# Hawaiʻi Natural Energy Institute

School of Ocean and Earth Science and Technology
University of Hawaiʻi at Mānoa

**OPTIONS FOR LITHIUM BATTERY DISPOSAL IN HAWAIʻI: REQUIREMENTS AND ANALYSIS**

**Prepared for the Hawaiʻi State Energy Office**

**December 2025**



# TABLE OF CONTENTS

# LIST OF FIGURES

# ACKNOWLEDGMENTS

The author would like to acknowledge the following contributors to the working group.

Tess Herman, Hank Benson, Allen Evans, Eric Frederickson (Call2Recycle), Greg Sakaguchi (Island Movers), Jason Gruver, Jordan Brandt, Jessica Dunn, Henry Gabriel, Munashe Chando (HSEO), Monique Schafer (HSEO), Kevin Moy (HSEO), Randall Lund (AGCS), Nick Garofalo (Radius Recycling), Todd Coy, Will Giese, David Thompson, Terry Surles, Marc Boolish (PBRA), George Kerchner, Wayne Tanaka (Sierra Club), Sandy Ferreira (ATLAS Insurance), Kiara Bacasen (Sierra Club), Calvin Matsushima (ATLAS Insurance), ADP Towing, Steve Sloop, Nate Pelczar (California Product Stewardship Council), Doug Kobold (California Product Stewardship Council), Gabbi Alvayay-Olson (Redwood Materials), Matt Terry (ATLAS Insurance), Travis Hesterberg (Ecobat), Matthieu Dubarry (HNEI).

# FOREWORD

The Hawai‘i Natural Energy Institute at the University of Hawai‘i at Mānoa was tasked by Act 92, Session Laws of Hawai‘i 2021, to report on the best practices for disposal, recycling, or secondary use of clean energy materials resulting from our transition to renewable energy. That **initial** report, titled ***Recommendations on Waste Management of Clean Energy Products in Hawai'i***, was submitted in time for the state legislature's first regular session of 2023 and is available at https://www.hnei.hawaii.edu/wp-content/uploads/2023-HNEI-Act92-Final-Report-Clean-Energy-Products-Waste-Management.pdf.

A **second** supplemental report, titled ***Policy Recommendations on Waste Management of Clean Energy Products in Hawai'i***, intended to add depth to policy recommendations for the disposal, recycling, or secondary use of clean energy materials (resulting from Hawai‘i's transition to renewable energy) was prepared and can be found at https://www.hnei.hawaii.edu/wp-content/uploads/HNEI-Act92-Supplemental-Report-Clean-Energy-Products-Waste-Management.pdf. For that report, input was obtained from a wide variety of sources but, as done in the original report, sources are referenced and notations are made when data has been approximated or translated to the Hawai‘i context.

A **third** report, titled ***Waste Management of EOL PV Panels and LIBs in Hawai'i***, was prepared for the Hawai‘i State Energy Office and can be found at https://www.hnei.hawaii.edu/wp-content/uploads/Waste-Management-of-EOL-PV-Panels-and-LIBs-in-Hawaii.pdf. The material contained therein added depth to the policy recommendations in the second report, i.e. for the end of life (EOL) treatment of lithium-ion batteries (LIB) in Hawai‘i. It specifically focused on the road blocks, costs, and risks associated with the processing of EOL LIBs in Hawai‘i, as well as introducing current state of the art efforts in California. For that report, input was obtained from a wide variety of sources but, as done in the original two reports, sources are referenced and notations are made when data has been approximated or translated to the Hawai‘i context.

This **fourth** report adds to the previous three by providing a detailed analysis of three potential remedies to the overall dilemma of expanding volume of used "waste" EOL lithium-ion batteries generated in Hawai‘i. In the first, used "waste" EOL lithium batteries are not physically treated by any method other than to package and ship them directly to mainland recyclers. In the second, the used "waste" EOL lithium batteries are deactivated using treatment by supercritical $CO_2$ prior to packaging and shipping them directly to mainland recyclers. In the third, the lithium batteries are deactivated by wet shredding them to an inert crude black mass that is then shipped directly to mainland recyclers. In addition, the insurance requirements of each treatment pathway were also examined. Finally, three frameworks of stewardship structures, each of which would manage and fund the collection, on-island transport, on-island temporary storage, on-island sorting, on-island treatment (by *any* of the three processes considered above), and off-island shipment to mainland recyclers were reviewed.

A **fifth** forthcoming report that provides a detailed analysis of the requirements of each of the three-stewardship structure considered will be presented in Spring of 2026.

# EXECUTIVE SUMMARY

This report provides a detailed requirements analysis of three potential remedies to address the overall dilemma presented in HNEI's three previous reports[1]: the expanding volume of used "waste" end of life (EOL) lithium-ion batteries (LIB) generated in Hawai'i. In the first report, used "waste" EOL lithium batteries are not physically treated by any method other than to package and ship them directly to mainland recyclers. In the second, the used "waste" EOL lithium batteries are deactivated using treatment by supercritical $CO_2$ prior to packaging and shipping them directly to mainland recyclers. In the third, the lithium batteries are deactivated by wet shredding them to an inert crude black mass that is then shipped directly to mainland recyclers. For all three reports, the physical requirements of each method are provided in great detail. In addition, three frameworks of stewardship structures, each of which would manage and fund the collection, on-island transport, on-island temporary storage, on-island sorting, on-island treatment (by *any* of the three processes considered above), and off-island shipment to mainland recyclers are presented. Finally, the insurance requirements of each treatment pathway are discussed.

Located in the middle of the Pacific Ocean, largely dependent upon ocean shipping, and working under a mandate to expand and accelerate Hawai'i's renewable resource development by 2035[2], the state of Hawai'i is facing an oncoming crisis with respect to the flow of used "waste" EOL LIBs at all formats entering the waste stream. Exasperating this crisis is the reality that LIBs share a concerning similarity to military bombs; they both release a tremendous amount of stored energy very rapidly. While such explosions are a dangerous malfunction and not the intended function of lithium batteries, their pervasive distribution at all scales and formats within every facet of our community, coupled with high ignorance of their proper treatment, use, and disposal, nonetheless imposes significant risk to Hawai'i's population and economy. Indeed, the warning signs are already appearing, such as many local salvagers refusing to accept EVs[3], tow truck drivers increasingly reluctant to tow abandoned/damaged EVs[4], the increasing occurrence of fires in refuse

---

[1] https://www.hnei.hawaii.edu/wp-content/uploads/2023-HNEI-Act92-Final-Report-Clean-Energy-Products-Waste-Management.pdf; https://www.hnei.hawaii.edu/wp-content/uploads/HNEI-Act92-Supplemental-Report-Clean-Energy-Products-Waste-Management.pdf; https://www.hnei.hawaii.edu/wp-content/uploads/Waste-Management-of-EOL-PV-Panels-and-LIBs-in-Hawaii.pdf.

[2] https://governor.hawaii.gov/main/governor-green-reinforces-commitment-to-renewable-energy/.

[3] Personal communications and, for example, https://www.kitv.com/news/dead-batteries-from-electric-vehicles-in-hawaii-find-dead-ends/article_92426e58-3279-11ee-8f25-3b6dbd36030e.html.

[4] Personal communications.

vehicles[5], at transfer stations[6], and refuse processing facilities (H-Power)[7], and the appearance of fires at homes containing e-bikes, e-scooters, and energy storage systems[8]. Moreover, the recent surge of fires on-board ocean-going vessels have catalyzed a recent decision by Matson[9] and Alaska Marine Lines[10] to forbid the shipment of new EV vehicles, let alone used EOL EVs. The shipping giant Mediterranean Shipping Company (MSC) has explicitly stated that it will not transport used or damaged LIBs in ocean containers[11]. Meanwhile, CMA CGM has banned shipment of electric and hybrid vehicles older than seven years[12]. Moreover, even when it's possible to ship lithium batteries (and equipment containing them), the restrictions are only getting tighter and the costs (to ship) only higher[13]. The presence of any quality statewide stewardship structure, therefore, that increases public and business access to readily accessible and cost-effective disposal solutions will only help to reduce these and all other concerns.

As was noted our third report[14], the working group noted the absence of mechanisms in place in Hawaiʻi to track the quantity of used "waste" EOL lithium batteries leaving the state, a result largely owing to their classification as universal waste in shipping manifests. The depth of the problem is thus difficult to quantitate but given the universal use of LIBs at all formats and corners of Hawaiʻi's economy, the working group concluded that the absence of a stewardship structure that can track lithium batteries and organize their collection and safe shipment off island poses a foremost threat to Hawaiʻi.

To counter this threat, the broad consensus of the working group was that the state of Hawaiʻi should develop an independent stewardship structure/framework that not only oversees/manages the collection, on-island transport, temporary storage, sorting, and deactivation of used "waste" EOL lithium batteries, but also is empowered in law to raise the funds that will be necessary to support the capture and disposal of over 95% of all used "waste" EOL lithium batteries produced in Hawaiʻi. Of the three stewardship structures studied, the one considered the most practical and effective is a state sanctioned non-government aligned professional responsibility organization that can/will oversee a broad portfolio of public/private efforts to manage the capture and

---

[5] https://www.youtube.com/watch?v=45UXxT4BUr0.
[6] Personal communications.
[7] Personal communications and, for example, https://www.hawaiinewsnow.com/2024/07/16/ems-5-men-treated-smoke-inhalation-2-alarm-fire-h-power-plant/.
[8] https://youtu.be/vgEFEZd9mEE?si=h1c6GGkMxfS35fJD.
[9] https://subscriber.politicopro.com/article/eenews/2025/08/05/hawaiian-shipper-stops-ev-deliveries-because-of-battery-fires-00492913.
[10] https://alaskapublic.org/news/public-safety/2025-08-20/alaska-marine-lines-will-no-longer-ship-electric-vehicles-due-to-fire-risk.
[11] https://www.icetransport.com/blog/can-i-ship-lithium-batteries-in-an-ocean-container.
[12] https://www.cma-cgm.com/assets/public/pdf/Client%20advisory%20Booking%20Guidelines%20for%20EVHEV%20cars%20%20General%20forms%20of%20vehicles%20CCAI467081123.pdf.
[13] https://www.iims.org.uk/transporting-li-ion-batteries-identifying-and-addressing-the-risks/.
[14] https://www.hnei.hawaii.edu/wp-content/uploads/Waste-Management-of-EOL-PV-Panels-and-LIBs-in-Hawaii.pdf

processing/pretreatment of used "waste" EOL lithium batteries. The working group recommended that options to fund the stewardship structure should include, but not necessarily be limited to, a combination of EPR laws, advanced disposed fees[15], taxes/registration fees, and tipping fees.

Of the three methods reviewed to pretreat the used "waste" EOL lithium batteries for marine transport, the most practical for Hawaiʻi was felt to be a state supported wet shredding operation[16], one that is easily accessible to the public. That being said, the working group strongly noted that additional treatment/shipping pathways, pursued by private businesses that prefer to handle the disposal of their own used "waste" EOL lithium batteries, should also be encouraged and supported by the stewardship structure as long as they meet standards acceptable to the stewardship program. The key advantages found to support the wet shred option included (but were not limited to): (i) modularity that supports easy repurposing and redesign; (ii) scalability that allows for expansion or contraction based upon market demand; (iii) production of an inert crude black mass this is both safe for marine transport[17] and readily acceptable to mainland recycle operations; and (iv) relative cost competitiveness at large scale. The other two options considered: deactivation by exposure to supercritical carbon dioxide and straight packaging of the used "waste" lithium batteries without any pretreatment were found less completive at large scale, owing to one or more of the following factors: (i) higher capital and/or operating costs; (ii) a lack of de-escalating risk during marine and/or land transport; (iii) a lack of successful demonstration/implementation at commercial scale; and (iv) a perceived lack of scalability relative to the volumes used "waste" EOL lithium batteries expected to be generated in Hawaiʻi.

In reaching these conclusions, the following attributes were weighted: (i) ability to reduce the overall cost of disposal at large scale; (ii) fit to the existing education/commercial expertise of Hawaiʻi's local work force; (iii) tolerance/acceptance of stewardship structure/treatment methods to shipping companies and their insurance underwriters; (iv) adaptability of design to other waste stream products in the event of new battery technologies entering the market; (v) ability to capture/process over 95% of *all* used "waste" EOL lithium batteries produced in Hawaiʻi regardless of format; (vi) ease of access to/or integration with existing waste management businesses in Hawaiʻi; and (vii) likelihood to reduce the illegal storage, abandonment, dumping, and/or misleading manifest declarations[18].

---

[15] Termed "Visible Fees" in California.

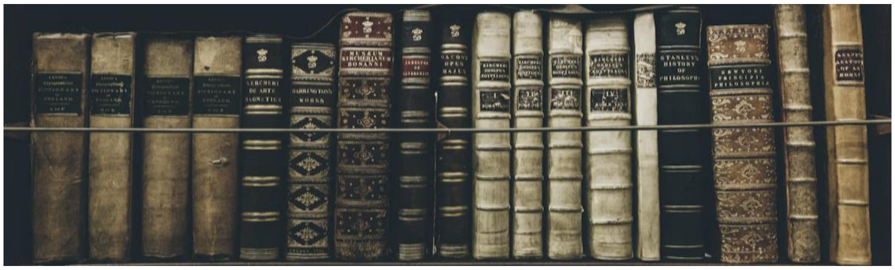
[16] Not considered by the working group was treatment option centered around crushing that was developed by the EPA and colleagues to treat the DDR lithium batteries recovered at the Lahaina fire debris. Despite some basic similarities to wet shredding, at the time of this report this was considered too immature in terms of development for a requirements study.

[17] With the obvious recognition that the crude black mass must be packaged to avoid risk of spillage to the environment.

[18] All of which could become unacceptably high, both to the shipping companies and to the insurance industry that covers ***all*** facets of exposure to lithium-ion batteries in the state.

In summary, if left unaddressed by a professional and independent stewardship program that has the authority to oversee a statewide operation that can ensure the capture and production of a "safe to ship" lithium battery waste streams, one that can certify/approve all participants involved in the overall logistic pathway, the state of Hawaiʻi will face the persistent threat of fires, accidents, and loss of access to the insurance and/or shipping necessary for the state's economy to function under a renewable energy mandate. Indeed, even homeowners/businesses possessing LIBs on their property will face similar risks of increased difficulty in obtaining homeowners/business insurance in the absence of a state solution that provides easy, cost-effective access to a state supported program that provides for their immediate removal and safe disposal[19]. Finally, the burden to homeowners, consumers, and small to medium sized businesses regarding the complexity of rules and regulations, coupled with the array of requirements of information all participations in the logistic pathway must provide to insurance companies, should be considered unacceptable. For these and all other reasons laid out in this report, it is recommended that the state seriously and immediately consider the enactment in law of a stewardship structure/format that manage/oversees a private/public program that can capture over 95% of all lithium batteries, regardless of format, and process them to a material that is safe to transport by marine shipment to off-island recyclers.

[19] https://abipdx.com/lithium-ion-batteries-pose-concerns-and-risks/.



# GLOSSARY

<u>*Battery cells.*</u> Battery cells are the individual units that store energy. A cell is a single encased electrochemical unit (with one positive and one negative electrode), which exhibits a voltage difference across its two terminals[20]. Battery cells can be aggregated into a battery module or pack. Battery cells are designed in various forms to fulfill specific applications. The three primary types are cylindrical, prismatic, and pouch cells. Cylindrical cells are commonly found in power tools, medical devices, computers, and e-bikes. A notable example of a battery cell is the 18650 cell, which is highly favored for its compact size and high energy density, making it ideal for aggregation into battery modules (power tool and laptop batteries) and battery packs (e-scooter and EV battery packs). Prismatic cells are typically encased in metal and primarily used in the electric powertrains of hybrid and electric vehicles. Pouch cells are commonly used in personal gadgets, defense equipment, and automotive applications. Most household batteries like the ones that power remote controls, alarm clocks, and flashlights are considered battery cells. Cell phone batteries are also considered a single battery cell.

***Figure 1. Examples of typical battery cells.***


[20] UN definition.

*Battery modules.* Battery modules are groups of cells connected together and housed within the same housing frame, case, or similar protective cover. In a battery module, the battery cells are connected in series or parallel in order to: (i) increase the overall capacity and power output and (ii) assemble additional key parts to the linked cells—a cooling system, a Battery Management System (BMS), and connectors. As such, battery modules are intermediate products between battery cells and battery packs. Battery modules each consist of a number of battery cells connected in series or parallel, forming units that produce the required voltage and energy capacity. Battery modules are housed in sturdy frames to provide structural integrity and protect cells from physical damage. Power tool and laptop batteries are considered examples of battery modules. Also, e-bike and e-scooter batteries are considered battery modules as they consist of multiple individual battery cells grouped together to deliver the necessary power. That said, the power of an e-scooter battery is higher than a laptop or power tool battery.

***Figure 2. Examples of typical battery modules.***

*Battery pack.* In this analysis, battery packs are taken to be assemblies of battery *modules*, along with additional components like casing, connectors, and thermal management systems that deliver power to devices. Most EV battery packs are built from groups of cells housed in modules interconnected within a case that provides structural support, thermal management, environmental protection, and connectivity with the rest of the drivetrain. Battery packs can further be aggregated to produce very large-scale battery systems. EV vehicles which are comprised of battery packs, are made up of hundreds or thousands of individual battery cells, connected in modules that are aggregated into the larger EV vehicle battery pack. Solar energy storage power systems are also examples of battery packs. That being said, pretty soon cells will be directly integrated into the full battery pack, without being divided up into individual modules (cell to pack) or directly integrated into the vehicle frame (cell to chassis).

*Figure 3. Examples of typical battery packs.*

*Battery banks.* Technically a battery bank is a utility-scale energy storage system as it utilizes large arrays of battery packs to store large amounts of electricity from the grid and release it when needed. A battery bank is typically composed of multiple individual battery cells grouped together into modules, which are then combined to form a larger "pack," with each cell containing a positive and negative electrode separated by an electrolyte, all held within a protective casing. The Kapolei Energy Storage facility on Oʻahu, Hawaiʻi is an example of a large grid-scale energy battery bank.

*Figure 4. Example of a typical battery bank.*

*Box.* A packaging with complete rectangular or polygonal faces, made of metal, wood, plywood, reconstituted wood, fiberboard, plastics, or other suitable materials. Small holes for purposes of ease of handling or opening or to meet classification requirements are permitted as long as they do not compromise the integrity of the packaging during carriage.

*Carbon dioxide.* Carbon dioxide is a chemical compound with the chemical formula $CO_2$. It is found in a gas state at room temperature and at normally -encountered concentrations, it is odorless. At higher pressures and relatively lower temperatures, $CO_2$ will deposit from a gas to a solid, otherwise known as dry ice. At higher temperatures and pressures, however, $CO_2$ will condense to a liquid. At higher temperatures but relatively lower pressures, $CO_2$ will remain a gas.

At high pressures and temperatures, however, $CO_2$ will transform into a supercritical state called supercritical $CO_2$[21].

*Damaged, defective, or recalled (DDR).* Damaged and defective lithium batteries mean in particular, but are not limited to: (i) cells or batteries identified as being defective for safety reasons; (ii) cells or batteries that have leaked or vented; (iii) cells or batteries that cannot be diagnosed prior to carriage; or (iv) cells or batteries that have sustained physical or mechanical damage. Damaged or defective batteries can have internal issues that lead to uncontrolled energy release, generating heat, and potentially flammable or toxic gases. Recalled batteries are those that have been identified by the manufacturer as having a safety issue, and should be handled and disposed of properly. DDR batteries pose potential hazards like heat, fire, or short circuits, requiring careful handling and disposal.

***Figure 5. Examples of DDR batteries; the bottom four were taken from sites around O'ahu.***

*Drum.* A flat-ended or convex-ended cylindrical packaging made out of metal, fiberboard, plastics, plywood, or other suitable materials. This definition also includes packaging of other

[21] P. Cattaneo et al, 2024. Supercritical CO2 technology for the treatment of end-of-life lithium-ion batteries. RSC Sustainability, 2024, 2, 1692.

shapes, e.g., round, taper-necked packaging or pail-shaped packaging. Wooden barrels and jerricans are not covered by this definition.

*Hazmat materials regulations (HMR).* The hazmat material regulations are regulations that classify materials by their hazards, using specific shipping papers and packaging, and adhering to rules for transportation, labeling, and emergency response under the Department of Transportation's 49 CFR[22].

*Independent power producer (IPP).* A non-utility entity that owns and/or operates facilities to generate electricity for sale to others, typically to utilities or other large energy users.

*Inspection frequency.* Inspection frequency refers to how often inspections of equipment, processes, or products are conducted to ensure they are in proper working order and meet required standards. It's a critical aspect of maintaining safety, quality, and productivity, especially in manufacturing, construction, and industries with regulated equipment.

*Non-government organization (NGO).* A non-governmental organization (NGO) is a mission-driven, typically non-profit organization that operates independently of government control, often serving as a vital part of civil society, addressing issues that governments and private sectors may not effectively address.

*Ocean freight transport.* The activity of transporting by ship the waste LIBs processed and packaged by one of the processing pathways discussed further in the section on general logistic pathways.

*Off-island transport.* The act of transporting the waste LIBs processed and packaged by any of the processing pathways from the offloading of the shipping vessel to a mainland recycler (discussed further in the section on general logistic pathways).

*On-island collection.* Defined as a place where waste LIBs are discarded for collection and where the discarded batteries are prepared for transportation after pick up.

*On-island generator.* Defined as the consumer owning the battery who either takes it to a collection site or who hires someone to come to their residence to collect the LIB.

*On-island sorting.* Defined as the act of separating waste LIBs from all other batteries temporarily stored prior to their processing in any of the pathways discussed further in the section on general logistic pathways.

[22] https://www.ecfr.gov/current/title-49.

*<u>On-island temporary storage.</u>* Defined as the location where waste LIBs are collected (discussed further in the section on general logistic pathways) and transported (discussed further in the section on general logistic pathways) are temporarily stored until they are sorted and then processed by any of the pathways discussed further in the section on general logistic pathways.

*<u>On-island transport.</u>* Defined as the act of picking up and driving the collected waste LIBs to a temporary storage location.

