version to emphasize the need for adequate and timely responses to identified deficiencies in the application following due to suggested changes by the advisory group.

revisions of permit applications to DTSC in a timely manner. Permit applicants must provide adequate and timely responses to identified deficiencies in the application**.**

Advantages

- Addresses the lengthy and uncertain permitting process in California compared to other states, which was identified as a barrier to the recycling industry
- Provides transparency and certainty
- Potentially lowers GHG impacts and cost by reducing transportation distance
- Create skilled labor jobs within California

Disadvantages

- If DTSC's budget is cut or they are not able to keep up with applications, application approval may be rushed and there is a risk that mistakes or flaws will be overlooked
- A process is needed to weed out frivolous applications and avoid the involvement of bad actors

Expand eligibility for relevant incentive programs to include reused and repurposed batteries[7]

Currently, reused or repurposed battery storage systems are not eligible for existing incentive programs that subsidize the cost of new battery storage. The advisory group recommends encouraging the CPUC Program Administrator to consider expanding eligibility for the self-generation incentive program (SGIP), provided repurposed and reused batteries meet specified performance and warranty criteria. The performance standards should be developed based on the best available research on safety, SOH, and battery lifetime.

Advantages

- Enables reused batteries to compete with new batteries

Disadvantages

- Further research is needed on the performance and safety of repurposed batteries

5.2.3 Circular economy and quality recycling

The following policies are recommended to promote circular economy principles, reduce the processing cost of reuse and recycling, and ensure that batteries are recycled using sustainable processes that recover strategic materials.

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[7] This policy option has been modified from its original version to specify that repurposed batteries must meet specified performance and warranty criteria following suggestions from the advisory group.

Minimum material recovery rates[8]

Required recovery rates for specific materials are recommended to guarantee that critical materials are recovered. The "recovery rate" is the output of a specific material in usable form as a percentage of total input of that material. "Critical material" refers to a material used in technology that is subject to supply risks, which has no easy substitutes. The U.S. Department of the Interior has defined the following materials used in lithium batteries to be critical: lithium, cobalt, and manganese. In addition, the White House report on America's supply chains includes Class I nickel as a critical material to the lithium-ion battery supply chain

Further research is needed to identify feasible target rates, which materials should be included, and the best process for implementation to ensure that domestic and international recyclers are on an even playing field. The targets should be phased in over time and reflect technological developments and commercial recycling capability in North America.

An example of target recovery rates for lithium-ion batteries is the proposed "medium ambition" revisions to the EU Battery Directive that specify the following material recovery rates in 2025. Please note these rates are an example and not the recommended rates by the Advisory Group.

- Cobalt: 90%
- Nickel: 90%
- Lithium: 35%
- Copper: 90%

While the majority of the advisory group supports establishing target material recovery rates, several members favor an aspirational target rather than a mandated requirement.

Advantages

- Requires recycling processes with a high yield rate
- Provides a method for targeting the recovery of critical materials
- Allows for flexibility and the increasing of targets as recycling technology matures

Disadvantages

- The rates established for the purposes of strategic material recovery and sustainability may not be profit-maximizing for the recycling industry

Design for repurposing, reuse, and recycling

Disassembly at end-of-life is time- and cost-intensive for repurposers and recyclers. The advisory group recommends requiring OEMS to design batteries in a way that facilitates repurposing, reuse, and recycling. Examples that are not binding or exhaustive include sealing battery packs with screws instead of adhesives, using an alternative binder than PVDF to

[8] The language of this policy has been modified for clarity and to emphasize the need for further research

increase end-of-life solubility, and converting to solid busbars that are in a standardized position.

Advantages

- Increasing the efficiency of repurposing, reusing, and recycling of LIBS at the end-of-life will decrease costs
- Can increase the safety of disassembling LIBS at their end-of-life
- Encouraging consideration of end-of-life during the design process promotes circular economy principles

Disadvantages

- Imposing strict prescriptions for recycling has the potential to hamper innovation. There are potential tradeoffs between designing for their end-of-life and other key aspects for their first use such as safety, cost, and performance
- Could increase manufacturing costs

Third-party verification

Lithium-ion batteries should be disassembled, processed, and recycled in facilities that have been verified by a third party to guarantee high-quality environmental performance (i.e. emissions control) and worker safety. This is intended to provide assurance that recycling facilities operating in any jurisdiction outside California are conforming to a minimum standard.

The advisory group recommends the legislature call for the establishment of a process standard for facilities where used lithium-ion batteries, production scrap, and derived materials are processed or recycled. This will require consensus standard development to address specific types of processes within recycling and processing facilities (e.g. dismantling, pyrometallurgical, hydrometallurgical). The process standard would then be approved by a designated state agency and verified by a third party through an initial and annual auditing process.[9]

The third party should be an independent source (e.g. certification body) that awards certification based on a facility meeting certain environmental criteria outlined in a certification standard and described in certification requirements. Examples of programs using third-party verification include E-stewards and PaintCare.

