

Lithium-ion Car Battery Recycling Advisory Group

DRAFT Report

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EXECUTIVE SUMMARY

BACKGROUND

The state of California has long been a leader in policies that support electric vehicle (EV) adoption and their success has made California home to 42% of the nation's EV fleet (U.S. Department of Energy, 2021a). EVs are powered by lithium-ion traction batteries. As EVs retire from service, a flow of end-of-life (EOL) lithium-ion batteries (LIBs) will be generated. These LIBs can be resold as-is, remanufactured, repurposed, recycled, or discarded in a hazardous waste landfill. In 2018, California Assembly Bill 2832 (AB2832) required the convening of the Lithium-Ion Battery Recycling Advisory Group whose mandate includes submission of policy recommendations to the Legislature to ensure "...that as close to 100% as possible of lithium-ion batteries in the state are reused or recycled at end-of-life"(Dahle, 2018).

ADVISORY GROUP MEMBERSHIP AND PROCESS

In compliance with AB2832, an Advisory Group was convened and met quarterly between fall of 2019 and spring of 2022. The Advisory Group process was broken in two primary periods: knowledge-building (November 2019-December 2020), and report development (January 2021 – March 2022). The report development period was further divided into four phases: phase 1 (January 2021-March 2021) to identify barriers, opportunities, and the existing landscape; phase 2 (April 2021-July 2021) to identify potential policy options; phase 3 (August 2021-December 2021) to incorporate feedback and create a rough draft; and phase 4 (January 2022-March 2022) to finalize the report with policy recommendations.

During the knowledge-building period, the Advisory Group heard from 26 experts from industry, academia, and government agencies. In the report development period, Advisory Group members participated in subcommittees to identify barriers and opportunities and develop policy recommendations specific to three key processes for EOL LIBs: recycling, reuse and repurposing, and logistics. Each subcommittee explored different barriers and opportunities and put forward proposals for policies.

Based on the proposed policy options and their barriers and opportunities and proposed policy options that emerged from subcommittees, further deliberation by the whole Advisory Group yielded a final list of proposed policies. Policies were divided into those that define EOL management responsibilities, and supporting policies that help achieve the goal of maximizing reuse and recycling of EOL EV LIBs in a cost-effective manner.

At the November 2nd, 2021 and December 7th, 2021 Advisory Group meetings, the members voted on each policy proposal. Members could either vote in favor, vote to oppose, vote to abstain, or could recuse themselves from the vote altogether. Policy proposals that received at least majority support from voting members of the Advisory Group are presented here as recommended policies.

The Advisory group approved the report for public review on December 7th, 2021, and the public comment period was open from December 17th, 2021 to February 16th, 2022. A total of 21 public comments were received and reviewed.

RECOMMENDED POLICIES

Policy proposals that define EOL management responsibility

Two policy proposals that define EOL management responsibility rose to the level of majority support: *core exchange with a vehicle backstop*, and *producer take-back*. These policies complement, and do not replace, current warranty regulations and programs that require the vehicle manufacturer to properly reuse, repurpose, or recycle a removed EOL battery that is still under warranty.

The **core exchange and vehicle backstop policy** garnered the most support from the Advisory Group at 93% of voting members. It builds on existing industry standards and policies for other vehicle components, specifically a core exchange and product take-back. This policy defines responsibility for out-of-warranty batteries under three possible circumstances:

1. **For EVs still in service**, if a battery pack, module, or cell is replaced before the vehicle reaches EOL, a core exchange program detailed by the EV battery supplier 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, or recycled. The entity selling an EV battery shall use a core exchange program to track that the used battery has been properly managed.
2. **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. If an EV battery is directly reused in another vehicle with no alterations, the process for EVs still in service shall apply. If the battery is refurbished or repurposed, the responsibility transfers to the refurbisher or repurposer.
3. **For EVs reaching EOL** where an EOL EV with an OEM-certified battery is not acquired and removed by a licensed dismantler, the vehicle manufacturer shall be responsible for ensuring that the vehicle is properly dismantled and the battery is properly reused, refurbished, or recycled.

The other policy proposal that received majority support at 67% of those that voted is a **producer take-back** policy, wherein the auto manufacturer is responsible for ensuring proper repurposing, reuse, or recycling of its EV traction batteries by a licensed facility at no cost to the consumer¹ if and 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 properly managed. 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; and documenting the proper disposal of the battery.

The auto manufacturer will also 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.

¹ No cost to the consumer at the time of battery retirement.

Some identified advantages of both policies include (i) clearly defined responsibility for the EOL battery that transfers if it is repurposed, and (ii) the ability for batteries to be sold to a third party at EOL which provides opportunity for growth in the remanufacturing, refurbishing, and repurposing industry without requiring a partnership with the vehicle OEM. Disadvantages include potentially higher costs for battery suppliers and vehicle OEMs who will likely only be called upon to manage LIBs with negative value.

Supporting policy proposals

Supporting policy proposals address specific barriers to reuse and recycling and are aimed at ensuring that reuse and recycling processes are safe and environmentally responsible. The proposed options are not mutually exclusive and should be considered complementary to the proposed policy defining responsibility for EOL management. In total, 11 of 19 proposed supporting policies garnered majority support, as reported in Table E1. These proposals fall into three categories: (i) access to battery information, (ii) support of repurposing, reuse, and recycling industry development, and (iii) safe and efficient reverse logistics. The areas of greatest consensus are reducing the cost of transporting EOL LIBs, and enhancing access to battery information.

Table E1: Supporting policy proposals with majority support from Advisory Group members who voted

Category	Policy	Purpose	Level of support (%)
Access to battery information	Physical labeling requirement	Facilitate sorting to improve process efficiency; enable easy identification of battery and vehicle OEM	93%
Access to battery information	Digital identifier	Identify LIB chemistry at EOL; identify responsible party for safe disposal; improve safety during disassembly	87%
Access to battery information	Universal diagnostic system	Reduce cost of testing; enable performance guarantees for reused and repurposed batteries	53%
Support repurposing, reuse, and recycling industry development	Recycling incentive packages	Mitigate upfront capital costs; encourage recycling within California	73%
Support repurposing, reuse, and recycling industry development	DTSC permit timeline	Reduce cost of locating processing facilities within California	60%
Support repurposing, reuse, and recycling	Expand eligibility for	Enable cost-competitiveness with new batteries	67%

Category	Policy	Purpose	Level of support (%)
industry development	battery storage systems		
Safe and efficient reverse logistics	Support enforcement of unlicensed dismantling laws	Prevent environmental hazards and stranded batteries due to unlicensed dismantling	87%
Safe and efficient reverse logistics	Develop training materials	Improve safety and workforce capacity	93%
Safe and efficient reverse logistics	Support transportation research	Reduce transportation cost	100%
Safe and efficient reverse logistics	Develop strategic collection and sorting infrastructure	Reduce transportation cost	93%
Safe and efficient reverse logistics	Universal waste regulations	Reduce transportation cost and administrative burden	100%
Safe and efficient reverse logistics	Require pre-approval to bid on EVs at auctions	Enable tracking of EVs purchased at auctions	60%

CONCLUSIONS

As the state of California continues its commitment to on-road transport decarbonization and EVs become more cost-competitive and attractive to consumers, the state will see an increasing flow of EOL LIBs that require proper management. To ensure that the maximum amount of EOL batteries are reused, repurposed or recycled, the Advisory Group’s recommended policies focus on two main areas of need:

- Clearly defining responsibility for the coordination and payment of recycling in cases where the cost presents a burden for the owner of the vehicle and the LIB is unwanted and,

- Mitigating barriers that may currently inhibit the reuse, repurposing, and recycling of EV LIBs.

The most broadly supported policy defining responsibility for EOL management was the core exchange and vehicle backstop proposal, which allocates responsibility under three possible retirement pathways. The majority of voting Advisory Group members also supported a producer take-back policy making the vehicle OEM or repurposer responsible for ensuring proper reuse, repurposing, or recycling at a licensed facility and at no cost to the consumer at LIB EOL. Under either policy, there should be a clear transfer of responsibility for EOL management when batteries are refurbished or repurposed. Both policies also require further consideration to define what constitutes “proper recycling” and how it should be verified.

Widely supported policies that address more specific barriers include labeling and digital identifier requirements, supporting the development of recycling facilities through incentive packages and a guaranteed permitting timeline, supporting the enforcement of unlicensed dismantling laws, and supporting the development of strategic collection and sorting infrastructure to reduce transportation costs. The Advisory Group also recommended creating training programs to ensure that the people who handle EOL vehicles have the skills they need to safely work with EVs and assist them in navigating regulatory requirements.

Throughout the process, the Advisory Group members and invited speakers emphasized that EVs are a relatively new technology and are not yet being retired in California at a large scale. Understanding, therefore, that reuse, repurposing, and recycling are still nascent industries, it is important to emphasize that the landscape is rapidly evolving, and policymaking aimed at supporting reuse and recycling should be iterative. Similarly, as the technologies continue to evolve, different battery formats and compositions may prevail. While the content of critical materials may change, reuse and recycling should remain a priority for the battery as a whole. The recommendations included in this report should be revisited periodically to assess their effectiveness and evaluate whether any changes are necessary.

ABBREVIATIONS

Abbreviation	Term
BMS	battery management system
CalEPA	California Environmental Protection Agency
CalRecycle	California Department of Resources Recycling and Recovery
CARB	California Air Resources Board
CCR	California Code of Regulations
CEC	California Energy Commission
CFR	Code of Federal Regulations
CPUC	California Public Utilities Commission
DRC	Democratic Republic of Congo
DTSC	Department of Toxic Substances Control
EOL	End-of-life
E-waste	electronic waste
EV	electric vehicle
g	gram
GWh	gigawatt-hour
IEEE	Institute of Electrical and Electronics Engineers
IOU	Investor Owned Utility
kg	kilogram
kWh	kilowatt-hour
LFP	lithium Iron phosphate
LIB	lithium-ion battery
LMO	lithium manganese oxide

Abbreviation	Term
LMO/LTO	lithium manganese with titanate oxide anode
Mt	million metric tons
MWh	megawatt-hour
NCA	lithium nickel cobalt aluminum oxide
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
ZEV	zero-emission vehicle

1. INTRODUCTION AND BACKGROUND

1.1 ADVISORY GROUP MANDATE

The Lithium-ion Car Battery Recycling Advisory Group (“Advisory Group”) was created in 2018 following a mandate from Assembly Bill 2832 (Dahle, 2018). The Advisory Group is tasked with developing policy recommendations aimed at ensuring that as close to 100 percent as possible of lithium-ion batteries (LIB) from electric vehicles (EVs) 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...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 18th, 2019. Its membership consists of representatives from the following organizations:

1. Alliance for Automotive Innovation
2. California Department of Toxic Substances Control (DTSC)
3. California Energy Commission (CEC)
4. California Environmental Protection Agency (CalEPA)
5. California New Car Dealers Association
6. Californians Against Waste
7. California Household Hazardous Waste at large
8. Department of Resources Recycling and Recovery (CalRecycle)
9. Earthworks
10. Ford Motor Company
11. Honda Trading America
12. Kinsbursky Brothers International (KBI)
13. PBRA - The Rechargeable Battery Association
14. SA Recycling

15. Southern California Association of Governments
16. Surplus Service
17. Sustainable Energy Solutions
18. Tesla
19. Umicore USA Inc.

1.2 ELECTRIC VEHICLE ADOPTION AND BATTERY TECHNOLOGIES

Electric vehicle adoption is a fundamental strategy to decrease greenhouse gas emissions from the transportation sector. Due to ambitious policies implemented by the State of California, adoption has drastically increased over the past decade. The Zero-Emission Vehicle (ZEV) program, first implemented in 1990 by the California Air Resources Board and then restructured in 2012, requires auto manufacturers to produce an increasing number of ZEVs and plug-in hybrids per year (California Air Resources Board, 2021b).

This policy has resulted in an insurgence of ZEV sales over the last decade, making California home to 42% of the U.S. EV fleet (U.S. Department of Energy, 2021a). In 2020 alone, EV sales totaled approximately 144,000, representing 7.7% of all car sales, and 2021 sales are on track to hit an all-time high (Figure 1) (California Energy Commission, 2021c).

In December 2020, Governor Newsom issued Executive Order N-79-20, setting the goal that all new passenger vehicles sold in California be ZEVs by 2035 and heavy-duty vehicle fleets be ZEVs by 2045 (State of California, 2020). This recent executive order demonstrates the strong commitment to decreasing transport-related emissions through vehicle electrification in California and will lead to continued increases in EV sales.

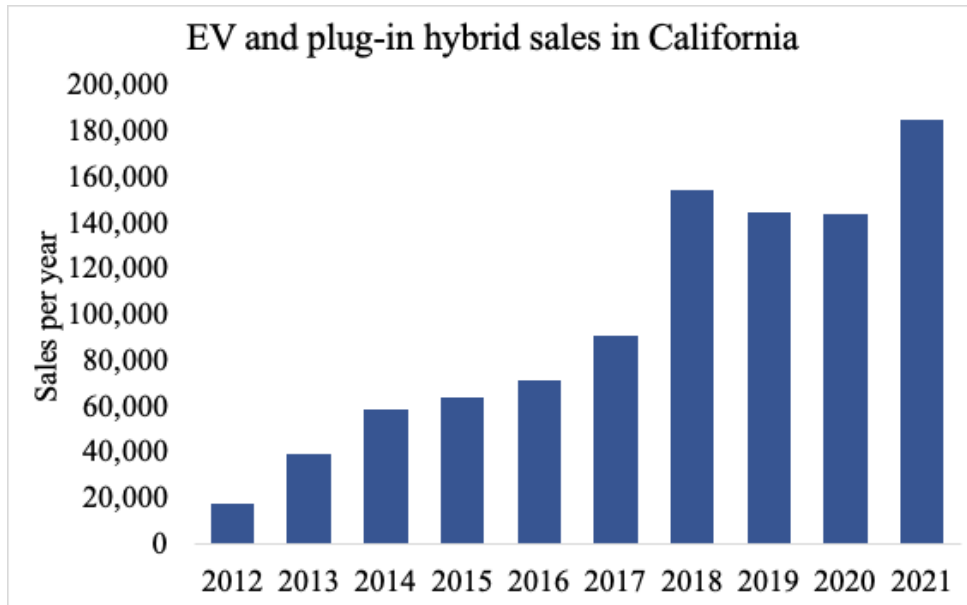


Figure 1: Sales of EVs and plug-in hybrids per year in California as reported by the California Air Resources Board (CARB). Plug-in hybrids are included because the majority are powered by LIBs. The 2021 value represents sales from January to October 29th, 2021 (State of California, 2020).

1.3 BATTERY TECHNOLOGY

As the market for EVs has developed, battery design and performance have evolved. United States' (U.S.) EV sales show a shift towards significantly higher capacity batteries with longer vehicle ranges (Ambrose *et al.*, 2020). The combination of a ramp-up in the deployment of EVs and the increased size of EV battery systems has dramatically increased the capacity of batteries on the road today. Over 60 GWh of LIBs have been deployed in U.S. light-duty EVs from 2010 to 2020 (EV Volumes, 2020), representing enough energy storage to exceed California's historical peak electricity load for one hour (California ISO, 2021).

LIBs consist of five key components: cathode, anode, separator, electrolyte, and cell container. The anode is typically made from graphite, the anode current collector is copper, the cathode current collector is aluminum, and the separator and cell container consist of various plastics. The cathode is a lithium metal oxide combined with a transition metal, typically nickel, cobalt, iron, or manganese (Miao *et al.*, 2019).

The different LIBs are distinguished by the metals that make up their cathode compound; for example, a battery using a nickel-cobalt-manganese cathode is referred to as an NMC battery. There are also a variety of chemical formulations within different cathode compounds that have important implications for material demand. 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.

The majority of early EV batteries sold in the U.S. were either NCA type (nickel-cobalt-aluminum, used by Tesla/Panasonic), LMO (lithium manganese oxide, used in early Nissan

Leafs), or higher-cobalt NMC 111 (nickel-manganese-cobalt) (Dunn *et al.*, 2021). Moving forward, lower-cobalt cathodes such as NCA, NMC 811 and 622, and LFP (lithium-iron-phosphate) are expected to occupy a growing share of the EV battery market (Xu *et al.*, 2020; Dunn *et al.*, 2021). Using different metals changes important characteristics such as the energy density, power density, cycle life, safety, and cost of batteries. In addition, replacing cobalt with lower-cost metals influences the profitability of recycling by changing the value of recoverable materials.

1.4 CRITICAL MATERIALS FOR BATTERIES

The term “critical material” refers to materials with high economic importance and high supply risk. Lithium, cobalt, natural graphite, and manganese are all classified as critical materials according to the U.S. Department of the Interior, and nickel is in the process of being added (U.S. Department of Interior, 2018; U.S. Geological Survey, 2021a). In the Biden Administration’s 100-day supply chain review, lithium, cobalt, and Class I nickel are listed as the most critical battery elements, and graphite, copper, and manganese as “elements of note” that require additional monitoring (The White House, 2021). Lithium and cobalt are generally considered the most significant supply risk due to the high geographic concentration of production (Olivetti *et al.*, 2017). 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 (Campagnol *et al.*, 2017; The White House, 2021).

Establishing a domestic recycling industry presents an opportunity to recover critical materials, thereby reducing reliance on imports and mitigating supply risk. Reducing the environmental and social burden of raw material production, particularly cobalt mining, is an equally important motivation for reuse and recycling. In parallel, identifying domestic resources is another high-priority strategy to increase supply resilience (Campagnol *et al.*, 2017).

The sections below describe some of the resource issues for critical battery materials in greater detail.

1.4.1 Cobalt

Nearly 70% of cobalt is produced in the Democratic Republic of Congo (U.S. Geological Survey, 2021b) through both industrial mining, which is primarily mechanized, and small scale or artisanal mining, which is practiced manually using simple tools (Sovacool, 2019). An estimated 15-30% of the country’s cobalt output is generated through artisanal mining, where adults and an estimated 40,000 children work up to 12-hour days in abusive work environments, exposed to hazardous conditions (Baumann-Pauly, 2020). Artisanal miners have little to no protective gear or tools, nor safety measures at mining sites, all while earning less than \$2 per day. A multitude of battery-using companies, from Apple to Tesla, as well as international mining companies, have engaged in programs to either assist local communities to improve economic and educational conditions or to formalize artisanal and small-scale mining enterprises in an attempt to create conditions where mine safety and child labor standards can be improved (Amnesty International and Afreewatch, 2016).

1.4.2 Nickel

Indonesia is the largest producer of nickel where strip mining for nickel leads to deforestation of tropical rainforests that are home to native people, act as crucial carbon sinks, and provide habitat for endangered species (Abood *et al.*, 2015; Supriatna *et al.*, 2020; U.S. Geological Survey, 2021b). After strip mining, the soil is depleted of nutrients, posing a significant challenge to rehabilitation efforts (Van der Ent *et al.*, 2013).

1.4.3 Lithium

Australia has recently become the largest lithium producer, accounting for approximately 49% of global production in 2020 and accessing spodumene, a hard-rock ore (U.S. Geological Survey, 2021b). Chile is second in the world for lithium production. Lithium in Chile is produced through evaporation from brines in the Salar de Atacama, a 1,200-square-mile salt flat in Northern Chile. While brine evaporation has typically been the lower-cost and lower-carbon footprint source for lithium, it can consume a substantial amount of water in water-scarce areas (Kelly *et al.*, 2021). Recently, conflicts over indigenous rights, land use, and water consumption have led to social movements opposing the lithium industry in Chile (Liu and Agusdinata, 2020; Schlosser, 2020).

Within California, lithium resources have been identified in geothermal brines in Imperial Valley near the Salton Sea. The brine contains various minerals, including lithium, which can be separated using direct lithium extraction technology (McKibben, Elders and Raju, 2020). An estimated 24,000 mt of lithium could theoretically be extracted annually from existing geothermal plants based on the total throughput of brine in 2019 (Warren, 2021). For reference, the total annual consumption of lithium in the United States from 2016-2020 has been between 2,000 and 3,000 t (U.S. Geological Survey, 2021b). While the environmental impacts of direct lithium extraction have yet to be quantified, they are expected to be substantially smaller than evaporation in terms of water use, energy input, and physical footprint (Grant, Deak and Pell, 2020; Vulcan Energy, 2021).

The feasibility, local impacts, and potential benefits are currently being explored by the Lithium Valley Commission, a blue-ribbon Commission convened by AB 1657 and overseen by the CEC (Garcia, 2020; California Energy Commission, 2021b). As stated in AB 1657, part of the motivation for the Commission is to establish a secure, domestic source of lithium. While the technology is still in a pilot phase, vehicle manufacturers have already announced agreements to purchase lithium from California (Wilson, 2021). However, there is currently no refining or cathode production capacity in the United States. Without these steps in the value chain, any materials recovered through recycling or extraction will need to be exported internationally for further processing.

2. OVERVIEW OF LITHIUM-ION BATTERY END-OF-LIFE MANAGEMENT

2.1 REVERSE LOGISTICS

Prior to reuse or recycling, LIBs must be removed and transported to the appropriate facility. To accumulate enough batteries for a cost-effective shipment or cost-effective recovery of materials, the batteries may need to be stored for a period of time before shipping. 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 (Slattery, Dunn and Kendall, 2021). The EV and/or LIB may follow one of several pathways depending on whether the vehicle is purchased or leased, and the reasons for retirement.

2.1.1 Within dealership and original equipment manufacturer (OEM) 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. Some vehicle OEMs, notably Tesla and Rivian, do not use dealership networks and retain direct customer relationships as well as real-time monitoring of vehicle and battery health. When the vehicle is intact and the battery has a good SOH, the returned vehicle may be sold as a used car through the vehicle OEM's retail system and monitoring of the health of the battery by the vehicle OEM continues.

If the battery is removed under warranty, the vehicle OEM will collect and ship the batteries to a repurposer or recycler (or coordinate the collection and shipment through a third party).

2.1.2 Outside the original equipment manufacturer (OEM) network

There is a higher degree of uncertainty surrounding cases where the EV is privately owned and outside of the warranty, 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 likely 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, though other interested parties bid on vehicles 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 licensed repurposer, remanufacturer, recycler, or sorting facility to ensure proper disposal. However, this is not currently required by policy.

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

2.1.3 Export

The U.S. is the third largest international exporter of used vehicles after the EU and Japan, exporting approximately 2.6 million vehicles between 2015-2018 (Baskin *et al.*, 2020). This means that significant changes, such as electrification, in the vehicle fleet of the U.S. will have implications for importing countries. While exporting used vehicles in good condition could improve access to affordable ZEVs and displace low-quality internal combustion engine vehicles, it will also shift the burden of battery disposal to the importing countries who may not have the infrastructure to recycle them safely. Used batteries that have been removed from EVs may also leave the US via exports. If batteries and materials are exported, the U.S. loses control of the critical materials that could be recovered through recycling.

2.1.4 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 emergent as EVs are only beginning to reach end of life at significant scale. Infrastructure is developing in a piecemeal fashion by vehicle OEMs themselves, through dealerships, and through the repair, dismantling and scrap recycling industries. The largest known facility within California is Retrieval Technology's consolidation location in Anaheim, CA (Retrieval Technologies, 2021).

Redwood Materials, a battery recycling company, recently announced a pilot program to identify the locations of EOL LIB packs in California and transport them to their Nevada facility for recycling. The project will work directly with dealers and auto dismantlers with the goal of establishing efficient recovery pathways. It is currently supported by Ford Motor Company and Volvo Cars (Ohnsman, 2022).

2.2 REUSE AND REPURPOSING

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, 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). The reuse and repurposing processes include removal from a vehicle as well as any needed repair, refurbishment, or remanufacturing.

In general, batteries will be retired from use in an EV when the range and performance is no longer acceptable to the driver. The remaining capacity of the battery at the time of retirement will vary depending on consumer preference, but it is generally assumed to be between 70-80% (Saxena *et al.*, 2015). Given the large capacity and high performance of modern vehicle batteries, retired batteries could still offer significant value in lower-power, secondary applications, such as storing energy from solar panels to be used in off-grid or peak demand-shaving applications (Berzi *et al.*, 2020). A growing body of research has examined the environmental impacts and technical and economic feasibility of repurposing batteries for use in second-life applications (Ahmadi *et al.*, 2017; Casals, Amante García and Canal, 2019; Braco *et al.*, 2020; Kamath, Arsenault, *et al.*, 2020; Kamath, Shukla, *et al.*, 2020).

Operational systems range from pilot- to commercial-scale facilities. The largest facility in California is an 8 MWh system by B2U Storage Solutions that is connected to a solar photovoltaic (PV) field in California (Figure 2). This facility is expected to reach 17MWhs by

Q2 of 2022 (B2U Storage Solutions, 2021). The approaches between repurposing companies vary; B2U repurposes entire packs without disassembly, while others reconfigure batteries at the module or even cell level. Testing the charge capacity of packs, modules, or cells, reconfiguring them into consistent packs if necessary, 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 (Neubauer *et al.*, 2012).



Figure 2: B2U Storage Solutions' storage system at a solar PV field in California. The current operational system capacity is 8MWh and will be increased to 17MWh by Q2 2022. (Photo credit: B2U Storage Solutions)

While LIB repurposing is happening at industrial scale, it is a relatively new industry and data about performance is uncertain because of the uneven degradation of battery cells over time. However, it is estimated that battery lifespan can be extended by 10 years or longer depending

on the application (Neubauer, Wood and Pesaran, 2015; Casals, Amante García and Canal, 2019; Mathews *et al.*, 2020). To enable more accurate predictions of battery lifespan and validate the ability of repurposed batteries to provide resilience and load-shifting services, the CEC is funding several ongoing demonstration projects in California (Table 1) (California Energy Commission, 2021a).

Table 1: Repurposed energy storage demonstrations funded by the CEC.

Recipient	Location(s)	Project Description
RePurpose Energy	Grass Valley, CA	Integrated solar + storage system at a food coop to demonstrate energy resilience and test degradation rate.
Smartville, Inc.	San Diego, CA	Integrated solar + storage system at a warehouse to demonstrate demand charge reduction, solar energy shifting, and critical load support and test degradation rate.
San Diego State University	Chula Vista and San Diego, CA	Repurposed battery storage added to existing PV systems at two community centers to demonstrate resilience in the case of a power outage and develop technology to optimize battery health.
ReJoule, Inc.	Signal Hill, CA	Two integrated site demonstrations at a homeless shelter and a commercial building. In addition, ReJoule is developing tools for rapid assessment of the health of retired EV batteries.

2.3 RECYCLING

By reducing demand for raw materials, recycling avoids negative environmental and social impacts from mining, and has the potential to grow a domestic supply chain for key battery materials (Dunn *et al.*, 2012, 2015; Ciez and Whitacre, 2019; Harper *et al.*, 2019). This section describes processes and pathways for recovering recyclable materials from LIBs.

- **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 pyrometallurgical or hydrometallurgical processes (Yao *et al.*, 2018).
- **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 (Assefi *et al.*, 2020).

- **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 and increase the purity of lithium, nickel, manganese, and cobalt (Yao *et al.*, 2018).
- **Direct Recycling:** Any combination of the processes described above where battery components, particularly cathode materials, are recovered in a suitable condition to be directly used in battery production, without breaking them down into individual material elements (Gaines *et al.*, 2021). This process is still mostly in the research and development phase, and the ReCell Center led by Argonne National Laboratory is leading research and development, while the CEC is funding additional projects at the University of California, San Diego and OnTo Technologies (Gaines *et al.*, 2021; Green Car Congress, 2021).

The environmental emissions vary by recycling process, with hydrometallurgical and direct recycling resulting in lower CO₂ equivalent (CO₂e) emissions than pyrometallurgical recycling (Richa, Babbitt and Gaustad, 2017). This is mainly due to the lower energy intensity of hydrometallurgical and direct recycling processes. Pyrometallurgy also recovers fewer usable materials, and thus offsets fewer emissions from avoided virgin material production (Ciez and Whitacre, 2019; Mohr *et al.*, 2020). The environmental impacts of recycling processes are highly influenced by the carbon intensity of the electricity used to run facilities, and the avoided emissions (which are used to estimate net impacts from recycling) are influenced by the cathode chemistry of the battery being recycling. Cobalt- and nickel-containing batteries (i.e. NCA and NMC) result in an overall higher avoided emissions of CO₂e than LFP due to their associated higher mining and processing emissions (Dunn *et al.*, 2015; Ciez and Whitacre, 2019).