*<u>On-island transport to harbor and ship.</u>* The act of transporting the waste but packaged LIBs processed by one of the pathways discussed further in the section on general logistic pathways

*<u>Processing at recycler.</u>* The act of the waste LIBs processed and packaged (discussed further in the section on general logistic pathways) and transported (discussed further in the section on general logistic pathways) being received and offloaded at the selected off-island recycling facility.

*<u>Professional responsibility organization (PRO).</u>* Similar to stewardship programs, professional responsibility organizations play a crucial role in upholding ethical standards and promoting professionalism within the legal field. The two terms can be used interchangeably.

*<u>Stewardship program.</u>* Stewardship programs encompass various initiatives focused on responsible management and care of resources, whether environmental, financial, or healthcare-related, aiming to ensure their preservation and long-term benefit. They have been applied, for example, in the context of PV panels and lithium-ion batteries. Niagara county, for example, has enacted a stewardship plan[23] that provides for takeback of photovoltaic modules and installation components at convenient locations within the County to minimize the release of hazardous substances into the environment and maximize the recovery of other components, including rare earth elements and commercially valuable. Stewardship programs for lithium-ion batteries, like the one in Illinois[24], aim to ensure responsible collection, transportation, recycling, and safe disposal of these batteries, particularly small-to-medium-sized portable ones, by requiring manufacturers to participate in the program and fund its operations.

*<u>Supercritical carbon dioxide (sCO2).</u>* Supercritical carbon dioxide ($sCO_2$) is a state of $CO_2$ existing above its critical point, exhibiting properties of both a gas and a liquid[25]. In addition to emerging applications, $sCO_2$ is most known as a non-toxic, non-flammable, and relatively environmentally friendly solvent, often used to replace traditional chemical solvents. Although historically $sCO_2$ has been used as an extraction solvent, with applications even proposed for the

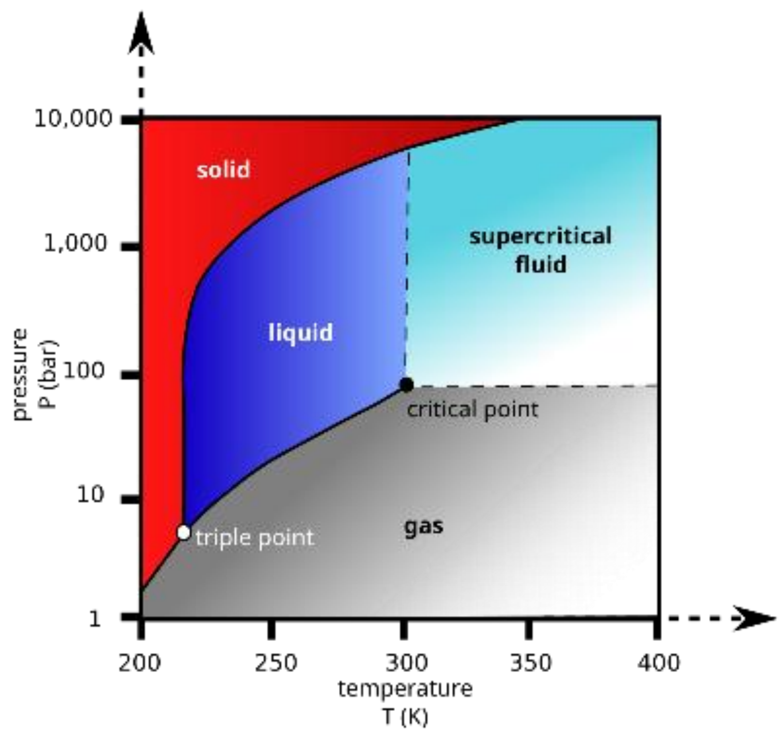
---

[23] https://portal.nyserda.ny.gov/servlet/servlet.FileDownload?file=00Pcr00000F1dhuEAB.
[24] https://productstewardship.us/press_releases/illinois-enacts-nations-16th-battery-recycling-law/.
[25] Span, Roland; Wagner, Wolfgang, 1996. "A New Equation of State for Carbon Dioxide Covering the Fluid Region from the Triple-Point Temperature to 1100 K at Pressures up to 800 MPa". *Journal of Physical and Chemical Reference Data*. 25 (6):1509–1596.

recovery of metals (i.e., Co, Li, Ni, Mn, P, Al, and Cu)[26] and solvents from lithium-ion batteries, in this analysis the permeability and reactivity properties of $sCO_2$ are used for its ability to penetrate LIBs and to react with the internal lithium salts to form lithium carbonates[27]. This action effectively renders the lithium-ion battery a non-battery for the purpose of road and ocean transportation.

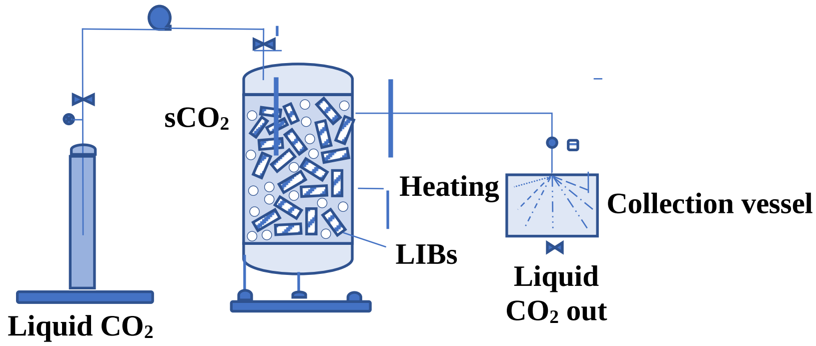
The operation is conducted in batch mode, wherein the waste lithium-ion batteries are loaded into a pressure vessel which is then closed and sealed. Liquid $CO_2$ is then added under pressure to the vessel chamber which is then heated. Combined, the pressure and temperature are elevated to conditions that render the liquid $CO_2$ to supercritical state, which then penetrates the waste lithium-ion batteries and initiates reactions with the lithium ions to form lithium carbonates. After completion, the supercritical $CO_2$ is released to a lower pressure collection vessel, which is recaptured as liquid $CO_2$ which can then be recycled, if desired[28].

***Figure 6. Supercritical fluid regime.***




[26] P. Cattaneo et al, 2024. Supercritical CO2 technology for the treatment of end-of-life lithium-ion batteries. RSC Sustainability, 2024, 2, 1692.
[27] Lilian Schwich et al. 2021. Early-Stage Recovery of Lithium from Tailored Thermal Conditioned Black Mass Part I: Mobilizing Lithium via Supercritical CO2-Carbonation. Metals 2021, 11,177.
[28] Khaw, K.-Y. et al 2017. Solvent Supercritical Fluid Technologies to Extract Bioactive Compounds from Natural Sources: A Review. *Molecules* 2017, *22*, 1186.

*Figure 7. Generic diagram of a supercritical $CO_2$ reactor.*




# REQUIREMENTS: OVERALL LOGISTIC PATHWAY

## General Considerations

This section covers the requirements of all logistic steps that bring the used "waste" EOL lithium batteries to the place of preprocessing prior to their marine transport to off-island recyclers[29]. As each step in the logistic pathway will impose requirements upon the businesses and people who handle the used "waste" EOL lithium batteries; the structure of any stewardship structure deployed to manage their flow through the logistic pathway needs to be considered in the context of Hawai‘i's unique geography and location. Any attempt to avoid or bypass this analysis will more than likely develop ineffective measures to address the growing threat used "waste" EOL lithium batteries pose for Hawai‘i.

### Hawai‘i's Context

The collection, on-island transport, temporary storage, sorting, and processing of used "waste" EOL lithium batteries for safe marine shipment from Hawai‘i to off-island recyclers encounter challenges that are unique to Hawai‘i's geography and location in the Pacific Ocean. One issue of significance in this regard is the reality that the transport of used "waste" EOL lithium batteries by marine transport is ultimately regulated by both the marine shippers *and* their insurance agencies, as well as the Coast Guard and regional Port Authorities who govern the permissibility of transport into and out of their mainland ports. From this perspective, the totality of requirements imposed upon Hawai‘i businesses attempting to ship used "waste" EOL lithium batteries out of the state is far above those governing mainland operators as defined in 49 CFR parts 171 to 180. In other words, unlike our mainland counterparts who can simply truck or rail used "waste" EOL lithium batteries, all businesses handling the used "waste" EOL lithium batteries have to address the added risks and costs associated with marine shipment. Both will dramatically increase costs and requirements of processing/packaging the used "waste" EOL lithium batteries prior to shipment. While the most likely scenario will lie somewhere between two extremes – permissibility to ship but with high costs[30] – the increasing risk that the ocean transport of specific formats of waste "used" EOL lithium batteries becomes outright banned should not be discounted. This threat derives from the real risk of insurance underwriters deciding to either deny insurance or imposing

[29] Asian or North American continent.
[30] Costs increase owing to higher risks and/or difficulties assessing it.

prohibitively high costs on their marine shipment. Unless addressed properly, these obstacles pose a significant risk to Hawai‘i’s goal of reaching full renewable power by 2045[31].

**Forbidden Materials and Packages**

Another subtle and underappreciated risk is the little-known issue of forbidden materials and packages[32]. As per CFR code, there are materials and packages that are forbidden to be transported *regardless* of how they are packaged. In terms of transporting used "waste" EOL lithium batteries, the key text is part (c)[33] which forbids:

> "*Electrical devices, such as batteries and battery-powered devices, which are likely to create sparks or generate a dangerous evolution of heat, unless* packaged *in a manner which* ***preclude*s** *such an occurrence.*"

The key word in this statement is "***preclude***." By definition, this means the packaging used during transport of lithium batteries must make it impossible for (i) a spark to be generated and (ii) a dangerous amount of heat to evolve. While this is technically impossible, currently accepted "best" practices to satisfy "***preclusion***" are to isolate battery terminals, use sturdy packaging, and protect batteries or devices that contain them from movement and damage. ***However, these steps are still open to post incident review***. As such, the key question to consider is what level of best practice will be considered sufficient by insurance underwriters, judges, and juries in the case of lawsuits and shipping owners to avoid liability under this law.

The answer to this question, if one exists, is ***critical*** to Hawai‘i because transporter(s) of used "waste" EOL waste lithium batteries will ***always be*** subject, in case of mishap[34], to post-accident reviews by experts knowledgeable in all applicable regulations of CFR 171-180[35]. They may also be subject to post-accident interpretation of the applicable regulations. As such, the transporter/shipper who acts independently and outside a ***state sanctioned stewardship program*** will need to invest significant time in self-education and training, if not the need to hire consultants, to help ensure that their techniques and methods were developed in full compliance of all applicable regulations and best practices, so as to survive the scrutiny of liability lawsuits.

**Unknowns to Unknowns – Changing Regulations and Tracking**

There are unknowns to unknowns. While it is already difficult for local businesses to keep up with current regulations and best practices, the load placed upon them to remain constantly up to date

[31] https://energy.hawaii.gov/clean-energy-vision/.
[32] 49 CFR § 173.21 - Forbidden materials and packages.
[33] 49 CFR § 173.21 Forbidden materials and packages (c).
[34] See, for instance, the recent sinking of a cargo ship carrying electric vehicles off the coast of Alaska.
[35] Especially the part on forbidden materials.

with evolving regulations is extremely high and perhaps unreasonable to expect across all participants in the general logistic pathway. As such, the value of an independent, professional, and state sanctioned stewardship program to oversee all participants participating in the logistic pathway, and to act as a go to source for education, clarification, and guidance should not be overlooked, especially when specific regulations and/or best practices may apply to each transporter/shipper on a case-by-case basis.

There is also the issue of tracking the flow of used "waste" EOL lithium batteries captured for disposal. Indeed, the recovery rate for waste LIBs worldwide is difficult to accurately assess. One study in 2010 proposed that less than 5% of lithium batteries were being recycled worldwide owing to the high recovery cost and low recovery value of metal resources[36]. A more recent study has largely debunked this number but failed to present a reliable adjustment[37]. There are many reasons for this, for example, waste cell phones and laptops flowing oversees or discarding of waste lithium batteries through the home hazardous waste exclusion or even labeling under the generic universal waste label. While the actual recovery rate worldwide might be as high as 20% (or even higher), the reality is that tracking mechanisms are largely lacking in supporting accurate assessments. As such, the value of an independent, professional, and state sanctioned stewardship program to oversee a comprehensive tracking program would provide great benefit to the state, particularly in the context of guiding policies designed for high capture rates.

**Regulations**

The overall complexity and span of regulations, uncertainty with their enforcement, and the burden they place on businesses should not be overlooked. Transporters of used "waste" EOL lithium batteries will have to know for each shipment: (i) how to prepare the batteries for transport; (ii) what type of packaging must be used to remain within the applicable regulations (i.e., under CFR 171-180 and IMDG Code); (iii) how to mark and label packages; and (iv) which documents to prepare to accompany the shipment. In addition to these requirements, transporters/shippers must also account for the specific requirements of each transport mode (i.e., ground, air, rail, **AND ocean**) as well as those imposed by the Coast Guard and Port Authorities. The provisions applicable in the various transport modes may differ because they are adapted to ensure maximum safety during transport in different mediums. Finally, transporters/shipping must be prepared to provide ***significant*** documentation to regulatory authorities, insurance providers, upstream and downstream partners of the logistic stream, as well as other interested parties, regarding their procedures for handling the waste "used" EOL lithium batteries.

[36] Zhijun Ren, et al (2023). Comprehensive evaluation on production and recycling of lithium-ion batteries: A critical review. Renewable and Sustainable Energy Reviews. 185:113585.
[37] Hans Eric Melin, 2020. Exploring the recycling rate of lithium-ion batteries. Circular Energy Storage. Contact author: hanseric@circularenergystorage.com.

**Costs and Profits**

The business realities of processing used “waste” EOL lithium batteries should not be overlooked. Currently, the lithium battery waste disposal industry operates under tight profit margins. One key example, lies with local salvagers. Unless properly compensated, they will not be able to accept EVs for salvage since the cost of metal does not cover the cost of removing and shipping the used “waste” LIB to the mainland via ocean shipping[38]. And this does not even consider the difficulties facing those businesses managing home and small business energy storage systems, owners of bicycle and scooter shops, as well as large department stores selling power tool lithium batteries. Numerous factors, such as the lack of standardized recycling procedures, the relatively high cost of recycling, and the difficulties associated with collecting and transporting spent batteries for recycling, continue to impose costs that undermine the collection and recycling of used “waste” lithium batteries[39]. Although the literature provides exhaustive information on various approaches for recycling used “waste” lithium batteries, and multiple large-scale facilities are under construction[40], detailed proven economic assessments of profitability for these processes[41] are still pending. In general, the main factors affecting economic feasibility of mainland-based recycling processes are material and energy prices[42]. Hawai‘i, unfortunately, will face the added costs of ocean transport.

Moreover, the lithium-ion battery industry is also changing in a manner that makes future expectations of profitability difficult to predict. The most significant changes in the future are expected to be in cell chemistry[43]. In particular, it is possible that current lithium batteries will be replaced by more advanced types, such as high voltage spinel (HVS), high-energy NMC (HE-NMC), solid-state batteries (SSB), lithium-oxygen ($LiO_2$) batteries, and lithium-sulfur (LiS) batteries, or alternative battery technologies like sodium-ion batteries. For these emerging battery types, the two main recycling routes being developed in industry (hydrometallurgical and pyrometallurgical) may not be optimal – these newer battery types have different chemical compositions and structures and efficient recoveries may require new recycling approaches[43]. Therefore, in a market dominated by new lithium battery types, neither recycling route is guaranteed to be profitable.

---

[38] Indeed, Radius Recycling, the large salvager of vehicles in Hawai‘i, currently will not accept EV’s because they cannot bear the costs associated with the handling and disposal of used “waste” EOL lithium batteries.
[39] Varsha Srivastava et al., 2023. A comprehensive review of the reclamation of resources from spent lithium-ion batteries. Chemical Engineering Journal. 474:145822
[40] Li-Cycle, Redwood Materials.
[41] i.e., comparing a pyrometallurgical and a hydrometallurgical recycling route.
[42] Zhijun Ren, et al (2023). Comprehensive evaluation on production and recycling of lithium-ion batteries: A critical review. Renewable and Sustainable Energy Reviews. 185:113585.
[43] Richard Woeste et al. 2024. A techno-economic assessment of two recycling processes for black mass from end-of-life lithium-ion batteries. Applied Energy. 361: 122921.

With these considerations, both the uncertainty over the industry even reaching a for-profit economic model, coupled with the added cost of marine transit, the impacts of costs on the disposal of used "waste" EOL lithium batteries should not be overlooked.

## The General Logistic Train

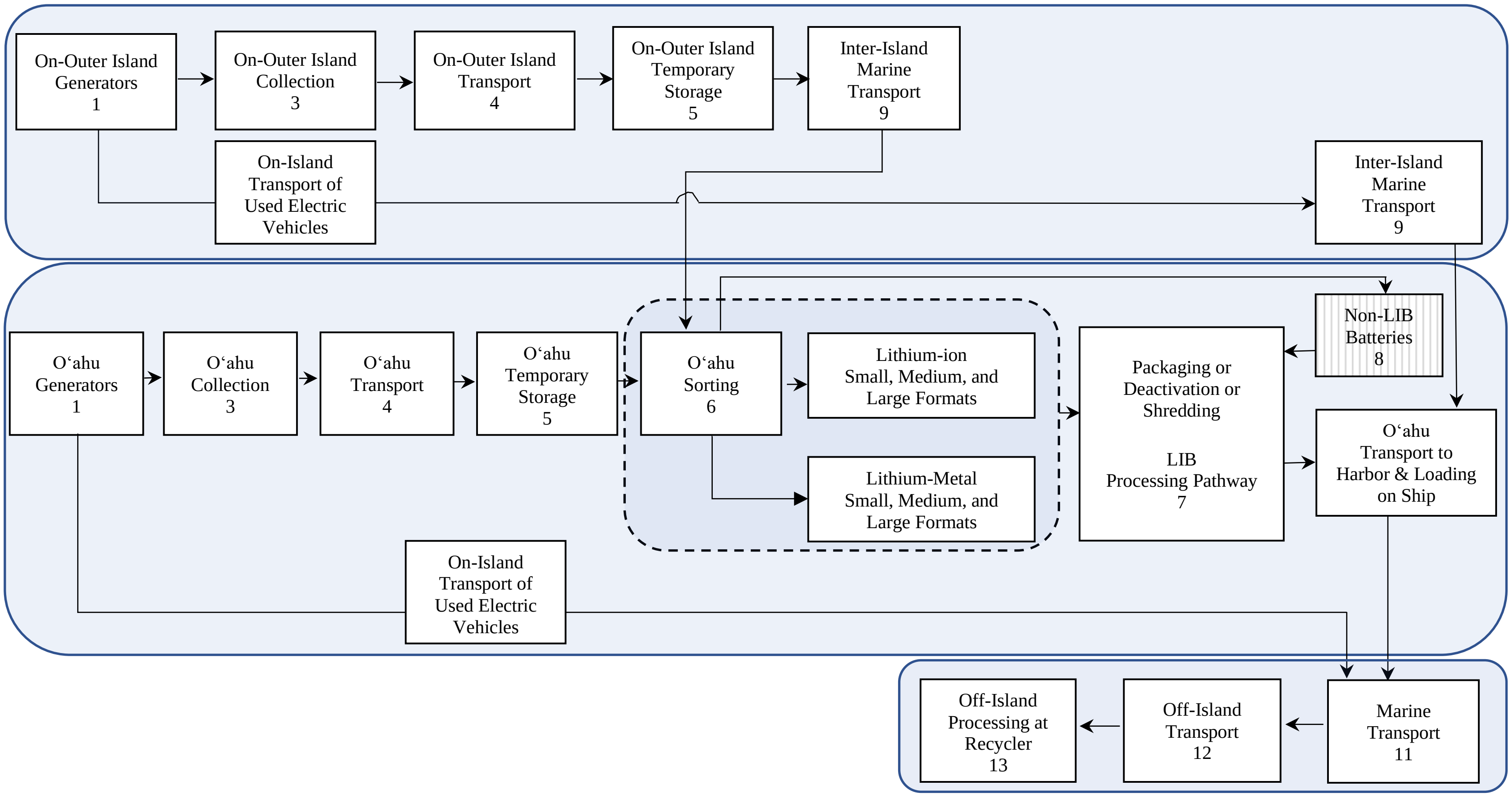
A general representation of the logistic pathway, from collection through marine shipment to off-island recyclers, is shown below (Figure 8). It includes consideration of how the logistic pathway is connected between the outer islands and the principal island/port of O‘ahu.

### Assumptions

For the purpose of this requirements analysis, the general logistical pathway is assumed to follow the process flow diagram depicted in Figure 8. Each unit block in the diagram represents a single unit operation or discrete "activity" in the overall logistic pathway. Sometimes a given entity/person will simultaneously execute two or more of the activities described in Figure 8, and in the process, blur the distinction between two adjacent unit operations. Regardless, none of the activities described can be avoided or executed out of sequence – they must all be executed in the order that they are depicted.

That being said, one activity not reflected in this train is the act of rebuilding, reusing, and repurposing used "waste" EOL lithium batteries. This is not an oversight or suggestion of its unimportance. In fact, these activities highlight important industries that will develop useful niches. However, these activities represent activities that will ***only*** extend the useful life of used "waste" EOL lithium batteries and thus extend the disposal date. Thus, in this exercise, any activity involving rebuilding, reuse, and repurposing is considered to occur before end of life and thus their collection for disposal (which is the starting point for this analysis).

*Figure 8. General logistics pathway for disposal of used "waste" lithium batteries.*



**Generators (#1)**

This activity describes the original act of generating lithium battery waste. At some point, the lithium battery (or batteries) are deemed no longer productive and require disposal as waste. This decision generates lithium battery waste across multiple scales – from the generation of a single cell battery to a large battery bank containing tens of thousands of single cells (all connected in series, through their aggregation in smaller battery modules/packs that are then encased in larger structures containing battery management systems). More simply, generation can be as simple as an individual deciding to discard a single consumer or portable battery at Home Depot, an installer uninstalling a home energy storage unit, a mechanic removing an EV battery from a car, or an engineering team replacing a battery bank at a power utility installation.