Advantages

- Discourages the export of LIBs to facilities that do not meet environmental standards
- Supports a level playing field for recyclers

Disadvantages

- Cost of oversight and administration
- Could increase the cost of recycling

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[9] This policy has been edited for clarity. The content has not been changed.

5.2.4 Reverse logistics

The advisory group recommends the following policies to support the safe and efficient removal, handling, and transportation of end-of-life batteries.

Support enforcement of unlicensed dismantling laws[10]

An ongoing concern in the state of California is the rise of unlicensed dismantling, which is problematic because unlicensed dismantlers do not take the same precautions when disposing of hazardous materials and fluids. Unlicensed dismantling is particularly undesirable for EVs given the hazards posed by large-format lithium batteries when handled incorrectly. Increased resources should be provided to improve enforcement of unlicensed dismantling facilities, for example through the existing Vehicle Dismantling Industry Strike Team which is led by the DMV.

Advantages

- Support businesses that operate safely and environmentally responsibly
- Improve the business environment for the licensed auto dismantling industry

Disadvantages

- Added enforcement creates an administrative burden for DMV

Develop training materials for parties handling end-of-life batteries

To support industries that will need to adapt to vehicle electrification and promote safe EOL management, funding should be made available to support training materials that provide clear, detailed guidelines on occupational safety, storage, and shipping protocol and requirements. Examples of current efforts to increase training include a course for first responders created by the National Fire Protection Association, and a webinar on the safe handling of LIBs (mainly portable) created in a joint effort by the US Department of Transportation (USDOT) and the EPA.

Advantages

- Develop workforce capacity and promote safety

Disadvantages

- None to report

[10] This policy has been modified to include information about the DMV's vehicle dismantling strike team

Universal waste regulation[11]

End-of-life lithium batteries are classified by DTSC and the US EPA as a universal waste. A key point of discussion for all subcommittees was defining at what point they become waste, which will affect what activities are considered hazardous waste treatment and who is considered a generator, handler, or treatment facility. It was suggested that batteries be considered waste only *after it has been demonstrated they do not have sufficient remaining capacity for reuse or repurposing.* However, such changes would need to be adopted at a federal level before it could be implemented by DTSC.

The advisory group recommends that if the U.S. EPA changes the status of retired batteries in a way that reduces regulatory burden, DTSC should evaluate those changes and adopt them as long as they are consistent with the continued protection of public health and the environment in California.

Advantages

- Reduces unnecessary administrative burden and provides clarity for parties handling end-of-life batteries

Disadvantages

- Reducing regulatory burden must be limited to actions that do not sacrifice safety, public health, or environmental stewardship

Identify strategies to reduce the burden of transportation[12]

The advisory group recommends the state support research on solutions to reduce the cost of collection and transportation. This research should include 1) technical solutions for regulatory compliance related to packaging and handling safety mechanisms, and 2) regulatory analysis focused on lowering the costs of federal regulation compliance without compromising safety. There is greater support among the advisory group for research focused on technical solutions related to packaging and handling than regulatory analysis on lowering the costs of compliance.

Advantages

- Shipping and handling costs are significant. Lowering these costs without compromising safety will improve the overall economics of reuse, repurposing, and recycling

Disadvantages

- Lowering the cost of compliance must not sacrifice safety

[11] This policy has been modified to emphasize that any changes adopted must continue to protect public health and the environment following suggestions from advisory group

[12] This policy has been modified to reflect the wider support for research on technical solutions

Develop strategic collection and sorting infrastructure

To support a more efficient reverse logistics network, the state should support the development of strategic reverse logistics, including but not limited to strategically located collection and sorting facilities. Such facilities can reduce transportation costs by accumulating batteries to optimize shipment volumes and distance travelled.

Advantages

- A spatially optimized collection network will reduce the transportation distance at end-of-life, which will make the system more efficient and reduce cost and environmental impact

Disadvantages

- State involvement could lead to unnecessarily high oversight costs and/or a less efficient system compared to allowing the marketplace to determine collection and sorting infrastructure

6. Additional policy options (not recommended)

6.1. Alternative options for defining responsibility (not recommended)

6.1.1. Producer take-back options

Producer take-back with no companion legislation

"The auto manufacturer is responsible to ensure proper repurposing, reuse, or recycling of its EV traction batteries by a licensed facility at no cost to the consumer if and/or when they are no longer wanted by the owner, and in the event no other entity has taken possession of the battery. Auto manufacturer responsibility initiates when the auto manufacturer has been notified the battery has reached its EOL and is available to be disposed of. If the battery is repurposed, the EOL responsibility transfers to the repurposing company. This responsibility includes:

- Arranging reverse logistics to transport the batteries to recycling hubs
- Being responsible for the recycling costs
- Documenting the proper disposal of the battery

The Auto manufacturer will provide educational materials to customers and the service/repair industry, explaining the return process. This material will be made available through the vehicle owner manual or in-vehicle display, in printed dealer materials, and online."