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, or a similar product serving the same industry. For LIB cathode recycling to be closed-loop, the constituent material must be refined, then resynthesized into a new cathode compound (Chan *et al.*, 2021). Open-Loop recycling means recovered materials are used as inputs in a different product system (Nakatani, 2014).

2.3.1 Recycling Industry Landscape

The existing LIB recycling industry has developed around recycling consumer electronics, with the majority taking place in China (Melin, 2019). Pilot and commercial facilities are operational to a smaller extent in Europe and North America (Table 2). Most North American recycling companies use a hydrometallurgical process. As EVs have not yet retired at a large scale, the feedstock for these facilities is primarily production scrap from manufacturing and consumer electronics.

In addition to the companies listed below, Glencore produces copper, nickel, and cobalt at their Sudbury Integrated Nickel Operations (Sudbury INO) in Northern Canada using mined ore as well as black mass from recycling. At the time of this report, Sudbury INO is considered the main destination for black mass generated in North America. However, newer recycling companies aspire to refine their own materials; for example, Li-Cycle will process black mass at their “hub” facility, and Redwood materials is developing a closed-loop system by using

recovered materials to manufacture cathode active materials and battery copper foils within the U.S.

Table 2: Lithium-ion battery recyclers in North America. The facilities listed represent those currently operational or planned for development at the time this report was published. Please note this table may not be exhaustive.

Company	Location(s)	Current capacity (metric tons/year)	Planned total capacity (metric tons/year)
American Battery Technologies (Recycling Coordinators, no date; Graham, 2020)	Fernley, Nevada	-	20,000
American Manganese (American Manganese, 2021)	Vancouver, British Columbia	-	182.5
Ascend Elements (PR Newswire, 2022) (formerly Battery Resourcers)	Worcester, Massachusetts Novi, Michigan; Covington, Georgia	Unknown	30,000
Interco (Interco, 2022)	Madison, Illinois	Unknown	Unknown
Li-cycle Corporation (Roberts, 2021; Li-Cycle, 2022)	Rochester, N.Y. (spoke)	5,000	5,000
	Kingston, Ontario (spoke)	5,000	5,000
	Phoenix, Arizona (spoke)	-	10,000
	Tuscaloosa, Alabama (spoke)	-	5,000
	Rochester, N.Y. (hub)	-	60,000
Lithion (Lithion, 2021)	Ajou, Quebec; Planned locations unknown	200	7,500
Princeton NuEnergy (PR Newswire, 2021)	Dallas, Texas	-	Unknown
Recycling Coordinators (Recycling Coordinators, no date)	Akron, Ohio	Unknown	Unknown
Redwood Materials (Carney, 2021)	Carson City, Nevada; Reno, Nevada	18,100	Unknown

Company	Location(s)	Current capacity (metric tons/year)	Planned total capacity (metric tons/year)
Retriev Technologies (Pinegar and Smith, 2019)	Lancaster, Ohio and Trail, British Columbia	4,500	4500
Umicore Canada Inc. (Umicore, no date)	Fort Saskatchewan, Alberta	Unknown	Unknown

3. REGULATORY LANDSCAPE

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 batteries at their EOL (Melin *et al.*, 2021). 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 LIBs playing a role in both (European Commission, 2020). 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 EOL batteries, but do not have holistic, overarching policies for batteries at their EOL. The following sections will briefly cover the policies managing these batteries in China and Europe, and then discuss the regulations currently impacting batteries retired in the U.S.

3.1 LITHIUM-ION BATTERY END-OF-LIFE POLICIES IN OTHER REGIONS

3.1.1 European Union

Since 2006, the EU has restricted LIBs from landfilling and required a 50% recycling rate through Directive 2006/66/EC (European Commission, 2006). This legislation was designed around battery markets dominated by lead-acid and cadmium batteries, and therefore did not support the specific EOL needs of LIBs. In October of 2020, the European Commission proposed repealing the Battery Directive and replacing it with an amendment to Regulation No 2019/1020. The new proposed legislation, referred to as the EU Battery Regulation, aims to decrease the environmental burden of batteries as well as increase the EU-based supply chain by creating sustainability-based barriers-to-entry, thus increasing the competitiveness of local companies (Melin *et al.*, 2021).

The proposed EU Battery Regulation contains several measures specific to battery EOL, including:

- Mandated extended producer responsibility (EPR) for proper EOL management and attainment of collection and recycling targets (Measure 10)
- Transfer of EPR when batteries are repurposed in second-life applications (Measure 2)
- A reporting system for EV and industrial batteries, and target EOL collection rates of 65% in 2025 and 70% in 2030 (Measure 4)
- Minimum material recovery rates that must be met or exceeded during each recycling process for cobalt, nickel, lithium, and copper (Measure 5)

In addition, as part of a Strategic Action Plan on Batteries, the European Commission identified the importance of locating more of the battery value chain within the region, including raw material extraction and battery production (European Commission, 2019). Measures in the proposed EU Battery Regulation which pertain to LIB manufacturing include the required use of

recycled materials (recycled content), battery labeling, information sharing, and supply chain due diligence (European Commission, 2020).

3.1.2 China

The Chinese government first began issuing policy to promote LIB recycling in 2012 (Li *et al.*, 2021). Later, in 2017, China enacted the Promotion Plan for Extended Producer Responsibility System, which proposed the creation of an LIB recycling system based on the EPR principles (Wang, 2020). China has implemented the Pilot EV Recycling Initiative in 17 cities/regions, controlling the number of new enterprises involved in recycling to make full use of existing infrastructure (Reuters, 2018). In addition, they launched a Battery Traceability Management Platform to better track EV batteries throughout their life cycle. In 2018, China enacted the Interim Measures for the Management of Recycling and Utilization of Power Batteries of New Energy Vehicles which requires manufacturers to work with recycling companies to improve the recycling process, by labeling batteries and encouraging design for recycling (Wang, 2020).

Most recently, the Chinese government has put forward a policy proposing to ban, at least temporarily, the use of repurposed batteries in large-scale energy storage applications (National Energy Administration, 2021). The policy does not propose a permanent ban and still allows second-life batteries for small-scale energy storage applications, so the impact of this policy on what could be a nascent repurposing industry is still uncertain (Shen, 2021).

3.1.3 International efforts

The Global Battery Alliance (GBA) is a partnership managed by the World Economic Forum that includes members from “across the battery value chain, the public sector, civil society, and relevant initiatives” (Global Battery Alliance, 2021). The GBA’s mission includes improving the sustainability of both production and EOL of batteries, with a focus on increasing LIB adoption in the transport and energy sectors, as well as considering battery circularity and human rights-related issues for production. Among other actions, the GBA has supported the development of a recently commercialized product in service of battery reuse and retirement, the Battery Passport. The objectives of the Battery Passport are to prolong the lifespan of a battery and provide clear and transparent information about battery health for enhanced EOL management (CodeSmith Technology Ltd., 2020). Data provided by the Battery Passport is valuable for determining whether a battery should be repurposed or recycled after its first use, and provides repurposers with reliable and detailed information about battery health before purchasing and testing.

3.2 LITHIUM-ION BATTERY REGULATIONS AND STANDARDS IN THE UNITED STATES AND CALIFORNIA

A complex set of regulations and standards cover the logistics, reuse, and recycling of LIBs within the U.S. and California (Table 2). This section identifies and discusses applicable regulations and the EOL phase that they apply to.

Table 2: 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	<i>Facility licensing requirements:</i> California Vehicle Code Division 5 <i>Fire and building codes and standards:</i> NFPA 855, Chapter 14; 2024 International Fire Code, Sections 321, and related sections in 2024 International Building Code
Transportation	<i>Hazardous materials regulations:</i> 49 CFR §173.185 (special consideration for damaged batteries)
Storage	<i>Fire and building codes and standards:</i> NFPA 855, Chapter 14; 2024 International Fire Code, Sections 321, and related sections in 2024 International Building Code <i>Federal Universal Waste regulations:</i> 40 CFR §273.15 <i>CA Universal Waste Laws:</i> Chapter 23 title 22 of CCR
Disassembly	<i>High voltage equipment and personnel safety references:</i> NFPA 70B/E; IEEE C2 and IEEE 3007.3; OSHA 29 CFR 1926 and 1910 <i>Fire and building codes and standards:</i> NFPA 855, Chapter 14; 2024 International Fire Code, Sections 321, and related sections in 2024 International Building Code <i>Universal waste regulations:</i> 40 CFR §273.15 <i>CA Universal Waste Laws:</i> Chapter 23 title 22 of CCR
Energy Storage System (ESS) Installation	<i>Interconnection:</i> CPUC Rule 21, CAISO/FERC Tariffs <i>Electrical storage requirements:</i> California Fire Code 1206; NFP 855; International Fire Code
Hazardous Waste Treatment	<i>Universal waste regulations:</i> 40 CFR §273, Subpart E <i>Permitting requirements:</i> 40 CFR §§124 and 270 <i>Standards for hazardous waste treatment, storage, and disposal facilities:</i> 40 CFR parts 264, 265, 266, 268, 270, and 124 <i>Notification requirement:</i> section 3010 of RCRA. <i>CA Universal Waste Laws:</i> Chapter 23 title 22 of CCR <i>CA specific:</i> Health and safety division 20 chapter 6.5
Export	<i>EPA:</i> RCRA export requirements for universal waste

3.2.1 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 EOL batteries, 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.

3.2.2 Storage fire codes and standards: 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 may include dealerships, auto recyclers, repair shops, repurposers, and recyclers. Both the International Fire Code and NFPA 855 are currently being adapted (The Rechargeable Battery Association, 2020). The requirements in NFPA 855 are currently being amended to align with the new Section 321 of the 2024 International Fire Code that provides a comprehensive set of new indoor and outdoor storage requirements for LIBs. California is expected to adopt these new requirements by 2023.

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 (e.g., 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.

3.2.3 Universal waste designations: Title 40 of CFR in part 273

The federal Standards for Universal Waste Management 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 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 batteries² exhibiting hazardous waste characteristics.³ While LIBs 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 batteries as universal waste is that they are subject to a more streamlined and less complex collection process at EOL to increase proper disposal by the public. The federal regulations require state standards to be either identical or more stringent. The California-specific universal waste laws are in chapter 23 title 22 of CCR and reflect similar requirements.

3.2.4 Lithium-ion battery recycling: 40 CFR parts 264, 265, 266, 268, 270, and 124; Resource Conservation and Recovery Act (RCRA) section 3010

The transportation and storage of LIBs are covered under the universal waste laws, as discussed above, although the recycling of LIBs is considered a hazardous waste treatment. The Standards for Universal Waste Management 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 regulations cover the permitting and siting of facilities and the emission and waste disposal requirements.

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 about 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 has historically taken an estimated 2 years to complete. The California *Hazardous Waste Control* guidelines applicable to battery EOL 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.

Finally, businesses who export used batteries internationally must comply with RCRA universal waste export requirements, which are specified in 40 CFR §262. This entails various forms of documentation, including but not limited to contracts, notice of intent, written consent of the

² Battery is defined in §273.9

³ Hazardous waste characteristics are found in § 261 Subpart C

receiving country and any transit countries, and confirmation of receipt (U.S. Environmental Protection Agency, 2015).

3.2.5 Transportation requirements: 49 CFR §173.185

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 shipped by any mode of transport 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 EOL EV batteries:

- (b)(5): Specifies packing requirements for batteries larger than 12 kg 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 prepares and ships the battery is responsible for ensuring that it is packaged safely and demonstrating compliance with DOT regulations, so knowledge of hazardous material regulations and safety protocols are necessary for dismantlers, disassemblers, and repurposers.

3.2.6 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 3: Battery storage interconnected to the electricity grid within California must comply with the following tariffs.

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 California Public Utilities Commission (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.

4. 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, from November of 2019 through December of 2020, were dedicated to knowledge-building. The Advisory Group heard presentations from the UC Davis researchers along with invited speakers from academia, industry, and government agencies. These meetings educated the Advisory Group on LIB technology; 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. Table 3 describes the content and invited speakers for each meeting.

In January 2021, knowledge-building continued, but the primary focus of Advisory Group meetings shifted to the report development process, which was divided into four phases:

- Phase 1 (January 2021-March 2021): Identify barriers, opportunities, and the 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 2022): 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 during Phase 2 of the process. Membership on each subcommittee was as follows:

Logistics:

1. Alliance for Automotive Innovation
2. California New Car Dealers Association
3. Earthworks
4. Tesla Inc.
5. PRBA – The Rechargeable Battery Association
6. Umicore USA Inc.

Reuse:

1. California Household Hazardous Waste at large
2. KBI
3. Southern California Association of Governments
4. Surplus Service
5. Sustainable Energy Solutions
6. Tesla Inc.
7. PRBA – 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 International⁴
7. SA Recycling LLC
8. Tesla Inc.

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

During phase 2 (April 2021-July 2021) each subcommittee developed potential policy options based on addressing the barriers or taking advantage of the opportunities identified during phase 1. Updates to the Advisory Group were provided at the May and July 2021 meetings.

During Phase 3 (August 2021-December 2021) the Advisory Group developed the final report and recommendations. The outcomes of subcommittee recommendations and group discussions were incorporated into draft report documents prepared by the UC Davis team. The policy options proposed by the subcommittees, which were in many cases elaborated on or altered during Advisory Group meetings, were turned into a survey that was distributed to Advisory Group members to aid in the process of prioritizing or eliminating policy options. The survey results are provided in the Appendix. Advisory group members determined the recommendations through a voice vote at the November 2nd, 2021 and December 7th, 2021 meeting. The survey results and the vote tabulations are noted in the appendix of this report. Finally, Advisory Group members provided final review of recommendations through edits and comments in drafts of this report. The Advisory group approved the report for public comment on December 7th, 2021.

During Phase 4 (January 2022-March 2022) the Advisory Group accepted comments from the public. The report was open for public review from December 17th, 2021 to February 16th, 2022. 21 individuals submitted public comment. The UC Davis team reviewed and documented each comment and any corresponding edits made to the report. For comments submitted as in-line edits to the report document, they were directly incorporated if they clarified or corrected background information. Comments that would have substantively changed the content of the report have been summarized and presented in Section 9, along with indications of support or opposition to specific policies. The verbatim public comments are included in the appendix.

Table 4 summarizes the main presentation topics and the experts who spoke on each topic for all Advisory Group meetings. The subcommittee meetings are described in greater detail in Section 5 of this report.

⁴ Occupational Knowledge International was a member of the Advisory Group until Nov. 3, 2021.

Table 4. Summary of Advisory Group meetings

#	Date	Main Presentation Topic(s)	Speakers/Discussants
1	11/18/2019	Bagley-Keene Open Meeting Act AB2832 Current Lithium-ion Car Battery Recycling Landscape Advisory Group Mission	Salwa K. Bojack, CalEPA; Mohammed Omer, DTSC
2	01/27/2020	Materials, Reuse, and Recycling of Lithium-ion Batteries for Motor Vehicles Schedule and Topics for Technical Presentations	Dr. Hanjiro Ambrose, UC Davis; Mohammed Omer, DTSC
3	05/27/2020	Testing, Reuse and Second-life Applications of Lithium-ion Batteries from Motor Vehicles Battery Lifecycle Tracking Battery Second Life.	Dr. Hanjiro Ambrose, Union of Concerned Scientists; Lauren Roman, Everledger; Ryan Barr, RePurpose Energy
4	07/16/2020	Fair Political Practices Commission Exemption from Conflict of Interest Code Requirement Material Recovery from Recycling Lithium-ion Batteries of Motor Vehicles Battery Recycling	Salwa K. Bojack, CalEPA; Dr. Hanjiro Ambrose, Union of Concerned Scientists; Kunal Phalpher, Li-Cycle; Jeffrey Spangenberger, ReCell Center at Argonne National Laboratory
5	10/13/2020	Electric Vehicle Battery Policies and Initiatives in the European Union Worldwide Electric Vehicle Battery Policies and Initiatives The Role of DTSC in California Policy	Dr. Oliver Heidrich, Newcastle University; Dr. Alissa Kendall, UC Davis; Dr. Meredith Williams, DTSC; Valetti Lang, DTSC;

#	Date	Main Presentation Topic(s)	Speakers/Discussants
6	12/14/2020	<p>Electric Vehicle Dismantling</p> <p>Overview of Draft Policy Recommendations Report Outline and Subcommittees</p> <p>Delegated Bodies under the Bagley-Keene Open Meeting Act of 2004</p>	<p>Jonathan Morrow, Automotive Recyclers Association;</p> <p>Dr. Alissa Kendall, UC Davis;</p> <p>Salwa Bojack, CalEPA</p>
7	01/26/2021	<p>Presentation on Used Vehicles and Spent Lithium-ion Battery Exports</p> <p>Updated European Union Battery Directive</p> <p>Battery, Automotive and Recycling Industry Presentation on Applicable Regulations</p> <p>Action to Formally Establish Subcommittee Membership Assignments</p>	<p>Perry Gottesfeld, OKI;</p> <p>Willy Tomboy, Recharge;</p> <p>George Kerchner, PRBA – The Rechargeable Battery Association;</p> <p>Dan Bowerson, Alliance for Automotive Innovation;</p> <p>Todd Coy, KBI;</p> <p>Mohammed Omer, DTSC</p>
8	03/23/2021	<p>CalRecycle Extended Producer Responsibility Programs and Electronic Waste Fee and Payment System</p> <p>Facility Permitting Requirements</p> <p>Discussion of Progress and Ideas Raised in Subcommittee Meetings</p>	<p>Matt Sheehan, CalRecycle;</p> <p>Heather Beckner, CalRecycle;</p> <p>Wayne Lorentzen, DTSC;</p> <p>Muzha Ferouz, DTSC;</p> <p>Lori Koch, DTSC;</p> <p>Meg Slattery, UC Davis.</p>
9	05/25/2021	<p>California Zero Emission Vehicle Market Development Strategy and Permit Assistance Program</p> <p>California Auto Dismantlers Association on Sustainable End-of-Life</p>	<p>Tyson Eckerle, California Governor’s Office of Business and Economic Development;</p> <p>Manjeet McCarthy, Go-Biz;</p>

#	Date	Main Presentation Topic(s)	Speakers/Discussants
		Policy Solutions for Lithium-ion Batteries Progress reports from Advisory Group subcommittees.	Tom Novak, Pick-n-Pull; George Kerchner, PRBA; Alison Linder, Southern California Association of Governments; Mohammed Omer, DTSC;
10	07/13/2021	Industry and Regulatory Challenges and Obstacles Preliminary Policy Recommendations Survey Draft Report Revisions and Comments	Lea Malloy, Cox Automotive Mobility; Meg Slattery, UC Davis; Jessica Dunn, UC Davis
11	09/28/2021	Automobile Industry Core Exchange and Takeback Concept Policy Recommendations Survey Results	Dan Bowerson, Alliance for Automotive Innovation; Meg Slattery, UC Davis; Jessica Dunn, UC Davis
12	10/22/2021	Initial Policy Recommendations Report Draft	Dr. Alissa Kendall, UC Davis
13	11/02/2021	Second Draft of Policy Recommendations Report	Dr. Alissa Kendall, UC Davis

5. SUBCOMMITTEE OUTCOMES: BARRIERS AND OPPORTUNITIES

5.1 LOGISTICS

The scope of the logistics committee includes activities that facilitate reuse, repurposing, 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.

The subcommittee met five times to review the reverse logistics landscape, identify barriers and opportunities to safe and efficient reverse logistics, and ultimately develop a list of policy options to present to the Advisory Group based on addressing the barriers and taking advantage of opportunities that were identified.

Table 5: Summary of Logistics Subcommittee meetings

#	Date	Main Discussion Topic(s)	Presenter(s)
1	2/19/2021	Subcommittee chair selection Group discussion defining goal and scope of subcommittee, identifying barriers and opportunities to safe and efficient reverse logistics, and establishing work plan	Meg Slattery, UC Davis
2	3/12/2021	Reverse logistics infrastructure Storage and transportation considerations Relevant regulations	Meg Slattery, UC Davis; George Kerchner, PRBA
3	4/22/2021	Group discussion of potential policy options	Meg Slattery, UC Davis
4	5/18/2021	Battery collection in North America Group discussion of potential policy options SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis of policy options	Eric Frederickson, Call2Recycle; Meg Slattery, UC Davis
5	6/22/2021	Group discussion of policy solutions and plan for recommendations	Meg Slattery, UC Davis

5.1.1 Barriers to Safe and Efficient Logistics

The barriers identified by the subcommittee mainly 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 LIBs. The following paragraphs further explore these barriers, which should not be considered an exhaustive list.

Capturing Out-of-Warranty Lithium-ion Batteries

Many of the barriers identified stem from the decentralized and unregulated nature of the vehicle afterlife market in the U.S. Retired EVs may end up being handled by several different parties who have unequal access to the resources and information necessary to manage EOL batteries properly. 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. Reduced battery recycling costs and increased lithium prices make recycling more attractive, which could potentially resolve this issue.

Safety

EV batteries have a significantly higher voltage than batteries previously used in vehicles 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 maximum temperatures between 600 and 1000 C due to thermal runaway (Feng *et al.*, 2014; Golubkov *et al.*, 2015, 2018; Md Said and Mohd Tohir, 2021). Facilities can mitigate fire damage by having proper fire suppression capacity onsite (e.g., copious amounts of water, fire blankets) and dismantling and storing EVs in an isolated area away from combustible materials.

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 EOL battery must follow certain storage and transport protocols. As noted in Section 3.2 of this report, storage requirements are defined by the local fire code (NFPA 855, Chapters 14) 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 vehicle OEM and their collection network, dismantlers may not have information about where to send batteries if they cannot find an

immediate buyer. According to an invited speaker from the Auto Recyclers Association, many are currently accumulating them onsite in the absence of a clear directive.

Transportation

The cost of transportation depends on a variety of factors, including fuel cost, distance traveled, transportation corridor, and load size. The transportation corridor is a factor because carriers may charge more to ship to a remote location, as they are less likely to generate revenue through backhaul. Meanwhile, the load size is important because it is more cost-effective to ship batteries using a full truckload vs. less-than truckload service. Estimates of the cost of transporting EOL batteries vary widely but are estimated on average to contribute 40-60% of the overall cost of recycling (Foster *et al.*, 2014; Wang *et al.*, 2014; Zhang *et al.*, 2018; Dai *et al.*, 2019; Slattery, Dunn and Kendall, 2021).

To ensure batteries are transported safely, the party handling the battery must comply with hazardous materials regulations for shipping as specified by the DOT, which increases the cost of transportation. Damaged batteries are subject to more stringent transport requirements, as specified by paragraph (f) in 49 CFR §173.185. Specifically, they must be shipped in a United Nations (UN)-certified container, which are custom-ordered from dangerous goods packaging manufacturers at great expense.

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 (Department of Motor Vehicles Investigations Divisions, 2020). 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 LIBs 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. Lack of infrastructure in California could encourage EV battery retirement in other states or international export. 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 regulations 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 such as independent repair shops or dismantlers.

- *Universal waste classification:* LIBs 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.

Basic 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 LIB is necessary to enable the party handling the battery to determine the next appropriate use for the battery and what shipping protocol is needed. 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 or higher-nickel chemistries, or at least cover the cost of transportation.
- *Information about how to safely handle batteries:* Participants pointed out that vehicle 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, Salvage Wire, and the Department of Transportation (United States Environmental Protection Agency, no date).

5.1.2 Opportunities and Benefits

The opportunities identified by the subcommittee mainly reflect the potential to reduce EOL management costs and improve safety, both of which would improve conditions for robust reuse and recycling systems.

Reduced Cost and Environmental Impact of Transportation

Given that transportation is estimated to contribute between 40 and 60% of EOL costs, there is a large opportunity to reduce the overall cost of recycling through more efficient reverse logistics (Slattery, Dunn and Kendall, 2021). Through increased information along the chain of custody, relevant stakeholders would be able to send batteries directly to the most appropriate destination, thus increasing efficiency and avoiding unnecessary transportation. Reducing the distance traveled also reduces the environmental impact and cost. Another strategy to decrease miles traveled is facilitating a collection system with strategic infrastructure that enables batteries to be regionally accumulated prior to transport to make the shipment more cost-effective and decrease transport related emissions (Hendrickson *et al.*, 2015). The transportation costs could be additionally reduced by preprocessing EOL batteries locally to make them non-hazardous, either by disassembly/shredding, or by more elegant techniques under development. Finally, the cost of transportation can be reduced by identifying strategies that ease the cost of regulatory compliance without sacrificing the need for safety. This point was brought up frequently in all subcommittees, and participants emphasized that the regulatory burden must be decreased at the Federal level.

Increased Recycling Rates

Reducing the cost of transportation may help increase the collection rate and thus the number of batteries recycled. In turn, this would allow California and the U.S. 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

Improving the logistics can lead to increased possibilities for testing and tracking which would 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 has the possibility to 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 EOL 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.

5.2 REUSE AND REPURPOSING

The scope of the reuse subcommittee included both reuse in another vehicle and repurposing for different applications, though as evident in the discussion that follows, the subcommittee mostly focused on repurposing. Table 6 describes the subcommittee meetings and their content.

Table 6: Summary of Reuse and Repurposing Subcommittee meetings.

#	Date	Main Discussion Topic(s)	Presenter(s)
1	2/23/2021	Subcommittee chair selection; Group discussion defining goal and scope of subcommittee, identifying barriers and opportunities to safe and efficient reverse logistics, and establishing work plan	Dr. Alissa Kendall, UC Davis
2	3/8/2021	Energy Stationary Storage Testing Standards, Relevant Regulations, Discussion of opportunities and barriers.	Jody Leber, CSA Group; Dr. Alissa Kendall, UC Davis
3	4/19/2021	The Second-life Battery Industry in California; discussion of policy solutions	Freeman Hall, B2U Storage Solutions; Dr. Alissa Kendall, UC Davis
4	5/17/2021	Product Stewardship Programs; discussion of policy solutions	Jeremy Jones, PaintCare; Dr. Alissa Kendall, UC Davis
5	6/22/2021	Discussion of reuse policy solutions, discussion of policy recommendations report plan	Dr. Alissa Kendall, UC Davis

Reuse and repurposing of EV batteries face a number of barriers, 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 disincentives for planned obsolescence. The following text describes the barriers and opportunities for reuse and repurposing in greater detail.

5.2.1 Barriers to Reuse and Repurposing

Cost

For used batteries to be competitively priced against new batteries they must be offered at a discount, which can be difficult to achieve given the falling costs of new batteries and the added cost of repurposing. Reuse or repurposing will also compete with the critical materials contained in the battery; if recovering materials through recycling provides more value than the reuse or repurpose application, the appropriate pathway may be recycling.

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 (California Public Utilities Commission, 2021). Their current exclusion may be due to uncertainty regarding lifespan and performance.

Allocation of Responsibility

The subcommittee identified the lack of clarity regarding legal obligations and responsibilities for second-life batteries as 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, several members expressed the opinion that the OEM should not be held liable if there is an accident. Similarly, responsibility for final disposition of the battery (i.e., recycling) remains an open question, especially under regulatory schemes without some form of producer responsibility.

In the case that the vehicle OEM is not liable if the battery is repurposed, 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.

Lack of Information or Data

- *State of health (SOH):* Repurposing and reuse companies need access to information about the battery's SOH to estimate the remaining lifespan and determine whether the battery is suitable for a second-life application (Sarmah *et al.*, 2019). 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 remaining battery capacity requires an expensive and time-consuming testing process.
- *Battery type:* Since most repurposers 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). However, Smartville is currently piloting a system that integrates heterogeneous batteries into the same system as part of the CEC's demonstration grant program (California Energy Commission, 2021a).
- *Battery history and condition:* 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 module or cell

level, disassembling the LIB pack. The lack of standardization between vehicle OEMs complicates the secondary market because the disassembly and dismantling process is different for each pack design. Since not all batteries are designed with disassembly in mind, the process can be dangerous and costly (Paul *et al.*, 2015).

Acquisition Challenges

The current small scale of EV retirement is a barrier to advancing the second-life industry, although the quantity of EVs currently being retired is low compared to the amount that will retire in the next decade (Xu *et al.*, 2020; Dunn *et al.*, 2021). 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.

5.2.2 Opportunities and Benefits

Environmental Benefits

Harnessing the remaining usable capacity in retired EV batteries may displace demand for new battery products, which avoids the negative impacts associated with mining, refining, and manufacturing as well as reduces reliance on imported critical materials. On the other hand, if stationary applications can equally be served by chemistries such as LFP, repurposing batteries which contain more constrained energy minerals – cobalt and nickel – may delay the recovery of these critical materials through recycling, which could diminish the environmental benefits of repurposing.