**Collection (#2)**

This activity represents the active of collecting used "waste" EOL lithium batteries, an action that can range from the collection of consumer or portable batteries in boxes at a Home Depot (or equivalent), their collection in drums at e-bike/e-scooter shops, on pallets at an auto dealership or mechanic shop, within containers at salvage yards, or even in shipping containers at utility scale power parks. Collection can also be made by individual(s) at a home or work where they are collected before being transported to a temporary storage facility. Usually, the amounts of batteries collected at home or work sites are low and they are not prepared the way they should be prior to transport.

The collection activity can occur over a long period (i.e., batteries being collected at a home or work site or Home Depot) or over a very short period (i.e., when a home energy system is deinstalled and collected at the home/facility before taken away). In all cases, the collected used "waste" EOL lithium batteries must be properly packaged *prior to* their transport to a temporary storage facility where they will be stored until they are further processed to make them acceptable for marine shipping.

In certain cases, such as those at utility or large commercial scale collection sites, the used "waste" EOL lithium batteries can be fully prepared for marine transport (usually comprised of discharging and inspection for damaged, defective, or recalled (DDR) components by a certified professional) at their site of generation (e.g., utility scale energy park), thus blurring the distinction between generators and collection. These distinctions, however, can be easily managed by a properly organized state-sanctioned stewardship structure[44].

[44] Also called a Professional Responsibility Organization (or PRO) in California.

**Transport (#4)**

This activity represents the transportation of the collected used "waste" EOL lithium batteries to a temporary storage facility. Prior to their transport, the lithium batteries should be appropriately prepared/packaged for transport at the collection site (either by employees at the collection site or by the transporter). In certain cases, such as at utility or large commercial scale collection sites, the batteries will already have been fully prepared for ocean transport at the collection site and will therefore be transported directly to the harbor ocean-going vessel (again blurring the distinction between the distinct unit operations laid out in the process flow diagram).

**Temporary Storage (#5)**

Most used "waste" EOL lithium batteries transported from a collection site will be delivered to a temporary storage facility where they will be stored until sorted[45] into one of five streams: (i) non-lithium, (ii) lithium-ion, (iii) lithium-metal, (iv) DDR lithium-ion, or (v) DDR lithium-metal. After sorting, they can be directly treated by any one of the three pretreatment[46] pathways considered in this analysis and described in #7 below.

**Sorting (#6)**

Sorting refers to the necessary step of separating and classifying lithium batteries based on their type, chemistry, and condition. This is important because pretreatment of mixed battery types can create significant hazards and/or inefficiencies. For example, if the preprocessing pathway of direct shipping (with no prior pretreatment) is used, the shipping of mixed type used batteries is generally a bad idea due to potential hazards such as leakage, rupture, or even fire. Different battery types, especially lithium-ion, have different chemistries and voltage levels, and mixing them can create unstable situations – particularly when they have already used and potentially damaged. For example, shipping used lithium-ion and lithium-metal batteries together is a bad idea because it significantly increases the risk of short-circuiting, which can lead to overheating, fire, and explosion. Also, treating a lithium battery with alkaline materials could cause a risk event. Moreover, if the preprocessing pathway of shredding is used, for example, the shredding of mixed battery types is also considered a bad idea as lithium metal batteries should not be shredded in water[47]. In particular, the shredding lithium-ion and lithium metal batteries together

---

[45] Batteries collected at an unfiltered collection site like Home Depot or during an open collection day will often contain both non-lithium batteries, mixes of lithium-ion and lithium-metal, as well as a percentage (of them) that are DDR).

[46] We are using the word pretreatment because these activities are not recycling but rather the pretreatment of these batteries in preparation of their shipment to recyclers.

[47] Not only does shredding mixed battery types interfere with the quality of the black mass produced, and thus its value in downstream purification processes, the chemistry of the two battery types can be particularly volatile and explosive. Wet shredding of lithium-ion batteries greatly reduces fire risk while shredding of lithium-metal in the presence of water increases explosivity.

creates a significantly higher risk of fire and explosion than shredding either type alone[48]. While both types involve shredding as part of their recycling process, lithium-ion batteries require more complex processes due to their construction and potential for hazardous reactions. Lithium metal batteries, often non-rechargeable, pose even greater fire and explosion risks during shredding if not handled appropriately[48].

**Processing Pathway (#7)**

In this study, three methods to process waste LIBs as a means to prepare them for ocean transport are considered. **First**, packaging without any preprocessing/pretreatment. This largely involves following U.S. Department of Transportation (DOT) and IMDG codes prescribed for transport of lithium batteries along with those added by non-government organizations (NGO)[49] that routinely arrange for or advise on the transport of waste or DDR lithium batteries. **Second**, the method of rendering the batteries thermally inert using supercritical $CO_2$ will be considered. This involves the application of supercritical fluid to penetrate the battery body where it reacts with the lithium ions to create lithium carbonates. This reaction results in changes in internal chemistry. These changes cause the systems to be unable to react and evolve heat. **Third**, the method of crude shredding is analyzed. Crude shredding involves the breaking/ripping apart lithium battery cells into sub-components that are small enough and disconnected enough to render them "non-batteries."

***Discloser on processing pathways not considered.*** Although initially considered, methods of chemical and physical discharge were discarded largely on the basis that neither process could be expected to work efficiently across all battery types and scales. First, although at utility and EV scale, resistance discharging is an accepted technique, the issue of rebound voltage has been noted in the literature, largely due to the interference caused by battery management systems[50]. In addition, this technique is also impossible to apply at large volume across smaller format batteries. There is no mechanism to rapidly and efficiently discharge entire boxes/crates of single cell batteries or even those from e-bikes, e-scooters, and power tools. Also, chemical discharge via submersion in salt solutions has been shown to undergo significant corrosion events that can limit that amount of charge actually dispersed[51]. There is also the observation that the use of saline solutions comprised of sodium chloride, widely mentioned in the literature for battery discharging, can shorten the lifespan of equipment due to the presence of chlorides, which are challenging to manage in steel and iron-based equipment. Moreover, hydrochloric acid formation could also

[48] Oliveira, et. al. 2024. Shredding of lithium-ion batteries: overview and industrial perspective. In (Bosam M. Saleh and Amal I. Hassan, editors) Waste Management for a Sustainable Future - technologies, strategies and global perspectives. DOI: 10.5772/intechopen.1008229.
[49] e.g., Call2Recycle, BatteriesTransport, Earth911, Electronic Recyclers International.
[50] Rouhi et al. 2022. Electrochemical discharge of Li-ion batteries – A methodology to evaluate the potential of charge electrolytes without corrosion. Journal of Energy Storage. 55:105734.
[51] Xu et al, 2023. Pretreatment options for the recycling of spent lithium-ion batteries: A comprehensive review. Journal of Energy Storage. 72: 108691.

occur. The metal alloy of the equipment would need to be reconsidered if handling these acidic compounds. Finally, saline soaking is inefficient as electrode corrosion often inhibits discharge and complicates recycling efforts.

### Inter-Island Marine Transport (#9)

In this activity the used "waste" lithium batteries processed and/or packaged in step #7, and loaded on the ships in step #10, are then transported to the mainland via ocean going vessels.

### On-Island Transport to Harbor and Ship (#10)

This activity describes the transport of the lithium batteries that have been processed by any one of the three pretreatment pathways described in step #7 to the harbor where they are loaded onto ships for marine transport to off island recyclers. These batteries, once processed by any of the pathways described above and in step #7 of the logistic pathway, must be repacked into containers suitable for transferring hazardous waste material (even if they have been rendered "non-batteries" by the application of supercritical $CO_2$ or crude shredding). Regardless of how they were processed in step #7 above, the relevant DOT and IMDG regulations must be followed. Also, the concerns of insurance underwriters and shipping companies must also be taken into consideration.

### Marine Transport (#11)

In this activity the used "waste" lithium batteries processed and packaged in step #7, and loaded on the ships in step #10, are transported to Asian or North American ports via marine transport.

### Off-Island Transport (#12)

In this activity the processed and packaged waste lithium batteries are offloaded and transported via highway or rail to the recycling facility.

### Processing at Recyclers (#13)

In this activity the transported processed and packaged waste LIBs are accepted by the recycling facility.

## Description of Requirements for Unit Operations in Logistic Pathway

### On-Island Transport of Used Electric Vehicles (#2)

This unit operations refers to the shipment of used lithium batteries installed within the vehicle itself. For shipment by road or marine, lithium-ion EV batteries are considered "lithium-ion batteries contained within equipment and, as there Wh rating is well above 300 Wh/battery, fully regulated[52]. As such, EV batteries are considered lithium-ion batteries contained in equipment for shipping purposes and are subject to specific UN regulations.

***Requirements.*** EVs are classified as dangerous goods under the IMDG Code, specifically as battery-powered vehicles or battery-powered equipment (UN 3171). Shippers must therefore comply, at minimum, with the IMDG Code, which also includes provisions for the safe transport of dangerous goods[53]. Some EVs may be exempt from certain IMDG Code requirements if they meet specific conditions outlined in Special Provision 961 (SP 961). SP 961 allows for the transport of EVs as non-dangerous goods on certain vessels, such as Ro-Ro (roll-on, roll-off) vessels[54] and vessels with designated storage areas. If EVs are shipped in container slots on Ro-Ro vessels, they must be declared as dangerous goods. Also, if an EV doesn't meet the criteria outlines in SP 961 to the IMDG Code, it must be declared as dangerous goods. Finally, vehicles powered by lithium batteries not meeting the conditions of IMDG SP 961 shall be assigned to class 9 and must adhere to specific requirements.

Specific requirements include[55]:

a. The vehicle must not show any signs of leakage from the batteries, engines, fuel cells, compressed gas cylinders or accumulators, or fuel tanks (when applicable);
b. The installed lithium batteries must be securely fastened and protected from damage, short circuits, and accidental activation, such as through use of non-conductive caps that cover the terminals entirely during transport;
c. Lithium batteries, both rechargeable and non-rechargeable, must adhere to the requirements outlined in 2.9.4 of the UN Recommendations on the Transport of Dangerous Goods[56];
d. Cells and batteries, cells and batteries contained in equipment, or cells and batteries packed with equipment, containing lithium in any form must be assigned to UN 3090, UN 3091, UN 3480 or UN 3481, as appropriate[57];
e. Vehicles equipped with theft-protection devices, installed radio communications equipment, or navigational system must have such devices, equipment, or system disabled;
f. Each battery containing cells or series of cells connected in parallel must be equipped with an effective means to prevent dangerous reverse current flow (e.g., diodes, fuses); and

---

[52] ebook Lithium Batteries 2024, page 125. https://lithiumusa.batteriestransport.org/124/
[53] It should not be lost on the reader that shippers also have to deal with their insurance underwriters.
[54] Ro-Ro (roll-on, roll-off) vessels are cargo ships designed to carry wheeled cargo that can be driven directly on and off the ship using ramps. This method of transportation is commonly used for vehicles, trucks, buses, trailers, and other machinery.
[55] ebook lithium batteries 2025 page 126. https://lithiumusa.batteriestransport.org/126/
[56] This section specifies that all lithium batteries, regardless of whether they are rechargeable or not, must first successfully undergo evaluations in accordance with the procedures detailed in section 38.3 of the UN Manual of Tests and Criteria.
[57] Cells and batteries, cells and batteries contained in equipment, or cells and batteries packed with equipment, containing lithium in any form must be assigned to UN 3090, UN 3091, UN 3480 or UN 3481, as appropriate.

g. Lithium batteries manufactured after December 31, 2015 must be marked with the Wh rating on the outside case.

The marking, labelling and placarding provisions of this Code shall not apply. Lithium batteries securely fastened in a vehicle shall meet the provisions of 173.185(a).

*The following regulations apply*: CFR 49 §173.185(a); CFR 49 §173.185(b); 49 CFR §173.220; UN3481.

**Collection (#3)**

This activity refers to the collection of used "waste" EOL LIBs at collection sites located on and around the island of Oʻahu and/or outer islands. The requirements for collection reflect federal regulations as well as established best practices[58]. It is also assumed that all collection sites will operate under the supervision or authorization of a state stewardship program or relevant state agency. Finally, it is assumed that the lithium batteries will be properly packaged prior to their pick up and subsequent transport to the temporary storage facility.

***Collection sites.*** With respect to collection operations, battery format must be taken into account. For example, small format (household, consumer and portable batteries will largely be picked up at organized collection sites placed at stores and other locals (e.g., Home Depot, Lowe's, Battery Bill's, etc.). The cross over to medium size format (e-bikes, e-scooters, weed eaters, leaf blowers) will likely be collected at municipal collection points (operated by the city and county or operators under contract of a nonprofit stewardship program) or select business (i.e., bike shops). Collection of large-scale formats will generally be self-managed by entities running their own operations. Examples of collection sites include:

- Public spaces such as post office, libraries, hardware stores, home improvement stores, grocery supermarkets, bottle/can recycling sites etc.;
- Sites that already accept hazardous waste (e.g., transfer stations);
- Shops that address LIBs in their work activity such as mechanic shops (small mechanic shops to large auto dealerships, e-bike or e-scooter shops);
- Private businesses that specialize in waste collection (e.g., private companies like electronic recyclers who expand into waste battery collection and create collection intake sites as part of their business model);
- Facilities that accept abandoned vehicles (e.g., junk or salvage yards that collect abandoned vehicles from the State under contract); and
- Businesses that sell large format (e.g., car dealerships), as well as those that sell and install them (e.g., PV installers).

[58] As articulated by professional stewardship groups such as PBRA and Call2Recycle.

***Collection best practices.*** Some examples of best practices that can be expected to be required by shippers and their insurance underwriters for all entities collecting used "waste" EOL lithium batteries in Hawai‘i are:

- Convenient and well-marked collection locations;
- Consistent and diverse outreach;
- Trained employees at collection sites;
- Well prepared response systems in case of fire outbreaks;
- Commitment to ensure that all collected used "waste" EOL lithium batteries are properly labeled and packaged for transport to temporary storage locations;
- Use of partnerships for program implementation (i.e., part of overall Stewardship Program); and
- Hub and spoke connections to temporary storage locations.

***Collection of DDR batteries.*** Collected used "waste" EOL lithium batteries must be assessed/evaluated for DDR status at the site of collection. Best practices for this may include, but is not limited to, activities that look for[59]:

a. Evidence of acute hazard, such as gas, fire, or electrolyte leaking;
b. Evidence of prior use or misuse of the cell or battery;
c. Visible signs of physical damage, such as deformation to cell or battery casing, or colors on the casing;
d. The presence of potential presence of external and/or internal short circuit[60]; and
e. Damage to any internal safety components, such as the battery management system.

***Requirements – Collection of waste lithium-ion cells/batteries.***

*Household, consumer, and portable lithium cells/batteries (small format).* The collection of household, consumer and portable lithium cells and batteries can be continuous (e.g., Home Depot or equivalent drop boxes) or one-off events (e.g., collection days). Regardless of which is used, the collection site is required to provide or have enough 13"x13"x9" appropriately labeled collection boxes (each lined with its own fire-retardant liner) along with rolls of plastic bags that can be easily accessed. At these collection sites, all lithium cells and batteries collected must be individually sealed in plastic bags[61] before being packed into their respective collection box.

Examples of methods to protect against short circuits include, but are not limited to[62]:

a. The individual protection of the battery terminals;

[59] ebook Lithium Batteries 2024 pg 21 https://lithiumusa.batteriestransport.org/.
[60] The use of voltage or isolation measures.
[61] To prevent shorting circuiting contact between batteries.
[62] ebook Lithium Batteries 2024 pg 21 https://lithiumusa.batteriestransport.org/.

b. The use of inner packaging to prevent contact between cells and batteries; and
c. The use of an electrically non-conductive and non-combustible cushioning material to fill empty space between the cells or batteries in the packaging.

Once the collection box has been filled, trained staff at the collection site are then expected to remove each cell or battery to verify that: (i) they have been individually wrapped in a plastic bag and (ii) are not DDR. Once these two criteria have been verified, the individually wrapped lithium cells and batteries are then repacked into new appropriately labeled boxes[63] that are filled with packing/insulating material (at ~2/3 insulation to 1/3 battery by volume) before being set aside (i.e., stored) until pickup and transport to the temporary storage facility[64]. The packing material/insulation is used to minimize the propagation of heat from one battery to the next, in case one ignites, which also minimizes the (i) evolution of gasses, (ii) formation of corrosive substances, and (iii) formation of unstable substances[65]. Although regulations allow vermiculite (as opposed to the more expensive granular fire-retardant suppressant) as packing material/insulation, more expensive fire-retardant packing material is recommended as best practice in order to address the concerns of insurance underwriters. On this point, a good rule of thumb to follow is:

> "***Just because the HI and Federal DOT regulations will let you does not mean the maritime shippers or their insurance agencies will allow it***"[66].

Every packaging box used must first be checked to be free from corrosion, contamination, and any defects[67]. No boxes showing signs of weakening can be used unless they are refurbished to the standards of their accepted prototype[67]. Small format used "waste" EOL lithium cells and batteries can be stored at a collection site for up to ***one year***, with some exceptions[68], and this storage period applies when the cells and batteries are held in quantities of one ton or more at a single location[69]. If more than one ton of used lithium-ion batteries is stored at one location, these can also be stored under the "universal waste" regulations for up to 12 months[69].

---

[63] Appropriately labeled means they must follow Class 9 regulations for LIB as defined in 40 CFR Lithium cells and batteries § 173.185 (c) (3).
[64] The boxes shall be strong enough to withstand the shocks and loadings normally encountered during carriage, including trans-shipment between transport units and between transport units and warehouses. The boxes shall be constructed and closed so as to prevent any loss of contents when prepared for transport which might be caused under normal conditions of transport, by vibration, or by changes in temperature, humidity or pressure.
[65] ebook Lithium Batteries 2024 pg 23. https://lithiumusa.batteriestransport.org/.
[66]Personal conversation, Eric Frederickson, Call2Recycle.
[67] ebook Lithium Batteries 2024 pg23. https://lithiumusa.batteriestransport.org/.
[68] For more information on these acceptations, which can change with time, it is recommended to contact a recognized stewardship program like Call2Recycle for advisement.
[69] 40 CFR § 273.15 Accumulation time limits.

*The following regulations apply*: 40 CFR Part 273 Standards for Universal Waste Management; HAR CHAPTER 11-273.1 Standards for Universal Waste Management; 49 CFR § 173.185 Lithium cells and batteries; § 173.21 Forbidden materials and packages; Fire codes (increasingly updated) including the Hawaiʻi State Fire Code and the international Fire Code (IFC); EPA site ID[70].

*What is the training required?* Collection staff must complete performance-based employee training. Specifically, staff must be trained to assess whether the cell or battery is damaged or defective, to possess knowledge of the cells or battery's safety features, as well as safety criteria from the cell, battery or product manufacturer. Staff must also be trained in basic labeling requirements for the accumulation collection containers[71].

*How often should the site be inspected?* A site collecting lithium batteries at small format scale should be inspected regularly, at least once every month for visual inspections and to ensure that fire extinguishers and suppression systems are adequate and in proper working order. More frequent inspections, especially if handling or storage conditions are not ideal and/or there is a high frequency of DDR batteries, are recommended.

*e-bikes, e-scooters, weed eaters, leaf blower batteries (mid-format).* For batteries in this format, the collection site must *have/provide* a designated appropriately labelled collection box along with large plastic bags. Specifically, the battery must first be visually inspected and subjected to a series of questions[72] that verify whether, or not, they are still in good condition and not DDR. Battery modules deemed in good condition must then be packed into boxes lined with fire retardant liners[73] for storage until they are transported to the temporary storage site.

Mid-format used "waste" EOL lithium batteries can be stored at a collection site for up to one year, with some exceptions[74], and this storage period applies when the batteries are held in quantities of one ton or more at a single location[75]. If more than one ton of used lithium-ion batteries is stored at one location, these can also be stored under the "universal waste" regulations for up to 12 months[75]. However, the exact holding time that constitutes storage may vary from jurisdiction to jurisdiction.

[70] As of 5/13 the EPA announced it is updating its Hazardous waste regulations which could include the requirement to have an EPA site ID.
[71] e.g., "Universal waste – batteries" or "Used batteries".
[72] These tests include review of whether the battery was damaged in an accident or exposed to excessive heat or salt water, as well as other visual inspection requirements. One will not use a physical test protocol as they are too small.
[73] The liners can be reused while the boxes cannot.
[74] As with all formats, a proper stewardship program (e.g., Call2Recycle) should be consulted for these exceptions.
[75] 40 CFR § 273.15 Accumulation time limits.

*The following regulations apply*: 40 CFR Part 273 Standards for Universal Waste Management; HAR CHAPTER 11-273.1 Standards for Universal Waste Management; 49 CFR § 173.185 Lithium cells and batteries; § 173.21 Forbidden materials and packages; Fire codes (increasingly updated) including the Hawaiʻi State Fire Code and the international Fire Code (IFC); EPA site ID[76].

*What is the training required?* A small quantity handler of this format must train all employees on the proper handling and emergency procedures appropriate to the type(s) of used "waste" EOL lithium batteries they are handling at the facility[77]. Specifically, for these batteries, the collection site must have staff who have been trained in the collection and packing of these types of batteries and format[78]. A large quantity handler must ensure that all employees are thoroughly familiar with proper waste handling and emergency procedures, relative to their responsibilities during normal facility operations and emergencies[77]. This includes understanding potential fire hazards, proper battery preparation, and following hazardous materials regulations (hazmat). Such training should cover how to secure terminals to prevent short circuits, assess fire risks, and prepare batteries for safe shipping. Some programs may also include safety materials, rider education, and UL 2849 certification[79] information for e-bikes.

*How often should the site be inspected?* Entities that collect mid-format batteries (e.g., bike shops) should be inspected for safety and potential hazards at least every three months for long-term storage[80]. This includes checking the battery's voltage, temperature, and for any signs of damage or swelling. More frequent inspections may be necessary depending on the volume of batteries stored, the storage conditions, and the frequency of DDR.

<u>*EV, home or commercial scale energy storage, portable power packs (large format).*</u> The collector of this format must first visually inspect the battery and apply a series of questions[81] to verify whether the battery pack is still in good condition and not DDR. Battery packs deemed to be in good condition must then be securely affixed to a wooden pallet in preparation of transport.