Advantages

- Clearly defines responsibility while providing the option for EV owners to sell the battery at the LIBs end-of-life or contact the OEM to correctly dispose of it

- The ability for batteries to be sold to a third party at the end-of-life provides opportunity for growth in the remanufacturing, refurbishing, and repurposing industry without requiring a partnership with the OEM
- Incentivizes design for recycling and disassembly

Disadvantages

- Potentially increases costs to the manufacturer under the assumption valuable LIBs at their end-of-life will be sold to a third party, and the OEM will be contacted to dispose LIBs with negative value

Producer take-back with companion legislation requiring return to OEM at the LIB end-of-life

The auto manufacturer is responsible to ensure proper repurposing, reuse, or recycling of its EV traction batteries by a licensed facility. Auto manufacturer responsibility initiates when the auto manufacturer or its agent takes custody of the battery at no cost to the consumer. This responsibility includes:

- Arranging reverse logistics to transport the batteries to recycling hubs
- Being responsible for the recycling costs
- Documenting the proper disposal of the battery

The Auto manufacturer will provide educational materials to customers and the service/repair industry, explaining the return process. This material will be made available through the vehicle owner's manual or in-vehicle display, in printed dealer materials, and online. In addition, companion legislation that requires all EV batteries to be returned to the manufacturer or its agent upon removal from the EV is necessary.

Advantages

- Clearly defines responsibility at the LIB end-of-life
- Provides the OEM with a stream of used LIBs that will likely be valuable

Disadvantages

- Considering the return of LIBs to the OEM at their end-of-life would be required, this policy deters from repurposing, reusing, or remanufacturing through a third party that does not have a partnership with the OEM

6.1.2 Environmental handling fee

Environmental handling fee applied at time of purchase

A one-time payment is assessed at the point of purchase of a new EV to finance an EOL collection and recycling program. Further research should be done to estimate the appropriate fee and fee structure (e.g. based on the size of battery or type of car). The fee should be reevaluated and adjusted yearly. These are dedicated funds for managing EOL batteries and should be preserved for this use.

Advantages

- Establishes a fund to cover end-of-life costs for all LIBs, including orphaned batteries

Disadvantages

- Increases upfront acquisition cost of EVs
- Considering the EV will retire on average in 10+ years, it is difficult to determine an accurate fee level to cover the cost of future recycling

Environmental handling fee gathered through vehicle registration fee

A recurring fee is gathered at the time of yearly vehicle registration to finance a lithium-ion battery collection and recycling program. Further research should be done to estimate the appropriate fee and fee structure (e.g. based on the size of battery or type of car). The fee should be reevaluated and adjusted yearly. These are dedicated funds for managing EOL batteries and should be preserved for this use.

Advantages

- Establishes a fund to cover end-of-life costs for all LIBs, including orphaned batteries and those purchased outside of California
- Avoids upfront acquisition cost to EVs
- The cost can be adjusted yearly based on the cost of recycling
- Burden is shared by all owners over the EV lifespan

Disadvantages

- Registration fees will be higher for EVs than internal combustion engine cars
- Increases ownership costs of EVs
- Total fee paid is dependent on the LIB lifespan

Hybrid Environmental handling fee

A recurring fee is gathered at the time of vehicle registration to finance a lithium-ion battery collection and recycling program. This yearly fee will be split between the EV owner and the auto manufacturer. Further research should be done to estimate the appropriate fee and fee structure (e.g. based on the size of battery or type of car). The fee should be reevaluated and adjusted yearly. These are dedicated funds for managing EOL batteries and should be preserved for this use.

Advantages

- Establishes a fund to cover end-of-life costs for all LIBs, including orphaned batteries and those purchased outside of California
- Shares costs between EV owners and the OEM

- Avoids upfront acquisition cost to EVs
- The cost can be adjusted yearly based on the cost of recycling
- Burden is shared by all owners over the EV lifespan

Disadvantages

- Registration fees will be higher for EVs than internal combustion engine cars
- Potentially increases the acquisition cost of EVs
- Total fee paid is dependent on the LIB lifespan

Additional feedback from advisory group on fund management:

The majority of the advisory group recommends any fund for EOL management should be managed by a third party and not a state agency. In addition, their recommended use of the funds are in figure 5 below and table 4 in the appendix.