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 repurposing is the job creation in California and the U.S. that would accompany the development of a new 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 (California Air Resources Board, 2021b).

Encourage Transparency and Coordination Across the Value Chain

A battery pathway where reuse occurs followed by recycling requires mechanisms for long term planning and collaboration across the supply chain. In supporting this approach, Advisory Group members 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 repurposers to connect with vehicle 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 manufacture for reuse and repurposing.

5.3 RECYCLING

The recycling subcommittee was formed to identify policy options that address barriers to recycling and opportunities for minimizing environmental and economic cost while maximizing material recovery. The scope covered includes material recovery via a recycling process. Table 7 summarizes the Recycling Subcommittee meetings.

Table 7: Summary of Recycling Subcommittee Meetings.

#	Date	Main Discussion Topic(s)	Presenter(s)
1	02/02/2021	Subcommittee Chair selection Group discussion of goal and scope Group discussion of barriers and opportunities to recycling	Jessica Dunn, UC Davis
2	03/15/2021	Review of goal and scope Review of barriers and opportunities to Recycling Relevant regulations and permitting requirements	Jessica Dunn, UC Davis
3	04/19/2021	Review of barriers and opportunities to recycling Review of relevant regulations and permitting requirements Group Discussion of Policy Solutions	Jessica Dunn, UC Davis
4	05/19/2021	Group discussion of policy solutions SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis of policy options	Jessica Dunn, UC Davis
5	06/23/2021	Group discussion of policy solutions Report update	Jessica Dunn, UC Davis

The recycling of LIBs at EOL faces a number of barriers, opportunities, and benefits that can be grouped into larger themes. Barriers identified by the subcommittee include existing regulations, cost, near-term low volume of EOL batteries, recycling industry development within the U.S., 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.

5.3.1 Barriers

Regulations

The regulatory environment within California, and at the national and international level, is considered a barrier for the LIB recycling industry. There is a lack of clarity as to regulations relevant to LIB recycling and a lack of alignment between regulations at the state and national scales.

A particular barrier within California is the lengthy permitting process for establishing a recycling facility within the state. The hazardous waste permit requires a six-step process designed to protect public health and safety. The process includes a review of the application materials by engineers, a revision period, and a public comment period (United States Environmental Protection Agency, 2015). DTSC, the department authorized to issue HW treatment permits, is tasked with balancing the speed of permitting and the rigor of review. They have expedited their permitting process to an average of two years (Lorentzen, 2021), which is still a long and costly timeline for a business developer. There is also added uncertainty for developers 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. 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 is a potential barrier for consolidating large flows of EOL batteries for recycling. This may change in the near future due to President Biden's Executive Order on America's Supply Chains, which outlined the importance of recycling to securing a domestic supply chain (The White House, 2021).

Economics

For recycling to proliferate without government intervention it must be economically compelling. While the recycling of EV LIBs is starting to become profitable under the right circumstances, logistical costs have proved to be a significant challenge, especially for lower volumes. 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.

As the industry develops globally and in the U.S, data sharing 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 End-of-Life Lithium-ion Batteries

Similar to the barrier identified by the reuse subcommittee, there is no guaranteed stream of EOL LIBs due to both the relatively small volume of EV battery retirements at this time (though this will change in the coming years), and inadequate collection infrastructure. The owner of the vehicle is currently responsible for the EV battery at EOL for vehicles or batteries outside of warranty, which may prevent batteries from reaching recycling facilities if there is a significant cost to recycle the battery and no clear direction for whom to contact or how to arrange transportation.

Both barriers (high cost and an unclear process for getting an LIB recycled) could result in the international export of EVs or spent LIBs. If LIBs are exported, recoverable critical materials will be lost. Furthermore, exporting spent LIBs could contribute to environmental justice issues if batteries are managed or processed using unsafe practices, an issue which has been documented for LIBs used in consumer electronics (International Energy Agency (IEA), 2020; Sovacool *et al.*, 2020).

Lack of Domestic Value Chain Infrastructure

Another barrier to the development of an industry within the U.S. is the lack of a LIB battery supply chain in North America to purchase the recovered materials after recycling. While LIB cells are manufactured within the U.S. (e.g., Panasonic for Tesla), there is currently no production capacity for the precursors to cell manufacturing, such as cathodes. This means recovered material will be exported to produce cathode materials, perpetuating the dependency on international markets for clean energy technologies.

Lack of Information

Recycling facilities operate at maximum efficiency when the batteries are processed in uniform batches. Identifying information about the cathode chemistry, anode chemistry and electrolyte type is not easily accessible, which adds time and cost to the recycling process.

5.3.2 Opportunities and Benefits

Reduced Environmental & Social Impact

The recycling of LIBs will reduce environmental impacts by offsetting demand for 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. 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 and within California presents an opportunity to create 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 U.S. vulnerability to price shocks and volatility. This national supply, along with increased economies of scale and technological and process improvements, have the potential to result in the decreased cost of batteries.

Support the Development of a Domestic Lithium-ion Battery Supply Chain

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 refined and returned to the battery supply chain to manufacture the precursors and cathode materials 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 an intermediary value chain industry 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.

6. POLICY PROPOSALS WITH MAJORITY SUPPORT

Based on the phase 2 subcommittee outcomes, a comprehensive list of proposed policy options was developed. Based on this list, the UC Davis team distributed a survey to Advisory Group members soliciting feedback on the proposed policy options. Members were asked to rate each policy option on a Likert scale indicating their strong support, support, support with modification, no opinion, opposition, or strong opposition. The results of the survey were used to focus discussion and solicit recommended changes to those policy proposals most likely to garner majority support from the Advisory Group during subsequent meetings.

On November 2nd, 2021, Advisory Group members were asked to vote on each policy proposal. Members could either vote in favor, vote to oppose, abstain, or could recuse themselves from the vote. Members that were absent for the initial vote were asked to vote at the December 7th, 2021 meeting. The level of support was determined by dividing those in support by all voting members. If Advisory Group members elected to recuse themselves, they were not counted among voting members and thus were excluded from the calculation of percent support. Majority support is defined as any policy proposal for which the level of support exceeds 50%. In total, 15 Advisory Group members participated in the final vote; the full results can be found in table A2 of the appendix.

The four state agency representatives recused themselves from voting for all policy options. As representatives of individual agencies within the Executive Branch, rather than the full Administration, these agencies felt it was inappropriate to endorse a specific policy outcome or recommendation in a report to the Legislature. Rather, should any of these recommendations be discussed within the Legislature, the Administration would provide input in due course and through the appropriate channels.

6.1 POLICIES 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 pathway depends on the economic value and feasibility of reuse and/or recycling. This could create “stranded batteries” if individual consumers or small operations end up in possession of LIBs that they do not have the resources or motivation to dispose of properly. Without a mechanism to collect stranded batteries, they may be unsafely accumulated, illegally abandoned, or improperly managed domestically and abroad.

To avoid improper management, the following EOL management policy options were developed through subcommittee deliberation and Advisory Group discussion. These policies seek to ensure that all batteries are captured and properly reused, repurposed, or recycled by defining a responsible party at EOL (options 1, 2a, and 2b), or by establishing a financing mechanism to pay for EOL management (options 3, 4, and 5). As documented in the November 2nd and December 7th meeting, policy proposals 1 and 2a received majority support, while the others did not (see Table 8).

Regardless of which option is adopted by the legislature, the following aspects must be carefully considered:

- There should be a clear transfer of responsibility for EOL management when batteries are reused or repurposed. This transfer happens when a transaction occurs between an OEM and repurposer. Responsibility includes re-labeling of batteries to identify the responsible party in the case of reuse or repurposing; arranging reverse logistics to transport batteries to recycling hubs; payment of recycling cost, if required; and documentation of recycling. How the responsible party should provide proof of proper reuse, repurposing, and/or recycling must be established.
- If responsibility for EOL management includes ensuring that batteries are properly recycled, it is necessary to define what constitutes “proper recycling”. This could mean requiring batteries be sent to a facility that is licensed to recycle batteries in the U.S., or to facilities that meet an international standard in terms of environmental performance and other metrics. There is currently no international standard, so the criteria and how it should be verified would need to be defined through a separate consensus-based process.

Table 8. Advisory Group vote outcomes and level of support for EOL management policy proposals.

Policy proposal	In Favor	Opposed	Abstain	Level of support (%)
1. Core exchange and vehicle backstop	14	0	1	93%
2a. Producer take-back	10	4	1	67%
2b. Producer take-back with companion legislation requiring return to OEM	4	10	1	27%
3. Environmental handling fee	6	7	2	40%
4. Environmental handling fee gathered through vehicle registration	5	7	3	33%
5. Hybrid environmental handling fee	5	9	1	33%

Sections 6.1.1 and 6.1.2 provide more detailed information for policy proposals 1 and 2a, the two that received majority support. For each of the proposals, the Advisory Group and UC Team provided advantages and disadvantages illustrating the complexity of each policy option. Proposals 2b-5, which did not receive majority support, are detailed in Section 7.1.

6.1.1 Core Exchange and Vehicle Backstop Policy

This policy is built upon existing industry standards and policies for other components, specifically a core exchange and product take-back. It is not intended to replace current warranty regulations or programs; if a battery is removed while under warranty, the vehicle manufacturer is responsible for properly reusing, repurposing, or recycling. The proposal defines responsibility for out-of-warranty batteries via three pathways:

- 1) For EVs **still in service**, if a battery pack, module, or cell is replaced before the vehicle reaches EOL, a core exchange program detailed by the EV battery supplier* 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, or recycled. The entity selling an EV battery shall use a core exchange** program to track that the used battery has been properly managed.
- 2) 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. If an EV battery is directly reused in another vehicle with no alterations, the process for EVs still in service shall apply. If the battery is refurbished or repurposed, the responsibility transfers to the refurbisher or repurposer.
- 3) In circumstances where an EOL EV with an OEM-certified battery is **not acquired and removed by a licensed dismantler**, the vehicle manufacturer shall be responsible for ensuring that the vehicle is properly dismantled and the LIB is properly reused, refurbished, or recycled.

Definitions:

*Supplier refers to the entity selling the battery, which could be a manufacturer or refurbisher.

**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 vehicle OEMs or battery suppliers and may or may not involve an added charge. Two examples provided by the Alliance for Automotive Innovation were 1) a case where the used battery is shipped to vehicle 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 vehicle OEM part sales, battery aftermarket sales, or a battery refurbisher. These entities return a replacement battery to the repair shop, and is then responsible for ensuring the used battery is properly recycled, refurbished, or sent for second-use.
- 2) The vehicle OEM, battery aftermarket sales, or battery refurbisher requires assurance that the repair shop removing the battery will properly recycle, refurbish, or put it into a non-vehicle secondary use market.

Considerations for implementation

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

Advantages

- The “vehicle backstop” will address LIBs that could potentially become stranded
- Depending on how the vehicle backstop is implemented, it may be the sole means of capturing batteries that are currently on the road and out of warranty.
- Does not add an upfront fee to the cost of the EV
- Encourages independent reuse and repurposing for batteries with available capacity
- Specifies transfer of responsibility for reused, refurbished, and repurposed batteries
- Incentivizes design for recycling and disassembly

Disadvantages

- Potentially increased costs to the OEM under the assumption valuable LIBs at their EOL will be sold to a third party, and the OEM will be contacted to dispose of EVs with negative value
- Could result in increased cost to the OEM and, consequently, higher prices for consumers and negative consequences for EV penetration
- If the OEM goes out of business this may result in orphaned batteries which do not have a party responsible for the EOL management

6.1.2 Producer Take-Back

The auto manufacturer is responsible to ensure proper reuse, repurposing, 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 reused, repurposed, or recycled. If the battery is repurposed, the EOL responsibility transfers to the repurposing company. This responsibility includes:

- Arranging reverse logistics to transport the batteries to repurposing or 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 EOL or contact the vehicle OEM to correctly dispose of it
- The ability for batteries to be sold to a third party at the EOL provides opportunity for growth in the remanufacturing, refurbishing, and repurposing industry without requiring a partnership with the vehicle OEM
- Incentivizes design for recycling and disassembly

Disadvantages

- Increases costs to the manufacturer under the assumption valuable LIBs at their EOL will be sold to a third party, and the vehicle OEM will be contacted to dispose LIBs with negative value
- Could result in increased cost to the manufacturer resulting in higher prices for consumers and negative consequences for EV penetration
- If the vehicle OEM goes out of business this may result in orphaned batteries which do not have a party responsible for the EOL management

6.2 SUPPORTING POLICY PROPOSALS

In addition to recommending a comprehensive policy defining responsibility at EOL, the subcommittees developed 19 policy options to address more specific barriers and opportunities in the following categories:

- Access to Battery Information
- Support Reuse, Repurposing, and Recycling Industry Development
- Reverse Logistics
- Circular Economy and Quality Recycling

The proposed policy options are not mutually exclusive and should be considered complementary to any potential policy that defines responsibility, such as those proposed in sections 7.1.1 and 7.1.2. In total, 12 of 19 proposed supporting policies garnered majority support according to the Advisory Group vote on December 7th. The remaining policies are presented in Section 6.2, and the detailed voting and survey outcomes are presented in Table A1 and A2 in the Appendix.

Table 9. Supporting policy proposals with majority Advisory Group support

Category	Policy	Purpose	Level of support (%)
Access to battery information	Physical labeling requirement	Facilitate sorting to improve process efficiency; enable easy identification of battery/vehicle OEM	93%
Access to battery information	Digital identifier	Identify LIB chemistry at EOL; identify responsible party for safe disposal; improve safety during disassembly	87%
Access to battery information	Universal diagnostic system	Reduce cost of testing; enable performance guarantees for reused and repurposed batteries	53%

Category	Policy	Purpose	Level of support (%)
Support repurposing, reuse, and recycling industry development	Recycling incentive packages	Mitigate upfront capital costs; encourage recycling within California	73%
Support repurposing, reuse, and recycling industry development	DTSC permit timeline	Reduce cost of locating processing facilities within California	60%
Support repurposing, reuse, and recycling industry development	Expand eligibility for battery storage systems	Enable cost-competitiveness with new batteries	67%
Safe and efficient reverse logistics	Support enforcement of unlicensed dismantling laws	Prevent environmental hazards and stranded batteries due to unlicensed dismantling	87%
Safe and efficient reverse logistics	Develop training materials	Improve safety and workforce capacity	93%
Safe and efficient reverse logistics	Support transportation research	Reduce transportation cost	100%
Safe and efficient reverse logistics	Develop strategic collection and sorting infrastructure	Reduce transportation cost	93%
Safe and efficient reverse logistics	Universal waste regulations	Reduce transportation cost and administrative burden	100%
Safe and efficient reverse logistics	Require pre-approval to bid on EVs at auctions	Enable tracking of EVs purchased at auctions	60%

6.2.1 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, refurbishing, or repurposing 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

Require OEMs to attach a standardized 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 California Air Resource Board (CARB) is developing a labeling requirement as part of their proposed Advanced Clean Cars II regulation (California Air Resources Board, 2021a). 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 the forthcoming CARB standard, as well as the Society for Automotive Engineers standard for EV batteries (SAE2936) (SAE International, 2012).

Advantages

- The label allows recyclers to easily sort LIBs by cathode chemistry, which maximizes process efficiency and material recovery rates and avoids complications
- Easy identification of the vehicle OEM and chemistry will streamline the repurposing process since most stationary repurposed systems are 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 elements present in the cathode are listed and not the full stoichiometry of the cathode (e.g., NMC 622) or the composition of the rest of the battery, 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
- If the vehicle OEMs delegate the labeling responsibility to the auto dealers, this could be overly burdensome to the dealerships
- Applying this label to the pack only may lead to information loss if the modules or cells are separated

Electronic Information Exchange (i.e., a QR code linking to 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 from the vehicle
- Vehicle OEM contact information to request safe disposal of the battery

Advantages

- Providing easily accessible disassembly instructions can increase safety at battery EOL
- Easily accessible vehicle OEM contact information can expedite the recovery of LIBs at their EOL, which would prevent stranded 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
- Applying this QR code to the pack only may lead to information loss if the modules or cells are separated

Universal diagnostic system

In addition to information about the contents of the battery pack, enabling third-party access to state-of-health (SOH) information could facilitate repurposing and reuse by reducing the time required for testing. A Universal Diagnostic System (UDS) installed on the battery 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 a 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 to avoid overlapping regulation.

Advantages

- Enables informed decisions about reusing, repurposing, and recycling, which ultimately reduces the overall costs
- Increased information on the use and SOH can enable maximum use and value out of the battery packs through repurposing and reuse
- May keep an EV on the road for a longer period of time before owners must purchase a new vehicle, reducing costs to vehicle owners.

- 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 and battery supplier algorithm and software
- Easily accessible information on state of health could encourage unlicensed repurposing

6.2.2 Support Reuse, Repurposing, and Recycling Industry Development

The high upfront cost and lack of large-scale battery retirement contribute to the challenging economics of reuse, refurbishing, 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 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 LIBs 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 EOL

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

Establish a timeline for hazardous waste processing permit

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 Senate Bill 158 (Committee on Budget and Fiscal Review, 2021). 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.

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
- Could lead to the establishment of a recycling facility in California, thus creating skilled labor jobs and reducing the cost and emissions of the LIB EOL by reducing transportation distance to the recycling facility

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

Currently, 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 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.

In addition, the Advisory Group recommends that responsibility for EOL management, including recycling and labeling, be required for all suppliers that participate in incentive programs for stationary batteries.

Advantages

- Enables repurposed batteries to compete with new batteries

Disadvantages

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

6.2.3 Reverse Logistics

The Advisory Group recommends the following policies to support the safe and efficient removal, handling, and transportation of EOL batteries.

Support enforcement of unlicensed dismantling laws

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 LIBs when handled incorrectly. Increased resources should be provided to improve enforcement of unlicensed dismantling laws, for example through the existing Vehicle Dismantling Industry Strike Team which is led by the Department of Motor Vehicles (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 the DMV

Develop Training Materials for Parties Handling EOL 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 U.S. Department of Transportation (USDOT) and the EPA.

Advantages

- Develop workforce capacity and promote safety

Disadvantages

- None to report

Universal Waste Regulation

LIBs at their EOL are classified by DTSC as a universal waste and meet the definition of hazardous waste under RCRA due to their risk of ignitability and toxicity. 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 EOL 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

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 and lowering these costs without compromising safety will improve the overall economics of repair services, as well as reuse, repurposing, and recycling

Disadvantages

- Lowering the cost of compliance must not sacrifice safety
- Research will cost money

Develop Strategic Collection and Sorting Infrastructure

To support a more efficient reverse logistics network, the state should support the development of strategically located collection and sorting facilities. State support constitutes assisting with site selection, permits, land use, etc., and not the construction of infrastructure.

Advantages

- A spatially optimized collection network will reduce the transportation distance at EOL, 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

Require Pre-Approval to Bid on Electric Vehicles at Auctions

To minimize unlicensed dismantling, the Advisory Group recommends requiring that interested parties apply for pre-approval before participating in auto auctions. The pre-approval process should include registering and verifying contact information (e.g. name, address, etc.) in order to track the battery.⁵

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.

⁵ Public comment pointed out that individual (public) buyers who wish to participate in California auto auctions are currently required to purchase vehicles through a broker and provide identification, including proof of address. They are also limited in the type of inventory they are allowed to bid on.

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

7. POLICY PROPOSALS WITH LESS-THAN-MAJORITY SUPPORT

The following policy options are worthy of consideration by the legislature but did not receive majority support from the Advisory Group vote.

7.1 ALTERNATIVE PROPOSALS TO DEFINE END-OF-LIFE MANAGEMENT

7.1.1 Allocating Responsibility

Producer Take-Back with Companion Legislation Requiring Return of the Lithium-ion Battery to the Original Equipment Manufacturer at End-of-Life

The auto manufacturer is responsible to ensure proper reuse, repurposing, 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 EOL
- Provides the vehicle OEM with a stream of used LIBs that will likely be valuable

Disadvantages

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

7.1.2 Environmental Handling Fees

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 EOL costs for all LIBs, including stranded 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 LIB 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 EOL costs for all LIBs, including stranded batteries and those purchased outside of California
- Reduces 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 which would negatively impact EV adoption and state pollution and climate goals
- 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 LIB 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 EOL costs for all LIBs, including stranded batteries and those purchased outside of California
- Shares costs between EV owners and the vehicle OEM
- Could avoid large 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 commentary

If a fund were to be established through an environmental handling fee, the majority of the Advisory Group recommended it be managed by a third party and not a state agency.

7.2 SUPPORTING POLICY OPTIONS WITHOUT MAJORITY SUPPORT

This section presents the policies that did not receive support by the Advisory Group during the vote on November 2nd and December 7th but may still be worthy of consideration by the legislature. Some of these policies received support during the initial survey, which will be noted and further discussed in the policy subsections.

Table 10. Additional supporting policies that are not recommended because they did not have majority support during the Advisory Group vote. An asterisk next to the policy indicates the policy received majority support in the survey, but not in vote.

Category	Policy	Purpose	Level of support (%)
Support industry development	Disassembly incentive packages*	Encourage disassembly within California	20%
Circular economy and quality recycling	Recycled content standards	Create demand for recycled material; improve sustainability of new EVs	47%
Circular economy and quality recycling	Minimum material recovery targets*	Ensure recovery of critical materials	47%
Circular economy and quality recycling	Third-party verification	Ensure batteries are recycled sustainably	40%
Circular economy and quality recycling	Require design for reuse and recycling*	Reduce reuse and recycling cost	33%
Circular economy and quality recycling	Reporting system for EV batteries retired from use	Improve access to information about location of LIBs at EOL	33%

Category	Policy	Purpose	Level of support (%)
Circular economy and quality recycling	Reporting system for LIB recycling and recovery rates	Improve access to information about recycling rate of LIBs	33%

Support Reuse, Repurposing, and Recycling Industry Development

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.

Comparison of voting and survey outcomes

While a majority of the Advisory Group did not support this policy in the vote, the survey resulted in support by a slim majority of 55%, with 30% of the members expressing no opinion.

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

7.2.2 Circular Economy and Quality Recycling

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

Minimum Material Recovery Rates

Required recovery rates for specific materials have been proposed in the EU 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.

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 LIBs 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%

Comparison of voting and survey outcomes

The survey resulted in support of this policy, although by a slim majority of 55%, with 10% of the members expressing no opinion.

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 critical material recovery and sustainability may not be profit-maximizing for the recycling industry
- Global consistency of definition and calculation process of materials recovery may be difficult to achieve causing incorrect recovery rate achievement

Design for Repurposing, Reuse, and Recycling

Disassembly at EOL is time- and cost-intensive for repurposers and recyclers. Requiring or incentivizing OEMs to design batteries in a way that facilitates repurposing, reuse, and recycling could make disassembly at EOL less time- and cost-intensive for repurposers. Examples of design for reuse or recycling that are not binding or exhaustive include sealing battery packs with screws instead of adhesives, using an alternative binder than polyvinylidene fluoride to increase EOL solubility, and converting to solid busbars that are in a standardized position.

Comparison of voting and survey outcomes

The survey resulted in support of this policy, with a slim 55% majority in support, 5% of the members responding support with modifications and 15% of the members expressing no opinion.

Advantages

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

Disadvantages

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

Third-Party Verification

LIBs 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 LIBs, 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.

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.

Comparison of voting and survey outcomes

The survey also did not show majority support of this policy, with only 45% in support, although the majority was close with 5% of members willing to support with modification. In addition, 30% responded with no opinion.

Advantages

- Discourages 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

Recycled Content Standards

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 have not been recommended 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.

Comparison of voting and survey outcomes

Recycled content standards only received 25% support in the survey, although an additional 25% supported with modifications. The modifications were mainly expressing the need for further research. The policy was opposed by 40% of members.

Advantages

- Can drive a robust recycling industry by creating demand for recycled material, particularly given the size of the EV market in California
- 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 LIBs) without specifying the end use
- Difficult to verify
- Could artificially inflate the value of battery materials and increase cost of manufacturing, and, ultimately, the cost of EVs

Develop a Reporting System for EV Batteries Retired from Use

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 EOL system, particularly vehicle or battery exports. An online database should be created to track and report LIBs 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.

Comparison of voting and survey outcomes

This policy was supported by 45% of Advisory Group members in the survey, with an additional 5% selecting support with modifications. It was opposed by 45%, with only 5% expressing no opinion.

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 EOL 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 LIB 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.

Comparison of voting and survey outcomes

This policy was supported by 30% of Advisory Group members in the survey, with an additional 15% selecting support with modifications. It was opposed by 40%. The remaining 15% expressed no opinion.

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

8. AREAS OF FUTURE RESEARCH

The LIB recycling and reuse industry is evolving in preparation for the influx of EV LIBs that will reach EOL in the coming years. The development of the industry will determine the environmentally and economically preferable EOL management strategy, and the best policy mechanisms to encourage these circular economy practices. Many of the policies recommended by the advisory group require future research and should be updated as the industry evolves. In addition, there were several policies discussed, and not recommended, largely due to unknown impacts to the nascent industry and the international market. Below, in no particular order, are several areas the Advisory Group recommends for further research.

- **Solutions to reduce the cost of collection and transportation:** Similar to the policy recommendation in section 6.2.3, Identify Strategies to Reduce the Burden of Transportation, research on the technical and regulatory solutions to decreasing the cost of transporting EOL LIBs is recommended. The cost of transporting LIBs at their EOL is a substantial portion of recycling costs, estimated to represent between 40-60%; as such, reducing transportation costs can significantly decrease the cost of EOL management (Slattery, Dunn and Kendall, 2021).
- **Recycling performance targets:** Performance target policies, such as minimum material recovery rates, maximum process emissions, or third-party verification, were not recommended by the Advisory Group. Hesitancy about these policies usually centered around the need for more information about the impact on domestic and international recyclers, and ensuring they are on an even playing field. In order to address this uncertainty, research on appropriate emission levels, material recovery rates, the process for implementation, and the impact on the global market is needed.
- **Feasible recycled content standards and analysis of the economic impacts:** Research is needed to determine the level of recycled content that can be met with retired materials and the impact to the U.S. and international LIB market.
- **Reevaluation of safety aspects if/as chemistry changes:** The materials used in LIBs, specifically the cathode, anode, and the electrolyte, are continuing to evolve to. As the materials used change, the material interactions present different safety hazards, and the impact to the safety of recycling and reuse must continually be evaluated.
- **More data on the performance and safety of repurposed batteries:** Since the repurposing of batteries is fairly new, the performance (i.e. lifespan, degradation rate) and safety is unclear. In order to increase the public confidence and ensure this is the best use of materials, more research should be conducted. The CEC is currently supporting demonstration projects for this purpose (see section 2.2.).
- **Utilization and application of second-life in reducing the life cycle environmental impact:** Research of the life cycle impact of repurposing LIBs, and the impact of the application the stationary storage battery is used in on those life cycle impacts.

9. PUBLIC COMMENTS

The public comment period spanned from December 17th, 2021 to February 16th, 2022. During this period, 21 members of the public submitted comments on the report. Comments were received from LIB recyclers, LIB repurposers, automobile dismantlers, automobile auction companies, environmental advocacy groups, and Universities. The full list of participants are below:

1. Alliance for Automotive Innovation
2. Argonne National Lab
3. Automotive Recyclers Association
4. B2U Storage Solutions
5. Basel Action Network
6. Call2Recycle
7. Cobalt Institute
8. Copart
9. Crown Battery Manufacturing Company
10. Insurance Auto Auctions
11. Institute of Scrap Recycling Industries
12. Li-Cycle
13. LKQ Corporation
14. National Auto Auction Association
15. Redwood materials
16. ReJoule
17. Responsible Battery Coalition
18. Rice University, Baker Institute for Public Policy
19. State of California Auto Dismantlers Association
20. University of Toledo
21. World Resources Institute

Overall, the public comments expressed their support for the increased recycling of EOL LIB batteries. The following paragraphs summarize comments received and discuss policies that were mentioned in many comments. Verbatim public comments are available in the Appendix.