[76] As of 5/13 the EPA announced it is updating its Hazardous waste regulations which could include the requirement to have an EPA site ID.
[77] 40 CFR § 273.16 Employee training.
[78] The training is best when administered by a stewardship program (like Call2Recyle) that has established a reputation for implementing best practices.
[79] UL 2849 is the safety standard for electrical systems in e-bikes, and it's crucial for lithium-ion batteries used in these bikes.
[80] https://www.renogy.com/blog/how-to-store-lithium-batteries-other-battery-maintenance-tips/.
[81] These tests include review of whether the battery was damaged in an accident or exposed to excessive heat or salt water, as well as other visual inspection requirements.

Large format used "waste" EOL lithium batteries can be stored at a collection site for up to one year, with some exceptions[82], and this storage period applies when the batteries are held in quantities of one ton or more at a single location**Error! Bookmark not defined.**. If more than one ton of used lithium-ion batteries is stored at one location, these can also be stored under the "universal waste" regulations for up to 12 months[83]. However, the exact holding time that constitutes storage may vary from jurisdiction to jurisdiction.

*The following regulations apply*: 40 CFR Part 273 Standards for Universal Waste Management; HAR CHAPTER 11-273.1 Standards for Universal Waste Management; 49 CFR § 173.185 Lithium cells and batteries; § 173.21 Forbidden materials and packages; Fire codes (increasingly updated) including the Hawai'i State Fire Code and the international Fire Code (IFC); EPA site ID[84].

*What is the training required?* Training for collecting large format EV or energy storage used "waste" lithium batteries requires a multi-faceted approach, including electrical safety awareness[85], hazmat training for hazardous materials handling, and specific training related to lithium battery transport regulations. Individuals handling these batteries must also be certified for DOT hazmat.

*How often should the site be inspected?* Collection sites for EV and energy storage system lithium batteries in this format should be inspected regularly, with physical inspections every six months. In addition, a thorough hazard assessment should be conducted to identify potential risks.

<u>*Utility scale.*</u> The permits and power purchase agreements (PPAs) for independent power producers (IPPs) require that they are responsible for the removal of EOL energy storage systems. To date, all of these systems are lithium-ion batteries. In the case of natural disasters, third parties may be brought in as deemed necessary by government authorities. These large-scale utility batteries are typically housed in battery banks. Prior to their transport, they will be fully discharged and subject to an appropriate level of disassembly prior to being appropriately packaged in wooden crates. Moreover, they will be professionally inspected for presence of DDR battery packs.

*The following regulations apply*: 40 CFR Part 273 Standards for Universal Waste Management; HAR CHAPTER 11-273.1 Standards for Universal Waste Management; 49

[82] As with all formats a qualified stewardship organization should be consulted. For example, used "waste" EOL lithium batteries at this scale that are stored outdoors under full elements may not qualify for the 1-year storage.
[83] 40 CFR § 273.35 Accumulation time limits.
[84] As of 5/13 the EPA announced it is updating its Hazardous waste regulations which could include the requirement to have an EPA site ID.
[85] OSHA regulations require only "qualified persons" to handle batteries with voltages exceeding 50V.

CFR § 173.185 Lithium cells and batteries; § 173.21 Forbidden materials and packages; Fire codes (increasingly updated) including the Hawai‘i State Fire Code and the international Fire Code (IFC); EPA site ID[86].

*What is the training required?* A collection site is not envisioned for waste EOL lithium batteries from utility scale parks other than the site itself. Under these circumstances, the training required will have already been established and would not fall under the responsibility of the Stewardship program.

*How often should the site be inspected?* It is assumed that collection sites won't exist for batteries at this scale. The batteries will likely be decommissioned and then prepared for marine transport directly on site and under expectations of the power agreements.

***Requirements – Collection of waste DDR lithium-ion cells/batteries.*** Used "waste" EOL lithium-ion cells and batteries identified as DDR must be handled separately. They require specialized handling and collection due to their potential hazards—e.g., these cells and batteries cannot be placed in standard recycling bins and require a different process for safe and compliant disposal. Specific requirements will include, but are not necessarily limited to:

a. Individually enclosed in a non-metallic inner package;
b. Surrounded by non-combustible, electrically non-conductive, and absorbent cushioning material; and
c. Placed in Packing Group I performance-level outer packaging that is clearly marked with "Damaged/defective lithium-ion battery" or "Damaged/defective lithium metal battery" in letters at least 12 mm (0.47 inches) high.

<u>Household, consumer and portable lithium batteries (small format).</u> Used "waste" EOL lithium-ion cells and batteries identified to be DDR in this format must be individually sealed in plastic "anti-static" bags before being placed into UN approved steel drums[87,88] with added granular fire suppressant to provide cushioning and resistance to heat and/or spark evolution. The filled drums (up to 11 pounds) are then placed in a box stamped with appropriate labeling before being set aside for pickup and transport to the temporary storage facility[89]. The specific packing procedures should meet the following performance level of packing group I[90]:

a. Packages shall be marked "DAMAGED/DEFECTIVE LITHIUM-ION BATTERIES" or "DAMAGED/DEFECTIVE LITHIUM METAL BATTERIES", as applicable;

---

[86] As of 5/13 the EPA announced it is updating its Hazardous waste regulations which could include the requirement to have an EPA site ID.
[87] In this format 5-gallon drums are general practice.
[88] The use of steel drums that can be sealed is currently considered best practice.
[89] https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2023-03/DDR-brochure.pdf.
[90] ebook Lithium Batteries 2024 pg. 21. https://lithiumusa.batteriestransport.org.

b. Cells or batteries shall be protected against short circuit;
c. Each damaged or defective cell or battery or equipment containing such cells or batteries shall be individually packed in inner packaging and placed individually inside an outer packaging;
d. Each inner packaging shall be surrounded by sufficient non-combustible and electrically nonconductive thermal insulation material to protect against a dangerous evolution of heat;
e. Appropriate measures shall be taken to minimize the effects of vibrations and shocks, prevent movement of the cell or battery within the package that may lead to further damage and a dangerous condition during carriage;
f. Cushioning material that is non-combustible and electrically non-conductive may also be used to meet this requirement; and
g. The inner packaging or outer packaging shall be leak-proof to prevent the potential release of electrolyte.

Larger DDR consumer and portable batteries (i.e., power tools, portable power or laptop) must be individually sealed and packed individually into 5-gallon steel drums prior to transport.

*The following regulations apply*: 40 CFR Part 273 Standards for Universal Waste Management; CFR 49 § 173.185 (f) Damaged, defective, or recalled cells or batteries; HAR CHAPTER 11-273.1 Standards for Universal Waste Management. Fire codes (increasingly updated). International Fire Code (IFC). Local jurisdictions adopt policies. fire codes (increasingly updated) including the Hawaiʻi State Fire Code and the international Fire Code (IFC); EPA site ID[91].

*What is the training required?* DOT-required hazmat training. DOT mandates hazmat training for all "hazmat employees" who participate in pre-transportation functions like packaging, labeling, and preparing shipping papers for lithium batteries.

*How often should the site be inspected?*[92] DDR battery collection sites should be inspected regularly, at least weekly, to ensure safety and proper handling of the batteries. This includes checking for leaks, damage, or any other issues that could pose a risk. Additionally, it's crucial to verify that the batteries are being stored and handled according to safety regulations.

---

[91] As of 5/13 the EPA announced it is updating its Hazardous waste regulations which could include the requirement to have an EPA site ID.
[92] See, for example, 40 CFR Parts 264, 265, and 266.

*e-bikes, e-scooters, weed eaters, leaf blower batteries (mid format).* Each DDR used "waste" EOL lithium battery identified as DDR must be individually enclosed into non-metallic inner packaging, plastic bags and then individually placed in an appropriately labelled drums[93] cushioned with non-combustible, electrically non-conductive, and absorbent material[94]. Also, the drum should be labelled/marked with "Damaged/defective lithium-ion battery" or "Damaged/defective lithium metal battery".

*The following regulations apply*: 40 CFR Part 273 Standards for Universal Waste Management; CFR 49 § 173.185 (f) Damaged, defective, or recalled cells or batteries; HAR CHAPTER 11-273.1 Standards for Universal Waste Management. Fire codes (increasingly updated). International Fire Code (IFC). Local jurisdictions adopt policies. Fire codes (increasingly updated) including the Hawaiʻi State Fire Code and the international Fire Code (IFC); EPA site ID[95].

*What is the training required?* DOT-required hazmat training. DOT mandates hazmat training for all "hazmat employees" who participate in pre-transportation functions like packaging, labeling, and preparing shipping papers for lithium batteries.

*How often should the site be inspected?* DDR battery collection sites should be inspected regularly, at least weekly, to ensure safety and proper handling of the batteries. This includes checking for leaks, damage, or any other issues that could pose a risk. Additionally, it's crucial to verify that the batteries are being stored and handled according to safety regulations.

*EV, home or commercial scale energy storage, portable power packs (large format).* There are a few options in this format. First, these batteries (EV batteries or power storage) can be individually packed into an appropriate fire proof crate[96]. Alternatively,[97], the commercial business can hire a professional to directly discharge the battery prior to disassembling (it) and packing the component modules into 55-gallon steel drums. The drum or crate must be marked with "Damaged/defective lithium-ion battery" or "Damaged/defective lithium metal battery".

*The following regulations apply*: 40 CFR Part 273 Standards for Universal Waste Management; CFR 49 § 173.185 (f) Damaged, defective, or recalled cells or batteries; HAR CHAPTER 11-273.1 Standards for Universal Waste Management. Fire codes

[93] Typically, 16-gallon tube shaped.
[94] https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2023-03/DDR-brochure.pdf.
[95] As of 5/13 the EPA announced it is updating its Hazardous waste regulations which could include the requirement to have an EPA site ID.
[96] See for example Viking damage battery crate. These can be and are generally expensive (~$15,000 for a small hybrid battery, or $60,000 for a larger EV battery. For grid applications, however, there are not crates – they have to be discharged and taken apart.
[97] This expensive option is the cheapest. It requires hiring fire professionals.

(increasingly updated). International Fire Code (IFC). Local jurisdictions adopt policies. Fire codes (increasingly updated) including the Hawai‘i State Fire Code and the international Fire Code (IFC); EPA site ID[98].

*What is the training required?* Training includes awareness of electrical hazards, safe handling procedures, and emergency response protocols. Additionally, individuals handling EV batteries must receive specialized training on the specific types of batteries, their risks, and how to handle them safely.

*How often should the site be inspected?* Any site collecting DDR EV or home energy storage lithium-ion batteries should be inspected monthly. Additionally, physical inspections of the collected batteries should be performed every six months.

*Utility scale.* The permits and PPAs for IPPs require that they are responsible for the removal of used “waste” EOL energy storage system lithium batteries. To date, all of these systems use lithium-ion batteries. These large-scale utility batteries are typically housed in battery banks. Prior to their transport, they will be fully discharged and subject to an appropriate level of disassembly prior to being appropriately packaged in wooden crates. Moreover, they will be professionally inspected for presence of DDR battery packs. In the case of natural disasters, third parties may be brought in as deemed necessary by government authorities. ***NOTE: There is no crate option at this scale.***

*The following regulations apply*: 40 CFR Part 273 Standards for Universal Waste Management; CFR 49 § 173.185 (f) Damaged, defective, or recalled cells or batteries; HAR CHAPTER 11-273.1 Standards for Universal Waste Management. Fire codes (increasingly updated). International Fire Code (IFC). Local jurisdictions adopt policies. Fire codes (increasingly updated) including the Hawai‘i State Fire Code and the international Fire Code (IFC); EPA site ID[99].

*What is the training required?* For collection of lithium-ion batteries at a utility scale, training is required to ensure safe handling, storage, and transportation, as these batteries are considered hazardous materials. Training must cover recognizing hazards, emergency response protocols, and compliance with DOT and OSHA regulations. All employees involved in handling, packaging, labeling, shipping, and loading of lithium-ion batteries in this format need training in accordance with DOT regulations. Personnel working with utility-scale battery systems need training on electrical safety protocols, including working with high-voltage systems. This includes: (i) training on emergency response

[98] As of 5/13 the EPA announced it is updating its Hazardous waste regulations which could include the requirement to have an EPA site ID.

[99] As of 5/13 the EPA announced it is updating its Hazardous waste regulations which could include the requirement to have an EPA site ID.

protocols, including procedures for leaks, spills, and fires, is essential; and (ii) training on fire prevention, detection, and suppression, as well as emergency response in case of a fire involving lithium-ion batteries.

*How often should the site be inspected?* Sites collecting used EOL utility-scale lithium-ion batteries should be inspected regularly, with a minimum frequency of monthly visual inspections and monthly voltage/current checks. Additionally, a thorough physical inspection, including cleaning, should be performed every six months. Finally, the entire system should be checked by a qualified technician at least once a year to ensure proper operation and identify potential issues.

***Requirements – Waste lithium metal batteries.*** Most lithium metal batteries in the community are found in common, single-use household products, particularly those with a long shelf life. Lithium metal batteries are non-rechargeable and should not be confused with rechargeable lithium-ion batteries, which power consumer electronics like phones and laptops. The requirements for collecting lithium metal batteries can vary significantly. Lithium metal (primary) batteries are often handled as hazardous waste, while lithium-ion batteries are generally classified as universal waste under the Resource Conservation and Recovery Act (RCRA) due to their potential ignitable and reactive characteristics. This distinction means lithium metal batteries require stricter, more specific handling and disposal protocols than lithium-ion batteries, though both are regulated under hazardous waste laws. More often classified as hazardous waste under RCRA, potentially carrying the waste codes D001 (ignitable) and D003 (reactive). This requires a more direct application of the hazardous waste regulations.

**Transport (#4)**

This section refers to the on-island transport of used "waste" EOL lithium batteries from local collection sites to a local temporary storage/sorting facility on the island of O'ahu. When transported, used "waste" EOL lithium batteries are regulated as Hazardous Materials/Dangerous Goods by DOT and other international transport authorities. These lithium batteries must be treated as "Class 9" Dangerous Goods when transported, in accordance with PHMSA's regulations. Prior to being transported, used "waste" EOL lithium batteries must also be evaluated individually to determine whether or not they are "damaged or defective". ***These responsibilities fall on the transporter***.

***Requirements – Transport of used "waste" EOL lithium-ion cells/batteries.***

*Household, consumer and portable lithium batteries (small format).* Although most of the boxes picked up at general collection sites (e.g., Home Depot, etc.) will contain mixed battery types[100], each box must still be inspected for the presence of lithium batteries. This is because

[100] i.e., non-lithium based (e.g., alkaline) with lithium based.

the transporter can only transport used "waste" EOL lithium batteries that have been verified by the collection site to be: (i) already enclosed in individual plastic bags; and (ii) packed into appropriately labeled cardboard boxes[101] weighing a maximum load of 60 pounds[102]. The boxes must be packed securely in the back of the truck, with no heavy objects resting upon them. The boxes must also be securely fastened to avoid movement during transport.

Prior to each transport shipment the following should be also verified:

a. The vehicle's good working condition;
b. All necessary paperwork, including shipping manifests, permits, and emergency response plans are in order;
c. All used "waste" EOL lithium batteries have been properly packaged, secured, and labeled according to regulations; and
d. All required safety equipment, such as fire extinguishers, spill kits, and personal protective equipment (PPE) are present and functioning.

Moreover, any transport of used "waste" EOL lithium batteries shall be accompanied with documentation required for dangerous goods, e.g., UN #, proper shipping name, hazard class, Packing Group (example: UN 3090, LITHIUM METAL BATTERIES, 9). Other needed information includes:

a. The number and a description of the packages;
b. The total quantity of each item of dangerous goods;
c. The name and address of the consignor;
d. Emergency response phone number & information;
e. The name and address of the consignee(s); and
f. Shipper's certification statement.

*The following regulations apply*: HAR 11-273-18; 49 CFR Part 173 (specifically section 173.185); 49 CFR Part 172, Subpart H - Training.

*What is the training required?* Hazmat employees involved in shipping small format lithium batteries will require training in accordance with 49 CFR Part 172, Subpart H. Such training should be conducted at least every three years and contain the following components:

a. General Awareness;
b. Safety Awareness;
c. Security Awareness;

[101] Typically, 7-gallon.
[102] Technically steel drums can be used but it is assumed that this is too much for the transport of used "waste" EOL lithium batteries from the collection site to the temporary storage location.

d. In-Depth Security Plan (if applicable); and
e. Function Specific Instructions

49 CFR regulations allow employees, for which required training has not yet been provided, to perform functions under the direct supervision of a trained person for up to ninety (90) days.

*How often should the transport vehicles be inspected?*[103] Vehicles should undergo regular scheduled maintenance, including inspections of the vehicle's structural integrity, tires, brakes, and other safety-related components to prevent accidents and to ensure compliance with relevant regulations, including those related to dangerous goods transport, waste management, and safety. While the frequency of inspections depends on various factors, including the type of vehicle, the quantity and type of batteries transported, and the applicable regulations, the quantity and type of used "waste" EOL lithium batteries transported may also influence the frequency and type of inspections.

*e-bikes, e-scooters, weed eaters, leaf blower batteries (mid-format).* The transporter must verify the used "waste" EOL lithium batteries to be transported in this format are: (i) in good condition, (ii) individually enclosed in plastic bags, and (iii) packed into boxes containing a fire-retardant liner, plastic tubes, or steel drums (i.e., 5 or 55) [104]. The boxes must be packed securely in the back of the truck, with no heavy objects resting upon them. The boxes must also be securely fastened. The fire-retardant liner can be returned to the collection site but the box cannot.

Prior to each transport shipment the following should be verified:

a. The vehicle's good working condition;
b. All necessary paperwork, including shipping manifests, permits, and emergency response plans are in order;
c. All used "waste" EOL lithium batteries are properly packaged, secured, and labeled according to regulations; and
d. All required safety equipment, such as fire extinguishers, spill kits, and PPE are present and functioning.

Also, any transport of used "waste" EOL lithium batteries shall be accompanied with documentation required for dangerous goods, e.g., UN #, proper shipping name, hazard class, Packing Group (example: UN 3090, LITHIUM METAL BATTERIES, 9). Other needed information includes:

[103] See, for example, 49 CFR Part 396 -- Inspection, Repair, and Maintenance.
[104] The 55-gallon drum can only weigh a maximum load of 450 pounds.

a. The number and a description of the packages;
b. The total quantity of each item of dangerous goods;
c. The name and address of the consignor;
d. Emergency response phone number & information;
e. The name and address of the consignee(s); and
f. Shipper's certification statement

*The following regulations apply*: HAR 11-273-18; 49 CFR Part 173 (specifically section 173.185); 49 CFR Part 172, Subpart H - Training.

*What is the training required?* Hazmat employees involved in shipping used "waste" EOL lithium batteries in this format may require training in accordance with 49 CFR Part 172, Subpart H. Training must be conducted at least every three years and must contain the following components:

a. General Awareness;
b. Safety Awareness;
c. Security Awareness;
d. In-Depth Security Plan (if applicable); and
e. Function Specific Instructions.

*How often should the transport vehicles be inspected?* Vehicles should undergo regularly scheduled maintenance, including inspections of the vehicle's structural integrity, tires, brakes, and other safety related components to prevent accidents and to ensure compliance with relevant regulations, including those related to dangerous goods transport, waste management, and safety. While the frequency of inspections will depend on various factors[105], including the type of vehicle, the quantity and type of batteries transported, and the applicable regulations, the quantity and type of EOL lithium batteries transported may also influence the frequency and type of inspections.

*EV, home or commercial scale energy storage, portable power packs (large format).* Prior to transporting the used "waste" EOL lithium battery[106] in this format, the transporter must first visually inspect the battery and apply a series of tests[107] to verify that it is still in good condition and not DDR. Large format batteries deemed to be in good condition must be securely affixed to a wooden pallet that is then well secured in the back of a truck bed.

[105] To obtain a very specific determination of these factors, a qualified stewardship organization (e.g., Call2Recycle) should be consulted.
[106] EV or energy storage batteries.
[107] These tests include review of whether the battery was damaged in an accident or exposed to excessive heat or salt water, as well as other visual inspection requirements any signs of damage or overheating.

Any transport of used “waste” EOL lithium batteries in this format shall be accompanied with documentation required for dangerous goods, e.g., UN #, proper shipping name, hazard class, Packing Group (example: UN 3090, LITHIUM METAL BATTERIES, 9). Other needed information includes:

a. The number and a description of the packages;
b. The total quantity of each item of dangerous goods;
c. The name and address of the consignor;
d. Emergency response phone number & information;
e. The name and address of the consignee(s); and
f. Shipper’s certification statement.

Prior to each transport shipment the following should also be verified:

a. The vehicle's good working condition;
b. All necessary paperwork, including shipping manifests, permits, and emergency response plans are in order;
c. All used “waste” EOL lithium batteries are properly packaged, secured, and labeled according to regulations; and
d. All required safety equipment, such as fire extinguishers, spill kits, and PPE are present and functioning.

*The following regulations apply*: HAR 11-273 Hazardous Waste Management – Standards for Universal Waste Management; 49 CFR Part 173 (specifically section 173.185); 49 CFR Part 172, Subpart H - Training.

*What is the training required?* Hazmat employees involved in shipping used “waste” EOL lithium batteries in this format may require training in accordance with 49 CFR Part 172, Subpart H. Training must be conducted at least every three years and must contain the following components:

a. General Awareness;
b. Safety Awareness;
c. Security Awareness;
d. In-Depth Security Plan (if applicable); and
e. Function Specific Instructions.

*How often should the transport vehicles be inspected?* Vehicles should undergo regular scheduled maintenance, including inspections of the vehicle's structural integrity, tires, brakes, and other safety-related components to prevent accidents and to ensure compliance with relevant regulations, including those related to dangerous goods transport, waste management, and safety. While the frequency of inspections depends on various factors, including the type of vehicle, the quantity and type of batteries transported, and the applicable regulations, the quantity, and type of EOL lithium batteries transported may also influence the frequency and type of inspections.

*Utility scale.* The permits and PPAs for IPPs require that they are responsible for the removal of EOL energy storage systems in this format. To date, all of these systems are lithium-ion batteries. These large-scale utility batteries are typically housed in battery banks. Prior to their transport, they will be fully discharged and subject to an appropriate level of disassembly prior to being appropriately packaged in wooden crates. Moreover, they will be professionally inspected for presence of DDR battery packs. In the case of natural disasters, third parties may be brought in as deemed necessary by government authorities.