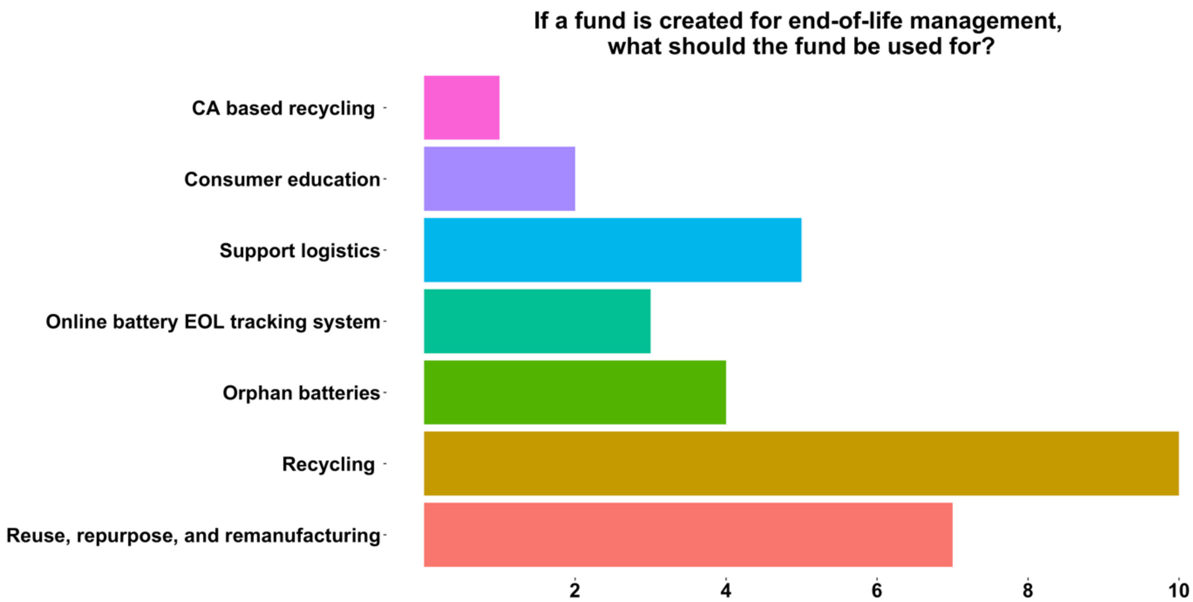

Figure 5: Recommended uses of funds generated from environmental handling fees

6.2. Supporting policy options (not recommended)

The following policy options were neither broadly opposed nor supported in the policy survey. These policies are worthy of consideration but not recommended by the advisory group.

Table 5. Additional supporting policies that are not recommended

Category	Policy	Barrier(s) addressed
Circular economy and quality recycling	Recycled content standards	Create demand for recycled material; improve sustainability of new EVs
	Reporting system for EV batteries retired from use	Unknown location of LIBs at end-of-life
	Reporting system for LIB recycling and recovery rates	Unknown recycling rate of LIBs
Safe and efficient reverse logistics	Require pre-approval to bid on EVs on auctions	Leakage through unlicensed dismantling

6.2.1. Circular economy and quality recycling

Recycled content standards[13]

Mandatory recycled content standards were suggested to ensure the use of recycled materials in battery manufacturing. "Recycled content" refers to the total percentage of recovered material used to manufacture a new product. The recycled content standard would be third-party verified by an independent source (e.g. certification body) that awards certification based on the product and facility meeting certain environmental criteria outlined in a certification standard and described in certification requirements. This requires consensus standard development to address specific types of processes within the manufacturing.

As an example, proposed revisions to the EU Battery Directive include the following minimum recycled content standards. Please note these rates are not the recommended rates by the subcommittee.

- January, 2030: 12% cobalt; 4% lithium; 4% nickel
- January, 2035: 20% cobalt; 10% lithium; 12% nickel

Further research is needed to determine achievable recycled content standards and analyze the economic impacts. These rates should be phased-in and reviewed/revised to account for technical developments.

Advantages

- Can drive a robust recycling industry by creating demand for recycled material, particularly given the size of the EV market in California

[13] This policy has been modified for clarity and to emphasize the need for further research following suggestions from the advisory group

- Reduce the environmental impact of producing new EVs

Disadvantages

- Manufacturing new LIBs may not be the most economical use of recovered material. As an alternative, one advisory group member suggested requiring minimal recovery of battery grade materials (materials refined to a sufficient quality to manufacture lithium-ion batteries) without specifying the end use.
- Difficult to verify
- Could artificially inflate the value of battery materials and increase cost of manufacturing

Develop a reporting system for EV batteries retired from use[14]

The ability to track EV batteries will enable policymakers and researchers to evaluate the effectiveness of recycling policies and identify sources of leakage from the end-of-life system, particularly vehicle or battery exports. An online database should be created to track and report lithium-ion batteries that are retired within California and used EVs that are exported from California. Companies recycling or repurposing EV batteries within California, and companies moving EV batteries from California for this purpose, are responsible for reporting the final recipients of the batteries.

Reporting retired batteries and their recipients could be facilitated with a digital identifier, aligning with traceability programs proposed by the Global Battery Alliance.

Advantages

- Increases transparency along value chain
- Facilitates evaluation and improvement of recycling policies

Disadvantages

- Hazardous waste processors already have to comply with reporting requirements
- Further research on implementation and enforcement is needed
- Creates administrative costs for government agencies to managing database and reporting requirements for industry
- Should be included as part of a comprehensive end-of-life strategy and not as a standalone policy

Develop a reporting system for lithium-ion battery recycling recovery rates

An online database should be created to track and report lithium-ion battery recycling recovery rates. Companies recycling batteries are responsible for reporting their total recovery rates, as well as the recovery rates of cobalt, lithium, manganese, and nickel.

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[14] This policy has been modified to explain the purpose of the reporting system following suggestions from the advisory group

Advantages

- Increased knowledge of industrial recycling capabilities
- Provides empirical data to forecast circularity potential and material forecasting

Disadvantages

- Additional database for government agencies to manage
- Additional reporting required of LIB recyclers

6.2.2. Safe and efficient reverse logistics

Require pre-approval to bid on EVs at auctions

Unlicensed dismantlers acquire most of their vehicles through auto auctions. To minimize unlicensed dismantling, the advisory group recommends requiring that interested parties apply for pre-approval before participating. The pre-approval process should include registering contact information (e.g. name, address, etc.) in order to track the battery.