9.1 Defining End-of-Life Responsibility

The core exchange and vehicle backstop policy proposal received written support from the following groups:

- Institute of Scrap Recycling Industries
- Redwood Materials
- World Resources Institute

Several comments expressed views in support of defining EOL responsibility generally, or in support of specific EOL responsibilities:

- Crown Battery Manufacturing Company supports mandated recycling of LIBs
- Li-Cycle supports defining responsibility for EOL management

- LKQ Corporation supports a mandatory take-pack program, believing it to be superior to the vehicle backstop proposal.

9.2 Access to Battery Information

Policies enabling the sharing of information, including physical labeling, digital identifiers, and a universal diagnostic system, received written support from the following groups:

- Automobile Recyclers Association
- LKQ Corporation
- State of California Auto Dismantlers Association
- Crown Battery Manufacturing
- World Resources Institute

Public comments on this topic also provided the following suggestions:

- Noted that there are four different diagnostic tools currently in development with different intended uses and benefits (Call2Recycle)
- Recommend creation of a list of trusted SOH providers who can capably test batteries to give accurate and vetted SOH information (ReJoule)
- Recommend including instructions for battery pack and module disassembly in an electronic information exchange (ReJoule)
- A universal diagnostic system must avoid sharing proprietary software and battery information as this will hinder innovation. Therefore, readable data should be limited to fault codes and diagnostic information (Call2Recycle)
- The benefits of physical labeling requirements will not be realized for years to come, since cars on the road today are not labeled. An interim strategy to train parties handling batteries on how to identify batteries will be necessary (Call2Recycle)

9.3 Circular Economy and Quality Recycling

Members of the public expressed their support for several of the policies included in Circular Economy and Quality Recycling categories. The following parties expressed support for **design for disassembly, reuse and recycling**:

- Institute of Scrap Recycling
- The Basel Action Network
- Crown Battery
- Rejoule
- World Resources Institute

In addition:

- Crown Battery Manufacturing supports the creation of a reporting system for LIB recycling and recovery rates
- Li-cycle expresses their commitment to ensuring recycling meets the highest environmental standards and supports establishing recycling efficiency and material recovery rates
- The Basel Action Network supports the third-party verification of recycling.

- The World Resources Institute expressed support for these circular economy policies as a whole.

9.4 Safe and Efficient Reverse Logistics

Requiring pre-approval to bid on EVs at auctions received a number of comments in opposition, although the policy was supported by the Automotive Recyclers Association. The following groups oppose this policy proposal:

- Copart
- Insurance Auto Auctions
- National Auto Auction Association
- Call2Recycle

The reasons stated for opposing this policy include 1) there is already a reporting process for wholesale auctions with the Department of Motor Vehicles (National Auto Auction Association), 2) insurance auctions already require an occupational or business license to purchase vehicles at their auctions (Copart), and 3) the process will be burdensome and insurance auctions will need to push the additional costs to policy holders (Insurance Auto Auctions).

Public commenters also made the following comments regarding reverse logistics:

- Emphasized role of auto dismantlers and support for the DMV strike team established by SB 266 (Auto Recyclers Association and State of California Auto Dismantlers Association)
- Supported education and safety equipment for first responders and service/repair companies (Crown)
- Suggested that to minimize transportation distances, the holder of the battery should be allowed to decide whether its next destination should be reuse, repurposing, or recycling (Call2Recycle)

9.5 Recommendations for further research

- Further validation programs for reused and repurposed batteries, similar to the CEC-funded demonstrations discussed in section 2.2 of this report (ReJoule)
- Research on the impact and prevention of exporting used EVs and LIBs (Basel Action Network)

10. CONCLUSION

Decarbonizing transportation is a cornerstone of California’s strategy to mitigate climate change. At the same time, transitioning away from internal combustion engines to battery-powered ZEVs requires a significant increase in demand for LIBs, whose life cycle includes a suite of environmental impacts from mining, refining, manufacturing, and disposal. The safe and environmentally responsible management of EV LIBs at EOL is therefore essential to achieving the State’s climate goals sustainably and equitably. Reusing batteries at vehicle EOL extends their usable life, potentially reducing the need for new batteries. Repurposing batteries for stationary storage may further support the State’s grid decarbonization goals by providing an affordable form of energy storage. Ultimately, recycling will be necessary to avoid unsafe final disposition and to recover critical materials for use in new LIBs or other products. Recycling that takes place regionally (i.e., within California or neighboring states) can best ensure processes meet a high standard for environmental performance and worker safety, reduce unnecessary cost and environmental impacts from transportation, and increase supply chain resilience by maintaining control of critical materials.

As a State with ambitious climate policies and the largest automotive market in the U.S., California is uniquely positioned to influence the sustainability of the EV value chain through leadership and proactive legislation. To assist the legislature in developing effective policy, this report outlines the existing landscape for reuse and recycling, summarizes key barriers that currently inhibit reuse and recycling according to a variety of stakeholders, and identifies some opportunities and benefits that could be realized through creating robust EOL programs and industries. Finally, we present a list of potential policies that support the goal of ensuring that as close to 100% of LIBs are properly reused, repurposed, or recycled at EOL and identify areas where further research is needed. This report does *not* do the following:

- Provide detailed guidance for implementation or enforcement
- Provide a specific definition for what constitutes “proper reuse or recycling” or how it should be verified.

The fundamental approach of the policies in this report is to 1) clearly define responsibility for the coordination and payment of recycling in cases where the cost presents a burden for the owner of the vehicle and the LIB is unwanted, and 2) mitigate barriers that add cost and inhibit the reuse and recycling of EV LIBs. Some of the key barriers addressed include capturing out-of-warranty batteries, the lack of access to important battery information, the burden of storing and transporting LIBs, uncertainty regarding the cost and performance of repurposed batteries, and the complexity of navigating universal and hazardous waste regulations. In recommending policies, the Advisory Group sought to understand and support the systems that already handle EOL vehicles, including the existing auto dismantling, LIB repurposing, and LIB recycling industries.

The most widely supported policy defining responsibility for EOL management was the core exchange and vehicle backstop proposal, which allocates responsibility under three possible retirement pathways. The majority of the Advisory Group also supported a producer take-back policy making the vehicle OEM or repurposer responsible for ensuring proper reuse, repurposing, or recycling at a licensed facility and at no cost to the consumer. Under either policy, there should be a clear transfer of responsibility for EOL management when batteries are

refurbished or repurposed. Both policies also require further consideration to define what constitutes “proper recycling” and how it should be verified.

Widely supported policies that address more specific barriers include labeling and digital identifier requirements, supporting the development of recycling facilities through incentive packages and a guaranteed permitting timeline, supporting the enforcement of unlicensed dismantling laws, and supporting the development of strategic collection and sorting infrastructure to reduce transportation costs. The Advisory Group also recommended training programs to ensure that the people who handle EOL vehicles have the skills they need to safely work with EVs and assist them in navigating regulatory requirements.

There are several areas where the Advisory Group recommends further research to understand the industry as it develops, rather than proposing binding policies. This represents a departure from EOL LIB policies from other regions, such as the EU’s proposed Battery Regulation, which sets specific targets and mandated requirements for recycling of batteries, collection rates, recycling recovery rates, and even recycled content standards. The Advisory Group considered, but ultimately did not recommend, several policies that were proposed by the EU; specifically, material recovery rates and recycled content requirements. While nearly half of the Advisory Group did support these policies as a means of ensuring that critical materials are recovered and used in battery production, others felt that they were too prescriptive and instead recommended establishing aspirational targets. Those who opposed these policies by and large believed that recycled content and material recovery rates provide valuable guidelines and goals for industry development, but more research is required to identify feasible targets and understand their economic impact.

This report also differs in scope compared to the proposed EU Battery Regulation, as it only addresses EOL LIBs from passenger EVs and therefore only applies to a subset of issues related to LIBs. This report intentionally does not address LIBs from heavy-duty vehicles, micro-mobility, or stationary storage because the Advisory Group convened by AB 2832 is specific to car batteries. The use of LIBs in these other applications, specifically large-format batteries for grid support, will increase as efforts to decarbonize continue. While many of the policies may indirectly support the reuse and recycling of these batteries through supporting the industry in general, it is necessary to have consistent EOL policy for LIBs used in all applications.

In addition, while policies in the two largest EV markets, the EU and China, have developed strategic plans encompassing the entire battery life cycle, this report does not include recommendations targeted to other activities in the value chain. Nonetheless, the importance of more localized refining and cathode manufacturing capacity was emphasized throughout this process, and the interconnection between recycling, refining, and manufacturing is something the legislature should be aware of when drafting legislation.

To that end, the legislature should understand the contents of this report in the context of several other aligning efforts taking place at a state, federal, and international level:

- The CEC’s ongoing support for repurposing demonstrations will provide better data around the performance and durability of second-life batteries, which will enable more informed policy decisions regarding incentives (California Energy Commission, 2021a)
- The ongoing work of the Lithium Valley Commission in exploring the opportunities of developing a local supply hub for EV LIBs and potential impact to the local community³²

- CARB’s Advanced Clean Cars II Act, which is expected to include standards for labeling, SOH determination, and performance and durability requirements (California Air Resources Board, 2021a)
- Support for supply chain resilience, vehicle electrification, and recycling in the Biden Administration’s Building Back Better agenda, including allocating \$6 billion for investment in the battery supply chain in the Infrastructure Investment and Jobs Act (DeFazio, 2021)
- Ongoing reuse and recycling projects supported by the Department of Energy’s Lithium-ion Battery Recycling Prize (U.S. Department of Energy, 2021b)
- Internationally, the efforts of the Global Battery Alliance to increase the transparency and sustainability of the LIB value chain (Global Battery Alliance, 2021)

Throughout the process, the Advisory Group members and invited speakers emphasized that EVs are a relatively new technology and are not yet being retired in California at a large scale. Understanding, therefore, that reuse, repurposing, and recycling are still nascent industries, it is important to emphasize that the landscape for EV EOL management is rapidly evolving, and policymaking aimed at supporting reuse, repurposing, and recycling should be iterative. Alternative technologies that reduce the need for critical materials may be developed, however the goals and intentions of reuse, repurposing and recycling in this report shall apply to all types of EV batteries. The recommendations included in this report should be revisited periodically to assess their effectiveness and evaluate whether any changes are necessary.

11. 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.

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

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

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

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.

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

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 -- The output of a specific material in usable form as a percentage of total input of that material

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

Recycling facility -- A facility which recycles lithium-ion batteries and is therefore considered a hazardous waste processor.

Recycling rate -- The percentage of batteries reaching their EOL that are recycled.

Refurbishing: “Modification of an object that is waste or a product to increase or restore its performance and/or functionality or to meet applicable technical standards or regulatory requirements, with the result of making a fully functional product to be used for a purpose that is at least the one that was originally intended” (UNEP and Panel, 2018)

Remanufacturing: “A standardized industrial process that takes place within industrial or factory settings, in which cores are restored to original as-new condition and performance or better. The remanufacturing process is in line with specific technical specifications, including engineering, quality, and testing standards, and typically yields fully warranted products. Firms that provide remanufacturing services to restore used goods to original working condition are considered producers of remanufactured goods.” (UNEP and Panel, 2018)

Repurposing -- Configuring used batteries into systems to be utilized in a different application, most commonly stationary storage. Also referred to as 2nd life or battery second use.

Reuse: Batteries from a retired vehicle are reused in another vehicle.

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.

Sorting facility -- A facility which tests and sorts LIBs based on their capability to be reused, repurposed, or remanufactured and then directs the batteries to be before being sent to either repurposing, reusing, remanufacturing or recycling.

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

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APPENDIX: ADVISORY GROUP VOTING OUTCOMES AND SURVEY RESULTS

Table A1: Voting outcomes for Dec 7, 2021 and levels of support for supporting policy proposals

Policy Proposal	In Favor	Opposed	Abstain	Percent in Favor
Identify strategies to reduce the burden of transportation	15	0	0	100%
Universal waste interpretation	15	0	0	100%
Physical Labeling Requirement	14	0	1	93%
Develop training materials	14	0	1	93%
Develop strategic collection and sorting infrastructure	14	0	1	93%
Electronic Information Exchange	13	0	2	87%
Support enforcement of unlicensed dismantling laws	13	1	1	87%
Economic incentive package provided to lithium-ion battery recyclers within California	11	1	3	73%
Expand eligibility for relevant incentive programs to include reused and repurposed batteries	10	1	4	67%
Establish a timeline for hazardous waste processing permit	9	0	6	60%
Require pre-approval to bid on EVs at auctions	9	2	4	60%
Universal Diagnostic System	8	4	3	53%
Minimum material recovery rates	7	6	2	47%
Recycled content standards	7	7	1	47%
Third-party Verification	6	7	2	40%
Design for reuse, repurposing and recycling	5	6	4	33%
Develop a reporting system for EV batteries retired from use	5	6	4	33%
Develop a reporting system for lithium-ion battery recycling recovery rates	5	5	5	33%
Economic incentive package to encourage disassembly within California	3	3	9	20%

Table A2: Full voting record of Advisory Group members. F = In Favor, O = Opposed, A = Abstain, R = Recused, X = Absent.
Legend for column titles: SA Recycling LLC: SA; Alliance for Automotive Innovation: AAI; Umicore USA: UMI; KBI: KBI; Honda Trading America: HO; CalEPA: CEPA; Ford Motor Company: FM; The Rechargeable Battery Association: PRB; Sustainable Energy Solutions: SES; Earthworks: EW; Californians Against Waste: CAW; Southern California Association of Governments: SCA; Tesla inc: TES; HHW at large: HHW; Surplus Service: SS; California Energy Commission: CEC; CalRecycle: CR; California New Car Dealers Association: CND; Department of Toxic Substances Control: DTSC

Organization	SA	AAI	UMI	KBI	HO	CEPA	FM	PRB	SES	EW	CAW	SCA	TES	HHW	SS	CEC	CR	CND	DTSC
Core exchange and vehicle backstop	F	F	F	F	F	R	F	F	F	F	F	F	A	F	F	R	R	F	R
Producer take-back with no companion legislation	F	O	F	F	O	R	O	F	F	F	F	F	F	F	O	R	R	A	R
Producer take-back with companion legislation	O	O	O	O	O	R	F	O	O	F	O	F	A	F	O	R	R	O	R
Environmental handling fee applied at the time of purchase	O	O	A	O	O	R	O	O	F	F	F	F	O	F	F	R	R	A	R

Organization	SA	AAI	UMI	KBI	HO	CEPA	FM	PRB	SES	EW	CAW	SCA	TES	HHW	SS	CEC	CR	CND	DTSC
Environmental handling fee gathered through vehicle registration fee	O	O	A	O	O	R	O	O	A	F	F	F	O	F	F	R	R	A	R
Environmental handling registration fee split between EV owner and manufacturer	O	O	O	O	O	R	O	O	F	F	F	F	O	F	O	R	R	A	R
Physical Labeling Requirement	F	F	F	F	F	R	F	F	F	F	F	A	F	F	F	R	R	F	R
Electronic Information Exchange	F	F	F	F	F	R	F	F	F	F	F	A	F	F	F	R	R	A	R
Universal Diagnostic System	F	O	A	F	O	R	O	O	F	F	F	F	A	F	F	R	R	A	R

Organization	SA	AAI	UMI	KBI	HO	CEPA	FM	PRB	SES	EW	CAW	SCA	TES	HHW	SS	CEC	CR	CND	DTSC
Economic incentive package provided to LIB recyclers within California	O	F	F	F	F	R	A	F	F	F	A	A	F	F	F	R	R	F	R
Economic incentive package to encourage disassembly within California	O	A	A	O	A	R	A	O	F	F	A	A	A	A	F	R	R	A	R
Establish a timeline for hazardous waste processing permit	F	A	A	F	F	R	A	F	F	A	A	A	F	F	F	R	R	F	R
Expand eligibility for relevant incentive programs	F	A	F	F	A	R	A	F	F	F	F	F	O	F	F	R	R	A	R
Minimum material recovery rates	O	O	F	O	O	R	F	A	F	F	F	F	O	F	O	R	R	A	R

Organization	SA	AAI	UMI	KBI	HO	CEPA	FM	PRB	SES	EW	CAW	SCA	TES	HHW	SS	CEC	CR	CND	DTSC
Design for reuse, repurposing and recycling	O	O	A	A	O	R	O	O	F	F	F	A	O	F	F	R	R	A	R
Third-party Verification	O	A	F	O	O	R	O	O	F	F	F	F	O	F	O	R	R	A	R
Support enforcement of unlicensed dismantling laws	F	F	F	F	F	R	F	F	F	F	A	F	F	F	O	R	R	F	R
Develop training materials	F	F	F	F	F	R	F	F	F	F	F	A	F	F	F	R	R	F	R
Identify strategies to reduce the burden of transportation	F	F	F	F	F	R	F	F	F	F	F	F	F	F	F	R	R	F	R
Develop strategic collection and sorting infrastructure	F	F	F	F	F	R	F	F	F	F	F	F	F	F	A	R	R	F	R
Universal waste interpretation	F	F	F	F	F	R	F	F	F	F	F	F	F	F	F	R	R	F	R

Organization	SA	AAI	UMI	KBI	HO	CEPA	FM	PRB	SES	EW	CAW	SCA	TES	HHW	SS	CEC	CR	CND	DTSC
Recycled content standards	O	O	F	F	O	R	O	O	F	F	F	F	O	F	O	R	R	A	R
Develop a reporting system for EV batteries retired from use	A	O	A	O	O	R	F	O	A	F	F	F	O	F	O	R	R	A	R
Develop a reporting system for lithium-ion battery recycling recovery rates	O	A	A	O	O	R	O	A	F	F	F	A	O	F	F	R	R	A	R
Require pre-approval to bid on EVs at auctions	F	F	F	F	F	R	F	F	A	F	A	A	O	A	O	R	R	F	R

Table A3: Survey results⁶

Policy	Strongly Oppose	Oppose	No opinion	Support with modifications	Support	Strongly support
Producer take-back (returning the battery to the auto manufacturer at end-of-life is required)	3	4	5	2	3	3
Producer take-back (returning the battery to the auto manufacturer at EOL is optional)	1	4	7	1	4	2
Core exchange and unwanted vehicle backstop proposal	1	1	7	2	7	2
Environmental handling fee used to finance an EOL management program	6	1	7	1	2	3
Added electric vehicle registration fee to finance an EOL management program	3	3	7	1	2	4
A yearly fee split between the auto manufacturer and the EV owner at vehicle registration	4	3	5	0	3	5
Define the current owner as the responsible party for EOL management	6	8	1	1	2	2
Physical labeling requirement	0	0	1	1	5	13
Electronic information exchange (i.e. QR code with online database)	0	0	2	1	10	7
Universal diagnostic system	3	2	3	0	5	7

⁶ The survey results include those from Occupational Knowledge International, which was a member of the Advisory Group until Nov. 3, 2021.

Policy	Strongly Oppose	Oppose	No opinion	Support with modifications	Support	Strongly support
SOH data made accessible to third parties without specifying the mechanism	1	2	4	5	2	4
Establish a timeline for hazardous waste processing permit	1	1	6	4	4	4
Economic incentive package provided to lithium-ion battery recyclers	2	0	3	1	8	6
Expand eligibility for relevant incentive programs to include repurposed and reused batteries	1	2	5	4	2	6
Incentivize a disassembly industry within California	2	1	6	0	6	5
Minimum material recovery rates	5	2	2	0	4	7
Third-party verification	3	1	6	1	4	5
Develop a reporting system for lithium-ion batteries retired from use / exported batteries	2	7	1	1	6	3
Develop a reporting system for lithium-ion battery recycling recovery rates	2	6	3	3	5	1
Recycled content standards	4	4	2	5	2	3
Design for repurposing, reuse, and recycling	3	2	3	1	4	7
Develop training materials to address knowledge and capacity gaps	0	1	1	1	9	8
Support enforcement of unlicensed dismantling laws	0	1	1	0	4	14

Policy	Strongly Oppose	Oppose	No opinion	Support with modifications	Support	Strongly support
Require pre-approval to bid on EVs at auctions	1	1	7	2	3	6
Interpretation of universal waste regulations	0	0	3	5	4	8
Develop strategic collection and sorting infrastructure	2	2	4	1	7	4
Identify strategies to reduce the burden of transportation	0	0	3	4	9	4

APPENDIX: PUBLIC COMMENTS

The following section includes letters from the public received during the public comment period. The title of the subsection represents the institution the letter was received from.

ALLIANCE FOR AUTOMOTIVE INNOVATION

Page	Section	Comment
5	Executive summary, Conclusion	‘Add “at the LIB’s end-of-life to the end” of the sentence’
11	1.4.3: Lithium	‘Add the following sentence: "Vehicle and battery manufacturers are setting up agreements to obtain lithium in California."'
11	1.4.2: Lithium	‘Consider modifying this sentence to "While there is currently no refining or cathode production capacity in the United States, auto manufacturers are beginning to develop partnerships to make cathode material domestically."'
13	2.1.2: Outside the original equipment manufacturer network	<p>‘This doesn't seem accurate. It seems the full vehicle would be sent to a dismantler, who would then be responsible for sending the battery to a sorting, repurposing or battery recycling facility, not a scrap metal recycler.</p> <p>Recommend replacing "scrap metal recycler" with "dismantler"’</p>
13	2.2: Reuse and Repurposing	<p>‘Recommend replacing text with "to have enough capacity to be considered in a secondary use application."</p> <p>The number is high, as the reference cited states "Our finding show that defining battery retirement at 70-80% remaining capacity is inaccurate." Some consumers will drive an EV battery at 60% capacity or lower when deciding between the expense of a new battery or new vehicle versus the range of their existing vehicle. Additionally, lower capacity batteries in the future may still meet the needs of the driver.’</p>
41	4.3.1: Opportunities and Benefits	‘delete this so the sentence reads: "A closed-loop LIB supply chain consists of used batteries sent to recycling to recover materials, which are refined and returned to the battery supply chain to manufacture the precursors and cathode materials used to manufacture batteries."'’

Page	Section	Comment
45	6.1.1: Core exchange and vehicle backstop policy	‘It's not feasible, from a timing standpoint, for the EV battery taken out of the vehicle to be properly recycled, refurbished, etc. before a replacement battery can be given. Suggest changing the text to "The vehicle OEM, battery aftermarket sales, or battery refurbisher requires assurance that the repair shop removing the battery will properly recycle, refurbish, or put it into a non-vehicle secondary use market.”’
45	6.1.1: Core exchange and vehicle backstop policy	Add a bullet for "Incentivizes design for recycling and disassembly"
46	6.1.1: Core exchange and vehicle backstop policy (disadvantages)	‘This isn't the intent of the policy, as the OEM will only be contacted for a complete vehicle, not individual batteries. Recommend deleting this, or at least changing "LIBs" to "complete vehicles"’
46	6.1.1: Core exchange and vehicle backstop policy (disadvantages)	‘Modify to "Could result in increased cost to the OEM resulting in higher prices for the consumer and negatively impact EV penetration.”’
46	6.1.1: Core exchange and vehicle backstop policy (disadvantages)	Add "and the OEM's assets are not purchased by another entity"
47	6.1.2: Producer takeback	‘Modify to "Increased cost to manufacturer resulting in higher prices to the consumer and negatively impact EV penetration.”’

ARGONNE NATIONAL LAB

Dear CalEPA,

The Advisory Group Report is excellent, thoughtful, and thorough. It clearly explains some important subtleties often overlooked by less astute commentators. I just have a few relatively minor comments, in no particular order.

1. I question the cited operational capacity of hydrometallurgical recycling in North America (p.20). It is my understanding that several of the facilities mentioned produce black mass and do not perform the hydrometallurgical step (or not yet). Links 63, 64, 65 didn't work for me. I could not find supporting information for those numbers on the company sites.
2. Transportation costs could be reduced by preprocessing EOL batteries locally to make them non-hazardous, either by disassembly/shredding, or by more elegant techniques under development.
3. The net cost of recycling can also be reduced through process R&D, such as that ReCell is doing.
4. It would be more accurate to say "the ReCell Center led by Argonne National Laboratory is leading research and development," since much work is also being done at our partners' facilities. (p.20)
5. Exports of used EVs and precursors were mentioned; it should be clear that used batteries and black mass are also leaking out via export. The proposed regulations require that the EOL material be destined for reuse or recycling, but there is no requirement that this be in the US. I'm guessing that was considered and vetoed by some board members.
6. The document does not consider manufacturing scrap, probably by design, but scrap is also being exported in large quantities, and may not be getting recycled in the most efficient ways. Since some scrap is rejected cells, it might be worth including with EOL batteries.

Great job; the report will be a good reference and contribute to sound policy decisions.

Sincerely,

Linda Gaines, Ph.D.

AUTOMOTIVE RECYCLERS ASSOCIATION

To Whom It May Concern at the California Environmental Protection Agency and Lithium-ion Car Battery Recycling Advisory Group:

The Automotive Recyclers Association (ARA) and the California Auto Dismantlers Recyclers Alliance (CADRA) appreciates the opportunity to submit the following comments for consideration by the California Environmental Protection Agency (CalEPA) and the Lithium-ion Car Battery Recycling Group (Advisory Group) to assist in the development of policy recommendations that will help ensure that as close to 100 percent of lithium-ion vehicle batteries in California are reused or recycled at their end-of-life.⁷ ARA and CADRA encourages CalEPA and the Advisory Group to incorporate the following recommendations and policies into their final report⁸ to the California legislature.

It must be noted that as part of the Advisory Group's knowledge-building period throughout 2019-2020,⁹ ARA was invited by the Advisory Group to give a presentation on electric vehicle dismantling.¹⁰ Also, automotive recyclers are defined as automobile dismantlers under Cal. Veh. Code § 220.

The automotive recycling industry has long played a pivotal role in the American supply chain and supported the U.S. war efforts during World War I and World War II. During both World Wars, automotive recyclers provided U.S. manufacturers with readily available scrap metal from motor vehicles and also served as a primary source for replacement motor vehicle parts. Twenty-one years later, World War II broke out and automotive recyclers were once again called upon to provide manufacturers with readily available scrap metal and replacement vehicle parts.¹¹ Not only did automotive recyclers provide the U.S. war effort with much needed resources, but automotive recyclers provided much needed replacement vehicle parts to citizens at the home front. The automotive recycling industry has long been at the forefront of reusing, repurposing, and recycling motor vehicles.

Since 1943, ARA has represented professional automotive recyclers. Professional automotive recycling facilities play an important role in the vehicle repair market by providing vehicle owners with cost-effective alternatives to the more expensive new original equipment manufacturer (OEM) replacement parts. Professional automotive recyclers supply (ROE)-Recycled Original Equipment® motor vehicle replacement parts to consumers around the world. In many cases, automotive recyclers are the only source for replacement vehicle parts.

In addition to the critical role professional automotive recyclers play in the automotive supply chain and replacement parts market, professional automotive recyclers play a valuable role in the efficient and environmentally friendly recycling of End-of-Life (EOL) vehicles. Professional automotive recyclers are the largest collective owners of EOL vehicles and are subsequently the

⁷ Cal. Pub. Resources Code § 42450.5(c).

⁸ *Id.*

⁹ Lithium-ion Car Battery Recycling Advisory Group, Draft Report 12/13/2021, 1 (December 13, 2021). <https://calepa.ca.gov/wp-content/uploads/sites/6/2021/12/Final-Draft-Policy-Recommendations-Lithium-ion-Car-Battery-Recycling-Advisory-Group-AB-2832-As-of-12-13-21-for-public-comment.pdf>

¹⁰ *Id.* at 26.

¹¹ Automotive Recyclers of Minnesota, Remember When. <http://www.autorecyclersmn.net/remember.html>.

largest generator of source material for scrap metal processors.¹² *Automotive recycling preserves natural resources, reduces the demand for scarce landfill space, and plays an important role in reducing air and water pollution.* A study conducted by the Worcester Polytechnic Institute in Massachusetts found that automotive recyclers in that state help to drive a circular economy in auto manufacturing and that the automotive recycling industry has a negative carbon footprint.¹³

I. Summary

ARA and CADRA commends the California State Legislature’s passage of Assembly Bill 2832, which established the Advisory Group for the purpose of developing policy recommendations “aimed at ensuring that as close to 100 percent [of] possible... lithium-ion vehicle batteries in the state are reused or recycled at end-of-life in a safe and cost-effective manner.”¹⁴ While Lithium ion Battery (LIB) powered Electric Vehicles (EVs) are only a small percentage of the total vehicle fleet in California and nationwide, as these EVs become a larger percentage of the total vehicle fleet, automobile dismantlers will become the largest collective owners of EOL electric vehicles and lithium-ion batteries. Automobile dismantlers are already the largest collective owners of EOL internal combustion engine vehicles and are the primary facilitator for reusing and recycling EOL vehicles. *Therefore, it stands to reason that automobile dismantlers will be a key party within the EV and LIB lifecycle and will be a primary facilitator for the reuse, repurposing, and recycling of LIBs.*

ARA and CADRA recommends that the Advisory Group include in its final report the following recommendations: (1) recognize the importance of automobile dismantlers and their ability to assist California in meeting its reuse and recycling goals for LIBs; (2) include in its final report a hierarchy describing the preferred highest and best use for LIBs so that it is clear how California can successfully decarbonize transportation and mitigate climate change; (3) CalEPA and the Advisory Group should consider a policy proposal that combines the Core Exchange and Vehicle Backstop policy¹⁵ and the Producer Take-back policy;¹⁶ and (4) ARA and CADRA respectfully requests that should the Advisory Group reconvene, ARA and CADRA be considered as a stakeholder within the group.