Prior to each transport shipment the following should also be verified:

a. The vehicle's good working condition;
b. All necessary paperwork, including shipping manifests, permits, and emergency response plans are in order;
c. All used "waste" EOL lithium batteries are properly packaged, secured, and labeled according to regulations; and
d. All required safety equipment, such as fire extinguishers, spill kits, and PPE are present and functioning.

Any transport of used "waste" EOL lithium batteries in this format shall be accompanied with documentation required for dangerous goods, e.g., UN #, proper shipping name, hazard class, Packing Group (example: UN 3090, LITHIUM METAL BATTERIES, 9). Other needed information includes:

a. The number and a description of the packages;
b. The total quantity of each item of dangerous goods;
c. The name and address of the consignor;
d. Emergency response phone number & information;
e. The name and address of the consignee(s); and
f. Shipper's certification statement

*The following regulations apply*: HAR 11-273-18; 49 CFR Part 173, specifically section 173.185; 49 CFR Part 172, Subpart H - Training.

***Requirements – Transport of waste DDR lithium-ion cells/batteries.*** DDR lithium batteries, including those misused and abused, pose an even greater risk than non-DDR lithium batteries during transport. All DDR lithium batteries, regardless of weight, are fully regulated under the hazmat materials regulations (HMR)[108]. Specifically, all hazard communication, emergency response, training, and packaging requirements apply—including, among others, shipping papers, markings, and Class 9 lithium battery labels.

*Household, consumer, and portable lithium batteries (small format).* Prior to their transportation DDR battery cells must be: (i) enclosed in individual plastic bags and (ii) packed into an appropriately labeled steel drums[109]. The drums must also be fixed securely to the truck bed while being transported.

Prior to each transport shipment the following should also be verified:

a. The vehicle's good working condition;
b. All necessary paperwork, including shipping manifests, permits, and emergency response plans are in order;
c. All used "waste" EOL lithium batteries are properly packaged, secured, and labeled according to regulations; and
d. All required safety equipment, such as fire extinguishers, spill kits, and PPE are present and functioning.

Any transport of used "waste" EOL lithium batteries in this format shall be accompanied with documentation required for dangerous goods, e.g., UN #, proper shipping name, hazard class, Packing Group (example: UN 3090, LITHIUM METAL BATTERIES, 9). Other needed information includes:

a. The number and a description of the packages;
b. The total quantity of each item of dangerous goods;
c. The name and address of the consignor;
d. Emergency response phone number & information;
e. The name and address of the consignee(s); and
f. Shipper's certification statement.

*The following regulations apply*: HAR 11-273-18; 49 CFR Parts 171-80, specifically 49 CFR Part 172, Subpart H – Training (specifically § 172.704 Training requirements, and § 173.185 (f) Damaged, defective, or recalled cells or batteries.

*What is the training required?* To transport DDR lithium-ion batteries by vehicle, individuals involved in packaging, marking, labeling, or loading these batteries must receive training as specified in 49 CFR Subpart H, Section 172.704.

[108] https://www.phmsa.dot.gov/standards-rulemaking/hazmat/hazardous-materials-regulations.
[109] Generally, 5-gallon.

*How often should the transport vehicles be inspected?* Vehicles transporting DDR lithium batteries should be inspected before each shipment. Also, it should be ensured before each transport that the batteries are packaged appropriately and that there are no signs of leakage or damage that could pose a hazard. Additionally, the vehicle itself should be inspected to ensure it is suitable for transporting hazardous materials, including having appropriate signage and fire suppression equipment.

*e-bikes, e-scooters, weed eaters, leaf blower batteries (mid format).* All mid-format used "waste" EOL DDR lithium batteries must be individually wrapped in non-metallic bats and packed into steel tubes[110] prior to transport.

Prior to each transport shipment the following should also be verified:

a. The vehicle's good working condition;
b. All necessary paperwork, including shipping manifests, permits, and emergency response plans are in order;
c. All used "waste" EOL lithium batteries are properly packaged, secured, and labeled according to regulations; and
d. All required safety equipment, such as fire extinguishers, spill kits, and PPE are present and functioning.

Any transport of used "waste" EOL lithium batteries shall be accompanied with documentation required for dangerous goods, e.g., UN #, proper shipping name, hazard class, Packing Group (example: UN 3090, LITHIUM METAL BATTERIES, 9). Other needed information includes:

a. The number and a description of the packages;
b. The total quantity of each item of dangerous goods;
c. The name and address of the consignor;
d. Emergency response phone number & information;
e. The name and address of the consignee(s); and
f. Shipper's certification statement.

*The following regulations apply*: HAR 11-273-18; 49 CFR Parts 171-80, specifically 49 CFR Part 172, Subpart H – Training (specifically § 172.704 Training requirements, and § 173.185 (f) Damaged, defective, or recalled cells or batteries.

*What is the training required?* To transport DDR lithium-ion batteries in this format by vehicle, individuals involved in packaging, marking, labeling, or loading these batteries must receive training as specified in 49 CFR Subpart H, Section 172.704.

[110] Generally, 16-gallon.

*How often should the transport vehicles be inspected?* Vehicles transporting DDR lithium batteries in this format should be inspected before each shipment. Personnel should ensure that the batteries are packaged appropriately and that there are no signs of leakage or damage that could pose a hazard. Additionally, the vehicle itself should be inspected to ensure it is suitable for transporting hazardous materials, including having appropriate signage and fire suppression equipment.

*EV, home or commercial scale energy storage, portable power packs (large format).* Large format DDR batteries must be placed into specially designed specialized fire proof crates[111] which must also be securely fixed in the back of the truck.

Prior to each transport shipment the following should also be verified:

a. The vehicle's good working condition;
b. All necessary paperwork, including shipping manifests, permits, and emergency response plans are in order;
c. All used "waste" EOL lithium batteries are properly packaged, secured, and labeled according to regulations; and
d. All required safety equipment, such as fire extinguishers, spill kits, and PPE are present and functioning.

Any transport of used "waste" EOL lithium batteries in this format shall be accompanied with documentation required for dangerous goods, e.g., UN #, proper shipping name, hazard class, Packing Group (example: UN 3090, LITHIUM METAL BATTERIES, 9). Other needed information includes:

a. The number and a description of the packages;
b. The total quantity of each item of dangerous goods;
c. The name and address of the consignor;
d. Emergency response phone number & information;
e. The name and address of the consignee(s); and
f. Shipper's certification statement.

*The following regulations apply*: HAR 11-273-18; 49 CFR Parts 171-80, specifically 49 CFR Part 172, Subpart H – Training (specifically § 172.704 Training requirements, and § 173.185 (f) Damaged, defective, or recalled cells or batteries.

[111] See, for example, Viking damaged battery crate.

*What is the training required?* To transport DDR lithium-ion batteries in this format by vehicle, individuals involved in packaging, marking, labeling, or loading these batteries must receive training as specified in 49 CFR Subpart H, Section 172.704.

*How often should the transport vehicles be inspected?* Vehicles transporting DDR lithium batteries in this format should be inspected before each shipment. Personnel should ensure the batteries are packaged appropriately and that there are no signs of leakage or damage that could pose a hazard. Additionally, the vehicle itself should be inspected to ensure it is suitable for transporting hazardous materials, including having appropriate signage and fire suppression equipment.

<u>Utility scale.</u> The permits and PPAs for IPPs require that they are responsible for the removal of EOL energy storage systems in this format. To date, all of these systems are lithium-ion batteries. These large-scale utility batteries are typically housed in battery banks. Prior to their transport, they will be fully discharged and subject to an appropriate level of disassembly prior to being appropriately packaged in wooden crates. Moreover, they will be professionally inspected for presence of DDR battery packs. In the case of natural disasters, third parties may be brought in as deemed necessary by government authorities.

Any transport of used “waste” EOL lithium batteries shall be accompanied with documentation required for dangerous goods, e.g., UN #, proper shipping name, hazard class, Packing Group (example: UN 3090, LITHIUM METAL BATTERIES, 9). Other needed information includes:

a. The vehicle's good working condition;
b. All necessary paperwork, including shipping manifests, permits, and emergency response plans are in order;
c. All used “waste” EOL lithium batteries are properly packaged, secured, and labeled according to regulations; and
d. All required safety equipment, such as fire extinguishers, spill kits, and PPE are present and functioning.

Prior to each transport shipment the following should also be verified:

a. The number and a description of the packages;
b. The total quantity of each item of dangerous goods;
c. The name and address of the consignor;
d. Emergency response phone number & information;
e. The name and address of the consignee(s); and
f. Shipper’s certification statement.

*The following regulations apply*: HAR 11-273-18; 49 CFR Parts 171-80, specifically 49 CFR Part 172, Subpart H – Training (specifically § 172.704 Training requirements, and § 173.185 (f) Damaged, defective, or recalled cells or batteries.

*What is the training required?* To transport DDR lithium-ion batteries in this format by vehicle, individuals involved in packaging, marking, labeling, or loading these batteries must receive training as specified in 49 CFR Subpart H, Section 172.704.

***Requirements – Lithium metal batteries.*** There is a difference in ground transport regulations for lithium metal vs. lithium-ion batteries, primarily in their risk assessment, which influences the permitted quantity and size limits, as well as specific packaging and labeling requirements under DOT ***regulations. Lithium metal*** batteries are regulated by their lithium content in grams ***per battery***, while lithium-ion batteries are regulated by their watt-hour (Wh) rating, with generally stricter limits for lithium metal batteries.

**Temporary Storage (#5)**

This section refers to the on-island temporary storage of used "waste" EOL lithium batteries prior to their preprocessing for marine transit. It is assumed that all previously collected batteries transported to the temporary storage location will have been appropriately packaged. In those cases, where the batteries are being collected at the same site as the temporary storage location, it is assumed that their collection will have followed the same rules as defined in the section on Collection (#3) above.

***Requirements – Temporary storage of waste lithium-ion batteries.***

*Household, consumer and portable lithium batteries (Small format).* Once at the temporary storage facility and prior to sorting, all transported batteries in this format should be both kept in the boxes there were delivered in and also stored in cool, dry locations, away from combustible materials, and ensuring adequate ventilation. While being stored, the following precautions should be taken during storage to protect against the chance of thermal runaway and fire:

a. The lithium-ion cells/batteries should be stored in climate-controlled spaces with good ventilation;
b. The lithium-ion cells/batteries must be stored in containers that limit the number of batteries within each container and group of containers;
c. When stored indoors, the containers in which the cells/batteries are stored must be separated from other containers and exits by specific distances;
d. When stored indoors, the battery storage areas must be separated from the rest of the building by fire barriers;

e. When stored outdoors, the battery storage areas must be located at a minimum distance from other buildings or potentially hazardous areas;
f. The containers filled with cells/batteries should be stored separately and away from other flammable materials and occupied spaces;
g. Advanced fire detection and suppression equipment must be installed;
h. Frequent visual and thermal inspections of batteries should be conducted;
i. Communications with local fire marshals and first responders about materials and processes happening on site should be ongoing; and
j. A plan for how to respond and evacuate in case of an emergency needs to be maintained.

*The following regulations apply*: 40 CFR Part 273, Standards for Universal Waste Management; 49 CFR § 173.185 Lithium cells and batteries; HAR CHAPTER 11-273.1 Hazardous Waste Management; Standards for Universal Waste Management. International Fire Code (IFC) Section 320 Lithium-Ion and Lithium Metal Battery Storage.

*What is the training required?* Workers handling and storing batteries in this format must be trained on the relevant DOT regulations and must be knowledgeable about potential hazards and corresponding safety measures. Training should cover how to store batteries in climate-controlled spaces with good ventilation, how to separate them from other flammable materials, and how to prevent their damage. Training should also include fire safety measures, such as installing fire detection and suppression equipment, and maintaining a plan for emergency response. Employees should also be trained in how to respond to a battery fire or other emergency, including evacuation procedures and communication with local authorities.

*How often should the storage site be inspected?* Sites storing used EOL lithium-ion batteries in this format should be inspected at least every six months to ensure proper storage conditions and safety. These inspections should include visual checks for damage (e.g., dents, bulges, or leaks), temperature monitoring (ensure batteries are stored within the recommended temperature range (typically 40-80°F).

*e-bikes, e-scooters, weed eaters, leaf blower batteries (mid-format).* Upon arrival at the temporary storage site, used "waste" EOL lithium batteries in this scale should be left in their steel drums[112] and be stored in cool, dry locations, away from combustible materials, and ensuring adequate ventilation. While stored, the following precautions should be taken during storage to protect against the chance of thermal runaway and fire:

a. Batteries should be stored in climate-controlled spaces with good ventilation;

[112] As described previously generally 16-gallons.

b. Lithium-ion batteries must be stored in containers that limit the number of batteries within each container and group of containers;
c. When stored indoors, containers must be separated from other containers and exits by specific distances;
d. When stored indoors, battery storage areas must be separated from the rest of the building by fire barriers;
e. When stored outdoors, storage areas must be located at a minimum distance from other buildings or potentially hazardous areas;
f. Batteries should be stored separately and away from other flammable materials and occupied spaces when possible;
g. Advanced fire detection and suppression equipment must be installed;
h. Frequent visual and thermal inspections of batteries should be conducted;
i. Communications with local fire marshals and first responders about materials and processes happening on site should be ongoing; and
j. A plan for how to respond and evacuate in case of an emergency needs to be maintained.

*The following regulations apply*: 40 CFR Part 273, Standards for Universal Waste Management; 49 CFR § 173.185 Lithium cells and batteries; HAR CHAPTER 11-273.1 Hazardous Waste Management; Standards for Universal Waste Management. International Fire Code (IFC) Section 320 Lithium-Ion and Lithium Metal Battery Storage.

*What is the training required?* Workers handling and temporarily storing batteries in this format must be trained on the relevant DOT regulations and must be knowledgeable about potential hazards and corresponding safety measures. Training should cover how to store batteries in climate-controlled spaces with good ventilation, separating them from other flammable materials, and preventing them from damage. Training should include fire safety measures, such as installing fire detection and suppression equipment, and maintaining a plan for emergency response. Employees should be trained in how to respond to a battery fire or other emergency, including evacuation procedures and communication with local authorities.

*How often should the storage site be inspected?* Sites storing used "waste" EOL lithium-ion batteries in this format should be inspected at least every six months to ensure proper storage conditions and safety. These inspections should include visual checks for damage (e.g., dents, bulges, or leaks), temperature monitoring (ensure batteries are stored within the recommended temperature range (typically 40-80°F).

<u>*EV, home or commercial scale energy storage, portable power packs (large format).*</u> Once at the temporary storage facility, the transported batteries are moved from their wooden pallets

and loaded into simple wooden crates and then stored in cool, dry locations, away from combustible materials, and ensuring adequate ventilation. While stored, the following precautions should be taken during storage to protect against the chance of thermal runaway and fire:

a. Batteries should be stored in climate-controlled spaces with good ventilation;
b. Lithium-ion batteries must be stored in containers that limit the number of batteries within each container and group of containers;
c. When stored indoors, containers must be separated from other containers and exits by specific distances;
d. When stored indoors, battery storage areas must be separated from the rest of the building by fire barriers;
e. When stored outdoors, storage areas must be located at a minimum distance from other buildings or potentially hazardous areas;
f. Batteries should be stored separately and away from other flammable materials and occupied spaces when possible;
g. Advanced fire detection and suppression equipment must be installed;
h. Frequent visual and thermal inspections of batteries should be conducted;
i. Communications with local fire marshals and first responders about materials and processes happening on site should be ongoing; and
j. A plan for how to respond and evacuate in case of an emergency needs to be maintained.

*The following regulations apply*: 40 CFR Part 273, Standards for Universal Waste Management; 49 CFR § 173.185 Lithium cells and batteries; HAR CHAPTER 11-273.1 Hazardous Waste Management; Standards for Universal Waste Management. International Fire Code (IFC) Section 320 Lithium-Ion and Lithium Metal Battery Storage.

*What is the training required?* Workers handling and storing batteries in this format must be trained on the relevant DOT regulations and must be knowledgeable about potential hazards and corresponding safety measures. Training should cover how to store batteries in climate-controlled spaces with good ventilation, separating them from other flammable materials, and preventing damage. Training should include fire safety measures, such as installing fire detection and suppression equipment, and maintaining a plan for emergency response. Employees should be trained in how to respond to battery fires or other emergency, including (but not necessarily limited to) evacuation procedures and communication with local authorities.

*How often should the storage site be inspected?* Sites temporarily storing used “waste” EOL LIBs in this format should be inspected at least every six months to ensure proper storage conditions and safety. These inspections should include visual checks for damage (e.g., dents, bulges, or leaks), temperature monitoring (ensure batteries are stored within the recommended temperature range, typically 40-80°F).

***Utility scale.*** The permits and PPAs for IPPs require that they are responsible for the removal of EOL energy storage systems in this format. To date, all of these systems are LIBs. These large-scale utility batteries are typically housed in battery banks. Prior to their transport, they will be fully discharged and subject to an appropriate level of disassembly prior to being appropriately packaged in wooden crates. Moreover, they will be professionally inspected for presence of DDR battery packs. In the case of natural disasters, third parties may be brought in as deemed necessary by government authorities.

*The following regulations apply*: 40 CFR Part 273, Standards for Universal Waste Management; 49 CFR § 173.185 Lithium cells and batteries; HAR CHAPTER 11-273.1 Hazardous Waste Management; Standards for Universal Waste Management. International Fire Code (IFC) Section 320 Lithium-Ion and Lithium Metal Battery Storage.

*What is the training required?* Workers handling and storing batteries in this format must be trained on the relevant DOT regulations and must be knowledgeable about potential hazards and corresponding safety measures. Training should cover how to store batteries in climate-controlled spaces with good ventilation, separating them from other flammable materials, and preventing damage. Training should include fire safety measures, such as installing fire detection and suppression equipment, and maintaining a plan for emergency response. Employees should be trained in how to respond to a battery fire or other emergency, including evacuation procedures and communication with local authorities.

*How often should the storage site be inspected?* It is not expected that batteries in this format will be temporarily stored. But if they are sites storing these used "waste" EOL LIBs should be inspected at least every six months to ensure proper storage conditions and safety. These inspections should include visual checks for damage (e.g., dents, bulges, or leaks), temperature monitoring (ensure batteries are stored within the recommended temperature range, typically 40-80°F).

***Requirements – Waste DDR lithium-ion.***

<u>*Household, consumer and portable lithium batteries (small format).*</u> DDR batteries are stored as described above but separately in non-combustible, and electrically non-conductive containers filled with a non-combustible absorbent material (e.g., like sand or cat litter).

*The following regulations apply*: 40 CFR Part 273, Standards for Universal Waste Management; 49 CFR § 173.185 Lithium cells and batteries; HAR CHAPTER 11-273.1

Hazardous Waste Management; Standards for Universal Waste Management. International Fire Code (IFC) Section 320 Lithium-Ion and Lithium Metal Battery Storage.

*What is the training required?* Workers handling and storing batteries in this format must be trained on the relevant DOT regulations and must be knowledgeable about potential hazards and corresponding safety measures. Training should cover how to store batteries in climate-controlled spaces with good ventilation, separating them from other flammable materials, and preventing damage. Training should include fire safety measures, such as installing fire detection and suppression equipment, and maintaining a plan for emergency response. Employees should be trained in how to respond to a battery fire or other emergency, including evacuation procedures and communication with local authorities.

*How often should the storage site be inspected?* Storage facilities storing DDR lithium batteries should be inspected daily for visual signs of damage and every three months for battery health. Additionally, daily thermographic scans and monthly inspections of connections and system components are recommended.

*e-bikes, e-scooters, weed eaters, leaf blower batteries (mid-format).* DDR batteries are stored as described above but separately in non-combustible, and electrically non-conductive containers filled with a non-combustible absorbent material (e.g., like sand or cat litter).

*The following regulations apply*: 40 CFR Part 273, Standards for Universal Waste Management; 49 CFR § 173.185 Lithium cells and batteries; HAR CHAPTER 11-273.1 Hazardous Waste Management; Standards for Universal Waste Management. International Fire Code (IFC) Section 320 Lithium-Ion and Lithium Metal Battery Storage.

*What is the training required?* Workers handling and storing batteries in this format must be trained on the relevant DOT regulations and must be knowledgeable about potential hazards and corresponding safety measures. Training should cover how to store batteries in climate-controlled spaces with good ventilation, separating them from other flammable materials, and preventing damage. Training should include fire safety measures, such as installing fire detection and suppression equipment, and maintaining a plan for emergency response. Employees should be trained in how to respond to a battery fire or other emergency, including evacuation procedures and communication with local authorities.

*How often should the storage site be inspected?* Storage facilities storing DDR lithium batteries should be inspected daily for visual signs of damage and every three months for battery health. Additionally, daily thermographic scans and monthly inspections of connections and system components are recommended.

*EV, home or commercial scale energy storage, portable power packs (large format).* At the temporary storage facility, the DDR battery remains in the specialized crate it was delivered in.

*The following regulations apply*: 40 CFR Part 273, Standards for Universal Waste Management; 49 CFR § 173.185 Lithium cells and batteries; HAR CHAPTER 11-273.1 Hazardous Waste Management; Standards for Universal Waste Management. International Fire Code (IFC) Section 320 Lithium-Ion and Lithium Metal Battery Storage.

*What is the training required?* Workers handling and storing batteries in this format must be trained on the relevant DOT regulations and must be knowledgeable about potential hazards and corresponding safety measures. Training should cover how to store batteries in climate-controlled spaces with good ventilation, separating them from other flammable materials, and preventing damage. Training should include fire safety measures, such as installing fire detection and suppression equipment, and maintaining a plan for emergency response. Employees should be trained in how to respond to a battery fire or other emergency, including evacuation procedures and communication with local authorities.

*How often should the storage site be inspected?* Storage facilities storing DDR lithium batteries should be inspected daily for visual signs of damage and every three months for battery health. Additionally, daily thermographic scans and monthly inspections of connections and system components are recommended.

*Utility scale.* The permits and PPAs for IPPs require that they are responsible for the removal of EOL energy storage systems. To date, all of these systems are LIBs. In the case of natural disasters, third parties may be brought in as deemed necessary by government authorities. These large-scale utility batteries are typically housed in battery banks. Prior to their transport, they will be fully discharged and subject to an appropriate level of disassembly prior to being appropriately packaged in wooden crates. Moreover, they will be professionally inspected for presence of DDR battery packs.