The logistics subcommittee also discussed including a safety training requirement, but ultimately decided this was outside the scope of the advisory group. Members noted that this policy should be implemented in a way that minimizes administrative burden for parties who are qualified to work on EVs.

Advantages

- Discourages illegal dismantling and unsafe DIY repurposing

Disadvantages

- Many individuals participate in insurance auctions to repair their own vehicles, not as unlicensed dismantlers. Several advisory group members as well as members of the public commented that this should be enforced in a way that allows this practice to continue
- Further research on implementation is needed

Terminology

Anode – A terminal which the current flows towards or the negative charge moves from during discharge in a battery. The material composition of an anode is typically some porous form of carbon and may fluctuate from battery to battery.

Battery Electric Vehicle (EV) – A motor vehicle that relies on an electric motor and battery system for primary tractive power.

Battery Management System (BMS) – An electronic system that manages operational components of a rechargeable battery. This could mean managing depth of discharge, tracking usage, controlling the environment and other aspects of the operation.

Brine -- An aqueous solution with a high concentration of salt.

Cathode – A terminal which the current flows from or the positive charge moves from during discharge in a battery. The energy density of a battery is typically determined by the material of the cathode; thus, the typology of Li-ion batteries refers to the cathode chemistry.

Collection rate -- Proportion of EOL products that are collected and enter the recycling chain

Cycle life -- A characterization of how many full charge/discharge cycles a battery can withstand. This number is variable and depends, in part, on battery application and environment.

Depth of discharge (DoD)-- A characterization of the amount of discharge of a battery in a given cycle compared to the overall capacity of the battery. 100% DoD can be detrimental to the overall health of the battery.

Direct cathode recycling-- Also referred to as refunctionalization. A recycling method where cathode materials are recovered as a mixture that can be directly used as an input into battery manufacturing, avoiding the need for refining of materials and resynthesis of cathode compounds.

Electrical grid—Also referred to as electric grid and power grid. The interconnected network of electricity generation, transmission, and distribution to final consumers and transmission .

End-of-life recycling rate -- Proportion of all EOL product material that is recovered by recycling; dependent on both process efficiency and collection rate.

Energy density -- The amount of energy stored per unit mass.

Gigawatt hour (GWh) – A unit of energy. 1 GWh is equivalent to the energy consumption of 32,800 houses for one day (2018, USA average household).

Hydrometallurgical-- Chemical treatment of a material to separate it into constituent materials.

Life Cycle Assessment-- A systematic approach to quantifying the environmental impacts of a product, process, or system considering all life cycle phases; from raw material acquisition, to manufacturing, to use, and end-of-life.

Lithium-ion Battery (LIB) – A battery with a cathode containing lithium. Generally, these batteries are known for being lightweight and energy-dense.

Lithosphere-- The outermost layer of terrestrial Earth containing the crust and upper mantle. The realm in which all terrestrial mining occurs.

Pyrometallurgical-- Thermal treatment of a material to separate it into constituent materials, requiring heating above the melting point of the material.

Recovery rate/process efficiency rate -- Proportion of collected material recovered in usable form

Recycled content -- Fraction of a product's manufacturing inputs that are recycled as opposed to virgin material.

Second-life – Use of a degraded electric vehicle battery in a stationary, secondary application, usually referring to a system where the battery pack has been removed from the vehicle after some years of service in a traction application.

Spinel – A classification of an electrode with general formula A[B]2X4. In the context of batteries, "A" typically refers to Lithium as the cation and "B" can refer to many different transition metals in order to achieve different working voltages. "X" refers to the anion, typically oxygen.

Transition metal -- A classification of elements indicative of metals that are harder and less reactive than alkaline earth metals.

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Appendix: Survey Results

The tables below contain the survey results broken down by number of responses and average response (Table A1) and percentages (Table A2). Table A3 contains verbatim modifications to policy options as suggested by advisory group members.

Table A1: Survey results and mean score. The mean score is calculated on a scale from 1-5 (Strongly oppose = 1, Oppose= 2. No opinion = 3, Support with modification = 3.5, Support = 4, Strongly support = 5)

Policy	Strongly Oppose	Oppose	No opinion	Support with modifications	Support	Strongly support	Mean score
Producer take-back (returning the battery to the auto manufacturer at end-of-life is required)	3	4	5	2	3	3	3.00
Producer take-back (returning the battery to the auto manufacturer at EOL is optional)	1	4	7	1	4	2	2.98
Core exchange and unwanted vehicle backstop proposal	1	1	7	2	7	2	3.45
Environmental handling fee used to finance an EOL management program	6	1	7	1	2	3	2.78
Added electric vehicle registration fee to finance an EOL management program	3	3	7	1	2	4	3.08