II. Automobile dismantlers are essential in assisting California reach its goal for having 100 percent of lithium ion batteries derived from end-of-life vehicles reused and recycled.

For California to achieve its goal of reaching 100 percent recycling or reuse of LIBs, the Legislature must understand the special role of automobile dismantlers in processing EOL vehicles. Professional automobile dismantlers are a first line of defense for protecting the environment. As soon as professional automobile dismantlers receive vehicles, trained

¹² 20 Auto Recycling Facts and Figures, <https://www.thebalancesmb.com/auto-recycling-facts-and-figures-2877933>.

¹³ Muhammad Siddiq et al., Assessing the Environmental Impact of Automotive Recyclers of Massachusetts, i, (April 27, 2017). <http://armmass.com/wp-content/uploads/2017/10/Full-Study.pdf>.

¹⁴ Dahle, B. Assembly Bill 2832: Recycling: Lithium-Ion Vehicle Batteries: Advisory Group; California Assembly, 2018. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB2832.

¹⁵ Lithium-ion Car Battery Recycling Advisory Group, Draft Report 12/13/2021, 44–45, (December 13, 2021). <https://calepa.ca.gov/wp-content/uploads/sites/6/2021/12/Final-Draft-Policy-Recommendations-Lithium-ion-Car-Battery-Recycling-Advisory-Group-AB-2832-As-of-12-13-21-for-public-comment.pdf>.

¹⁶ *Id.* at 46-47.

staff remove fluids and conduct a thorough depollution process on each vehicle. Depollution processes are conducted in strict compliance with federal, state, and local laws and regulations.

Automobile dismantlers provide cost-effective solutions for vehicle repairs by providing vehicle owners and vehicle repairers with (ROE)-Recycled Original Equipment® automotive parts. After vehicles have been processed and (ROE)-Recycled Original Equipment® parts have been extracted, the remaining vehicle hulk is crushed and sent to a facility for shredding and metal reclamation. At the shredder, metals such as steel, aluminum, and eventually copper are broken down and sent to mills to be recycled. These recycled materials are eventually reused in manufacturing and help minimize the need for mining and the resulting pollution including greenhouse gases. For example, the automotive recycling industry provides enough steel to produce roughly 13 million new vehicles annually.¹⁷ Automobile dismantlers are a critical component in creating a circular and environmentally friendly economy.

As the primary recipient and purchaser of EOL electric vehicles, automobile dismantlers are in a position where they possess enormous quantities of readily available EV LIBs. These electric vehicle batteries can be put to their highest and best use by serving as replacements for vehicles with damaged batteries. Automobile dismantlers are essential in assisting California meet its reuse and recycling goals for LIBs because automobile dismantlers are: (1) the largest collective owners of EOL vehicles; (2) becoming familiar with emerging technology related to dismantling high voltage vehicles; (3) have existing logistical infrastructure throughout the state of California that will assist in reducing LIB transportation costs; and (4) experts in restoring an EOL vehicle and its components to its highest and best use.

a. Automobile dismantlers are the largest collective owners of end-of-life vehicles.

According to the Argonne National Laboratory, between 10 and 15 million EOL vehicles are retired from service each year and enter the domestic recycling infrastructure.¹⁸ Out of the 10 to 15 million EOL vehicles retired each year, a substantial majority of those vehicles go to automobile dismantlers. For example, ARA's largest member company processes over 800,000 EOL vehicles annually.¹⁹ Automobile dismantlers are the largest collective owners of EOL vehicles and will be the largest industry coming into possession of EOL electric vehicles and consequently LIBs. As an industry, automobile dismantlers are will be the main facilitator and sorting mechanism for LIBs to be reused and recycled.

i. Automobile dismantlers acquire end-of-life vehicles from many sources besides insurance auctions like Copart and IAA.

Automobile dismantlers in California (and nationally) acquire EOL vehicles from many sources besides Copart and IAA. Consequently, automobile dismantlers have a broadly established network from which they acquire inventory in the form of EOL vehicles, which may contain LIBs. Automobile dismantlers commonly acquire EOL vehicles from insurance auctions,

¹⁷ 20 Auto Recycling Facts and Figures, <https://www.thebalancesmb.com/auto-recycling-facts-and-figures-2877933>.

¹⁸ B.J. Jody et al., End-of-Life Vehicle Recycling: State of the Art of Resource Recovery from Shredder Residue, Argonne National Laboratory, Energy Systems Division, 1, (September 2010). <https://publications.anl.gov/anlpubs/2011/02/69114.pdf>.

¹⁹ LKQ Corporation, 2020 Sustainability Report, 7, https://s24.q4cdn.com/628382107/files/doc_downloads/4833_LKQ-Sustainability-Report-040921-v2.pdf.

charities, state and municipal abandoned vehicle programs, tow operators, and private individuals. Therefore, not only are automobile dismantlers the most logical party to dismantle and process EOL electric vehicles but they will be the central party collecting LIBs from EVs because of their established networks. Automobile dismantlers' existing acquisition networks should be leveraged so that LIBs are not "unsafely accumulated, illegally abandoned, or improperly managed domestically and abroad."²⁰

To ensure that EOL electric vehicles are safely collected and result in LIBs being reused or recycled, EOL electric vehicles need to be processed by automobile dismantlers that are licensed and equipped to safely handle, remove, and process LIBs. ARA and CADRA recommends enacting policies limiting the processing of EOL electric vehicles to licensed dismantlers who have been trained and certified to safely handle electric vehicles containing high voltage batteries. ARA and CADRA applauds the Advisory Group for recommending that dismantlers become pre approved to purchase EVs at automotive auctions.²¹ These policies will help promote reuse and recycling of EV batteries and should be expanded to take into account EOL electric vehicles sold to and through charities, abandoned vehicle programs, and tow operators when acquiring and selling EOL electric vehicles. The Advisory Group should consider recommending that vehicle identification numbers be applied to EV battery units to reduce theft, which will encourage safe processing of EV batteries.

b. The Automotive Recyclers Association has been educating automobile dismantlers on the emerging technology related to dismantling electric and hybrid vehicles.

ARA and CADRA recognizes that while "dealership, repair, dismantling, and scrap metal industries are well-established... the facilities for collecting, sorting, and potentially disassembling (from pack to module) large format LIBs... are emergent as EVs are only beginning to reach end of life at significant scale."²² Even though the infrastructure for managing EOL vehicle batteries is in its infancy, automobile dismantlers have been developing resources and training that will allow for the safe removal, handling, and reuse of EV batteries. ARA has been working to develop partnerships and relationships within the entire EV battery recycling space over the last several years.

In the absence of a formalized training program provided by vehicle manufacturers, ARA has endeavored to collect safety information to create a training program that is freely accessible to all automobile dismantlers. ARA and its certification committee has been helping automobile dismantlers learn more about processing EVs through the publication of training modules and an Electric and Hybrid Vehicle Technology Training Guide (Appendix). ARA has also developed and provides to automobile dismantlers an EV Readiness Checklist,²³ Hybrid and Electric High Voltage Vehicle Handling and Dismantling Protocol,²⁴ and an EV Battery Data

²⁰ Lithium-ion Car Battery Recycling Advisory Group, Draft Report 12/13/2021, 43, (December 13, 2021). <https://calepa.ca.gov/wp-content/uploads/sites/6/2021/12/Final-Draft-Policy-Recommendations-Lithium-ion-Car-Battery-Recycling-Advisory-Group-AB-2832-As-of-12-13-21-for-public-comment.pdf>.

²¹ *Id.* at 55.

²² *Id.* at 13.

²³ Automotive Recyclers Association University, EV Readiness Checklist, <https://img1.wsimg.com/blobby/go/ce5f5a84-ace1-49a2-8823-f959ad0cdb84/downloads/EV%20Readiness%20CHECKLIST.pdf?ver=1643919686139>.

²⁴ Automotive Recyclers Association University, Hybrid and Electric High Voltage Vehicle Handling and Dismantling Protocol, <https://img1.wsimg.com/blobby/go/ce5f5a84-ace1-49a2-8823->

Base.²⁵ The EV Battery Data Base contains access to information for 1650 models from 65 manufacturers specific to over 7,700 different high voltage batteries.

ARA's resources on EV processing are designed to help automobile dismantlers learn about electric and hybrid vehicles and the issues and safety risks associated with processing them. ARA's Electric and Hybrid Vehicle Technology Guide does not replace the need for proper training and does not serve as a substitute for needing to acquire manufacturer's information prior to carrying out EV processing. In addition to resources developed by the automobile dismantling industry, vehicle manufacturers and battery manufacturers will have to support LIB reuse and recycling efforts through transparent data practices. ***ARA encourages manufacturers and other stakeholders to contribute to this training and certification program that provides necessary information for the proper handling and storage of LIBs.***

c. Automobile dismantlers have existing logistical infrastructure that will assist in reducing LIB transportation costs.

Despite EV batteries and their market for reuse and recycling being in its infancy, automobile dismantlers have existing capacity to assist in reducing the transportation costs associated with moving LIBs. As the Advisory Group correctly identifies, the cost of transportation for LIBs is currently a major barrier disincentivizing the reuse and recycling of EOL batteries.²⁶ The Advisory Group found that current transportation costs contribute to 40-60 percent of the overall cost of recycling.²⁷ The high cost of shipping LIBs are a result of the current regulatory environment where the Department of Transportation classifies LIB shipments as Class 9 ("Miscellaneous) hazardous material.²⁸ In the coming years, as LIB powered vehicles are increasingly retired, the demand and need to cost-effectively transport LIBs will become necessary and will likely result in a reduction in transportation costs due to free market principles.

Experts have identified that the best way to reduce transportation costs is to minimize transport distance.²⁹ Automobile dismantlers have an existing network that will minimize the distance EV batteries will need to be transported, which will make reuse and recycling more financially viable. Unlike a theoretical model that would only permit a few select entities to take possession of EOL electric vehicles, professional automobile dismantlers can already be found in every city. Many leading automobile dismantlers are currently participating in regional trading groups with well established transportation hubs and routes. When electric vehicles reach their EOL,

[f959ad0cdb84/downloads/Hybrid%20and%20Electric%20High%20Voltage%20Vehicle%20Handl.pdf?ver=1643919686139](https://www.arauniversity.org/resources/ev-battery-data-base/).

²⁵ Automotive Recyclers Association University, EV Battery Database, <https://arauniversity.org/resources/ev-battery-data-base/>.

²⁶ Lithium-ion Car Battery Recycling Advisory Group, Draft Report 12/13/2021, 30-31, (December 13, 2021). <https://calepa.ca.gov/wp-content/uploads/sites/6/2021/12/Final-Draft-Policy-Recommendations-Lithium-ion-Car-Battery-Recycling-Advisory-Group-AB-2832-As-of-12-13-21-for-public-comment.pdf>.

²⁷ *Id.*

²⁸ Slattery, M.; Dunn, J.; Kendall, A. Transportation of Electric Vehicle Lithium-Ion Batteries at End-of-Life: A Literature Review. *Resour. Conserv. Recycl.* 2021. <https://www.sciencedirect.com/science/article/pii/S0921344921003645>.

²⁹ *Id.*

transportation costs can be greatly reduced due to the fact that an automobile dismantler is geographically close by.

d. Automobile dismantlers are experts in restoring an end-of-life vehicle and its components to its highest and best use.

Every year, automobile dismantlers in California process an estimated 840,000 of approximately 1.2 million vehicles that reach EOL each year.³⁰ Automobile dismantlers are the only industry that takes millions of vehicles each year and determine what makes the most economic sense for each vehicle. This analysis identifies how to put EOL vehicle parts to their highest and best use whether that part is best used as a replacement part for a motor vehicle repair or if it has no economic value.

III. The Lithium-ion Car Battery Recycling Advisory Group should create a hierarchy describing the preferred highest and best use for lithium-ion batteries so that it is clear how California can successfully decarbonize transportation and mitigate climate change.

The Advisory Group correctly identifies that EOL vehicle batteries should be reused, repurposed, and recycled. By reusing, repurposing, and recycling EOL vehicle batteries, California can reduce the carbon footprint associated with the manufacture of LIBs and create a more circular economy.

To best assist the California Legislature with its work in creating policy that will bring the state close to 100 percent of LIBs reused or recycled, the Advisory Group should clearly state (in order of priority) the most preferred journey an EOL battery takes. ***If EOL vehicle batteries are going to be reused and repurposed, there needs to be sufficient data access to battery information.*** The Advisory Group correctly identifies several policy proposals that are necessary to support EOL battery reuse. The most important policy proposals are physical labeling requirements, digital identifiers, and universal diagnostic systems.³¹ Without access to battery information, the only EOL conclusion for EV batteries will be shredding and reclamation of materials.

The Advisory Group should also consider recommending that EV batteries be marked with a vehicle identification number which will promote reuse by tying a battery unit to a specific make and model vehicle. This will support both the labeling and digital identifier policies.

In order of best environmental outcome to least, LIBs from EOL vehicles ideally will be: (1) reused as originally intended and unmodified; (2) repaired or reconditioned for original reuse; (3) repurposed for secondary applications; (4) recovered for raw materials for manufacturing; and (5) disposal. By knowing the preferred highest and best use for LIBs, policymakers will be able to make better decisions that will lead to a substantial majority of LIBs being reused or recycled.

a. Reused as originally intended and unmodified

As the primary recipient and purchaser of end-of-life electric vehicles, automobile dismantlers are in a position where they possess enormous quantities of readily available electric vehicle batteries. These electric vehicle batteries can be put to their highest and best use by serving as

³⁰ Lithium-ion Car Battery Recycling Advisory Group, Draft Report 12/13/2021, 31, (December 13, 2021). <https://calepa.ca.gov/wp-content/uploads/sites/6/2021/12/Final-Draft-Policy-Recommendations-Lithium-ion-Car-Battery-Recycling-Advisory-Group-AB-2832-As-of-12-13-21-for-public-comment.pdf>.

³¹ *Id.* at 47-48.

replacements for vehicles with damaged batteries. The need for replacement electric vehicle batteries will become ever more important as the global supply chain sees increased demand for electric vehicle batteries and the materials needed in their manufacture. *Therefore, automobile dismantlers have the largest readily available supply of electric vehicle batteries that can be used as vehicle replacement parts, which can help insulate the U.S. from market volatility as it relates to the supply of electric vehicle batteries, their materials and components.*

The best and highest use for an EOL electric vehicle battery is for the battery to be unmodified and to be used as a replacement part in vehicle repairs. This scenario requires the lowest level of energy output and also reduces the need for newly manufactured battery units while keeping EOL batteries out of landfill. The Advisory Group's policies on physical labeling requirements, digital identifiers, and universal diagnostic systems are all necessary if EOL batteries are to be reused.³²

b. Repaired and reconditioned for original reuse

The second-best use for EV batteries is to reuse them as a vehicle replacement part after being repaired or reconditioned. In cases where a battery pack's modules and/or cells need to be repaired or reconditioned prior to reuse in a vehicle, access to battery information is required. Access to battery information must exist if EOL batteries are to be repaired and reconditioned for its original reuse. Depending upon the extent of the cost to restore the battery to full functionality, either repair for original use or repurposing for secondary applications may be a best-case alternative for reuse.

c. Repurposed for secondary applications

Automobile dismantlers are also a primary provider of electric vehicle batteries for applications other than vehicle repairs. The American management consulting firm, McKinsey & Company defines *second-life batteries as electric vehicle batteries that no longer meet electric vehicle performance standards but that can be reused in stationary energy storage applications such as maintaining a utility's power reliability at low cost.*³³ Electric vehicle batteries that are no longer effective enough to serve as vehicle replacement parts can still serve as strategically important power storage devices helping to more effectively power the U.S.'s critical infrastructure.

d. Recovered for raw materials for manufacturing

Lastly, as the largest owner of readily available electric vehicle batteries, automobile dismantlers are a critical source of supply for the metal recycling industry. According to the Institute of Scrap Recycling Industries, Inc., scrap metal recyclers shred approximately 365,000 metric tons of automobile scrap per day.⁷ Therefore, the scrap metal recycling industry heavily relies on the automobile dismantling industry to supply end-of-life vehicles for processing into raw materials. As the U.S. becomes ever more reliant on electric vehicle batteries and the critical minerals contained in lithium-ion batteries, the U.S. supply chain will depend upon the reclamation of the raw materials contained in electric vehicle batteries that cannot be repurposed. Currently,

³² *Id.* at 47-48.

³³ Engel, Hertzke, Siccardo, Second-Life EV Batteries: The Newest Value Pool in Energy Storage, McKinsey & Company (April 30, 2019). <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/second-life-ev-batteries-the-newest-value-pool-in-energy-storage>.

traditional metal shredding facilities are unequipped to handle and recover the volatile chemical components of EV batteries and LIBs.

e. Disposal

In cases where EOL electric vehicle batteries have no value to be reused, repurposed, or recycled, there needs to be an outlet for these batteries to be collected and recycled. Efforts should be taken to ensure that these batteries do not end up in landfill and that the critical materials are recovered.

IV. The Advisory Group should consider a policy proposal that combines the benefits of the Core Exchange and Vehicle Backstop policy and the safeguard provided by the Producer Take-back policy.

If California hopes to come close to its goal of reaching 100 percent of possible LIBs being reused or recycled, *CalEPA and the Advisory Group should consider a policy proposal that combines the Core Exchange and Vehicle Backstop policy³⁴ and the Producer Take-back policy.³⁵* This proposal would take all the benefits of the Core Exchange and Vehicle Backstop policy, where existing industry practice is applied to EOL batteries but would protect the public and the environment from batteries being abandoned. In almost all cases, EV batteries should be reused, repurposed, and recycled. The Core Exchange and Vehicle Backstop Policy will encourage EOL vehicle batteries to be put to their highest and best use. However, there will be limited situations where an EOL vehicle battery will have no economic value, which will create the potential for that battery to fall out of the ordinary established recycling industry. Battery manufacturers and vehicle manufacturers need to provide a limited program that ensures that EOL vehicle batteries with no value can be collected and safely disposed of – not unlike the National Vehicle Mercury Switch Recovery Program.³⁶ By adding a limited producer take-back policy to the Core Exchange and Vehicle Backstop policy, battery manufacturers and vehicle manufacturers will be incentivized to manufacture batteries that can be reused or recycled.

V. The Automotive Recyclers Association and the California Auto Dismantlers and Recyclers Association respectfully requests that should the Advisory Group reconvene, that the Automotive Recyclers Association or one of its affiliates be considered as a stakeholder.

As the voice of the professional automotive recycling industry since 1943, ARA and CADRA thanks the Advisory Group for allowing ARA to provide input and would like to be considered as a stakeholder on any future advisory group meetings. AB 2832, which was the law responsible for the creation of the Advisory Group, requires that “an automobile dismantler or an organization that represents one or more automobile dismantlers” be appointed to the advisory group.³⁷ ARA and CADRA believes that it is important that the automobile dismantling industry

³⁴ Lithium-ion Car Battery Recycling Advisory Group, Draft Report 12/13/2021, 44–45, (December 13, 2021). <https://calepa.ca.gov/wp-content/uploads/sites/6/2021/12/Final-Draft-Policy-Recommendations-Lithium-ion-Car-Battery-Recycling-Advisory-Group-AB-2832-As-of-12-13-21-for-public-comment.pdf>.

³⁵ *Id.* at 46-47.

³⁶ Memorandum of Understanding to Extend the National Vehicle Mercury Switch Recovery Program, December 29, 2017. <https://www.epa.gov/sites/default/files/2018-11/documents/signedmercuryswitchprogmou11-15-2018.pdf>.

³⁷ Cal. Pub. Resources Code § 42450.5(a)(7).

representative be actively engaged in acquiring vehicles for the purpose of dismantling vehicles and selling integral parts and components to be sold as used motor vehicle parts³⁸ be appointed to the Advisory Group.

VI. Conclusion

As the voice of the professional automotive recycling industry, the Automotive Recyclers Association along with the California Auto Dismantlers Recyclers Alliance appreciates the opportunity to submit these comments concerning the Advisory Group's draft report on lithium ion battery recycling. We would be happy to participate on any future Advisory Group discussions. Please feel free to call or e-mail if you have any questions, or if you would like any additional information concerning the issues raised in these comments.

Sincerely,

Sandy Blalock

³⁸ Cal. Veh. Code § 220(a).

B2U

- I wanted to check if the team assembling the final version of the report felt that a picture of B2U's large scale demonstration project can be included in the final report to further highlight that repurposing for stationary storage, while a "relatively new phenomena, is being demonstrated to be commercially viable and should therefore be a focus of policy recommendations?
- It's important for the report to highlight that repurposing is ready to scale. Table 1 and Figure 2 in the current draft (see excerpt below) don't necessarily convey that message.

BASEL ACTION NETWORK

Thank you for this opportunity to provide public comments on the Lithium-ion Car Battery Recycling Advisory Group draft report. We commend the Advisory Group on a well-written report that takes an in-depth look into this important and complex topic.

Our comments today highlight the need for a re-vote by the Advisory Group in favor of recommending two important policy proposals that earlier did not find majority support. Our request is made particularly in light of the mandate to the Advisory Group as stated in California Assembly Bill 2832 (AB2832) to “submit policy recommendations to the Legislature aimed at ensuring that as close to 100% as possible of lithium-ion batteries in the state are reused or recycled at end-of-life in a safe and cost-effective manner.”

Finally, we also suggest inclusion of an additional issue to be recommended for further study.

1. Design for Repurposing, Reuse, and Recycling, Disassembly policy proposal. Without OEM design for recycling, such as ease of removal, disassembly and sorting of battery packs, the recycling of EV car batteries will be less effective and moreover more expensive and thus less likely to take place at all. It is widely recognized that the gap between design and recycling is one of the largest impediments to enhancing recycling rates and preventing harmful contamination downstream. The success of a circular economy begins with recognizing that products must be designed to be circular. It is thus inexplicable how this proposal could not be included in a set of recommendations to approach 100% recycling. Since the Advisory Group was tasked to provide policy proposals to advance the interests of recycling and reuse, we would hope that the Advisory Group will reconsider its vote. Perhaps some re-wording of this policy proposal will allow those who were uncomfortable, or did not understand the fundamental need for such a policy, to reconsider and a re-vote taken.
2. Third-Party Verification policy proposal. BAN recommends the Advisory Committee support this policy proposal because, in the words of the report, “there needs to be some way to guarantee high-quality environmental performance (i.e., emissions control) and worker safety.” Given the potential dangers of Li-ion battery recycling and repurposing, especially if batteries are exported abroad to avoid the higher costs of proper recycling, the additional costs of a third-party verification program including downstream tracking mechanisms are both necessary and merited. Currently, there are no certifications specifically addressing performance requirements for battery recyclers, but these could be easily added to existing e-waste Recycling Certifications. The e-Stewards Standard currently operated and owned by BAN is investigating this possibility as we speak. Well run, verified Certifications have already proven themselves as a valuable tool to achieve both legal compliance as well as preventing harmful emissions and other liabilities.
3. Export of Li-ion EV car batteries. While the draft report does touch on export and the possibility that batteries may end up in countries without infrastructure to recycle them safely, there is no policy proposal that addresses prevention of this outcome. We strongly suggest that the matter of export be included in the recommendations for further research. BAN, as the US organization exclusively working on the issue of transboundary movements of wastes, volunteers to assist in drafting this recommendation.

Thank you for your thoughtful consideration of our comments.

Sincerely,
Jim Puckett

CALL2RECYCLE

Page	Section	Comment
2	Executive summary: Background	“End-of-vehicle life. EOL LIB implies any Lithium ion battery, however we must be clear end-of-vehicle life batteries are the ones with the options stated next.”
2	Executive summary: Background	"Remanufactured, repurposed, resold as is, recycled,"
2	Executive summary: Background	"This is probably what was written at that time, however its too narrow for what really will happen."
2	Executive summary: Background	"In all other instances, it’s just battery; however, here, LIB is used – would be consistent."
2	Executive summary: Background	<p>Comment on ‘at no cost to the consumer’:</p> <p>"This is not realistic. It may not be a ‘visible’ cost, however the manufacturer must recoup the cost of recycling and build this into the price of the vehicle."</p> <p>"Agreed. Whether the obligated party (i.e. auto manufacturer) decides to cover the entire cost, pass the cost to the consumer in the price of the vehicle, or make it visible, should be left to the discretion of the obligated party. "</p>
3	Executive summary: Supporting policy proposals	"Did the advisory group discuss how the REPAIR Act, if passed, would impact (i) and (ii)?"
3	Executive summary: Supporting policy proposals	Table E1 comment on labelling : "While this may be the end goal, the labeling benefits would not be realized for years to come. Since many EV batteries are already manufactured, in-use, or reaching its end of life, there would need to be an interim strategy to educate on how to identify a battery chemistry in the absence of harmonized labeling. "
3	Executive summary: Supporting policy proposals	Table E1 comment on UDS: "This would not be executable. One common diagnostic tool is limiting and not even usable. Would remove innovation. We know of 4 different diagnostic tools already in development, each with its own intended use and benefit. "

Page	Section	Comment
4	Executive summary: Supporting policy proposals	Table E1 comment on requiring pre-approval to auctions: "For what purpose and benefit? Remember all cars will become EVs... in essence we add a layer of work which is increased costs that eventually are passed to drivers."
5	Executive summary: conclusions	"Per note above...while there may be no cost to the consumer at the battery's EOL, we know that likely the recycling costs will be passed along to the consumer and embedded in the price of the vehicle. So, when talking about 'no cost to the consumer', language will be important."
9	1.3: Battery Technology	"Why no discussion of NiMH chemistry used in hybrids? This is the majority of batteries in market today and with auto recyclers."
16	2.3.1: Recycling Industry Landscape	"Interco is missing from this list. Also missing are NiMH recyclers Inmetco and RCI" "Note: Battery Resourcers has changed their name"
30	5.1.1: Barriers to safe and efficient reverse logistics	"Many are accumulating onsite as auto recyclers look for buyers, not because there is no clear directive. EV batteries do sell, particularly Nissan Leafs, Teslas, Toyota Prius, and some GM. The ones that sit for a while have less demand. On average there are about 10 hybrid and lithium EV batteries at an auto recycler at any given time, with the highest number we have seen at 50"
32	5.1.1: Barriers to safe and efficient reverse logistics	Re: Condition of battery: "This is not needed by everyone and should not be mandated as part of an end-of-life program. What is needed is basic battery information that is on the label. It is true now the SOH helps the holder make decisions as to where to send the battery, however that is a choice of the holder."
32	5.1.1: Barriers to safe and efficient reverse logistics	Re: Information about how to safely handle batteries: "As mentioned above – will this be addressed if the REPAIR act moves forward?"
33	5.1.2: Opportunities and benefits	Re: reduced transportation: "Yes. Can also be even more specific by saying the regulation should not mandate what type of remanufacturing, repurposing, or recycling... this is up to the holder and the buyer to decide. This will allow for batteries to travel shorter distances"

Page	Section	Comment
33	5.1.2: Opportunities and benefits	<p>Re: increased collection rates: “Maybe rephrase: Reducing the cost of transportation will help increase the collection rate and thus the number of batteries recycled.</p> <p>There should be not collection rate target set. If one is set we risk forcing good batteries to recycling prematurely, which will have the effect of increasing the price of vehicles.</p> <p>The average life of an EV battery is 16 years for Circular Energy.”</p>
35	5.2.1: Barriers to reuse and repurposing	<p>“The repurposer will need to create a diagnostic tool that will allow them to evaluate the battery they are considering purchasing.”</p> <p>“The BMS is a proprietary piece of technology and should not be accessible without OEM’s permission. Instead consider creating a battery health certificate template to which the seller produces in a report format.</p>
35	5.2.1: Barriers to reuse and repurposing	<p>“In the same way that vehicle engines are not the same, the batteries packs and software are not the same. That is what allows many versions of vehicles, each with its own market segment. Standardization will stop innovation and that will result in a higher cost per vehicle with not as long battery life.”</p>
43	6.1: Policies defining responsibility for EOL management	<p>“Clarify that 1st life ends when a transaction occurs and/or transfer of battery occurs between OEM and repurposer. 2nd life begins and is defined as a new product once again, with all the same regulations applying to 1st owner now applying to 2nd owner.”</p>
43	6.1: Policies defining responsibility for EOL management	<p>“Some vehicles are exported instead of recycling. Need to allow for this to continue. Further its not about recycling as noted above, it may include repurposing.”</p>
46	6.1.2: Producer take-back	<p>“Or repurposing or resale as is”</p>
50	6.2.1: Access to battery information	<p>Re: Universal Diagnostic System: “This is not a good idea. OEMs spend millions on proprietary software and battery information. Suggest instead to have a mechanism that allows for a battery health report to be created.”</p>

Page	Section	Comment
55	6.2.3: Reverse logistics	<p>Re: require pre-approval to bid on electric vehicles at auctions: “Recommend removing this as it will add a layer of cost and complexity that adds no value. All vehicles will be EVs hence what is benefit of knowing who is bidding on them? Everyone will bid and all cars will be sold and purchased.</p> <p>If tracking is the desire there are better methods of tracking batteries than to know what went to auction and was purchased by who. (we must remember the battery is lost again once the auto recycler sells it)”</p>
66	10: Areas of future research	<p>Re: recycling performance targets: “Recycling recovery rates will force batteries to travel further distances which will have a negative carbon footprint. The policy should allow for the battery holder to decide where to send the batteries.”</p>

COBALT INSTITUTE

Dear Mr. Omer:

The Cobalt Institute represents over 75% of global cobalt production and processing. It is a non-profit trade association composed of producers, users, recyclers, and traders of cobalt. We promote the sustainable and responsible production and use of cobalt in all its forms.