***Requirements - Waste lithium metal batteries.*** Compared to lithium-ion batteries, lithium metal batteries have a much longer shelf life and don't require this specific charge level. That said, they should be stored in a cool, dry, well-ventilated area, protected from direct sunlight.

**Sorting (#6)**

This section refers to the on-island sorting of temporarily stored used “waste” EOL lithium-ion cells/batteries in preparation of their being processed/prepared for marine transit. The containers holding the cells/batteries brought in from collection sites[113] will (almost certainly) contain mixed battery types as the staff at the collection site are not expected to differentiate. At storage facilities, lithium-ion batteries and other battery types should be sorted as soon as possible, ideally within 12 months. This is especially important for lithium-ion batteries, which should not be stored for extended periods.

***Requirements – Waste lithium-ion cells/batteries.***

*Household, consumer, and portable lithium batteries (small format).* During sorting, the transported boxes must be emptied and the contents sorted into one of three battery categories: non-lithium, lithium-ion, and lithium-metal[114]. Also, those identified as DDR cells/batteries should be isolated from non-DDR.

*The following regulations apply*: 49 CFR Parts 171-180 (Specifically, 49 CFR § 173.185); HAR CHAPTER 11-273.1 Hazardous Waste Management; Standards for Universal Waste Management.

*What is the training required?* To safely sort used, EOL lithium-ion batteries, individuals need training on both the general safety procedures and the specific hazards associated with these batteries. Specific training should cover:

a. How to handle, store, and transport lithium-ion batteries, as well as the necessary precautions to prevent fires and other safety issues;
b. The potential hazards of lithium-ion batteries, including electrical, chemical, thermal, and explosive risks;
c. The proper use of PPE, such as gloves, eye protection, and other necessary gear for handling batteries;
d. How to respond to emergencies, such as fires or battery malfunctions, and the proper evacuation procedures;
e. The methods for identifying different types of lithium-ion batteries and classifying them for proper recycling or reuse;
f. The proper techniques for handling and storing batteries, including isolating terminals, preventing damage, and in climate-controlled environments;
g. An overview of hazardous materials and their handling, as well as the specific requirements for lithium-ion batteries; and

[113] Or even collected at the temporary storage facility.
[114] For practical purposes a DDR/non-DDR ratio of .01 can be expected.

h. Safety procedures, security protocols, and emergency response plans for handling hazardous materials.

_e-bikes, e-scooters, weed eaters, leaf blower batteries (mid-format)._ The sorting of these batteries is unnecessary.

_EV, home or commercial scale energy storage, portable power packs (large format)._ The sorting of these batteries at this scale is not applicable.

_Utility scale._ The sorting of batteries at this scale is not applicable.

***Requirements – Waste DDR lithium-ion cells/batteries.***

_Household, consumer and portable lithium batteries (small format)._ During sorting, the transported boxes must be emptied and DDR batteries must be sorted out and removed from the other batteries. DDR batteries, particularly lithium-ion, can be damaged, defective, or recalled and may have an increased risk of thermal runaway, fire, or explosion when crushed or exposed to high temperatures. Regardless of how they are processed (packaging "As Is", subjected to supercritical $CO_2$, or shredding), the way in which DDR batteries are processed by those processes can vary. Moreover, DDR batteries may require specialized processing techniques, including cleaning and sorting, before they can be recycled.

*The following regulations apply*: 49 CFR Parts 171-180 (Specifically, 49 CFR § 173.185); HAR CHAPTER 11-273.1 Hazardous Waste Management; Standards for Universal Waste Management.

*What is the training required?* To properly sort DDR batteries, training in hazmat handling, particularly regarding lithium batteries, is crucial. The training should cover identifying DDR batteries, safe packaging and labeling, and appropriate shipping procedures. Specific components should cover:

a. The basics of what constitutes a hazardous material, including the nine classes of hazardous materials; and
b. Safety awareness, emergency response procedures, and security awareness related to handling hazardous materials.

_e-bikes, e-scooters, weed eaters, leaf blower batteries (mid-format)._ The sorting of DDR batteries at this scale is not necessary as they are already sorted.

_EV, home or commercial scale energy storage, portable power packs (large format)._ The sorting of DDR batteries at this scale is unnecessary as they would have already been sorted.

*Utility scale.* The sorting of DDR batteries at this scale is not applicable.

***Requirements – Waste lithium metal batteries.*** Although the lithium metal batteries should have been sorted/segregated from the lithium-ion batteries at the collection point, it is still required to recheck and resort at the temporary storage facility upon arrival. Lithium metal batteries must be segregated to prevent mixing prior to the processing stages. The lithium metal battery sorting is more rigorous. The process involves identifying the battery type through labeling and visual inspection, then physically separating them into different containers for specialized recycling processes that are tailored to their unique chemistry.

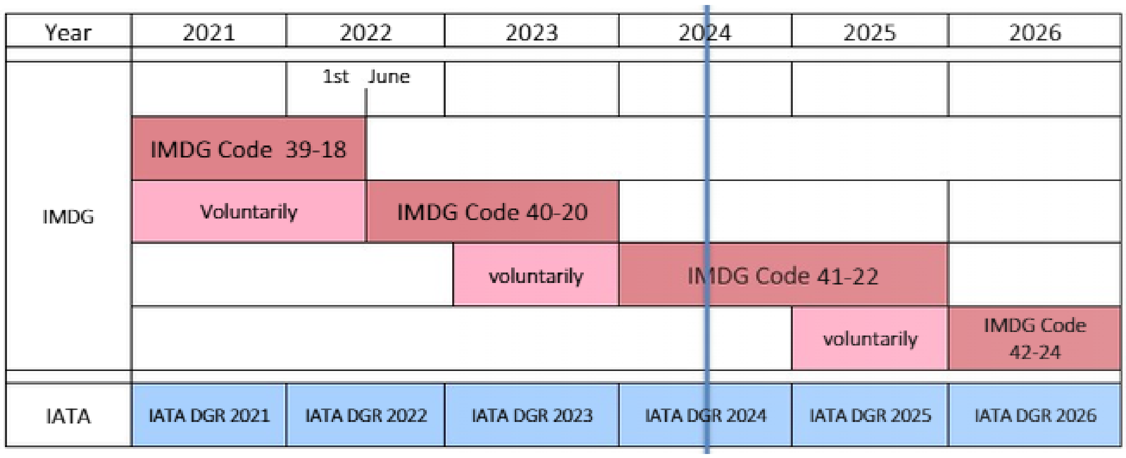
**Transport to Harbor and Ship (#10)**

Requirements for this activity are identical to the section above on *On-island Transport (#4)*.

**Marine Transport (#11)**

As stated above, when transporting within the United States and its territories, transporters are subject to all applicable regulations in CFR 171-180. While transporters do not need to adhere to international standards (i.e., "*Recommendations on the Transport of Dangerous Goods—Model, Regulations*", and "*Recommendations on the Transport of Dangerous Goods—Manual of Tests and Criteria*"), when transporting over the ocean (even between U.S. states or territories) transporters *should* align with the "*International Maritime Dangerous Goods (IMDG) Code*," which harmonizes the practices and procedures followed in the carriage of dangerous goods by sea and ensures compliance with the mandatory provisions of the SOLAS Convention (International Convention for the Safety of Life at Sea) and of Annex III of MARPOL (International Convention for the Prevention of Pollution from Ships). When transported by ocean, transporters will need to keep updated with new and evolving international codes as these maritime codes are all international (Figure 9).

***Figure 9. IMDG codes as function of year updated.***




Adding to all these regulations are the fire code regulations as they apply to transport/shipping of LIBs. For transporters/shippers in Hawai‘i, this includes both state national fire code regulations for on-island transport/shipping as well as international fire code regulations when transporting/shipping over water.

Any carriage of dangerous goods governed shall be accompanied by the documentation, such as UN #, proper shipping name, hazard class, Packing Group (*) (example: UN 3090, LITHIUM METAL BATTERIES, 9).

Other information needed includes:

a. the number and a description of the packages
b. the total quantity of each item of dangerous goods
c. the name and address of the consignor;
d. Emergency response phone number & information
e. the name and address of the consignee(s).
f. Shipper’s certification statement

*The following regulations apply*: IMDG Code 40-20.

*Additional information required*: Emergency response information, use in emergency response to accidents and incidents involving dangerous goods in transport.

# REQUIREMENTS: INSURANCE

## General Considerations

The requirement to secure insurance dominates every step of the logistic pathway governing the disposal of used "waste" EOL lithium-based batteries. Every entity performing as tasked in this logistical pathway must hold a number of insurance instruments. Entities involved in the disposal of used "waste" EOL lithium batteries are confronted with their potential for internal short circuits that lead to thermal runaway reactions and explosions[115]. These risks are even greater for damaged, defective, or recalled lithium-based batteries[116]. Unfortunately, the ability to assess risk is both substantial and difficult. For example, although signs of damage, like swelling or leaking electrolyte, unusual heat or temperature, and corrosion can indicate a potential hazard[116], not all DDR lithium batteries are directly detectable. Non-obvious factors contributing to difficulty in risk assessment include: (i) hidden damage, (ii) unusual behavior, (iii) misuse and abuse, and (iv) lack of awareness. In particular, the insurance providers will want to know how the business addresses all risk factors, with their scrutiny increasing with the overall exposure (of the business) to lithium batteries. Thus, the insurance providers will not only assess the competence of the business applying for coverage, but also the competence of the other business (in the logistic train) that that business interacts with.

Given that the willingness of insurance companies (and their reinsurers[117]) to provide such insurance instruments is directly tied to their ability to accurately assess risk[118], it has become increasingly difficult for entities involved in the disposal of used "waste" EOL lithium batteries to obtain and afford the required insurance. Moreover, Hawai‘i businesses involved in the disposal of used "waste" EOL lithium batteries will also have to address the added risks associated with marine transport. Ocean transport brings much greater risks to property damage and safety than

[115] https://www.phmsa.dot.gov/lithiumbatteries.
[116] PHMSA, 2023. Understanding the Risks of Damaged, Defective or Recalled Lithium Batteries. https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2023-03/DDR-brochure.pdf.
[117] Insurance companies, or reinsurers, provide insurance to other insurance companies to help them manage their risk exposure. Reinsurance allows insurance companies to transfer a portion of their risk to other insurers, particularly when dealing with large or complex risks. Reinsurance helps insurance companies maintain solvency and avoid potential defaults due to large payouts from covered events.
[118] Paul A. Christensen et al. (2021). Risk management over the life cycle of lithium-ion batteries in electric vehicles. Renewable and Sustainable Energy Reviews 148: 111240.

transport by rail or road. As such, business in Hawaiʻi will have to manage the additional risk concerns of ocean carriers and their insurance companies. Of these, perhaps the most worrying is the potential for ocean shippers and/or their insurance carriers to simply decide it is not worth the risk of shipping waste EOL lithium batteries—no matter how extensive the packaging precautions taken. It is also possible (and perhaps more likely) that those ocean shippers who are willing to provide access will only do so after imposing extremely rigid and high-cost packaging requirements. Concomitantly, their insurance carriers may only comply after imposing extremely high rates and/or requirements for packaging.

Under these circumstances, an overlooked risk to Hawaiʻi is a decision by local businesses to: (i) cut corners when packaging; (ii) improperly or inappropriate label manifests; (iii) to disengage entirely from the business of handling used "waste" EOL lithium batteries; or (iv) some combination of the three. If any of these occur at significant scale, the ability to dispose of used "waste" EOL lithium batteries in Hawaiʻi will become significantly threatened. To counter this undesired outcome, it may become mandatory that Hawaiʻi accepts the use of on-island pre-processing pathways that sufficiently "de-risk" the batteries through mechanisms that "de-energize" and/or "deactivate" the batteries prior to their ocean shipping[119].

**Insurance Types**

The types of insurance coverage required are both broad and numerous. Moreover, all participants in the logistic train will need to hold many of these types of coverage. While the types of coverage available are not "new" instruments, nor specific to waste EOL LIBs, the inherent risks (to their handling/shipping) are forcing insurance carriers to reassess the premiums they impose to any businesses with exposure to used "waste" EOL lithium batteries. One of the key issues driving this added scrutiny is to assess the true risk associated with lithium batteries[120]. As a result, all participants in the logistic waste management streams (even those that are not supposed to be involved with lithium batteries, such as municipal waste carriers, transfer stations, and treatment facilities) are facing restricted access to insurance, rising premiums[121], or even the threat of being dropped by their insurance carriers.

In all cases, insurance underwriters will seek information that allows them to evaluate each individual risk, inclusive of fire hazards, before assessing premiums. That being said, specialty or surplus carriers may be available where insurance carriers decline or unsustainably increase.

The types of insurance instruments that are available are identified in Figure 10.

---

119 https://www.hnei.hawaii.edu/wp-content/uploads/Waste-Management-of-EOL-PV-Panels-and-LIBs-in-Hawaii.pdf.
120 https://www.chubb.com/uk-en/businesses/resources/the-challenges-of-insuring-lithium-ion-batteries-as-cargo.html.
121 https://blog.labelmaster.com/why-lithium-battery-shippers-must-examine-insurance-costs-and-coverage/.

*Figure 10. List of insurance coverage types and application.*

| Type of insurance coverage | Description | What it's for | Those required to carry it | How are premiums determined | Need with LIBs |
|---|---|---|---|---|---|
| **General Liability** | Liability insurance for a business that usually covers losses from products liability, premises liability, and some liabilities that the insured assumes under a contract (as a lease). | Protects against financial losses from claims of bodily injury, property damage, and other accidents that could arise during normal business operations. | **Owner of goods and hired contractors**. Although typically not required by law, many business contracts, lease agreements, and professional licenses may require it. | Will be rated on how the lithium batteries are moved and the presence of codes. Handling hazardous materials, for example, will have a code that sets a rating used to determine premiums. | High |
| **Environmental (Pollution Liability)** | Provides coverage for financial losses and damages resulting from unexpected releases of pollutants, typically excluded in standard general liability and property insurance policies. | Used to cover cleanup costs, claims related to bodily injury, damage to environmental components, damage to location, leakage to third party, and business interruption arising from pollution-related incidents. | **Owner of goods and hired contractors.** Any businesses involved in activities that could potentially pollute the environment are generally required to carry environmental liability insurance. Even those not directly handling pollutants can benefit from having it. | A variety of factors, including the industry of the insured, the size and scope of their operations, the potential for pollution events, the location of their business, the financial impact of those events, their history of claims, and the level of risk management practices they have in place. | High |
| **Commercial Property insurance** | Protects a business's physical assets from fire, explosions, burst pipes, storms, theft, and vandalism. | Designed to provide financial protection from the costs of repairing or replacing damaged property, and potentially for injuries or damage caused to others while on the property. | **Owner of goods.** While no state or federal law mandates it, many businesses choose to have it to protect their assets and ensure business continuity in case of events like fires, theft, or vandalism. | A complex combination of factors, including replacement cost (likely low with used LIBs), the property location, age, and condition, as well as the risk of natural disasters and claims history. | Medium to Low |
| **Auto/Truck** | Insurance that provides financial protection against various risks associated with owning and operating vehicles, especially those used for commercial purposes. | Liability for injuries or property damage caused by the vehicle, and in some cases, the cargo being transported. | **Hired contractors**. Anyone operating a vehicle on public roads. | Are the drivers licensed to carry LIBs, are the auto/trucks designed for to carry them, are they equipped with fire suppression systems. | High |

| Type of insurance coverage | Description | What it's for | Those required to carry it | How are premiums determined | Need with LIBs |
|---|---|---|---|---|---|
| **Motor Truck Cargo (Transit)** | **Insurance** against loss resulting from damage to goods in transit by motor truck. A specialized type of insurance that covers the liability of the trucking company for damages or losses to the cargo while it's in their care, whether due to accidents, theft, or other events. | Protects for-hire trucking companies against financial losses caused by the loss or damage of the goods they are transporting. Often based on contractual relationship between the owner of the goods and the Motor Truck Cargo company. | **Owner of goods or hired contractors**. Typically required for businesses that haul cargo for hire, such as trucking companies, freight forwarders, and shipping companies. | A variety of factors, including the value of the cargo, the type of cargo, the route, and the carrier's risk profile. | Low |
| **Storage (Warehouse or Equivalent)** | Business insurance that protects against potential losses and liabilities associated with storing goods in a warehouse. | To cover both the warehouse operator's legal liability for damage or loss to stored goods and the warehouse building itself. | **Owner of goods.** While warehouse owners may have some level of insurance, the owners of the goods are generally required to have their own coverage. | Little value in the battery, so might not be useful. | Low |
| **Ocean Marine (Transit)** | Insurance against risks incident to transportation by sea. | Covers the loss or damage of goods during transportation by sea, protecting the cargo owner. | **Owner of goods or hired contractors**. Typically required for businesses involved in the import, export, and transportation of goods via sea or ships. This includes companies that own vessels, those who contract with others to transport goods, and businesses that rely on ocean shipping for their operations. | Several factors, primarily focusing on the risk associated with the shipment. Key factors include the value of the goods, the nature of the cargo, the vessel's characteristics, the shipping route, and the level of coverage desired. | Low |
| **Marine Liability** | Insurance that covers the legal responsibilities and property damage caused by a vessel or related operations—essentially automobile insurance for boats. | Protects vessel owners, operators, and other entities from financial losses due to negligence or accidents involving their vessels. | **Owner of goods or hired contractors.** Any business involved in marine activities that has the potential to cause damage or injury to others or their property. This includes businesses like marine service providers, marine transportation companies, importers, exporters, and recreational boat owners. | A variety of factors, including the type of vessel, the nature and value of cargo, the route and destination, and the policy terms. Higher-value assets and risky routes generally result in higher premiums. Can buy limits but would not be possible to buy enough limit to cover entire ship. | Low |

| Type of insurance coverage | Description | What it's for | Those required to carry it | How are premiums determined | Need with LIBs |
|---|---|---|---|---|---|
| **Hull Insurance** | A specialized type of insurance that protects the owners against loss caused by damage or destruction of waterborne craft or aircraft. | To cover the physical damage or loss of a ship or vessel, including its hull, machinery, and equipment. It provides financial protection against unforeseen events like collisions, piracy, or adverse weather conditions, offering reimbursement for damages sustained. | **Ship owner**. It can be required by lenders who finance boat purchases | A variety of factors, including the type and age of the vessel, its value, tonnage, operating area, and the risks associated with the insured vessel. On periphery but can impact ability to ship batteries. | Medium to High |
| **Workers Compensation** | Legally mandated insurance purchased by an employer or created through self-insurance that provides coverage for workers' compensation claims by injured employees. | To provide benefits (i.e., medical expenses, lost wages, disability benefits, and in some cases, vocational rehabilitation) to employees who are injured or become ill due to work-related causes. | **Hired contractors**. Any employer with one or more employees. | A variety of factors, including the industry, class code (likely just working with hazardous waste and not specific to working with LIBs), payroll, and claim history of the business. | High |
| **Error and Omissions** | A type of liability insurance that protects businesses and individuals from claims arising from professional negligence, errors, or omissions in their services. | Protects businesses from claims arising from errors or omissions in professional services they provide. It covers legal fees, settlements, and other costs associated with claims of negligence, faulty advice, or other mistakes that cause financial harm to clients. | **Hired contractors**. Businesses such as freight forwarders and logistics companies that provide professional advice or services to customers for a fee. | A variety of factors, primarily based on the risk associated with the specific business or profession and the level of coverage desired. Key factors include the industry, business size and number of employees, revenue, claims history, coverage limits, and location. | Low |

| Type of insurance coverage | Description | What it’s for | Those required to carry it | How are premiums determined | Need with LIBs |
|---|---|---|---|---|---|
| **Contingent Auto or Cargo** | A supplementary policy that kicks in when a primary policy (like the carrier's auto or cargo insurance) fails to cover a loss. It acts as a safety net for the freight broker or broker when the primary policy is inadequate, insufficient, or doesn't pay out. | To provide coverage for losses or damages to cargo or vehicles when the primary insurance policy fails to cover the situation. It's a secondary layer of protection, stepping in if the carrier's own insurance isn't sufficient or if a claim is denied. | **Whomever is responsible for the cargo**. While not always legally mandated, freight brokers and other transportation intermediaries frequently require contingent auto liability (CAL) and contingent cargo insurance. | Various factors, including the nature of the cargo, the mode of transportation, the route, safety measures, claims history, and the broker's annual revenue. | Low |
| **Umbrella Insurance** | A type of extra insurance that provides protection beyond existing limits and coverages of other policies. | To provide additional liability coverage beyond existing policies, acting as a safety net for unexpected losses. | **Owner of goods or hired contractors** with a net worth exceeding $500,000. | A variety of factors, including the amount of coverage purchased, your location, and your risk profile and limits to underlying insurances. | Medium |

**Collection (#3)**

This section refers to those businesses that collect used "waste" EOL lithium-ion batteries.

***Types of insurance required.*** Those collecting used "waste" EOL lithium batteries are expected to carry the following insurance: (i) General Liability, (ii) Environmental, (iii) Storage, and (iv) Workers Compensation.

***Types of questions/information to be answered/provided.*** Insurance underwriters evaluating general liability insurance for businesses involved in collecting used "waste" EOL lithium batteries will focus on assessing the risks associated with handling and transporting these hazardous materials. General questions insurance underwriters will/may ask are:

- What percent of the company's business operations are exposed to the collection of waste EOL LIBs? Of this, what fraction are expected to be DDR?
- What measures are being taken and/or are in place to prevent fires or accidents during collection (e.g., handling and storage of batteries, use/installation of fire suppression systems)?
- How are employees trained in the hazards of lithium-ion batteries and the necessary safety protocols for their collection (e.g., safe storage, fire prevention, and emergency procedures)?
- Are there specific procedures for handling damaged or malfunctioning batteries while being collected (e.g., containment, disposal, and reporting)?
- If specific procedures for handling damaged or malfunctioning batteries are in place, what are safety protocols utilized to identify, segregate, and quarantine items with increased safety risk based upon accepted assessment methods (e.g., visible inspection or temperature monitoring)?
- Is there equipment and capability present that is able to maintain separation of heating, damaged, mishandled, impacted or dropped collected waste EOL LIBs from other collected waste EOL LIBs?
- What percent of the EOL LIBs being collected will have a state of charge percentage under 50%, 30%, or lower?
- What is the storage location for collected batteries, and how is it designed to prevent fire hazards and environmental contamination (e.g., fire-resistant storage, ventilation, and containment)?
- Are there procedures in place to monitor the temperature and condition of collected batteries while being stored prior to their pick up and transport?
- What actions are taken if overheating or other issues (of any waste EOL LIB) are detected?
- Is there thermographic (infrared scanning) equipment present to monitor heating?
- Is there 24/7 continuously monitored fire detection system present and operational?