A yearly fee split between the auto manufacturer and the EV owner at vehicle registration	4	3	5	0	3	5	3.10
Define the current owner as the responsible party for EOL management	6	8	1	1	2	2	2.33
Physical labeling requirement	0	0	1	1	5	13	4.58
Electronic information exchange (i.e. QR code with online database)	0	0	2	1	10	7	4.23
Universal diagnostic system	3	2	3	0	5	7	3.55
SOH data made accessible to third parties without specifying the mechanism	1	2	4	5	2	4	3.13
Establish a timeline for hazardous waste processing permit	1	1	6	4	4	4	3.55
Economic incentive package provided to lithium-ion battery recyclers	2	0	3	1	8	6	3.83
Expand eligibility for relevant incentive programs to include repurposed and reused batteries	1	2	5	4	2	6	3.60
Incentivize a disassembly industry within California	2	1	6	0	6	5	3.55

Minimum material recovery rates	5	2	2	0	4	7	3.30
Third-party verification	3	1	6	1	4	5	3.38
Develop a reporting system for lithium-ion batteries retired from use / exported batteries	2	7	1	1	6	3	3.08
Develop a reporting system for lithium-ion battery recycling recovery rates	2	6	3	3	5	1	2.93
Recycled content standards	4	4	2	5	2	3	2.93
Design for repurposing, reuse, and recycling	3	2	3	1	4	7	3.53
Develop training materials to address knowledge and capacity gaps	0	1	1	1	9	8	4.23
Support enforcement of unlicensed dismantling laws	0	1	1	0	4	14	4.55
Require pre-approval to bid on EVs at auctions	1	1	7	2	3	6	3.65
Interpretation of universal waste regulations	0	0	3	5	4	8	4.13
Develop strategic collection and sorting infrastructure	2	2	4	1	7	4	3.48
Identify strategies to reduce the burden of transportation	0	0	3	4	9	4	3.95

Table A2: Survey results by percent of responses

Policy	Support + Strongly support	Oppose + Strongly oppose	No opinion	Support with modifications	Support + Strongly support + support with modifications	Support + Strongly support	Support + Strongly support + support with modifications
Producer take-back (returning the battery to the auto manufacturer at end-of-life is required)	30%	35%	25%	10%	40%	40%	53%
Producer take-back (returning the battery to the auto manufacturer at EOL is optional)	30%	25%	35%	5%	35%	46%	54%
Core exchange and unwanted vehicle backstop proposal	45%	10%	35%	10%	55%	69%	85%
Environmental handling fee used to finance an EOL management program	25%	35%	35%	5%	30%	38%	46%
Added electric vehicle registration fee to finance an EOL management program	30%	30%	35%	5%	35%	46%	54%
A yearly fee split between the auto manufacturer and the EV owner at vehicle registration	40%	35%	25%	0%	40%	53%	53%
Define the current owner as the responsible party for EOL management	20%	70%	5%	5%	25%	21%	26%
Physical labeling requirement	90%	0%	5%	5%	95%	95%	100%

Policy	Support + Strongly support	Oppose + Strongly oppose	No opinion	Support with modifications	Support + Strongly support + support with modifications	Support + Strongly support	Support + Strongly support + support with modifications
Electronic information exchange (i.e. QR code with online database)	85%	0%	10%	5%	90%	94%	100%
Universal diagnostic system	60%	25%	15%	0%	60%	71%	71%
SOH data made accessible to third parties without specifying the mechanism	30%	15%	20%	25%	55%	38%	69%
Establish a timeline for hazardous waste processing permit	40%	10%	30%	20%	60%	57%	86%
Economic incentive package provided to lithium-ion battery recyclers	70%	10%	15%	5%	75%	82%	88%
Expand eligibility for relevant incentive programs to include repurposed and reused batteries	40%	15%	25%	20%	60%	53%	80%
Incentivize a disassembly industry within California	55%	15%	30%	0%	55%	79%	79%
Minimum material recovery rates	55%	35%	10%	0%	55%	61%	61%
Third-party verification	45%	20%	30%	5%	50%	64%	71%
Develop a reporting system for lithium-ion batteries	45%	45%	5%	5%	50%	47%	53%

Policy	Support + Strongly support	Oppose + Strongly oppose	No opinion	Support with modifications	Support + Strongly support + support with modification s	Support + Strongly support	Support + Strongly support + support with modifications
retired from use / exported batteries							
Develop a reporting system for lithium-ion battery recycling recovery rates	30%	40%	15%	15%	45%	35%	53%
Recycled content standards	25%	40%	10%	25%	50%	28%	56%
Design for repurposing, reuse, and recycling	55%	25%	15%	5%	60%	65%	71%
Develop training materials to address knowledge and capacity gaps	85%	5%	5%	5%	90%	89%	95%
Support enforcement of unlicensed dismantling laws	90%	5%	5%	0%	90%	95%	95%
Require pre-approval to bid on EVs at auctions	45%	10%	35%	10%	55%	69%	85%
Interpretation of universal waste regulations	60%	0%	15%	25%	85%	71%	100%
Develop strategic collection and sorting infrastructure	55%	20%	20%	5%	60%	69%	75%
Identify strategies to reduce the burden of transportation	65%	0%	15%	20%	85%	76%	100%