Cobalt is essential for making today's high performing rechargeable lithium-ion batteries. It is used in electric vehicles, stationary energy storage applications like load-balancing of renewable electricity, and in modern portable electronic devices. Batteries comprise over half of all cobalt uses and the total volume of cobalt-containing batteries is expected to continue growing as the green economy expands. Cobalt is part of vitamin B12, an important nutrient in animal feed, and is also used in medical devices, high-performance tools for machining of metal parts, and superalloys in machines like jet turbines, where high-temperature strength is critical.

1. Responsible sourcing

About 70% of all cobalt mined today comes from the Democratic Republic of the Congo (DRC). Globally cobalt is typically a by-product of either copper (60%) or nickel mining (38%), with only 2% of cobalt being mined as the primary product. In the DRC it is found alongside copper in the so-called "copperbelt".

The majority (80-90%) of cobalt coming from the DRC "copperbelt" is mined by large-scale commercial mining companies in controlled conditions using modern technologies and a trained and properly protected workforce. The balance is sourced from the "artisanal and small-scale mining" (ASM) sector. ASM mining is informal and often involves local people mining valuable minerals of their own volition, using basic hand tools in both unsupervised and supervised work environments.

ASM mining is inexorably linked to poverty in the region. While wages are low compared to the West, they are comparatively high in this part of the world. This is why so many people participate in this form of mining. ASM provides jobs in a region where they would otherwise not exist and provides the money needed to pay for education, which is not free in the DRC. Consequently, a rush to ban ASM outright would result in severe unintended consequences. However, the industry recognizes that steps must be taken to prevent illegal child labor and hazardous or otherwise unfair working conditions in the ASM sector.

Accordingly, the cobalt industry is playing an active role in supporting the formalisation of artisanal mining. In the last year, the Entreprise Générale du Cobalt (EGC) has taken on the task of purchasing the majority of artisanally mined cobalt, partly to ensure it is being responsibly sourced. Industry is also investing in initiatives and projects that support the development of responsible ASM practices. The DRC is also keen to invest in new downstream facilities like refining and processing to allow DRC citizens to realize greater economic benefit from the entire cobalt value chain.

There remains the opportunity for the US and California – in cooperation with the cobalt industry – to support the proper development of the DRC mining sector, and to ensure that there are legitimate routes out of poverty for people in the poor regions of the DRC. These efforts will support the development of responsible supply chains and reliable access to cobalt to enable high efficiency clean energy technologies.

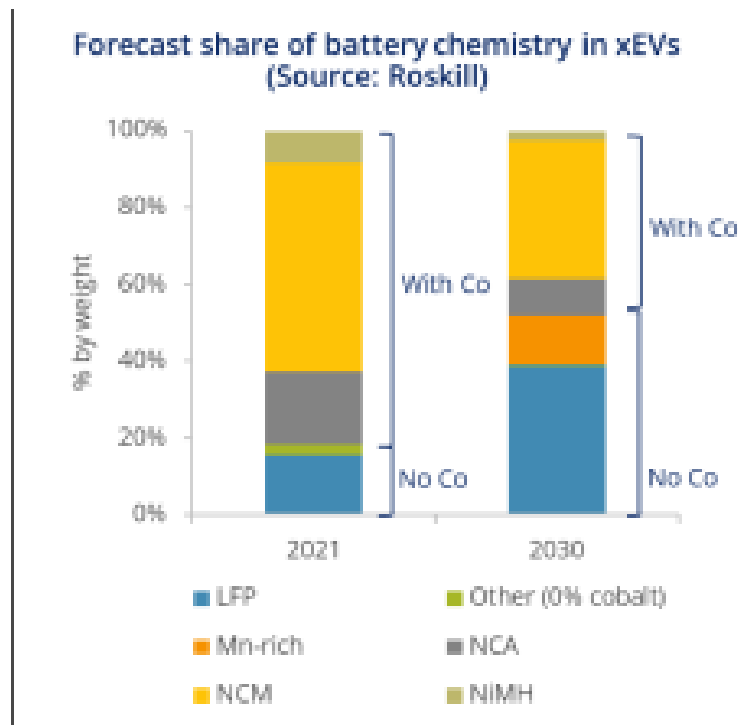
1. Recycling

According to Roskill, by 2030 the market for electric vehicle batteries will move towards a great diversification of cathode chemistries. The graph on the right shows how lithium iron phosphate (LFP) batteries will increasingly be used, with cobalt containing ones representing about 50% of the market.

It is important to note that the market in 2030 will likely be considerably larger, meaning more cobalt will be used in gross terms by 2030. This would likely be true even with a shift to nickel manganese cobalt (NMC) 811 or NMC9.5.5 cathode chemistries (from the 622 ratio typically used today).

However, this shift also presents a challenge. LFP batteries have significant economic challenges when it comes to recyclability, whereas the cobalt containing chemistries (NMC and nickel cobalt aluminium oxide (NCA)) are highly recyclable. Phosphates used in LFP batteries are also high demand critical materials, primarily due to their use in fertilisers and concentration of reserves in Morocco and the Western Sahara. Unlike cobalt containing batteries, which present an opportunity for California to establish a circular economy for these battery chemistries over time, the economics for recovering secondary materials from LFP chemistries is a major impediment to a sustainable circular economy for these batteries.

Cobalt is endlessly recyclable. Cobalt that comes from recycling can be reused in batteries. There is no difference in quality or performance once cobalt is recovered to similar purity. Given the likely trajectory for cobalt demand outlined above and the recyclability of cobalt we don't consider the statement on page 39, "this reduction in cobalt reduces the value of the recovered material", to be accurate. The presence of cobalt will still make it economically attractive to recycle 811 chemistries as, typically, in NMC and NCA chemistries the cobalt is the main economic driver for recycling.



2. US value chain

It is possible to develop the value chain in the US for cobalt. Umicore's Kokkola plant in Finland is one of the world's largest cobalt refineries, proving that it is possible to establish facilities that process secondary material in developed markets. At present, it may be cheaper for producers to use "virgin" cobalt in batteries, creating barriers to entry for recycled cobalt, but the EU Battery Regulation (cited in the paper) provides a good model for stimulating a circular economy. However, we do believe any such proposal needs to be technology neutral, so that all battery chemistries are held to the same standards.

Over time a domestic value chain for cobalt will not only create security and jobs domestically, but also stimulate responsible growth in the battery sector, where increasingly the co-location of facilities is being explored.

3. Conclusion

The Cobalt Institute is a leading global expert on cobalt in batteries and recycling of cobalt-containing chemistries. We are happy to support you in your inquiries.

Yours sincerely,

Mike Blakeney

COPART

To the Lithium-ion Car Battery Recycling Advisory Group:

Founded in 1982 out of a single facility in Vallejo, Copart is now a global automobile auction company with over 200 facilities located in 11 countries, including nineteen locations in California. Copart helps a wide variety of vehicle sellers, including insurance companies, dealers, fleet operators, rental car companies, charities, and municipalities. We thank you for the opportunity to provide comments on the draft report provided by the Lithium-ion Car Battery Recycling Advisory Group. Copart supports the effort of the State of California to study and foster an effective and efficient process for recycling lithium-ion batteries.

After our review of the draft report, we do have two concerns that we believe need to be addressed and result in an amendment to the final draft.

Inaccurate and Misleading Statements

Our first concern is with inaccurate and misleading statements regarding auto auctions and dismantlers. Once such inaccurate statement appears on page 12 where the following comment is made about Copart's sales practices in California:

“any interested party can bid on and purchase a vehicle as well, including parties that may be unqualified to safely repurpose or recycle it.”

The statement *“any interested party can bid on and purchase a vehicle”* is not accurate. Copart limits who can bid on vehicles located at its facilities in California. Only potential bidders that provide Copart with a business or occupational license from their home state or country are allowed to purchase vehicles from Copart's California based auctions. All buyers are required to provide Copart with a copy of their driver's license, government issued identification card or passport, as well as a copy of the licenses held by them or their business. Copart employees review these documents to confirm the information provided. These same buyers are also checked against various databases including BIS, OFAC Non-SDN, OFAC Sanctions, OFAC SDN, Terrorist exclusion, FinCEN Primary Money Laundering Concern, and others.

Further, the statement that buyers at auctions include *“parties that may be unqualified to safely repurpose or recycle [lithium-ion batteries]”* is misleading because this also happens to be true of the buyers of every other sales channel in California, including dealerships, dismantlers, direct consumer to consumer sales, and vehicle marketplaces such as eBay Motors, Craigslist, Autotrader, etc. Copart only makes up a small portion of all vehicles sales in California; for comparison, in 2021, Copart sold over 275,000 vehicles in California, while the CNCDA reports that residents purchased 1,856,391 new and about 3,730,000 used vehicles in 2021.³⁹ The statement is misleading because it applies to any of these sales involving a lithium-ion battery.

In addition, the statement on page 55 that *“[u]nlicensed dismantlers acquire most of their vehicles through auto auctions...”* is offered without any evidence. Similarly, the statement on page 31 that *“an ongoing concern is the rise of unlicensed dismantling in the state”* is unsupported by any evidence. Both statements are also potentially misleading. While the dismantling industry has repeated these allegations in many forums, Copart is unaware of any facts that exist to support these statements. Moreover, Copart works closely with California Department of Motor Vehicles

³⁹ California New Car Dealers Association, Annual California Auto Outlook (2019, 2020, 2021).

and is unable to recall a single instance in the past 40 years when it has been requested by California DMV to terminate the bidding privileges of a buyer because of unlicensed dismantling activities.⁴⁰ For this reason, these statements should be removed, or at the very least, mentioned as a representation of the dismantling industry that is unsupported by the evidence.

“Pre-Approval” Proposal

Our second concern is with the Require Pre-Approval to Bid on Electric Vehicles at Auctions section of the draft that starts on page 55. The proposal does not describe what is meant by “pre approval” or how “pre-approval” would achieve the goal of “tracking” end of life lithium-ion batteries. The proposal is vague, unnecessary, and discriminatory towards auctions.

The report recommends at page 55 *“requiring that interested parties apply for pre-approval before participating [in an auction]. The pre-approval process should include registering and verifying contact information (e.g., name, address, etc.) to track the battery.”*

The report does not describe who an interested party would apply to for pre-approval prior to participating in an auction, whether “approval” would be automatic or conditional, what conditions there would be – if any – on participation in an auction, or how such pre-approval would lead to or enable tracking individual vehicle batteries. This recommendation is incomplete without addressing these issues.

Further, the single concrete aspect of this recommendation is unnecessary because auto auctions themselves already collect and verify the contact information of all potential bidders of any vehicle prior to allowing participation in an auction. Like its competitor Insurance Auto Auctions, Copart collects and maintains this information in its systems and could report this information to a regulating agency.

With this in mind, the proposal to require “pre-approval” is vague and unnecessary since the only concrete actions suggested by the recommendation **are already the industry practice**. To impose additional requirements on auctions without also imposing the same requirement on all dealers, dismantlers, consumers, and all other sales channels – which make up the bulk of all sales in the state, as detailed above – is unfair and discriminatory against auctions. Further, the recommendation as proposed in the Draft Report would fail to achieve the purported goal of “tracking batteries.”

Conclusions

Based on the foregoing, our specific requests after review of the DRAFT Report are that the Advisory group:

- Remove the incorrect information contained on page 12 regarding who is qualified to purchase vehicles at Copart auctions.
- Remove any language unsupported by verified facts purporting that unlicensed dismantling is a growing problem.

⁴⁰ Copart strongly supports DMV enforcement of law prohibiting unlicensed dismantler activities and has a decades long history of providing assistance to DMV in its enforcement efforts against buyers and sellers that are not operating in accordance with the law.

- Remove any language unsupported by verified facts purporting that unlicensed dismantlers acquire most of their vehicle inventory from auctions.
- Remove the Require Pre-Approval to Bid on Electric Vehicles at Auctions proposal. This proposal is unnecessary, vague, and discriminatory.

We believe that overall, the draft contains important information that is critical to the long-term success of electric vehicle adoption in the state. With our suggested changes, Copart believes the accuracy of the document and its effectiveness is increased for all.

Thank you again for the opportunity to comment and please do not hesitate to reach out if you have any questions, concerns or need more information.

Sincerely,

Mark Binder

CROWN BATTERY MANUFACTURING COMPANY

Dear Advisory Group Members,

Whatever the cost to reuse and recycle batteries, half-measures will carry a far heavier price tag for California and the entire country.

It's a sad fact: Today, 19 out of every 20 lithium-ion batteries go directly to the trash.

(Source: "It's time to get serious about recycling lithium-ion batteries" en.acs.org/materials/energy-storage/time-serious-recycling-lithium/97/128)

That's not the legacy any of us wants to leave behind. And it's not a cleanup bill anyone wants to pick up. But one way or the other, we'll all pay the cost of batteries at end of life (EOL) -- whether they're landfilled or recycled.

Without robust policies and infrastructure for Li-ion battery recycling, we face millions of tons of hazardous waste. Cleanup bills and water pollution. Unnecessary, carbon-intensive mining. "Surprise" disposal surcharges for EV owners. And a piecemeal recycling system. We even risk falling behind on recycling R&D and rollout (other countries will take the lead).

Today's policies will determine whether a battery's EOL is a lasting environmental blight and economic burden -- or a sustainable investment opportunity. And as the State with the most car sales and strong environmental policies, California can lead the nation in creating a comprehensive lithium-ion recycling system -- one that creates jobs, reduces emissions and pollution, and decreases dependence on conflict minerals and mining.

We need forward-thinking, long-term policies now: to make sure that people, our environment, and the climate thrive as we electrify (*we* have a unique perspective as a battery manufacturer, and our comments will include strategies that worked in another battery industry).

At Crown Battery, *we've* been powering electric vehicles and homes for nearly 100 years. We're deeply invested in California, from our distributors to our subsidiary, Industrial Powersource, in Santa Fe Springs. *We're* the first (and only) US battery manufacturer to use 100% renewable energy for manufacturing. And we sell 99% recyclable lead-acid batteries and expect that our future offering will include Lithium-ion batteries.

We applaud California's efforts to move toward near-100% reuse or recycling of Li-ion batteries.

We agree that green energy storage and electric vehicles - both personal and public -- are an important part of the fight against climate change. *We* agree that we need to continue moving away from fossil fuels and electrify, on the road and at home. And we recognize the need to simultaneously invest heavily in a sustainable recycling/reuse infrastructure, technology, and legislation.

We agree on all of this because we need a clear path to full recycling... and time is running out.

Experts predict there will be 145 million EVs by 2030 -- a 14.5X increase over 2020 numbers. And the goal of California's Executive Order N-79-20 is that all new passenger vehicles be ZEVs by 2035. But by 2035, most of today's EV and hybrid batteries are expected to be at EOL, even according to conservative estimates. And even if large-scale Li-ion recycling technology were feasible today... recycling plants take years to design, permit, build, and make operational.

So, we need to lay the groundwork now.

And to do that, we need to close the Battery Recycling Gap. Here's what we mean:

As you know, lead-acid batteries are 99% recycled -- the most recycled product in North America (source: US EPA's "Facts and Figures about Materials, Waste and Recycling"). And roughly 98.9% of the raw materials in lead-acid batteries are recyclable. That's why these batteries are considered a closed loop; they can be recycled to make more batteries, almost indefinitely.

"A vast recycling supply chain collects, stores, transports, recycles, and re-introduces more than 99% of lead back into the lead-acid battery supply chain." -- US Department of Energy

Meanwhile, Li-ion batteries are 0%-60% recyclable and mainly built with virgin materials.

That, in a nutshell, is the Battery Recycling Gap -- and we must close it.

Now, we all know the barriers to widespread lithium-ion battery recycling, including technology, economics, policy, and logistics. But the good news is, we've solved the battery recycling problem before -- for lead acid. And by working together, the government, nonprofits, industry associations, and corporations can solve it again.

Here are some of the key takeaways to adapt from lead-acid's recycling success:

1) Make recycling easier and safer.

Lead-acid batteries are easy to safely recycle by machine.

Recycling is better than new mining.

Recycling mitigates social and environmental costs (and emissions). Today's Li-ion battery materials are almost entirely virgin-mined. Their cobalt, copper, lithium, and nickel often come from the DRC, Indonesia, Russia, and other countries with reduced environmental and labor oversight. As a battery producer, we want our materials to come from recycled sources. So, we hope to see minimum material recovery targets. And we support the scientists and government agencies working hard to advance lithium ion recycling to 90% recovery in the USA.

Li-ion batteries will be easier to recycle if they're designed for recycling.

Today's Li-ion batteries are complex and vary widely in size, shape, internal chemistry, electronics, and raw materials. And they're rarely designed for disassembly.

Physical labeling and battery information are critical to safe disposal.

With Li-ion's complexity and variety of raw materials, responsible parties need to know *what* they're recycling.... and how to recycle it safely and effectively. To speed up the recycling process, we strongly support labels that include information about anode and cathode chemistry, along with electrolyte type.

Education is vital for consumers.

Many consumers aren't aware of how to properly dispose of lithium-ion batteries. Improper disposal and recycling are partly responsible for an increasing number of Li-ion fires during collection, storage, and sorting at recycling facilities.

First responders, recyclers, and service/repair companies need education and safety equipment.

According to the EPA's "An Analysis of Lithium-ion Battery Fires in Waste Management and Recycling," Li-ion scrap batteries started at least 245 fires at recycling centers from 2013 to 2020.

Education and safety equipment will go a long way toward protecting people and property. It will also protect our country's recycling network; our recycling partners tell us that Li-ion-related fires are a major threat to their ability to operate safely and successfully.

2) Profits help ensure recycling.

Lead-acid recycling is profitable. It's simple, it's automated, and lead has a high market value.

Current lithium-ion recycling/downcycling often isn't profitable.

For Li-ion, most recycled materials are about three times more expensive than virgin-mined equivalents. The economics against recycling may tilt further as expensive materials like cobalt are removed from Li-ion batteries. But if raw materials prices increase, then it may make more financial sense to recover lower-value materials. In either case...

We need new lithium-ion recycling methods -- to improve profitability and extract more materials.

Most lithium-ion disassembly today is time-consuming and technical. And current Li-ion recycling methods burn lithium and manganese and present their own sustainability issues. More importantly, these recycling systems aren't in use at scale. New policies and investments in R&D give us the best chance for reaching full, profitable recycling sooner.

3) Infrastructure is critical.

A key part of lead-acid batteries' success is our nationwide recycling infrastructure.

We support and are eager to see a similar infrastructure for lithium-ion batteries, so they can be collected at scale.

California's report mentions a "Reporting system for LIB recycling and recovery rates." We support this because it's common sense. After all, if we don't measure recycling and recovery, how can we tell how well new policies are working?

4) Recycling is most effective when it's mandatory and cost-free or affordable.

Government regulations and battery industry support ensure that lead-acid batteries are collected and recycled.

Right now, there's no nationwide lithium-ion recycling infrastructure or recycling legislation.

Although landfilled Li-ion batteries can leach toxic chemicals, the USA lacks (for now) the recycling laws and collection infrastructure for Li-ion batteries that have been put in place for lead-acid batteries. As a producer of energy storage batteries, we believe that society and industry both benefit from public policies that direct recycling of batteries, and we support the mandated recycling of all battery technologies.

Take-back programs work – and are needed.

We've seen their effectiveness with lead-acid batteries, which have the highest collection rate of any item in North America. Collection is frictionless; it's mandatory; it's built into purchasing and end of life; and it's supported by a robust infrastructure and policies.

Other high-impact policies could include: banning landfilling, making transporting hazardous batteries easier/more affordable (while still safe), and creating battery design standards to simplify disassembly for recycling.

Effective policies can speed up adoption and R&D, protect the environment, and create jobs. And AB 2832 will have a ripple effect on energy storage far beyond just EV batteries. Demand for energy storage has also skyrocketed for electronics and other markets.

We hope that Li-ion battery recycling becomes widespread and profitable. But hope alone won't turn this looming crisis into an opportunity.

Ten years down the road, we could be years behind our goals -- and other countries -- in the fight to mitigate climate change and create sustainable jobs.

Or we could be building lithium-ion batteries made with recycled materials – as we do for lead-acid batteries. And we could enjoy the benefits of more domestic jobs, reduced dependency on fragile supply chains, and lower carbon emissions. It will take smart policies, expanded infrastructure, and new technology to make that dream a reality.

That's why Crown Battery supports your efforts to close the Battery Recycling Gap, just like we supported lead-acid battery recycling from its infancy.

California can and must lay a strong foundation for full battery collection and recycling across the country... now, while we can all still afford it. After all, full battery recycling is the right move for our environment, our communities, our economy, our society -- and our future.

On behalf of Crown Battery Manufacturing Company, thank you for your consideration of our comments.

INSURANCE AUTO AUCTIONS

Regarding California AB 2832 Advisory Group Policy Proposals

On behalf of Insurance Auto Auctions (IAA), I am submitting the following comments.

The Final Draft of Policy Recommendations includes a proposal to “require pre-approval to bid on EVs at auctions”. The purpose is stated to be to “enable tracking of EVs purchased at auctions”. This policy proposal is addressed on pages 4, 48, 55 and 56 of the Final Draft.

Insurance Auto Auctions (IAA) opposes this policy proposal for the reasons set forth below.

Although insurance companies and insurance auctions, such as IAA, are discussed in the Final Draft, these industries were not represented on the Advisory Committee. However, the automobile dismantling industry did provide input. The policy proposal would limit the competition dismantlers face at insurance auctions. Unfortunately, the resulting bargain for dismantlers would come at the expense of insurance companies and their policyholders.

The policy proposal is burdensome. EVs make up a tiny portion of the vehicles sold at insurance auctions. Potential bidders at an insurance auction are registered to bid on a wide variety of vehicles. The policy proposal does not indicate what agency would be pre-approving bidders, the mechanism for such pre-approval, including verifying contact information, or the timeliness of such pre-approval. The report itself, on page 56, raises the concern that this requirement will have a chilling effect on individuals who participate in insurance auctions to repair their own vehicles.

As noted above, the stated purpose of the policy proposal is to “enable tracking of EVs purchased at auction”. This goal could be accomplished in a far less costly and onerous manner. If it is determined that it is important to be able to track EVs purchased at auctions and if an unregulated purchaser buys an EV at insurance auction, the insurance auction could promptly report the contact information of the buyer to the appropriate agency. Regulated purchasers are as set forth in Section 6092.5 of California Revenue and Tax Code in subdivisions (a)(1) through (a)(3). This solution would accomplish the stated purpose while not imposing the overreach of the proposal.

Thank you for the opportunity to comment.

Sincerely,

Katerina Dotzeva

INSTITUTE OF SCRAP RECYCLING INDUSTRIES

To Whom It May Concern at CalEPA:

The Institute of Scrap Recycling Industries, Inc. (ISRI) would like to submit for CalEPA's consideration the following comments on The Lithium-Ion Car Battery Recycling Advisory Group's draft report of policy recommendations to the California Legislature as required by California Assembly Bill 2832 (AB2832) (henceforth, "the Draft Report").

ISRI is the *Voice of the Recycling Industry*[®]. With headquarters in Washington, DC and 18 chapters nationwide, including the West Coast Chapter that includes California, ISRI represents more than 1,300 companies that process, broker, and consume recyclable commodities, including metals, paper, plastics, glass, rubber, electronics, and textiles. ISRI provides education, advocacy, and safety and compliance training, and promotes public awareness of the essential role that recycling plays in the U.S. economy, global trade, the environment, and sustainable development. Generating nearly \$117 billion annually in U.S. economic activity, the recycling industry supports more than 500,000 Americans with good jobs. In California, the recycling industry contributes a total (direct) economic impact of \$12.2 (\$4.7) billion, providing 51,000 (16,700) jobs that pay \$3.9 (\$1.4) billion in wages and generating \$1.4 billion in federal and state taxes (\$0.8 and \$0.6 billion, respectively).

A. Background

ISRI's membership includes companies involved in the recycling of vehicles at end-of-life (EOL), including EOL electric vehicles (EVs) with traction lithium-ion batteries (LIBs).

Some ISRI member companies operate facilities that recycle EOL vehicles (ELVs) and other recyclable metal using hammermill shredders and automated separation technologies. ELVs are prepared prior to recycling by removal of batteries, fluids, mercury switches, and other materials. Often known as "shredder facilities", these recycling facilities produce commodity-grade ferrous and nonferrous metal products that are purchased by secondary metal industries (e.g., electric arc furnaces (EAFs) for making steel) as industrial input materials. There are more than 300 shredder facilities in the U.S., and their annual production of commodity-grade ferrous metal composes 30% of the annual input to domestic EAFs.⁴¹

Other member companies operate facilities that purchase "new" ELVs for dismantling and harvesting of reusable parts for resale. These dismantling facilities remove batteries, fluids, mercury switches, and other materials from the ELVs as part of their process. The remainder of these prepared ELVs, after densification, are purchased by shredder facilities for recycling into commodity-grade ferrous and nonferrous metal products.

Some shredder facilities purchase "new" ELVs for recycling, preparing them and harvesting some reusable parts for resale prior to shredding. It is worth noting that such shredder facilities can qualify for an "automobile dismantler exclusion" under the Dismantler License regulations.⁴² Lastly, some member companies operate both shredding and dismantling facilities.

Based on past and projected sales of EVs⁴³, ISRI expects that the number of EVs reaching EOL will increase more than tenfold within a decade, especially in California. It is necessary to be

⁴¹ U.S. Geological Survey. "Iron and Steel Scrap in November 2021". January 2022.

⁴² See <https://www.dmv.ca.gov/portal/vehicle-industry-services/occupational-licensing/occupational-licenses/dismantler-license/>.

⁴³ These data were obtained from InsideEVs.com, HybridCars.com, GreenCarReports.com, and EVAdoption.com.

prepared for this eventuality and the large number of LIBs that will become available for reuse, repurposing, and recycling. ISRI members that operate shredder and dismantling facilities in California and nationwide are essential to the safe, environmentally responsible, and efficient reuse, repurposing, and recycling of EOL EVs and their LIBs.

For these reasons, ISRI takes interest in the Draft Report. Its policy recommendations to the California Legislature have the potential to influence, if not set the standard for, similar policies in other states and hence nationwide.

B. Comments

ISRI appreciates the work of the Advisory Group and its members' efforts in developing the policy recommendations in the Draft Report to maximize the reuse, repurposing, and recycling of LIBs from EOL EVs.