- What additional steps are being taken to further mitigate risks and improve safety procedures?
- Where are the formats of the waste EOL LIBs being collected, and where are they coming from?
- Where are the collected batteries being delivered to?
- What steps are being taken to prevent environmental contamination of waste EOL LIBs being collected, such as leaks or spills, during battery handling (e.g., spill containment, cleanup procedures, and reporting)?
- Are there any permits or licenses required for the collection of waste EOL LIBs, and are they in compliance?
- Are there any previous incidents or claims related to the collection of waste EOL LIBs, and what were the outcomes?
- What other types of insurance are in place to cover potential losses, such as workers' compensation or property insurance?

**Transport (#4)**

This section refers to those businesses that transport used “waste” lithium batteries from a place of collection (i.e., public spaces, transfer stations, dealerships, bike shops, private business that specialize in waste collection, junk, or salvage yards) and transport them by motor vehicle to a temporary storage facility that serves as a staging place prior to sorting and processing.

***Types of insurance required.*** Those transporting waste EOL LIBs are expected to carry the following insurance: (i) General Liability, (ii) Environmental, (iii) Auto/Truck, (iv) Motor Truck Cargo, and (iv) Workers Compensation.

***Types of questions/information to be answered/provided.***

- What percent of the company’s business operations are exposed to the collection of waste EOL LIBs? Of this, what fraction are expected to be DDR?
- How are the waste EOL LIBs transported?
- What percent of the EOL LIBs being transported will have a state of charge percentage under 50%, 30%, or lower?
- What are the formats and quantities (with receipts) of the waste lithium-ion batteries being transported?
- What are the designated vehicles involved in this hauling job, and what is the schedule of their use to transport hazardous materials?
- Descriptions of from where the waste EOL LIBs are being picked up and to where are they being delivered?
- Complete driver information of the individual who will be hauling the batteries (e.g., is this driver CDL licensed and hazmat certified to haul these batteries)?
- How long has the driver been employed by the insured?

- What measures are being taken and/or are in place to prevent fires or accidents during transport (e.g., appropriate vehicles, securing of batteries, use/installation of fire suppression systems)?
- What emergency plans/procedures are in place should an accident occur during the transport of the waste EOL LIBs?
- What additional steps are being taken to further mitigate risks and improve safety procedures?
- What are the State and Federal permits or licenses required for handling and/or transporting the waste EOL LIBs, and are they in compliance?
- What steps are being taken to prevent environmental contamination, such as leaks or spills, during the transport of the waste EOL LIBs (e.g., spill containment and cleanup procedures, and incident reporting)?
- Copies of the job contract/transportation agreements with the client for this hauling job.
- MSDS forms and product labels for waste EOL lithium-ion batteries being transported/shipped.
- Are there any previous incidents or claims related to LIBs, and what were the outcomes?
- What other types of insurance are in place to cover potential losses, such as workers' compensation or property insurance?

**Temporary Storage (#5)**

This section refers to those businesses that temporarily store used “waste” LIBs prior to being sorted in preparation for any one of the processing steps being considered in this report.

***Types of insurance required.*** The temporary storage of waste EOL lithium-ion batteries are expected to carry the following insurance: (i) General Liability, (ii) Environmental, (iii) Storage, and (iv) Workers Compensation.

***Types of questions/information to be answered/provided.***

- What percent of the company’s business operations are exposed to the temporary storage of waste EOL LIBs? Of this, what fraction are expected to be DDR?
- What percent of the EOL LIBs being collected will have a state of charge percentage under 50%, 30%, or lower?
- What measures are being taken and/or are in place to prevent fires or accidents during the temporary storage of the waste EOL LIBs (e.g., handling and storage of batteries, use/installation of fire suppression systems)?
- How are employees trained on the hazards of waste EOL LIBs and the necessary safety protocols for their temporary storage (e.g., safe storage, fire prevention, and emergency procedures)?
- Are there specific procedures for handling damaged or malfunctioning batteries while being collected (e.g., containment, disposal, and reporting)?

- Are there procedures in place to monitor the temperature and condition of the temporarily stored EOL waste LIBs, and what actions are in place to be taken if overheating or other issues are detected?
- What actions are taken if overheating or other issues (of any waste EOL LIB) are detected?
- Is there equipment and capability to maintain separation of heating, damaged, mishandled, impacted, or dropped items from other items?
- Is there thermographic (infrared scanning) equipment present to monitor heating?
- Is there 24/7 continuously monitored fire detection system present and operational?
- What additional steps are being taken to further mitigate risks and improve safety procedures?
- If specific procedures for handling damaged or malfunctioning batteries are in place, what are the safety protocols utilized to identify, segregate, and quarantine items with increased safety risk identified by accepted assessment methods (e.g., visible inspection or temperature monitoring)?
- Are there automatic sprinkler systems in warehouses, if possible, installed per NFPA 13 or equivalent with hose stations installed per NFPA 14 or equivalent?
- What steps are taken to prevent environmental contamination, such as leaks or spills, during the temporary storage of the waste EOL LIBs (e.g., spill containment, cleanup procedures, and reporting)?
- What are the storage practices, standard operating procedures, what is sprinkler system like in the warehouse (ESFR system preferred)?
- Are there standard operating procedures for shipping, receiving, handling, and daily inspection?
- Standard operating procedure of identifying, segregating, and quarantining items with increased safety risk based on visible inspection or temperature monitoring.
- Are there any previous incidents or claims related to lithium-ion batteries, and what were the outcomes?
- What other types of insurance are in place to cover potential losses, such as workers' compensation or property insurance?

**Sorting (#6)**

This section refers to those businesses involved in the sorting of used “waste” EOL lithium batteries in preparation of their processing for off-island shipment.

***Types of insurance required.*** The temporary storage of waste EOL LIBs are expected to carry the following insurance: (i) General Liability, (ii) Environmental, (iii) Storage, and (iv) Workers Compensation.

***Types of questions/information to be answered/provided.***

- What percent of the company's business operations are exposed to the sorting of waste EOL LIBs? Of this, what fraction are expected to be DDR?
- What are the sorting practices and standard operating procedures used during the sorting of the waste EOL LIBs?
- What measures are being taken and/or are in place to prevent fires or accidents during the sorting of the waste EOL LIBs (e.g., handling and storage of batteries, use/installation of fire suppression systems)?
- What is the sprinkler system used in the warehouse (ESFR system preferred) hosting the sorting of the waste EOL LIBs?
- What are the standard operating procedures used for the sorting? How often are these standard operating procedures inspected (e.g., daily inspection)?
- What are the standard operating procedures to identify, segregate, and quarantine items with increased safety risk based on visible inspection or temperature monitoring?
- Are there specific procedures for handling damaged or malfunctioning batteries while being sorted (e.g., containment, disposal, and reporting)?
- If specific procedures for handling damaged or malfunctioning batteries are in place, what are safety protocols utilized to identify, segregate, and quarantine items with increased safety risk based upon accepted assessment methods (e.g., visible inspection or temperature monitoring)?
- Is there equipment and capability present that is able to maintain separation of heating, damaged, mishandled, impacted, or dropped waste EOL LIBs during the sorting?
- What percent of the EOL LIBs being collected will have a state of charge percentage under 50%, 30%, or lower?
- Are there procedures in place to monitor the temperature and condition of the used EOL LIBs while being sorted?
- What actions are taken if overheating or other issues (of any waste EOL LIB) are detected during the sorting operation?
- Is there thermographic (infrared scanning) equipment present to monitor heating?
- Is there 24/7 continuously monitored fire detection system present and operational?
- What additional steps are being taken to further mitigate risks and improve safety procedures?
- Is there equipment and capability to maintain separation of heating, damaged, mishandled, impacted, or dropped items from other items?
- Is there automatic sprinkler system in the sorting facility, if possible, installed per NFPA 13 or equivalent with hose stations installed per NFPA 14 or equivalent?

**Processing Pathways (#7)**

This section refers to any business involved in the processing of the sorted used "waste" EOL lithium batteries for marine shipment. While this report will analyze multiple processing pathways (e.g., packaging and shipping the batteries "As Is", the use of supercritical $CO_2$ ($sCO_2$) to deactivate the batteries, the application of crude shredding to transform the batteries into "non-battery components", and even the smelting of the batteries prior to their shipment), any business involved in any of these processes will likely need the same insurance and meet the same scrutiny.

***Types of insurance required.*** Any business involved in any of the three types of processing technologies considered in this analysis be expected to carry the following insurance: (i) General Liability, (ii) Environmental, (iii) Storage, and (iv) Workers Compensation.

***Types of questions/information to be answered/provided.***

- What percent of the company's business operations are exposed to the sorting of waste EOL LIBs? Of this, what fraction are expected to be DDR?
- What percent of the EOL LIBs being processed will have a state of charge percentage under 50%, 30%, or lower?
- What are the standard operating procedures used during the chosen processing pathway of the waste EOL LIBs? How often are these standard operating procedures inspected (e.g., daily inspection)?
- What measures are being taken and/or are in place to prevent fires or accidents during the processing of the waste EOL LIBs (e.g., loading of batteries, use/installation of fire suppression systems)?
- What is the sprinkler system used in the processing facility (ESFR system preferred) processing the waste EOL LIBs?
- Are there procedures in place to monitor the temperature and condition of the used EOL LIBs while being sorted?
- What actions are taken if overheating or other issues (of any waste EOL LIB) are detected during the processing of the waste EOL LIBs?
- Is there thermographic (infrared scanning) equipment present to monitor heating?
- Is there 24/7 continuously monitored fire detection system present and operational?
- What additional steps are being taken to further mitigate risks and improve safety procedures?
- Are there automatic sprinkler systems in processing facility, if possible, installed per NFPA 13 or equivalent with hose stations installed per NFPA 14 or equivalent?

**Inter-Island Marine Transport (#9)**

This section refers to those businesses transporting used "waste" EOL lithium batteries, whether it be those collected on the outer islands (prior to processing) and shipped to O'ahu or those being transported from O'ahu to the mainland (or Asian) ports.

***Types of insurance required.*** Ocean Cargo transporters/shippers of the processed waste lithium-ion batteries are expected to carry the following insurance owing to their on-site collection of end-of-life LIBs: (i) Transit Ocean Marine, (ii) General Liability, (iii) Environmental, (iv) Ocean Marine, and (v) Workers Compensation.

***Types of questions/information to be answered/provided.***

- Describe the lithium battery format, chemistry, and quantity of the processed waste EOL LIBs being transported.
- Provide the MSDS forms and product labels for the processed waste EOL LIBs being transported.
- Where are the processed EOL LIBs being delivered to?
- Describe the safety measures/details in place for the transport of these processed waste EOL LIBs.
- Who is doing the loading/unloading of these processed waste EOL LIBs?
- What safety measures are in place during the loading/unloading of these batteries?
- If the loading/unloading is not being done by the insured, is the other party naming the insured as additional insured?
- Describe the emergency plan/procedure in place should an accident occur while transporting these waste EOL LIBs.
- What percent of the EOL LIBs being processed will have a state of charge percentage under 50%, 30%, or lower?

**Transport to Harbor and Loading on Ship (#10)**

This section refers to the motor transport of the packaged processed material the harbor where they will be loaded onto ships.

***Types of insurance required.*** Those processing waste EOL LIBs are expected to carry the following insurance: (i) General Liability, (ii) Environmental, (iii) Auto/Truck, (iv) Motor Truck Cargo, and (iv) Workers Compensation.

***Types of questions/information to be answered/provided.***

- Who is doing the loading/unloading of the processed waste EOL lithium batteries?
- What safety measures are in place during the loading/unloading of these processed batteries?
- If the loading/unloading is not being done by the insured, is the other party naming the insured as additional insured?
- Describe the emergency plan/procedure in place should an accident occur while transporting and loading these processed batteries?
- What is the complete driver information of the individual who will be hauling the processed batteries? Is this driver CDL licensed and hazmat certified to haul these batteries? How long has the driver been employed by the insured?
- What is the designated vehicle involved in this hauling job?

- What is the receipt amount being generated from this hauling job?
- What is the schedule of vehicles used to transport hazardous materials?


# REQUIREMENTS: STEWARDSHIP STRUCTURES

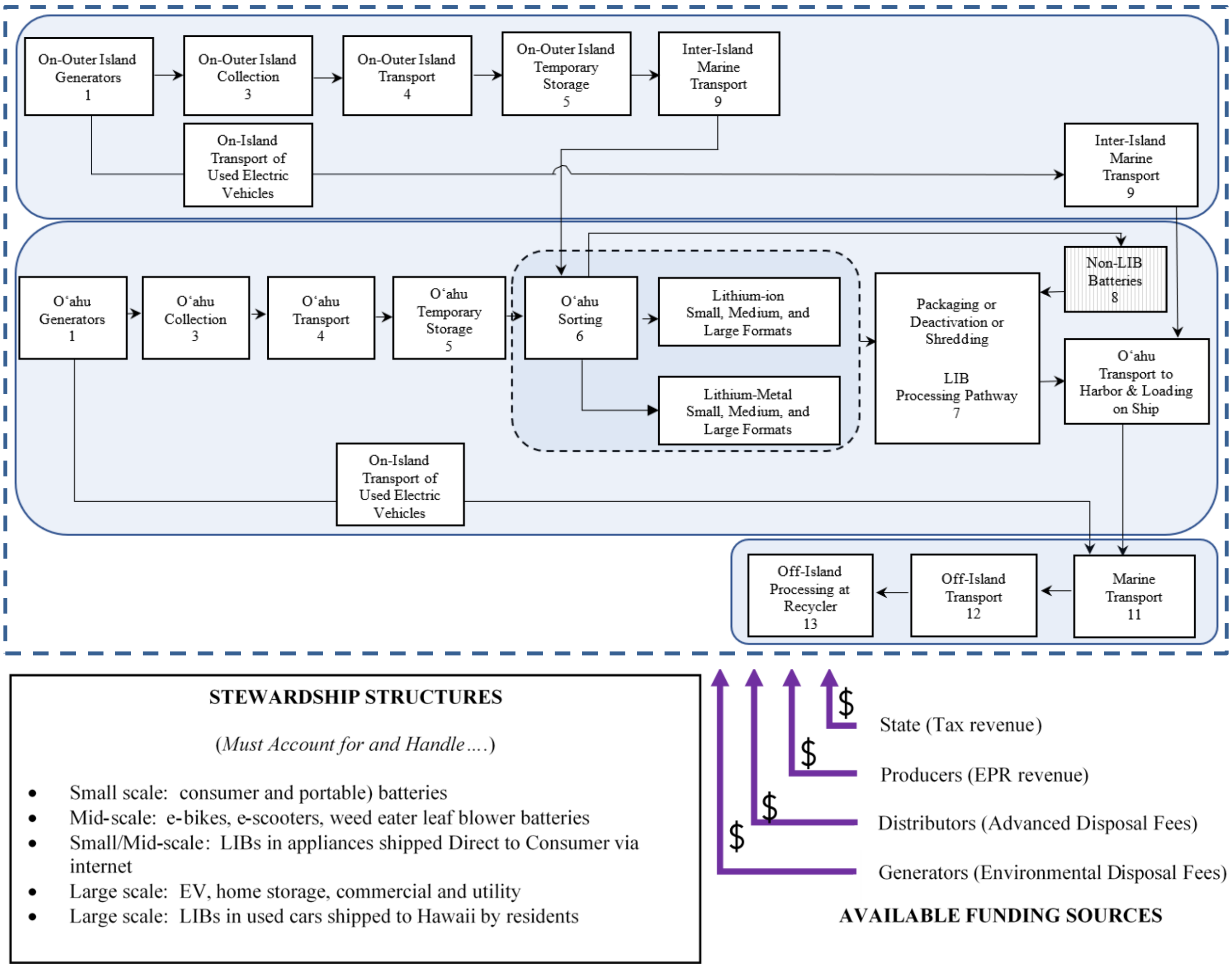
## General Considerations

### Overview

This analysis considers three different stewardship structures to manage the disposal of used "waste" EOL lithium batteries. In the first, termed **Model A**, the Hawai‘i State Department of Health (DOH) directly manages a full range of Extended Producer Responsibility (EPR) laws passed by the State legislature. In the second, termed **Model B**, the DOH oversees a non-government organization (NGO) stewardship program that directly manages the disposal of *all* pathways to dispose of used "waste" EOL lithium batteries generated in Hawai‘i. In the third, termed **Model C**, the DOH oversees an NGO stewardship program that manages a hybrid system wherein some manufacturers will create, manage, and fund their own EPR program to directly manage their own used "waste" lithium batteries (**Model A**) while other manufacturers pay a fee to the Stewardship program to manage the disposal of their used "waste" EOL lithium batteries (**Model B**).

***NOTES***: Various funding sources for all stewardship structures presented above are noted in Figure 10. Both Models B and C will also address/handle orphaned used "waste" EOL lithium batteries.

*Figure 11. Logistic pathway for processing LIBs in Hawai‘i.*




## Model A: Distributed Extended Producer Responsibility

Under this stewardship structure, the DOH will oversee/enforce EPR laws, passed by the State legislature, that govern *all* manufacturers of *all* formats of lithium batteries sold into Hawai‘i. Under this structure, every manufacturer selling lithium batteries into Hawai‘i must present to the DOH a comprehensive stewardship plan[122] inclusive of descriptions of how they will fund, track, and report the collection and disposal of every lithium battery they sell into Hawai‘i.

[122] Multiple examples abound, from those on PV panels written for Niagara County and Washington State, and those on lithium batteries written in several States such as California and Washington.

***Pros and cons of a distributed Extended Producer Responsibility (Model A).***

***Figure 12. Pros and cons of a distributed Extended Producer Responsibility stewardship structure (Model A).***

| Pros | Cons |
|---|---|
| • Producer responsibility and direct accountability. Each brand/operator is directly responsible for end-of-life management for its products, meaning that there are clear lines for liability, compliance, and enforcement. This reduces ambiguity about who pays.<br>• Encourages design-for-recovery and competition (Green Design). When individual producers internalize end of life costs, they have market incentives to design batteries that are safer, more recyclable, or use less hazardous materials.<br>• Flexibility & product-specific plans. Companies selling different battery chemistries/sizes can tailor collection, transport, and processing to product specifics and distribution channels.<br>• Market signals for innovation. Transparent producer costs (e.g., fees) can incentivize lightweighting, modular designs, and improved packaging to lower stewardship costs.<br>• Avoids a single point of failure. If one producer's program underperforms, others still operate, meaning that there is likely less systemic risk than a sole provider model.<br>• Easier to quantify producer burdens. Regulators can demand and compare product-level metrics (collection rates, per-unit fees), which can inform policy adjustments.<br>• Potentially lower administrative cost for government. The state agency primarily sets goals, reviews/approves plans, and enforces standards rather than running logistics.<br>• Consumer transparency. If producers report separately, consumers and retailers can see which brands are compliant and which are not (brand pressure). | • In the absence of similar laws in high demands states such as California, high likelihood of high costs leading to manufactures leaving the market—Hawaiʻi is too small to dictate terms on its own. Fragmentation & duplication. Multiple parallel programs (many producers) create duplicated collection networks, transport routes, packaging protocols, and admin functions, likely resulting in higher overall system cost and complexity.<br>• Scale inefficiencies. Smaller producers may lack bargaining power to obtain cost-effective collection/processing contracts, potentially leading to higher per-unit costs or consolidation behind third-party stewards.<br>• Enforcement burden on state. The state agency must review many distinct plans, monitor individual compliance, audit metrics, and pursue multiple enforcement actions, which may create significant regulatory workload.<br>• Risk of gaming/free-riders. Without strict cascading/transfer rules and robust registration, producers may try to evade obligations or mis-declare products; orphaned products from out-of-state sales can complicate responsibility.<br>• Consumer confusion. Different takeback rules, drop-off locations, and labeling per brand frustrate consumers and lower participation rates.<br>• Inconsistent service levels. Some producers may provide extensive curbside/retailer collection while others provide minimal access, resulting in inequitable services across geographies and communities.<br>• Higher transaction costs for retailers. Retailers may have to accommodate many producers' pick-up schedules or paperwork requirements.<br>• Small producers compliance burden. Micro-brands and startups face disproportionate administrative and legal costs to prepare a DOH-approved plan.<br>• Coordination challenges with emergency safety protocols. Standardizing battery handling for |

| Pros | Cons |
|---|---|
| | transport and fire safety across multiple programs is harder and likely raises workplace and recycling facility safety issues.<br>• Potential for uneven coverage in rural/island areas. Individual producers may prioritize high-density markets; state must ensure remote islands/neighborhoods in Hawaiʻi are covered.<br>• Complex obligation transfers & warranty/insurance edge cases. Determining responsibility when ownership transfers, in insurance claims, or when OEMs exit the market requires detailed legal rules; without them, responsiveness suffers. |

**Model B: All-Inclusive Stewardship Program**

Under this stewardship structure, the DOH indirectly oversees/enforces the disposal of used "waste" EOL lithium batteries through supervision of an independent[123] professional responsibility organization (super-PRO) that is responsible for the organization of the collection and disposal of *all* used "waste" EOL lithium batteries at all scales. Such a "super-PRO" would also manage revenue collection and would also hire staff or sub-contract businesses to manage disposal of various sub-fractions (sub-PROs) of the lithium battery waste stream. Under this stewardship structure, the "super-PRO" would directly manage the disposal of *all* used "waste" EOL lithium batteries generated in Hawaiʻi, including those that are orphaned[124]. The "super-PRO" would also manage all revenue streams and participants in the logistic pathway, and would report to supervising bodies (e.g., DOH, HSEO, or both).