* Percent out of 20 advisory group members; responses of “no opinion” not counted*

Table A3: Suggested modifications to policies

Policy option	Suggested modification by advisory group members
Producer take-back (returning the battery to the auto manufacturer at end-of-life is required)	"'Documenting the proper disposal of the battery' should include reporting to responsible state [or federal] agency. Secondly if there is no in-state "licensed facility" this should be a facility with third party certification that meets CA requirements." "In the event no other entity has taken possession of an EOL battery, we believe it is appropriate to place some responsibility for EOL management with the OEM. We are not commenting on the companion legislation sentence since this reads as if it is a matter of fact and irrelevant to the proposal at hand."
Producer take-back (returning the battery to the auto manufacturer at EOL is optional)	"Eventually, someone should have a take-back obligation. If the battery, after 1st life, is refurbished for another application, this refurbishment operator should have a take-back obligation."
Core exchange and unwanted vehicle backstop proposal	"I support this as long as the core exchange is limited to a paperwork/tracking system." "OEMs like Tesla already have a core exchange program in place for batteries in need of repair or refurbishment. This service should be viewed as a complementary to EOL recycling, especially for batteries that can be refurbished. Battery pack life extension is the superior option to recycling for both environmental and business reasons. This is why before decommissioning and recycling a consumer battery pack, Tesla does everything it can to extend the useful life of each battery pack, including sending out over-the-air software updates to Tesla vehicles to improve battery efficiency when our engineers find new ways to do so. Vehicle dismantlers may choose to manage EOL batteries with or without the rest of the vehicle. Regardless, Tesla believes suppliers/manufacturers should be responsible for the proper reuse, repurposing, refurbishment or recycling of the battery packs they deployed on the market, if and when those batteries are offered back to the suppliers/manufacturers. Suppliers/manufacturers should include battery refurbishers and repurposers to ensure a clear transfer of responsibility for re-manufactured and re-purposed battery products."

Environmental handling fee used to finance an EOL management program	“Support a fee system to manage abandoned or unwanted batteries, or "orphan" batteries.”
Added electric vehicle registration fee to finance an EOL management program	“Support to manage unwanted, abandoned, or orphan batteries. Also for DMV enforcement of unlicensed facilities”
A yearly fee split between the auto manufacturer and the EV owner at vehicle registration to finance an EOL management program	
Define the current owner as the responsible party for EOL management	“I support this, so long as there is information provided to and readily available for consumption by the general public on how to safely handle and recycle these batteries.”
Physical labeling requirement	“We defer to CARB proposed regulatory proceeding (ACC2) and believe it has sufficient authority to address any labelling requirement”
Electronic information exchange (i.e., QR code with online database)	“Should be developed in consultation with industry”
Universal diagnostic system	
Please rate your level of support for requiring OEMs to make SOH data accessible to third parties without specifying the mechanism	“Standardized UDS is the preferred option. If not following that route, having a mechanism to share SOH data is necessary.” “UDS is preferred; however, if this it is not utilized then having another method to indicate SOH is necessary.” “Standardized UDS is preferable, however if not following that route, having a mechanism to share SOH data remains necessary” “Standardized UDS is preferable, however if not following that route, having a mechanism to

	share SOH data remains necessary” “Must be provided at no additional cost.”
Establish a timeline for the Department of Substance Control (DTSC) and all hazardous waste processors applying for a processing permit	“Timelines can only be met when the applicants provide initial information and required updates in a timely manner.” “DTSC supports this policy recommendation, with modifications. As part of the existing hazardous waste facility permitting process, a timeline is established. The successful completion of this process in a timely manner depends on the applicant providing adequate revisions of permit applications to DTSC in a timely manner. Permit applicants must provide adequate and timely responses to identified deficiencies in the application.” “CalEPA supports this policy recommendation, with modifications aligned with DTSC's comments. As part of the existing hazardous waste facility permitting process, a timeline is established. The successful completion of this process in a timely manner depends on the applicant providing adequate revisions of permit applications to DTSC in a timely manner. Permit applicants must provide adequate and timely responses to identified deficiencies in the application.”
Economic incentive package provided to lithium-ion battery recyclers	“Ensure that companies eligible go through a competitive and non-discriminatory selection process”

Expand eligibility for relevant incentive programs to include repurposed and reused batteries	“Support CPUC or administrator to examine and consider eligibility, so long as the second-life batteries meet other applicable safety, warranty, etc. requirements.” “Support encouraging CPUC Program Administrator to consider expanding eligibility, provided repurposed and reused batteries meet performance and warranty criteria” “Support encouraging CPUC Program Administrator to consider expanding eligibility, provided repurposed and reused batteries meet program criteria.” “Encourage CPUC Program Administrator to consider expanding eligibility provided repurposed batteries meet warranty and performance criteria.”
Incentivize a disassembly industry within California	
Minimum material recovery rates	
Third-party verification	“Essential and needs to be subsidized for reasons explained previously.”
As part of an overall end-of-life management system for the state of California, develop a reporting system for lithium-ion batteries retired from use / exported batteries	“Should also include tracking for "repurposed" used li-ion batteries”
As part of an overall end-of-life management system for the state of California, develop a reporting system for lithium-ion battery recycling recovery rates	“With details to include definitions and audits to be provided by applicable state regulation” “The list of reported minerals should be reviewed and updated at regular intervals by a panel of experts.” “To be in line with Q6.2.1, Cu, not Mn, should be reported.”