As described in the Draft Report, ISRI could support the two policy proposals with majority support that define EOL management responsibility:

1. Core exchange and vehicle backstop policy; and
2. Producer take-back policy with no companion legislation.

Concerning the second policy proposal, ISRI does not support “product stewardship” policies if they “disrupt the current recycling infrastructure...or disrupt the recycling of materials or products that are being successfully recycled and consumed in existing markets”.⁴⁴ ISRI further “encourages policy that incentivizes manufacturers to design their products for recycling”.

Regarding the supporting policy proposals, ISRI does support those for improving the safety and efficiency of reverse logistics and design for reuse, repurposing, and recycling. The latter includes better design of EVs to allow easier and safer removal of their LIBs at EV EOL, which is an expensive and time-consuming process.

Beyond the Draft Report's policy recommendations, ISRI believes that the regulatory status of a used LIB from an EOL EV is clear both federally and in California. Under both the Federal and California regulations for hazardous waste (40 CFR §261.1(c)(6) and 22 CCR §66260.10, respectively), an ELV as a single item meets the definition of “scrap metal” and is exempt from regulation when being recycled (§261.6(a)(3)(ii) and §66261(a)(3)(B), respectively).

Once a component of the exempt ELV is removed, its regulatory status is based on its own attributes. In the case of a reusable or repurposable LIB that was removed from an EOL EV, this used LIB can be a “safe and effective substitute” for a new LIB, which is a commercial product. Under Federal regulation (§261.2(e)(1)(ii)) and California law (HSC 25143.2(b)(2)), such a used LIB is not a (solid) waste when it is “[u]sed or reused as a safe and effective substitute for commercial products [if the material is not being reclaimed⁴⁵]”. This also applies to any other reusable part of an ELV that can substitute for a new part.

If an EV LIB is not reusable or repurposable, then the LIB meets the Federal and California regulatory definition of “battery” (§273.9 and §66273.9, respectively) and is subject to the

⁴⁴ ISRI Position on Product Stewardship adopted July 16, 2021.

⁴⁵ This clause appears only in the California law.

universal waste regulations (§273.2 and §66273.2, respectively). Status as universal waste will facilitate the recycling of used LIBs.

These regulatory frameworks currently allow a used EV LIB to be reused or repurposed as a product (not waste) and, if not reusable or repurposable, recycled as universal waste. They will be extremely helpful in the effort to maximize the safe, environmentally responsible, and efficient reuse, repurposing, and recycling of used EV LIBs in California and nationwide.

In closing, ISRI appreciates this opportunity to provide comment on the Draft Report and CalEPA's consideration of these comments.

Sincerely,

David L. Waggoner, Ph.D.

LI-CYCLE

Dear CalEPA Lithium-ion Car Battery Recycling Advisory Group,

With the public release of the draft of policy recommendations to the Californian Legislature by the Lithium-ion Car Battery Recycling Advisory Group, Li-Cycle wanted to provide feedback and industry context from a commercially operational, leading lithium-ion battery recycling company and assist with the recommendation-making processes.

Areas of Support:

1. **Defined Responsibility for End-Of-Life Management:** Li-Cycle is highly supportive of the continued regulatory push to propel carbon reduction initiatives in the battery supply chain, and beyond. We believe EOL management serves as an important piece in ensuring that all batteries are collected and properly reused, repurposed, or recycled and create a sustainable and circular economy to meet global drives for carbon footprint reduction. Sustainability is at the core of all Li-Cycle operations and decision making and we are encouraged by the recommendations for definition of EOL management policies from our peers.
2. **Ensuring Recycling Meets Highest Environmental Standards:** It is critical that increased battery recycling in California does not lead to adverse environmental impacts created by the processes of battery recyclers. As such, Li-Cycle supports the encouragement of battery recycling within California and enforcement of unlicensed dismantling laws. This helps ensure that recyclers in the state use an environmentally friendly process that does not create additional ecological impacts, such as toxic air or solid waste emissions, to meet the state's high environmental standards.
3. **Targeted Incentives for Recycling:** Incentives for recyclers will serve as an important piece to mitigate upfront costs and accelerate the scale-up of the recycling industry. Li Cycle supports the recommendation for added financial incentives, as well as the expansion of eligibility for existing relevant incentive programs in the forms of tax breaks or grants to hazardous waste processors that recycle lithium-ion batteries. Incentives will play a critical role in ensuring California has the necessary capabilities to responsibly recycle the rapidly increasing amount of EOL batteries while making California-based recycling competitive with other states.

Areas of Recommendation:

1. **Importance of Establishing Recycling Efficiency Rates and Material Recovery Rates:** Li-Cycle has maintained its strong support of the policy efforts worldwide to establish and achieve Recycling Efficiency Rates and Material Recovery Rates throughout the battery recycling industry. We believe in the importance of reducing the environmental burden of batteries and promoting circular economy principles with a focus on the sustainable recovery of critical materials. Li-Cycle stands ready to be a key partner in helping governments achieve material recovery rate goals and have demonstrated this through our >95% material recovery rates and >90% recycling efficiency rates.
2. **Proposed Targets and Levels of Ambition:** In conjunction with establishing Recycling Efficiency Rates and Material Recovery Rates, Li-Cycle shares the view

that establishing medium and long-term targets to spur continued innovation within the battery recycling industry is critical. Li-Cycle believes the way in which these targets are communicated need not be mutually exclusive. While establishing EOL management responsibility is certainly an important step towards supporting the needs of lithium-ion battery recycling, we believe it would be effective to communicate a potential 'medium level ambition' recycling efficiency rate target by 2025 and a 'high level ambition' target by 2030 as a unified objective, ambitious in nature but providing an allowance for a ramp-up period between 2025-2030.

We hope our feedback will help inform your policy recommendations to the California legislature.

Yours sincerely,

Kunal Phalpher

LKQ CORPORATION

Dear Advisory Group:

On behalf of LKQ Corporation, thank you for the opportunity to provide comments in response to the Lithium-ion Car Battery Recycling Advisory Group's draft report. LKQ is the largest automotive dismantler in North America processing approximately 800,000 end-of-life vehicles per year. Additionally, LKQ is a leader in many other automotive aftermarket industries including remanufacturing NiMH batteries commonly found on older hybrid vehicles. California is an important market for LKQ, and the company employs over 1,700 people in 67 facilities throughout the state in various operations.

LKQ shares your objectives that "as close to 100% as possible of lithium-ion batteries in the state are reused or recycled at the end of life." The auto dismantling industry will process virtually every end of-life automotive battery and is an essential partner for recycling and reuse of lithium-ion batteries. As the largest auto dismantler in the state, LKQ respectfully requests to participate in the advisory panel to provide input and technical expertise to formulate workable guidelines that represent this specific segment of the industry.

In response to the draft report, LKQ supports an Original Equipment Manufacturer (OEM) mandatory take-back program. There are three reasons for this:

- First, it creates the foundation for a competitive market among auto dismantlers to retrieve and recycle or reuse end-of-life batteries. Aside from the benefits of competition, it provides a purchase requirement essential for any program seeking to recycle virtually all batteries. Without this purchase requirement, small and difficult to retrieve batteries most probably will be overlooked or simply not purchased by auto dismantlers in California.

LKQ forecasts that mild hybrids will be the dominant form of electrification through 2030 not only in new car sales, but also relative to dismantling. These vehicles contain lithium-ion batteries that are approximately 100x smaller than ones found in a typical Tesla. Their economic value may be negligible due to the cost of dismantling them relative to their size.

Today mild hybrid vehicles hide in plain sight, and many modern Ram 1500 pickup trucks and Jeep Wranglers are mild hybrids with lithium-ion batteries smaller than 1 kW. To recycle these, an OEM take-back program provides the best chance auto dismantlers will have to receive a fair and competitive market price to locate, dismantle and recycle small batteries often encased in difficult to access locations within a vehicle.

- Second, a take-back program incentivizes OEMs to install batteries in a location where they can easily be removed, and to provide labeling and dismantling instructions. As noted earlier, batteries may be difficult to locate and retrieve. A take-back program aligns economic incentives for OEMs to provide greater transparency for auto dismantlers, thus increasing recycling yields.
- Third, a take-back program provides economic incentives for OEMs to utilize a universal diagnostics system allowing auto dismantlers to identify the highest and best

use of a battery, which may include remanufacturing or repurposing it in a non-automotive application.

While a producer take-back program is the most favored proposal, the next best option would be an environmental handling fee to subsidize auto dismantlers. Subsidies are essential if a mandatory take back program is not available. However, subsidies are still a second option because they are government mandates that tend to disrupt market forces. Subsidies provide less incentive to the OEMs to provide transparent access to battery information and possibly disqualify smaller operators that would opt out of a recycling program.

LKQ believes that a mandatory take-back program is superior to a state mandated core charge. Innovation and competition are essential ingredients to reduce the cost of replacement batteries and to stimulate demand for recycling. As such, LKQ does not support state regulations that permit the OEMs to place core charges on service parts as they create disincentives against innovation and competition from third parties who may seek access to the core.

LKQ strongly supports regulatory structures providing non-discriminatory, transparent, and full access to OEM battery information at the VIN level and to battery health diagnostics via the battery management system. Physical labeling requirements and physical OQ codes are necessary but insufficient for a vehicle with a 20+ year lifespan as stickers may not stand the test of time and batteries may get exchanged within a vehicle. To cure this, LKQ supports the development of a universal, open, and non-discriminatory access to battery diagnostics and management systems. Transparency allows vehicle owners and their authorized agents to access the battery health. In turn, this creates a far more efficient market for battery recycling and reuse.

Without diagnostic access to the battery health, recycling and reuse market participants will likely have to make probabilistic assumptions. Given the rapid changes in battery chemistries, the range of vehicle vocations and operating environments, best guesses are far less efficient than access to specific battery information from the vehicle's diagnostic system.

Battery information must be available via VIN decoding. Due to potential changes within a model year, transparent battery information at the VIN level must include size and chemistry of the battery, the number of packs and modules, location/position within the vehicle, and best practices for dismantling and retrieving the battery.

In closing, LKQ encourages the development of a regulatory structure that aligns recycling and reuse objectives with the competitive market incentives. We look forward to working with the advisory group and stakeholders to develop economically attractive solutions. Economic disincentives and overregulation would undermine California's recycling objectives, a goal that LKQ supports.

LKQ Corporation (www.lkqcorp.com) is a global leading auto dismantler and provider of alternative and specialty parts to repair and accessorize automobiles and other vehicles. LKQ offers its customers a broad range of replacement systems, components, equipment and parts

for automobiles, trucks, and recreational and performance vehicles. LKQ recently became the largest U.S. provider of mobile, on

site vehicle services to automotive collision repairers, mechanical repairers and national fleets, providing a full array of repair solutions including diagnostics and calibration, re-flashing, programming, pre and post collision repair diagnostics and other mechanical services. LKQ has a global industry leading team of over 44,000 employees and operates over 1,600 locations in 31 countries.

Respectfully,

Josh Meyer

Dismantling a Battery Case – A Simplified Explanation with Photos

Many lithium-ion batteries are encased in an electronics bay weighing over 1,000 pounds and approximately 6 x 4 feet in size. Photo credit: LKQ.



After removing the case from the vehicle, auto dismantlers remove wiring, electrical busbar, relays, an inverter, cooling systems, sensors, and controls to access a battery module.

Photos Inside of the Case

Photos from left to right: Busbars & high voltage connections, Inverter & controls, Electrical & cooling. Photo credit: LKQ.



Battery modules are often tiny relative to the size of the case. Photo of modules at ~7 x ~14 inches. Photo credit: LKQ.



NATIONAL AUTO AUCTION ASSOCIATION

Dear Lithium-ion Car Battery Recycling Advisory Group:

Thank you for the opportunity to provide comments to the Lithium-Ion Car Battery Recycling Advisory Group Final Draft Report.

By way of background, the National Auto Auction Association (“NAAA”) is a trade association for wholesale motor vehicle auctions headquartered in suburban Washington, D.C. It comprises more than 340 domestic and international wholesale member auctions and more than 140 associate members, including 20 member auctions located within the state of California. NAAA’s mission is to promote and support the interests of its members and safeguard the wholesale auto auction industry. NAAA member auctions provide the marketplace for consignors to sell vehicles to licensed dealers, who in turn sell the vehicles to retail consumers. NAAA member auctions facilitate the sale of over 9.8 million vehicles per year. The wholesale remarketing space assumes a licensed dealer purchasing for resale.

The report identifies auctions as one of the “complex network of actors” involved in managing an electric vehicle’s (EV) battery life cycle as the EV approaches end of life. I write to share information about how auctions (specifically wholesale auctions) operate in California today and hope this information will be helpful as the group considers ways to promote a large-scale battery retirement industry in the state.

It is industry standard for California wholesale auctions, with limited exceptions, to sell vehicles on consignment only to licensed motor vehicle dealers. To ensure that access is restricted to valid, licensed motor vehicle dealers and their authorized representatives only, wholesale auctions implement a robust screening and credentialing process. NAAA member auctions electronically collect and store names, addresses, dealers’ licenses, state-issued identification, authorized representatives, and more. This information is regularly cross-referenced with licensing agencies (and other authorities) to (1) ensure a safe and secure marketplace for our clients, and (2) limit the transfer of vehicles to trusted industry partners.

In addition to the long-established industry standards for auction credentialing, California state law requires wholesale auctions to provide a report of sale to the California Department of Motor Vehicles for every transaction in California.

The report, in its section highlighting policy proposals with majority support from the advisory group, recommends that the State of California require a pre-approval process for potential purchasers of EVs at auctions. The report further recommends that the pre approval process include registering and verifying contact information (e.g. name, address, etc.) in order to track the battery and prevent it from falling into the hands of unlicensed dismantlers. While I agree with the policy objectives, I strongly urge the group to reconsider this recommendation. As described above, wholesale auctions already comply with DMV regulatory requirements to report all purchases on state-controlled forms. The report is silent on which state agency this information should go to and fails to mention how this information would be used. Further, our members abide by long-established industry standards that pre-date California state law and ensure that our marketplaces are limited to trusted industry partners that are similarly regulated by the state. With these controls in place, wholesale auctions are already doing their part to track the transfer of used vehicles among regulated commercial entities and should be excluded from any further state requirements.

Wholesale auctions will continue to evolve as the industry evolves and will continue to partner with the state to promote an EV battery recycling industry. However, further regulation on our members is misguided and unnecessary given existing law. As such, I respectfully request that the group reconsider the need for this proposal and/or exclude wholesale auctions from any pre-approval process for EV bidders.

Respectfully submitted,

Tricia Heon

REDWOOD MATERIALS

Redwood Materials is developing a fully closed-loop, domestic supply chain for lithium-ion battery materials. To close the loop and create a secure domestic supply chain, Redwood is (a) collecting and recycling end-of-life lithium-ion batteries from consumer devices, electric vehicles, and energy storage systems, (b) refining the materials sustainably, and (c) re-manufacturing them into battery materials – specifically, cathode active materials and battery copper foils – that can go directly to U.S. battery manufacturers, including current partners Panasonic and Ford. Increasing our nation’s production of these resources will serve as a key enabler to decrease the environmental footprint of batteries and scale-up U.S. battery manufacturing. With increased domestic battery production, we can then in turn increase production of electric vehicles in the U.S. and decrease our foreign reliance on materials, batteries, and vehicle manufacture.

Today, 6 GWh of lithium-ion batteries or the equivalent of 60,000 EVs, come through Redwood’s doors annually, representing most of the lithium-ion batteries recycled in North America today. We continue to steadily ramp our recycling processes in preparation for the first large wave of electric vehicles to come off the roads, and we are ready to support the battery market in identifying and creating pathways to collect vehicle battery packs and reduce the costs of electric vehicles.

Redwood believes the most effective way to understand the end-of-life vehicle battery pathways is to learn by doing. That is why, in California, we’re launching a comprehensive electric vehicle battery recycling program, to establish efficient, safe, and effective recovery pathways for end-of-life hybrid and electric vehicle battery packs. Ford Motor Company and Volvo Cars are the first automakers to directly support the program, but we will accept all lithium-ion (Li-ion) and nickel metal hydride (NiMH) batteries in the state of California as part of our recycling program.

In the pilot, we will work directly with California dealers and dismantlers to identify and recover end-of-life packs. Redwood will then safely package, transport, and recycle these batteries at our facilities before returning high quality, recycled materials back into domestic cell production. Our goal is to learn and share our findings with the industry. We aim to demonstrate the value of end-of-life packs today and optimize both logistics and our process to reduce costs and return more value in the future.

Today, the most significant cost of battery pack collection and recycling is related to logistics. However, Redwood is working to optimize the logistics process and we are confident that, over time, as end-of-life (EOL) battery pack volumes increase, the cost of logistics will decrease significantly, and these packs will become valuable assets that will help make EVs more sustainable and affordable. Today, Redwood’s recycling process is already profitable for smaller batteries like consumer devices and production scrap, and we expect the same to be true for electric vehicle battery packs in the near future.

Regarding logistics, there isn’t data to show that logistics pose an insurmountable cost long term. Furthermore, the key to reducing logistics costs is increased volumes; economies of scales achieved through full container-load quantities for transportation. Therefore, we are opposed to creating any fees to address what we believe are short term costs. Creating such collection fees or costs could hinder the battery industry and electric vehicle growth and create the unintended consequence of promoting fossil fuel burning vehicles. Today, the industry is already paying for NiMH packs because of the scale of these batteries coming off the road and the value of the material that can be recovered. We expect the same will happen with lithium-ion batteries in the next few years, as logistics become a small component of the overall value proposition. Instead,

we support initiatives that promote the recycling of EV batteries for use in a closed-loop supply chain for new battery production.

Until that time, production scrap will be the dominant material available for recycling in the US. Production scrap will support the growth of the battery recycling industry, generating revenue as recycling companies continue to establish and automate processes for end-of-life EV pack collection and recycling.

Of the policy proposals recommended by this paper, we would be most supportive of Core Exchange and Vehicle Backstop Policy followed by the Producer Take-back as we believe these packs present an opportunity for the industry, through recycling and remanufacturing, to drive down the costs of future domestic battery production and secure our country's supply of these critical materials. We are unsupportive of any proposals that add additional costs to the EV battery value chain.

Redwood is certainly supportive of policy that governs the safe transport and handling of EV packs, as well as any research to understand how the industry can lower costs without compromising safety. Existing regulatory laws were not intended to address recycling pathways for large electric vehicle battery packs.

The technologies named in this paper are not all inclusive and are significantly more nuanced than what is shared. The industry has attempted to bucket several technologies into easily identifiable categories, but, the best process is a combination of many technologies, some of which are not listed in this paper. Today Redwood Materials is pursuing several recycling processes we developed in-house. Because of the wide range of feedstock, we receive— everything from large packs from EVs and energy storage systems to small consumer electronics like wireless headphones and toothbrushes – we employ the best technology for each of our feed streams and are continually working to further optimize it in-house. All of our material is processed in our hydrometallurgy (chemical) process and some batteries begin the recycling process either in mechanical separation or in our calcination process, where our low temperature, proprietary technology allows us to make use of residual energy in the end-of-life battery to power the process without the use of any fossil fuels.

REJOULE

To the Lithium-ion Car Battery Recycling Advisory Group,

Thank you so much for putting together the draft report and making it open to public comments. I'm Zora, the cofounder and CFO of ReJoule, and our work on 2nd life batteries was actually listed in the report! We have some brief comments below, and we'd be happy to chat further. Thank you!

Page #	Section	Comments
44	6.1.1 part 3	Requiring vehicle OEM <u>only</u> can be dangerous as they may not be able to trace this back - will require tracking and means to recover "stranded vehicles and their batteries" which can potentially add cost. Perhaps include insurance or salvage companies as partners.
36	5.2.1 First-life Battery Design	Recommend that newly produced batteries are designed with disassembly in mind to greatly enhance safety for both repurposing and reuse applications
48	6.2.1 Access to Battery Information	SOH is a critical piece of battery information that can vary wildly if provided by an inaccurate source. Recommend creation of a list of trusted SOH providers who can capably test batteries to give accurate and vetted SOH information.
50	6.2.1 Electronic Information Exchange	Recommend including instructions for battery pack/module disassembly as well, not just disassembly from vehicle. Some repurposing and all recycling will require this knowledge.
52	6.2.2 Expand eligibility for relevant incentive programs to include reused and repurposed batteries	Recommend establishment of further validation programs for reused and repurposed batteries, similar to CEC-funded demonstrations on Page 14 of this document. Used batteries offered at a lower cost with incentives are likely to have positive impacts to energy equity and overall welfare.

RESPONSIBLE BATTERY COALITION

Dear Members of the AB2832 Advisory Group,

The Responsible Battery Coalition (RBC) appreciates the opportunity to provide comments on the draft report of policy recommendations prepared by the Lithium-ion Car Battery Recycling Advisory Group on behalf of the AB2832 Advisory Group.

Overview

The Lithium-ion Car Battery Recycling Advisory Group was created to advise the California Legislature on policies pertaining to the recovery and recycling of lithium-ion vehicle batteries sold with motor vehicles in the state. It is being led by the California Environmental Protection Agency (CalEPA), the Department of Toxic Substances Control (DTSC), and the Department for Resources Recycling and Recovery (CalRecycle). Additional members come from the environmental community, auto dismantlers, public and private representatives involved in the manufacturing, collection, processing and recycling of electric vehicle batteries, and other interested parties. The advisory group was formed in 2019 in response to Assembly Bill 2832.

RBC is pleased to see that the Advisory Group Council recognizes the vital importance of recycling spent lithium ion batteries (LIBs) and is working diligently to meet its mandate of providing policy recommendations to the Legislature to ensure "...that as close to 100% as possible of lithium-ion batteries in the state are reused or recycled at end-of-life."

As the Advisory Group notes, there are more than 400,000 zero emission vehicles on the road in California. The lifespan of the batteries in those vehicles is estimated to be between 10 to 20 years. Those batteries contain metals and other toxic or corrosive materials but are also potentially valuable sources of recyclable metal. When the LIBs that power electric cars reach their end-of-life, they must be managed in a way that is safe for the public and the environment.

Our comments herein are focused on concerns around potential battery durability policies and requirements and are provided to the Advisory Group so that its final recommendations are informed by, and eventually aligned with, the California Air Resources Board's anticipated action on the Advanced Clean Cars II Act, which is expected to include standards for LIB labeling, SOH determination, and performance and durability requirements.

About RBC

RBC is a coalition of companies, academics and organizations committed to the responsible management of the batteries of today and tomorrow. We were created to advance the responsible production, transport, sale, use, reuse, recycling, and resource recovery of transportation, industrial and stationary batteries and other energy storage devices. Members include Advance Auto Parts, AutoZone, Clarios, Club Car, Environmental Restoration, FedEx, Ford Motor Company, Honda Motors, LaFarge Holcim, Li-Cycle, O'Reilly Auto Parts, Renova Energy, Terracycle, and Walmart.

Our priorities are to promote battery life-cycle management regardless of technology, to address current vehicle batteries that are not recycled each year, and to develop best practices for the next generation batteries. Our objectives are to advance responsible practices by developing tools and promoting best practices for managing batteries throughout their life cycle; to create closed-loop solutions for emerging battery technologies; and to build public/private programs to ensure the economic, social, and environmental benefits of responsible battery management.

RBC Comments

California has done more than any other state to facilitate the widespread adoption of electric vehicles (EVs), and it recently announced new measures to do so again. We are concerned, however, that this time the state is pursuing an EV policy whose tradeoffs have not yet been sufficiently evaluated.

A recent proposal from the California Air Resources Board (CARB), the state's clean air agency, would require EVs built in 2026 and beyond to have batteries that maintain 80% of their power for at least 15 years. This "durability requirement" is intended to promote the resale of used EVs by assuring purchasers that the battery still has enough remaining life to run the car.

Current federal rules require EV batteries to last eight years or 100,000 miles. Manufacturers design batteries to meet that standard, and most will replace batteries that fall below 70% capacity.

We recognize that promoting the broad use of EVs, including used ones, supports California and national goals of reducing greenhouse gas emissions. But potential undesirable outcomes of CARB's proposal include batteries being replaced before the end of their useful life, adding weight and decreasing vehicle efficiency, and increasing the cost of batteries, which together could slow down market adoption of EVs. It could also overwhelm the nascent EV battery recycling industry, which is racing to prepare for the nearly 16 billion pounds of lithium-ion EV batteries (approximately 403 million batteries) expected to reach end of life by 2040.

The proposed mandate will also influence battery-related environmental emissions in ways that haven't been analyzed or fully understood. All stages of the battery lifecycle – from raw materials extraction through manufacturing, use and charging, secondary use outside the EV, and eventual recycling – have emissions properties that must be considered and weighed when creating public policy.

RBC believes that a better approach would be to focus on maximizing value and minimizing emissions in every stage of the EV battery life cycle. We encourage policy leaders in California to drive policy toward creating a "circular economy" for EV batteries, similar to what has already been achieved for lead-acid batteries. This approach is embodied in a set of principles developed by the University of Michigan Center for Sustainable Systems – and sponsored by RBC – known as the "Green Principles for Vehicle Energy Storage," which are linked [here](#) and submitted as part of the record.

At their core, these green principles focus on informing battery technology development through a sustainability lens as the EV market continues to grow. With a data-driven framework, the green principles are intended to educate material suppliers, battery and vehicle manufacturers, national labs, consumers, and recyclers so they can make informed decisions on sustainable battery management practices.

As the world moves steadily towards adopting EVs, policy mandates, such as those being advanced by CARB, need to be supported by extensive data and science, comprehensive analysis of the tradeoffs involved in battery technology, production, and use, and multi stakeholder review prior to enactment. As an organization comprised of the world's largest battery manufacturer and recycler, several of the world's largest battery users and retailers, and supported by ground-breaking scientific and academic research, we urge California authorities

not to prioritize a singular outcome of sufficient battery life in used EVs over sound, science-based public policy

One of the main goals of adopting EVs is to reduce greenhouse gas emissions, and we believe that the starting point of public policy discussions about advanced batteries should be focused on establishing a true circular economy for batteries that minimizes full life cycle environmental and emissions impacts.

RICE UNIVERSITY, BAKER INSTITUTE FOR PUBLIC POLICY

Dear California Lithium-ion Car Battery Recycling Advisory Group:

The Baker Institute for Public Policy, Center for Energy Studies,¹ is pleased to submit comments to the California Lithium-ion Car Battery Recycling Advisory Group on the draft report of policy recommendations pertaining to the recovery and recycling of lithium-ion vehicle batteries sold with motor vehicles in the state.

The global energy market is undergoing dramatic change in terms of supply, demand and price. Emerging political and regulatory issues have raised uncertainty for market developments in this new paradigm. The Center for Energy Studies at the Baker Institute provides in-depth analyses of these market developments and policy issues. The Center is committed to providing unbiased, data-driven policy recommendations to policymakers and industry on energy-related matters.

The Center for Energy Studies has been involved in numerous efforts related to life cycle battery management and has developed tremendous relationships throughout the battery supply chain. We have also been actively engaged in the quarterly advisory group public meetings. Additionally, we have testified before the U.S. House of Representatives, Committee on Energy & Commerce, Subcommittee on Energy, "The CLEAN Future Act: Driving Decarbonization of the Transportation Sector."

The Baker Institute, Center for Energy Studies, appreciates the effort California is making to create policies pertaining to the recovery and recycling of lithium-ion vehicle batteries. We would like to highlight the following general comments:

Development and use of comparable attributes to internal combustion engine vehicles

The established, conventional internal combustion engine vehicle (ICEV) industry is characterized by a large and lucrative pre-owned vehicle market as well as a large and lively salvage and after market industry for parts. The ICEV industry also has a long tradition of recycling metals, including platinum from catalytic converters, and batteries, with roughly 90% recovery for refurbishment and recycling and well-established practices for ultimate disposal. Development and use of electric vehicles (EVs) should demonstrate comparable attributes, or EV transportation is unlikely to be achieved successfully.

Evolution of secondary and salvage markets

Our main concern is whether the recommendations, as they are presented and if accepted by the California State Legislature, will foster evolution of an efficient, effective, organic electric vehicle battery (EVB) salvage marketplace. That marketplace will need to incubate investment in innovative services and technologies for aggregation and appropriate treatment of EVBs for dismantling, re-use, recycling and/or disposal.