Recycled content standards	"Further research of the minimum recycled content standards is needed to identify the required levels, as well as economic impacts over time." "Further study of the minimum recycled content standards is needed" "The option "battery grade materials" should be preferred option. It guarantees that critical materials are qualitatively recycled, but it does not really matter in which application they are used. If Li is refined to battery grade, but used in pharmaceutical application, this is also a high end application. Furthermore, it reduces the market research work about what is a "challenging but realistic target" and avoids allocation criteria and reporting by downstream users." "Further study of the minimum recycled content standards is needed to identify the required levels, as well as economic impacts over time." "Further study of the impact of minimum recycled content should be undertaken"
Design for repurposing, reuse, and recycling	"Design for recycling is great, but mandates and "requirements" may not be in the best interest of the consumer"
Develop training materials to address knowledge and capacity gaps	"If resources are made available for agencies to undertake this effort"
Support existing efforts to improve the enforcement of unlicensed dismantling laws	
Require pre-approval to bid on EVs at auctions	"Provided this effort does not increase administrative burdens for those who are qualified to work on the EVs they bid on." "Pre-approval requirements should be more comprehensive and defined in state regulation by applicable agency"

Interpretation of universal waste regulations	"Reduction of administrative burden is supported, but any regulatory status changes made by US EPA would have to be evaluated" "DTSC supports this policy proposal, but it is dependent on the nature of the change. Reduction of administrative burden is supported, but any regulatory status changes made by US EPA would need to be evaluated to ensure continued protection of public health and the environment in California." "Support as long as the then-current federal administration is not gutting environmental standards and regs." "CalEPA supports this policy proposal in alignment with DTSC, but it is dependent on the nature of the change. Reduction of administrative burden is supported, but any regulatory status changes made by US EPA would need to be evaluated to ensure continued protection of public health and the environment in California."
Develop strategic collection and sorting infrastructure	"Support with modifications. Support, assuming fee for this is collected at point of sale or funded by vehicle manufacturers"
Identify strategies to reduce the burden of transportation	"Support the research and development of technical solutions for regulatory compliance related to packaging and handling." "We support the research and development of technical solutions for regulatory compliance related to packaging and handling." "Support part (2) of this suggestion"

List A4. Verbatim comments on how funds should be spent

“Proper reuse, repurpose, refurbish, or recycle.”

“Cover the cost of battery recycling so that a consumer, dealer, repair shop, or dismantler can have a battery picked up for recycling at end of life at no cost.”

“Orphan batteries and second life batteries”

“The fees should be used to subsidize U.S. domestic recycling and reuse of lithium ion batteries as follows: Promote recycling by subsidizing costs of tipping fees for U.S. domestic recycling at facilities meeting minimum third party certification standards for recycling efficiency, transparency, occupational health and safety, environmental pollution controls and restrictions on exporting components; Promote reuse and possible subsidize collection and transportation costs of used lithium ion batteries if needed; Mitigation or remediation of abandoned batteries and storage or processing sites; ,Develop and maintain an online manifest system to track domestic and international shipments of used lithium ion batteries originating in California; Ensure collection and recycling of spent lithium ion batteries used in electric bicycles and scooters with regional collection centers or other means as needed; Develop and maintain an online database of lithium-ion batteries used in each new vehicle model available for sale in California to include chemical composition for anode and cathode, type of separator, outer casing material, and instructions on safe discharge and removal from the vehicle.”

“Consumer education, support with storage, removal, handling, and transport/logistics for battery movement (or subsidy for those entities handling these details), recycling facility for the batteries, repurpose projects/sustainability projects.”

“Transport, dismantling, and recycling costs”

“The fund should only be used for the intended purpose and not appropriated for other uses.”

“The fund should be used to treat "orphan battery packs" where the battery manufacturer or the automotive OEM is no longer active in the market.”

“logistics, removal, and recycling”

“Storage, transportation, recycling, and logistics”

“Costs of transportation and recycling”

“To ensure proper re-purposing, reuse, or recycling. Part of the funding should be utilized to bolster a CA based recycling and reuse industry so it can compete with out of state and offshore options which would not meet CA standards.”

“Explicitly, the handling, recycling, and repurposing infrastructure and operations. In no way should the fund be allowed to roll over for non-affiliated uses (Ca General Fund). Should be structured like the Paint care program.”

“Management of EOL program, recovery of unwanted vehicles, reporting regularly on results.”

“Consumer awareness of return requirements administration and tracking of battery locations and documentation of ownership and eventual disposal Manufacturer should still be responsible for costs of logistics of collection and transportation and the costs of recycling and repurposing the batteries.”