Definition of "end of life"

A distinct omission from the recommendations is a clear and definitive definition of "end of life" (EOL) and how that definition applies relative to the key recommendations – core exchange and vehicle backstop policy. How the EOL concept is established has an enormous bearing on the recommendations and how they would be implemented. The definition of EOL should distinguish the "vehicle" as separate from the "battery" given that post-EOL treatment and chains

of custody will vary for non-battery vehicle components. For the most part, non-battery vehicle components that reach EOL can enter legacy, conventional salvage operations.

- Clearly, EVBs that remain in warranty are subject to warranty terms and conditions including original equipment manufacturer (OEM) certification of the battery, as the recommendations acknowledge.
- Core exchange and vehicle backstop seem most compatible for EVBs that are under warranty and for which EOL is a consequence of recalls or failure of warranty performance. In these situations, standard OEM practices for repair and replacement would apply. These should include replacement of the battery by the OEM supplier.
- Likewise, the producer take-back policy also seems most compatible with, and applicable to, EVBs that are under warranty but for which EOL is a consequence of recalls or warranty performance failure.
- For EVBs under warranty, EOL that is *not* a result of recalls or warranty performance failure implies damage to or destruction of EVBs from crashes. In these situations, chains of custody and regulatory responsibilities as potential hazardous waste generators transfer to dismantlers and salvage operators as stated.
- What determines EOL for EVs and EVBs that are out of warranty? How will that EOL declaration and classification affect disposition of the EVB and eventual chain of custody? In these situations, producer take-back seems incompatible. How will original equipment manufacturers (OEMs) and/or their powertrain vendors be incentivized or even legally required to retain chain of custody?
- Once custody is established at EOL, how long is it retained, or how is it transferred and with what obligations?
- Nowhere in the primary policy recommendations is there discussion of ultimate disposal. EVBs that reach EOL because of crash damage may not be appropriate for anything other than disposal as a regulated hazardous waste. We assume that chain of custody and responsibilities as “generators” of hazardous waste will transfer to dismantlers and salvage operators in these instances, but this should be clarified in the document.

Incompatibility of policy recommendations

Because of how the Advisory Group recommendations were solicited and how they are presented, there is a lack of consistency. Indeed, various policies have been voted on, and according to the number of votes, they appear as preferred among advisors. But some policies are incompatible with one another as we point out above. In particular, we view the producer take-back policy as outlined in the document to be inconsistent with evolution of an efficient, effective EVB salvage marketplace, as we state at the outset, and will suppress the innovation that will be needed. We also believe that the producer take-back policy will undermine efforts to make EVs more affordable and practical as a transportation option. For the Legislature to adopt a practical and implementable recommendation, they must carefully assess how one approach enables the other and not the opposite.

Insights and cooperation outside California are needed

Although the Advisory Group did excellent work in analyzing what was done in other regions and thoroughly understanding the problem of EV batteries, some essential elements are lacking such as

cooperation outside California, e.g. other neighboring states and cross-border partnership with Mexico, a major trade partner of the United States.

Flexibility to account for uncertainties

With respect to the two main recommendations and the supporting policy proposals summarized in Table E1, we note that the Advisory Group and State are acting within a contextual milieu of great uncertainty regarding any number of variables. Consequently, the State initiative must be flexible to accommodate rapidly changing developments as the EV transportation industry expands and matures. Uncertainties include, but are not limited to:

- EVB chemistries and designs;
- Ability of OEMs to meet production targets in view of emerging and pronounced materials supply chain challenges;
- Pace of adoption and EV consumer behavior;
- Public perception of recycling and siting of hazardous waste/recycling facilities; • Protracted timeline to cite, permit and construct lithium ion battery recycling facilities to meet recycling targets;
- Quality and purity of products from recycled materials and effect on performance and safety
- The development of a well-functioning secondary materials markets to receive recycled materials that may or may not be suitable for use in lithium-ion batteries
- Emergence of data on the range of life cycle impacts across EV supply chains (economic, environmental, social) and/or life cycle metrics specific to battery recycling processes that could offset sustainability and climate goals, environmental justice initiatives and “zero waste” targets;
- The developing federal policy and regulatory landscape for EVs and EVB handling, consumer product information, labeling and data transparency; and
- The emerging international landscape for trade, including international protocols for waste and waste management, product information, labeling and transparency. o For example, in the Basel Convention, there is a clear lack of harmonized regulatory definitions for resource recovery, reclamation, reuse, and recycling, especially for lithium and cobalt, which has been major barrier to developing a common understanding and subsequently a business case for these processes.

Considerations for federal policies, public acceptance, and material recovery rates

Federal policies and regulations that affect industrial recycling businesses, state responses and public acceptance of these facilities all will have bearing on the extent of material recovery from EVBs. California currently has no permitted lithium-ion battery recyclers in the state, and permitting of such facilities can span a decade or more and challenge timelines and recycling goals. Additionally, recycling efforts are unlikely to supplant the need for primary battery metals and materials for many decades to come. This is because the volume of EVBs available for materials recovery will remain at low levels relative to manufacturing requirements until the EV industry and EV market penetration are large enough to yield.

Logistics, supply chain management and life cycle insights

The greater the extent of logistics and supply chain management associated with EVB life cycle management, especially with respect to longer distances domestically and international exchanges, the less attractive EVs are on a full life cycle basis, much less for affordability.

In addition to the above comments, we offer the Advisory Group the following suggestion for future consideration:

Blockchain for achieving transparent, accountable EOL management and a sustainable circular economy

Blockchain is an emergent technology that has significant potential to manage data underpinning materials with complex supply chains such as lithium-ion batteries in EVs. Blockchain can necessitate and provide great impetus for a transparent, accountable, and more circular and sustainable management system for EOL batteries in the complex global waste and resource management network. Decentralization brought by blockchain facilitates traceability and enables reliable monitoring of value chains. This can respond to challenges in a circular economy by tracking the flow of resources and materials by identifying opportunities to reinforce feedback loops and circularity process. It also reinforces reliability and trackability of policy, regulation, and official documentation, in particular in developing economies where much of the sourcing, processing, and EOL management for used EVs are retained. Blockchain can also be utilized to automate certification of authenticity of data and optimize the operations of governmental and private organizations. Incorporating the use of blockchain for EOL management of batteries can reduce the cost of transactions, simplify the transactional process, and provide unique social value by guaranteeing transparency, traceability and responsible EOL management.

The Baker Institute appreciates the California Lithium-ion Car Battery Recycling Advisory Group's consideration of our comments and would welcome working with you on any issues pertaining to the draft policy.

STATE OF CALIFORNIA AUTO DISMANTLERS ASSOCIATION

The State of California Auto Dismantlers Association (SCADA) has appreciated the opportunity to be an active participant in the CalEPA Lithium-Ion Battery Advisory Group and the Logistics, Recycling and Reuse Working Groups. SCADA, in particular, appreciated being able to make a presentation to the Advisory Group in late May 2021 on “California Automobile Dismantlers & Sustainable End-of-Life Policy Solutions for Lithium-Ion (Li-Ion) Batteries.” With the Lithium-Ion Car Battery Recycling Advisory Group Draft Report now available for review and public comment, we wanted to offer the following comments and recommendations on the draft report and note that the framework laid out within this report provides a positive roadmap for a successful long term EOL management program for lithium ion batteries.

Automobile dismantlers in California are occupationally licensed and regulated by the Department of Motor Vehicles (DMV) and are the entity in California responsible for managing and properly processing end-of-life (EOL) vehicles through proper removal, recycling and/or disposal of unused batteries, gasoline, brake fluid, engine oil, catalytic converters, tires, mercury switches and more. As part of their regulatory requirements under DMV, they must document, complete paperwork, and remit required fees and taxes to the state. Further, they are regulated by over a dozen local, state, and federal environmental, worker safety, tax and public safety agencies.

From a source reduction, environmental protection, greenhouse gas reduction and economic impact perspective, reuse of lithium-ion batteries should be the top priority. Unnecessary regulatory and economic barriers to the safe and effective handling, storage and shipping of the lithium-ion batteries should be minimized to the maximum extent feasible. Reuse of the batteries should include authorization for and them being made readily available by licensed automobile dismantlers to repair shops and the public as a cost effective option for vehicle repairs and replacement, and for micro energy storage systems.

To the extent that unnecessary regulatory and cost barriers are erected to limit reuse and repurposing as viable options, substantial numbers of these batteries will end up in the hands of unlicensed and unregulated bad actors operating inside and outside of California. It is estimated by industry and CA DMV that at least 40% of the 1.2 million end-of-life vehicles, or 480,000 vehicles annually, are being acquired and processed by unlicensed and unregulated automobile dismantlers who do not comply with DMV licensing requirements, environmental regulatory requirements, insurance obligations, workplace safety requirements and tax and fee payment liabilities as required for licensed dismantlers. The consequences of unnecessary regulatory and cost barriers related to EOL management of lithium-ion batteries will lead to more illegal dumping, improper hazardous waste handling, violations of workers safety protections, lack of compliance with DMV requirements and much more.

The serious problem of unlicensed automobile dismantlers is solvable. To that end, legislation was passed in 2021, Senate Bill 366 by Senator Tom Umberg, to reauthorize the Vehicle Dismantling Industry Strike Team (VDIST). VDIST is a multi-agency task force of DMV, CalEPA, DTSC, CalRecycle, CARB, SWRCB and CDTFE that will coordinate enforcement and compliance activity related to unlicensed and unregulated automobile dismantling. With the enactment of SB 366, VDIST can build on the successes it accomplished from 2017 to 2020. During that time, VDIST opened a total of 1105 cases, 824 which were for unlicensed automobile dismantling. These cases led to 556 citations for violation of unlicensed automobile dismantler laws and other associated crimes. In addition, the strike team referred 202 cases to state

environmental agencies and 81 cases to the California Department of Tax and Fee Administration for further investigation and enforcement. VDIST's January 21, 2020 report to the Legislature recommended the continuation of the coordinated enforcement and compliance activities of the Strike Team. The Report also made several recommendations for statutory and regulatory changes to help address the problem of unlicensed automobile dismantling, including escalating fines for repeat violators and to add in statute the authority for use of public nuisance and abatement laws for locations where unlicensed dismantling is occurring. Those recommendations were incorporated into Senate Bill 366.

With the reauthorization of VDIST, the foundation is set for the legislature and regulatory agencies to properly fund and sustain the necessary long-term commitment to solve the problem of unlicensed automobile dismantling. Solving this problem is essential for the success of the EOL management program for lithium ion batteries as outlined in this report.

We should note that while there were discussions in the lithium ion working groups about streamlining the hazardous waste permitting process for battery recyclers that may want to locate their facilities in the state, we would have significant concerns with any new hazardous waste permit requirements for licensed automobile dismantlers that are handling lithium ion batteries. Such requirements would be unnecessary, extremely costly and burdensome, and would undoubtedly lead to large numbers of the batteries being acquired and improperly processed by unlicensed and unregulated automobile dismantlers.

To facilitate optimal EOL pathways for these batteries, we concur with the recommendation in the report that parties involved must have easy access to information from the OEMs about the battery and instructions for disconnecting, dismantling and handling the battery. Such information should include proper labeling on year, make and model of the battery/vehicle, accessible information on battery chemistry, mechanisms for ease of diagnosing and assessing battery condition, and contacts of responsible entities for proper recycling and disposal. We highly recommend including labeling on the door frame similar to how tire pressure labeling is handled. Labeling just on the battery only helps once the battery is removed. The safety and dismantling information is best available prior to doing any work to remove the battery.

Ultimately, a successful outcome to addressing EOL management of lithium-ion batteries will be enacting a legislative and regulatory work product that results in a substantial number of these batteries being reused through regulated, licensed entities as a safe and affordable option for vehicle repairs and micro energy storage systems. SCADA and its membership look forward to utilizing our expertise and proficiency as EOL processors to make this program a huge success and major contributor to the state's transition to a greener economy.

UNIVERSITY OF TOLEDO

I realize the material in the monograph below is too long for your report, but I wanted to raise the issue of Second Life (or Repurposed) cell capacity spread since previous publications have failed to offer any realistic and low cost solutions for this. Also, please pass this along to those in your organization who might have an interest.

Thanks.

Tom Stuart

The Bilevel Equalizer: A Low-Cost System to Fully Utilize the Capacity of Second Life EV Batteries

Thomas Stuart, PhD, PE

Professor Emeritus of Electrical Engineering

University of Toledo

There have been numerous studies on the merits of Second Life (SL) applications for used lithium ion electric vehicle (EV) batteries. However, virtually none of these address the effect of the spread in cell capacity as the battery is cycled and ages. They also provide no original ideas as to what can be done about this.

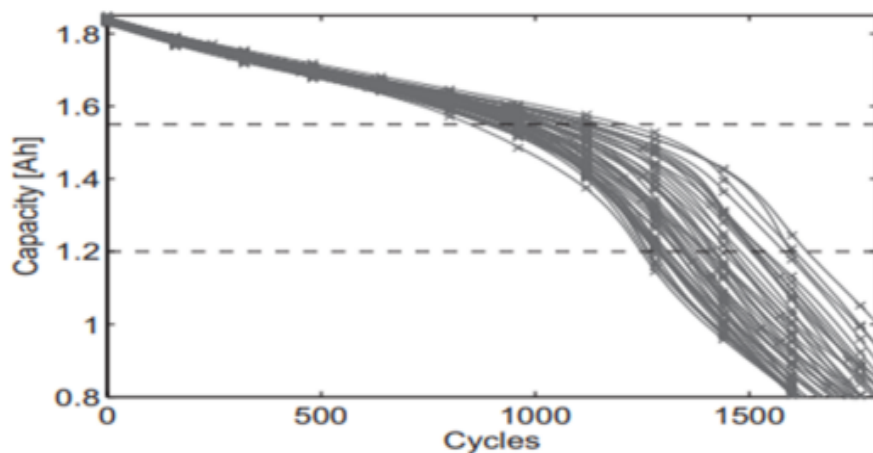


Fig. 1. Capacity vs. number of charge/discharge cycles for 48 NMC cells. Reproduced with permission.⁴⁶

Fig. 1 shows plots of capacity vs. the number of charge/discharge cycles for 48 nickel manganese cobalt (NMC) cells. Plots of this type are very important for SL analysis, but they are very rare in the published literature, probably because obtaining them is very expensive and time consuming. In fact, Fig. 1 is the only published set of plots of this type known to the author. Although these 48 cells were not EV cells, the upper dashed line at 1.55 Ah (~80%) might represent the start of SL, and the lower line at 1.2 Ah (~65%) might represent the end of SL.

⁴⁶ This figure was published in Journal of Power Sources, 247, Baumhofer, T.; Bruhl, M.; Rothgang, S.; Sauer, D. Production Caused Variation in Capacity Aging Trend and Correlation to Initial Cell Performance, 332-338, Copyright Elsevier (2014).

If a battery composed of these 48 cells used a standard EV Passive Equalizer (PEQ) to balance the cell voltages, the battery capacity would be the same as the lowest plot, i.e. the worst cell in the battery. However, if it used a more recent Bilevel Equalizer (BEQ,⁴⁷ shows the capacity would be almost equal to the average capacity of the cells. A simplified diagram for this is shown in Fig. 2. These figures also indicate the SL capacity and lifetime for the BEQ (plot B in Fig. 2) will be about 50% higher than for the PEQ (plot A in Fig.2).

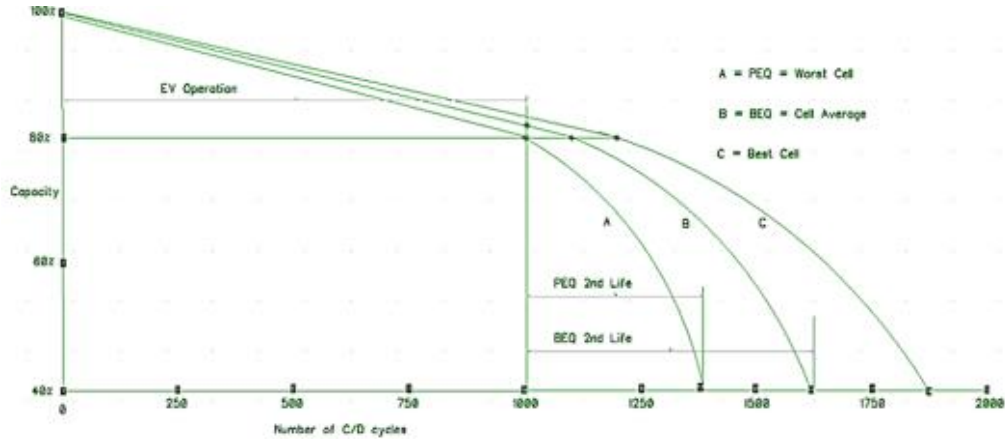


Fig. 2. Capacity vs. number of charge/discharge cycles for EV and SL operation. Figure credit to Dr. Stuart.

As explained in Mubenga et al. (2021), the BEQ is a hybrid equalizer (EQU) that divides the battery into sections, each with about 4 – 8 series connected cells. Passive EQUs (PEQ) with resistors are used at the cell voltage level to compensate for differences in cell self-discharge (SD) within the sections, and active EQUs (AEQ) with inductors are used at the section voltage level to compensate for differences in capacity fade (CF). Fig. 3 shows a block diagram of a battery with 4 sections and a BEQ, and Fig. 4 shows the schematic of the AEQ drivers for a battery with 3 sections. This PEQ/AEQ combination is used to reduce the number of AEQ drivers, which are more expensive than PEQ drivers. For example, a 96 cell battery with only an AEQ would require 95 AEQ drivers ($N - 1$), but a BEQ with 8 cells/section would only require 11 AEQ drivers. Although a BEQ is more expensive than a PEQ, the extra cost is much more than compensated for by the increased performance of the SL battery.

⁴⁷ Mubenga, N.; Salami, B.; Stuart, T. Bilevel vs. Passive Equalizers for second life EV batteries. *Electricity* 2021, 2, 63-76.

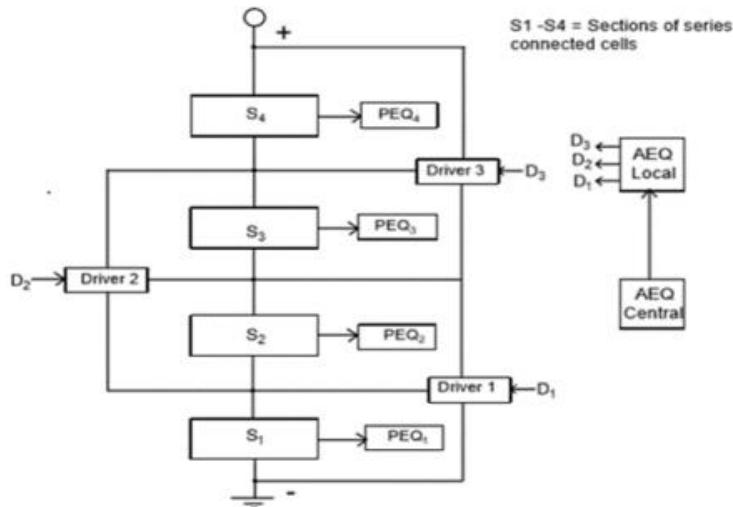


Fig. 3. BEQ connections for a battery with 4 sections. Figure credit to Dr. Stuart.

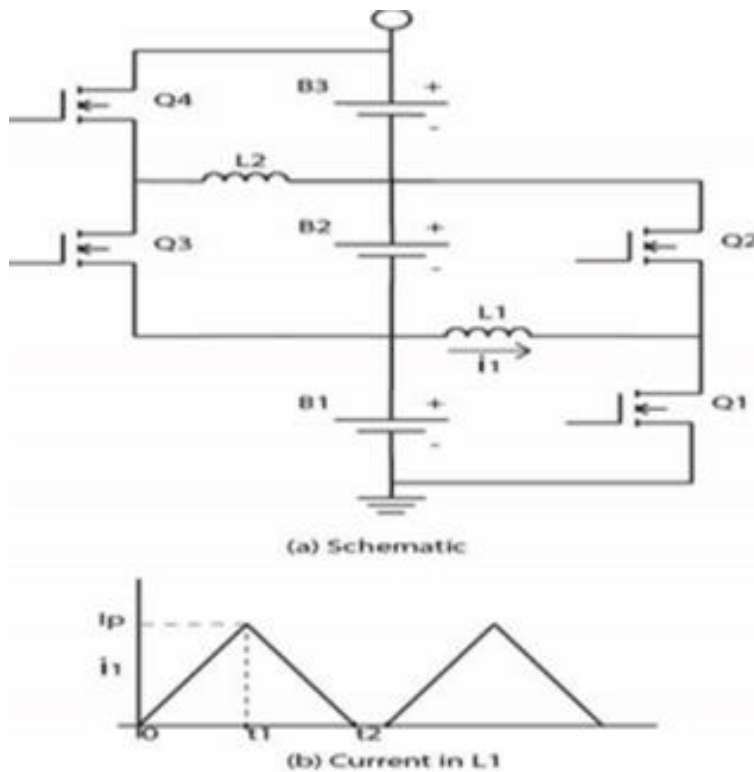


Fig. 4. BEQ connections for a battery with 3 sections. Figure credit to Dr. Stuart.

Although the BEQ will provide better SL battery performance, the first question is, how much better? This can only be answered by plots similar to Fig. 1 for used EV batteries operated in the SL region, but obtaining this data has been very labor intensive, time consuming, and expensive. The second question is, even if you have the data, what can you do about it? PEQs have no effect on CF, and AEQs have proven too expensive, especially large ones that would be required to compensate for differences in CF. Fortunately, the BEQ provides the answer to both questions.

Regarding the first question, it is not really necessary to obtain the plot for each cell as in Fig. 1. All that is actually needed are plots for the worst cell and the cell average, such as plots A and B

in Fig. 2.⁴⁸ describes an automated low cost procedure that can be used to obtain these two plots, using the same battery with a BEQ for both plots. By changing the software, a BEQ can be operated either as a BEQ or a PEQ. On the first cycle, the battery is charged using the PEQ and then discharged. The PEQ discharge capacity is recorded to provide the first point for plot A in Fig. 2. On the next cycle, the battery is charged using the BEQ and then discharged. The BEQ discharge capacity is recorded to provide the first point for plot B. The process is continued using the PEQ and the BEQ on alternate C/D cycles. This provides an automated life test that can be run 24/7 with very low labor requirements.

The BEQ is also the answer to the second question. Previously, there was no known EQU that could economically provide operation on plot B in Fig. 2. Now the BEQ is available for this. As seen from Figs. 1 and 2, there is not much reason to use a BEQ for EVs since the cell capacity spread in this region is fairly low. However, if the SL cell capacity spread is wide, as in Fig. 1, the BEQ can be of great benefit. It is also noted that when a battery reaches the end of its SL life and is replaced, the replacement battery can still use the same BEQ, i.e. the BEQ doesn't need to be replaced when the battery is replaced.

⁴⁸ Mubenga, N.; Stuart, T., Capacity Measurements for Second Life EV Batteries, University of Toledo, January 2022.

WORLD RESOURCES INSTITUTE

On behalf of the [World Resources Institute](#), and its [Electric School Bus Initiative](#), we appreciate the opportunity to offer comments to the California Environmental Protection Agency (CalEPA) and the Lithium-Ion Car Battery Recycling Advisory Group on the [Final Draft Report](#).

SUMMARY FEEDBACK:

- **We emphasize these two elements as necessary for a successful recycling program:**
 - a clearly defined chain of battery responsibility throughout the battery life cycle from manufacturing until the end-of-life and beyond
 - data transparency including physical labeling, digital identifiers, and universal data processing to enable safe and efficient dismantling
- **We strongly support:**
 - the producer take-back policy
 - the core exchange and vehicle backstop policy
- **We recommend:**
 - supporting state incentives to prioritize job skills training on battery recycling and growing a nascent lithium-ion battery (LIB) recycling market in-state
- **We encourage reconsidering:**
 - circular economy and quality recycling policies, which are critical to maximizing reuse and recyclability and minimizing environmental waste
 - Such principles can be supported further through additional CalEPA studies that could then inform voluntary guidelines developed jointly with industry.
 - The Platform for Accelerating the Circular Economy (PACE), hosted by WRI, offers [insights on circular economy applications for electronics](#), which can be applied to LIBs in the state.

WRI overall supports the policies proposed, which have the potential to reduce reliance on raw material extraction, prevent toxic or hazardous safety conditions, create Californian jobs in the nascent battery recycling industry, and aid in training opportunities for communities.

- WRI supports the key issues and concerns raised by the Advisory Group and need for urgent action on LIB recycling:
 - The consequence of not enacting any lithium-ion car battery recycling regulation could lead to environmental contamination, battery storage hazards, and other detrimental outcomes. The benefits of recycling include strengthening a domestic supply of raw materials, diverting waste, and creating economic opportunities by supporting a new industry.

- California contains 42% of the U.S. electric vehicle (EV) fleet and the need for battery responsibility policies are urgent. The state should consider drafting policies that can be easily adapted by other states or regions.
- WRI supports clarity of Li-ion battery responsibility in the following scenarios from the report:
 - For vehicles under warranty, vehicle manufacturers are held responsible for reusing, recycling, or repurposing batteries. Ensuring that manufacturers have proper plans and storage protocols for LIBs will be key for this scenario.
 - WRI supports the producer take-back policy, which has the automotive manufacturer take responsibility at the EOL and then transfers that responsibility as needed.
 - This policy simplifies the chain of custody and centralizes battery responsibility.
 - WRI supports the core exchange and vehicle backstop policy for out-of-warranty vehicles, which segments responsibility for EVs in service and those reaching end-of-life (EOL) to entities performing removals, battery suppliers, dismantlers, or vehicle manufacturers.
- There may be potential areas that require further analysis and definitions:
 - If OEMs will take considerable responsibility across the battery life cycle, including outside of warranty periods, by how much might this increase retail EV prices?
 - Are there ways to prevent the supply chain from avoiding LIB recycling responsibility in California?
 - For example, could state officials create a deposit/refund system for new EVs registered in the state to make it uneconomical to ship batteries out of state. We encourage further analysis to understand EV cost implications.
 - Will the recommended policies apply and be consistently implemented across vehicle classes from light-duty to heavy-duty and for on- and off-road vehicles and equipment?
- Data transparency and traceability across the battery value chain will require specifying the types of data and stakeholders that need to be engaged in data verification
 - Physical battery labeling requirements in addition to a digital identifier would allow for universal ability to identify LIB chemistry.
 - Addressing data gaps such as battery chemistry, battery condition, and battery safety guidelines will enable quicker disassembly and data transparency.
 - An efficient and more accurate diagnosis of batteries at EOL will help save time and costs, improving the business case for recycling and reuse.
 - Data shared by battery manufacturers, suppliers, OEMs, third party battery diagnosis tools will need to be standardized and verified to ensure trust across the value chain.

- If proposed third party data verifications occur through an online database system or through non-profit/university partners, it is important to ensure an equitable approach to data sharing and eligible third parties.
- We suggest the potential use of tools like the International Dismantling Information System (IDIS) or the EU-supported Battery Passport for EV batteries. This would provide visibility over materials and component construction of batteries to ensure end of life recycling can be standard.
- Skills training for safe battery disassembly should be made accessible to all communities o While the report notes the need for training programs to safely work with EOL vehicles, an emphasis on battery disassembly training made widely accessible to all communities would ensure safe handling across the supply chain.
 - Handling EV battery disassembly can be a dangerous task if carried out by untrained and/or uncertified technicians. Unlicensed dismantlers need to be engaged to ensure training and prevent safety incidents.
 - Training programs should be made available online and through technical and community colleges, which will accelerate upskilling and participation in the emerging EV battery recycling and reuse marketplace.
- State incentives to support the battery dismantling, repurposing, and recycling companies should be implemented
 - These incentives can mirror CA state investments made in the zero-emission vehicle manufacturing sector like grants and loans.
- Promote and reconsider circular economy principles like design for reuse, recycling, and repurposing despite lack of majority advisory group votes
 - Processes to increase ease of end-of-life dismantling and reuse, consistent with circular economy principles, could be voluntarily encouraged among battery suppliers and vehicle manufacturers. Incentives like innovation grants or R&D funding may aid in this effort.
 - CalEPA could consider additional data, advisory group development, and analysis for future circular economy policies following the initial proposed LIB Recycling policies.

WRI and its Electric School Bus Initiative thanks the Advisory Group for accepting public comments and developing the policy proposals. WRI welcomes the opportunity to further support these efforts.