***NOTE***: Under this stewardship structure, the NGO "super-PRO" would have the authority to: (i) negotiate revenue streams from the State, *all* manufacturers, distributors, and generators; (ii) manage the revenue raised; (iii) disperse the revenue raised as needed to all participants in the logistic pathway; (iv) manage membership in the stewardship program; and (v) certify all participants within stewardship program that contact/handle used "waste" lithium batteries. The stewardship program will also have responsibility to report and respond to the governance board.

[123] i.e., non-government aligned organization (NGO).
[124] e.g., those bought over Amazon or EV vehicles that have been sold to 2nd or 3rd parties.

***Pros and cons of an all-inclusive stewardship program (Model B).***

***Figure 13. Pros and cons of an all-inclusive stewardship program stewardship structure (Model B).***

| Pros | Cons |
|---|---|
| • There is precedent in this model. To improve management of their energy efficiency programs, the Hawaiʻi Public Utilities Commission (PUC) set up Hawaiʻi Energy to be run by a private contractor, Leidos, which now manages the energy efficiency activities for the PUC.<br>• Economies of scale. One centralized program consolidates logistics, procurement, transport, processing, and admin, which is likely to lower per-unit costs, standardized contracts, and better negotiation power with recyclers and carriers.<br>• Uniform consumer experience. Single collection rules, labeling, drop-off networks, and communications will likely reduce confusion and raise participation.<br>• Simplified compliance for regulators and producers. DOH approves/oversees one comprehensive plan rather than many. Producers join the PRO and have a single compliance path.<br>• Stronger safety & operational standards. Centralized training, handling protocols, and emergency procedures can be uniformly implemented, improving fire and worker safety (important given growing battery-related facility fires).<br>• Reduced administrative burden for small producers/retailers. Small brands can participate as members rather than build their own programs.<br>• Data centralization. One database yield consistent metrics for collection rates, orphan batteries, costs, which is generally better for state reporting and policy evaluation.<br>• Ability to provide a backstop. The PRO can be structured with a dedicated fund or bond to manage orphaned batteries and insolvency events.<br>• Professionalization & experience. Experienced stewardship orgs (e.g., Call2Recycle) already | • Single point of control/concentration risk. If the PRO fails, underperforms, or becomes captured by industry interests, the entire state's stewardship suffers. Regulators must build strong oversight and termination provisions.<br>• Loss of competitive pressure for Green Design. Producers may pay into a pooled system and not internalize product-specific disposal costs, reducing incentives to improve product design unless fee methodologies are carefully calibrated.<br>• Governance complexity & fairness. Designing fair fee allocation (by chemistry, format, weight, product type) and governance (producer seats vs. public interest) may be politically and technically challenging.<br>• Potential for cross-subsidization. Larger or cleaner producers may subsidize smaller/higher-cost products if fees are averaged improperly.<br>• Barriers to innovation/options. Centralized procurement may select a limited set of processors or technologies, reducing innovative pathways for recycling or remanufacture.<br>• Regulatory capture risk. Industry could exercise outsized influence over the PRO's rules, disadvantaging consumer/municipal interests without robust public oversight.<br>• Start-up complexity and financing. Creating a PRO requires initial capitalization, governance bylaws, IT systems, and procurement processes, namely upfront complexity and cost.<br>• Interstate/market friction. Producers selling nationwide may resist state-specific PRO rules if they conflict with national programs or increase administrative friction.<br>• May require statutory prohibition on non-participating sales. To be effective, the law often must prevent sale of batteries from non-participating producers; enforcement will be needed at retail/online level. |

| Pros | Cons |
| --- | --- |
| have networks and know-how to scale a program quickly. | • Potential for litigation. May result in a lawsuit filed by manufacturers that are forced by law or regulation to join one PRO. |

***Model C: Hybrid Distributed EPR - Stewardship Program***

Under this stewardship structure, the DOH would indirectly oversees/enforces the disposal of used "waste" EOL lithium batteries through a single "super-PRO" that manages a variety of "independent sub-PRO(s)" (i.e., manufacturers that manage their on EPR programs (**Model A**) as well as "dependent sub-PRO(s)" that manage, for the "super-PRO" the disposal of used "waste" lithium batteries that are not covered by EPR agreements (i.e., manufactures who pay the super-PRO to manage the disposal of their lithium batteries (**Model B**). In other words, the sub-PRO(s) can vary from manufacturers that create their own stewardship plans (independent sub-PRO(s)) to those organized by local businesses (i.e., dependent sub-PRO(s)) to manage the remaining used "waste" EOL LIBs (i.e., that are either not managed by their manufacturers or orphaned).

***NOTES***:

[1] Unlike **Model A**, it is envisioned that active participation in the stewardship structure will be voluntary for all manufacturers who sell lithium batteries into Hawai‘i—those who wish to manage their own activities with lithium-ion batteries independent of the stewardship program are able to. However, they cannot opt out of responsibility for their lithium batteries. Hence, like **Model B**, manufactures choosing this option will have to pay the "super-PRO" a fee to organize the collection, tracking, disposal, and reporting of all lithium batteries they sell into Hawai‘i[125].

[2] The "super-PRO" would have the authority to: (i) negotiate revenue from State, all manufacturers, distributors, and generators; (ii) manage revenue raised; (iii) disperse revenue as needed to all participant in the logistic pathway; (iv) manage membership in the stewardship program; and (v) certify[126] all participant within stewardship program that contact used "waste" EOL lithium batteries. The stewardship program will also have responsibility to report and respond to governance board.

[3] In all models, all participants in the logistic train are subject to review by the stewardship program for the purpose of being an "certified/authorized" participant. In **Model A**, the reviewers are staff at DOH. In **Models B and C**, the reviewers are the "super-PRO." The certification/authorization process is critical. Those that receive it will be recognized as following all the required safety rules and regulations, and any additional expectations of the reviewers. The importance of this recognition is considered critical to the procurement of insurance and authorization by the shipping companies—the insurance agencies and

[125] Most likely at the time of their purchase through an Advanced Disposal Fee (also called a "Visible Fee").

[126] Certify is a term, used here, to connote verifying they participants are following all applicable laws (State and Federal) and operating at a "Best Practice" level that satisfied insurance underwriters and shipping companies.

marine shippers will all look to participation in and authorization by as key criteria for their willingness to both ensure and accept used "waste" EOL lithium battery cargo. While any participant is free to remove themselves from the certification/authorization process, it is envisioned that participants remaining outside the stewardship program will be scrutinized by the relevant state and federal agencies and far more likely to subjected to audits by insurance underwriters and ocean shippers.

***Pros and cons of a hybrid distributed EPR - stewardship program (Model C).***

***Figure 14. Pros and cons of a hybrid distributed EPR - stewardship program (Model C).***

| Pros | Cons |
|---|---|
| • Best of both worlds (flexibility and scale). Producers that want to run brand-specific, high-quality programs can do so (independent sub-PROs), while others can opt into the centralized, efficient program for economies of scale.<br>• Encourages innovation while maintaining baseline service. Independent sub-PROs can trial advanced collection/process models; the PRO ensures universal baseline coverage so no community is left behind.<br>• Clear mechanism for orphaned batteries. The hybrid explicitly includes a sub-PRO for orphaned batteries, making funding and operations for orphan management explicit, which will likely reduce municipal burden.<br>• Layered governance & oversight. The PRO can set minimum standards and audit all sub-PROs, ensuring safety and uniform reporting while allowing operational differentiation.<br>• Mitigates free-riding. Cascading rules and centralized registration make it easier to identify non-participants; the PRO can refuse processing of non-compliant producers' batteries or charge higher handling fees.<br>• Producer choice reduces pushback. Allowing producer opt-in to run their own program lowers political resistance from brands with existing stewardship capacity.<br>• Shared backstop & pooled risk. The PRO can maintain a backstop fund for orphaned batteries and insolvency that applies to the whole system, which may be a form of protection for public entities. | • Design & regulatory complexity. Very complex to draft and administer: rules to define who may run independent sub-PROs, minimum standards, audit protocols, fee harmonization, switching/transfer rules, and conflict resolution mechanisms.<br>• Potential inequity between producers. Independent sub-PROs with better resources may capture prime collection sites, leaving the dependent program with more expensive or remote collection burdens.<br>• Fee allocation & cross-subsidy tensions. Setting fees so independent producers pay fairly (or benefit) versus those in dependent sub-PRO is a political and economic challenge; disagreements may trigger litigation or system failure.<br>• Monitoring burden. DOH and the PRO need robust audit capacity to ensure independent sub-PROs meet standards, which may create the risk of inconsistent service and safety gaps.<br>• Transaction and coordination costs. Interfaces between multiple sub-PROs and the PRO (data sharing, transfers, joint procurement) may create overhead and IT costs.<br>• Governance capture at multiple levels. Multiple governance bodies increase the potential for capture by industry players or dominant producers who can influence both sub-PRO and PRO rules.<br>• Complicated orphan handling if responsibilities overlap. If independent sub-PROs claim certain orphan categories, conflicts may arise about |

| Pros | Cons |
| --- | --- |
| • Facilitates regional coordination. The PRO can coordinate transport and exports for small independent sub-PROs to achieve better logistics outcomes. | which sub-PRO should cover costs for a given orphaned battery.<br>• Legal complexity in obligation transfers and insurance scenarios. Multi-layered responsibility rules (producer, owner, insurer, PRO) require careful statutory drafting; otherwise, disputes may proliferate.<br>• Onboarding and exit rules. Defining how and when producers can leave or join independent sub-PROs, or merge programs, and how liabilities transfer will likely be administratively heavy. |

## Detailed Requirements of Stewardship Structures

A detailed description of the requirements of each model, including examples of model bills, that would be needed in any legislative bill enacted by the Hawaiʻi state legislature is being prepared as a supplement to this report.

## Stewardship Structures Diagrams

***Model A: Distributed Extended Producer Responsibility.*** Under this model, manufacturers would submit individual (or group) stewardship plans to DOH for approval (Figure 15). More specifically, the manufacturers would create and fund their own independent[127] professional responsibility organizations (sub-PROs)[128] that would manage, under supervision by DOH, the disposal of their personal product-line of lithium batteries.

***Model B: All-Inclusive Stewardship Program.*** Under this model (Figure 16), the state would enact in law a single independent[129] "super-PRO" that would manage, under supervision of DOH and/or HSEO, disposal of all waste EOL LIBs at all scales[130].

***Model C: Hybrid Distributed EPR - Stewardship Program.*** Under this model (Figure 17), the State would enact into a law an independent "super-PRO" that would manage a *hybrid* stewardship program that blends features of both Model A and Model B. Specifically, the super-PRO would manage: (i) a dependent sub-PRO that would manage the disposal of all lithium batteries not covered by their manufactures and (ii) those lithium batteries being covered by individual manufacturers who prefer to manage their own battery lines.

[127] Another way of saying non-government aligned.
[128] In some cases, multiple manufactures would come together to create a cooperative sub-PRO.
[129] Non-government aligned.
[130] See, for example, how the State of Hawaiʻi set up "Hawaiʻi Energy".

*Figure 15. Stewardship structure for a distributed Extended Producer Responsibility (Model A).*

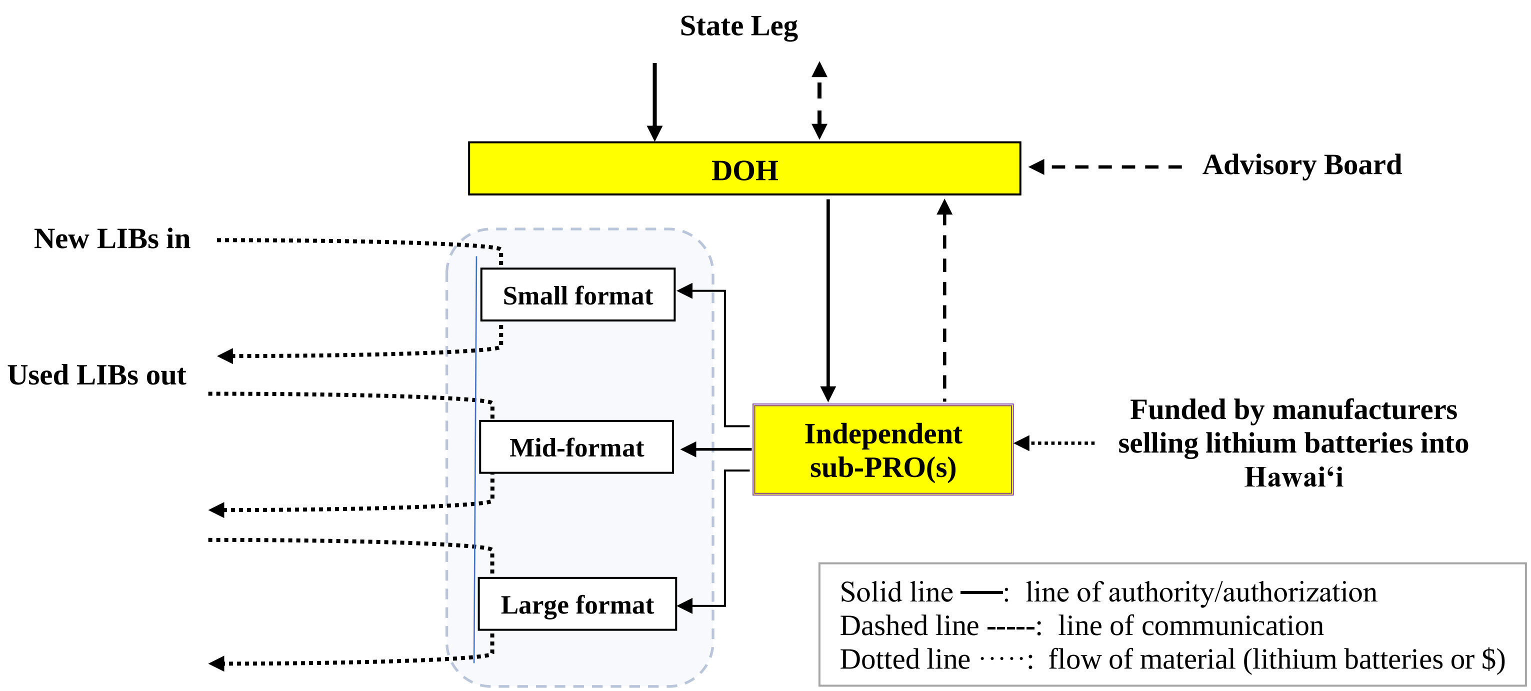


*Figure 16. Stewardship structure for an all-inclusive stewardship program (Model B).*

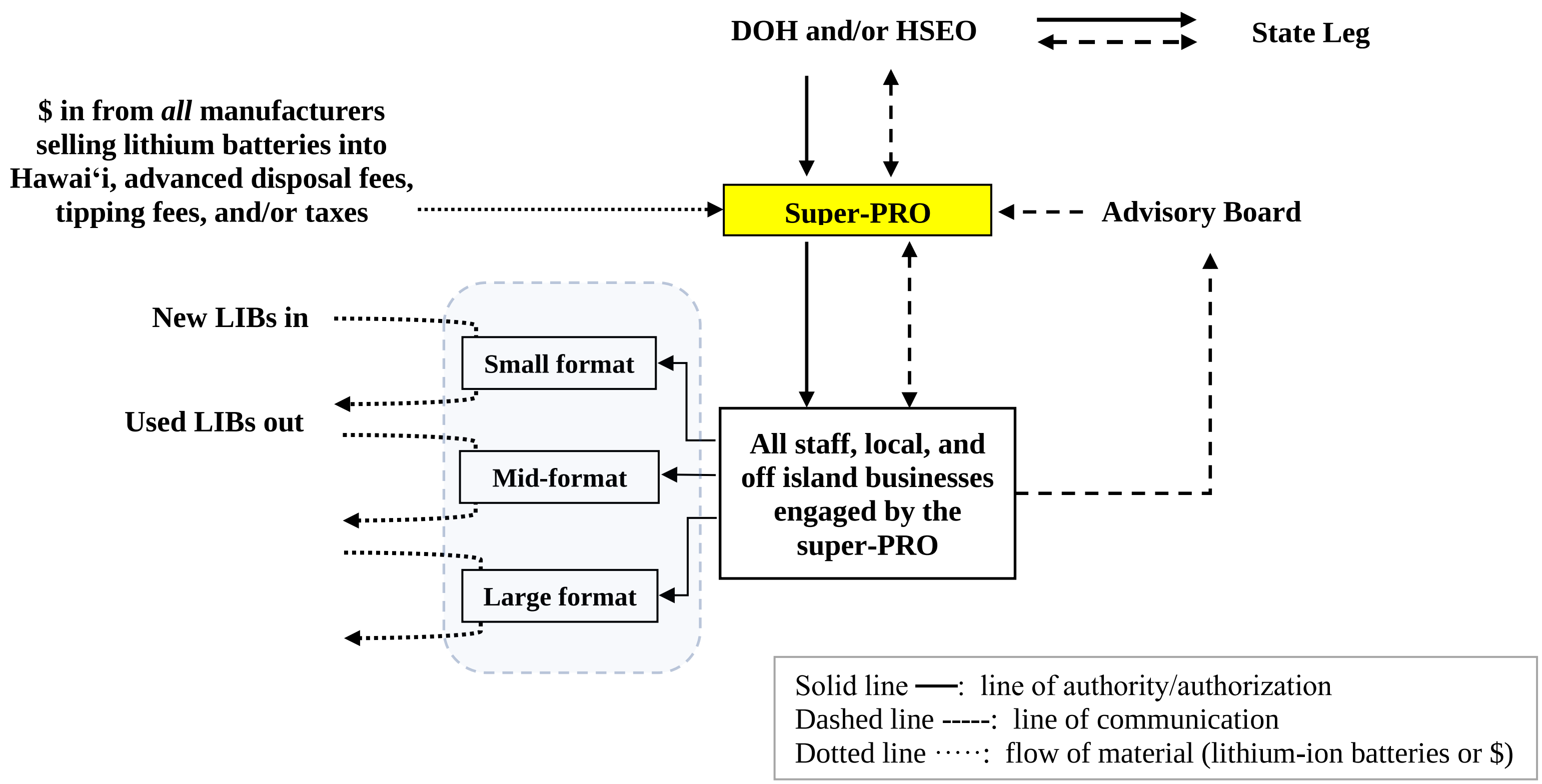
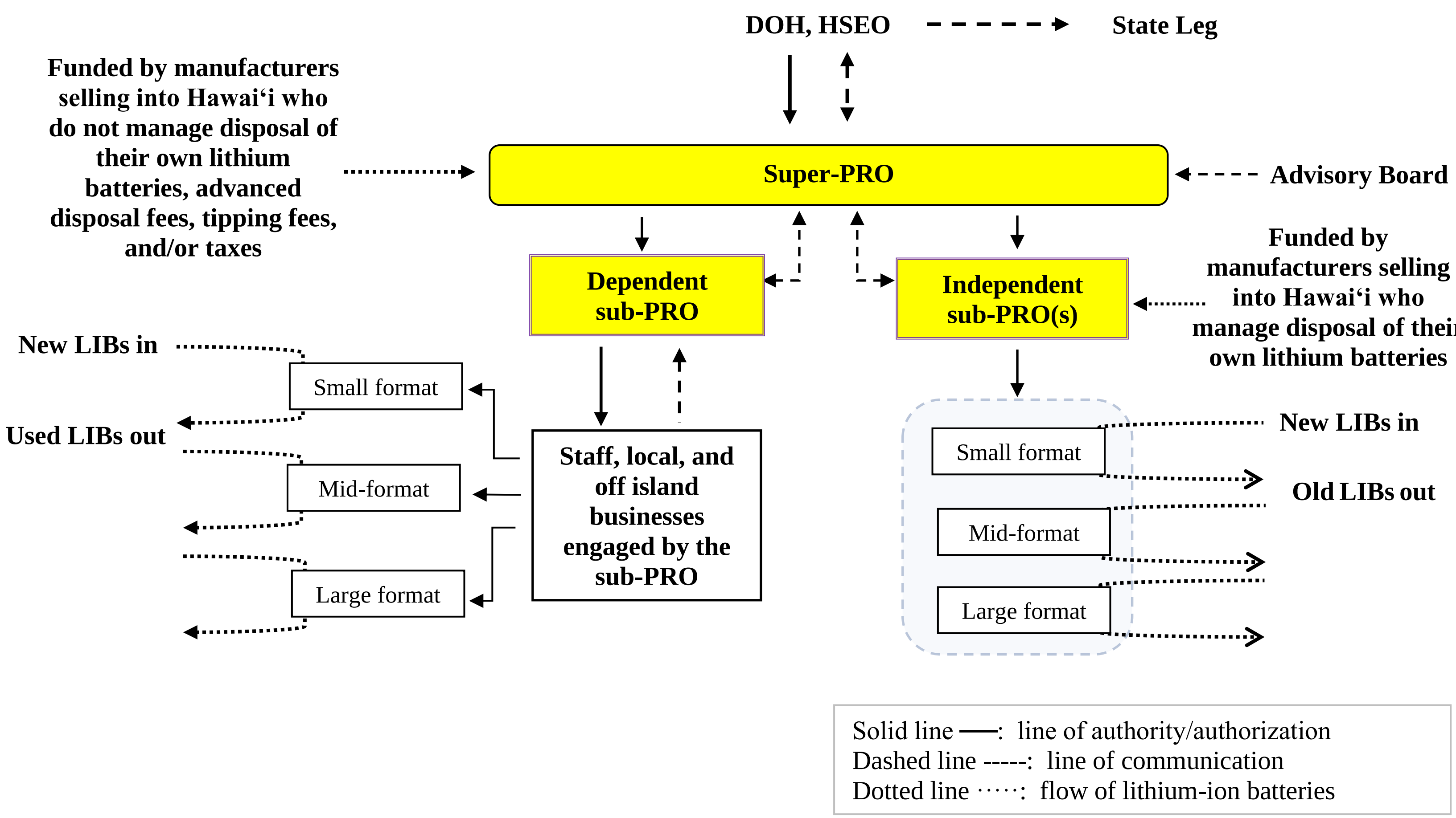


*Figure 17. Stewardship structure for a hybrid distributed EPR – stewardship program (Model C).*



## REQUIREMENTS – PACKAGING "AS IS" WITHOUT PREPROCESSING

### Packaging – As Is (#7)

This section refers to the packaging of collected and sorted waste EOL LIBs without any prior preprocessing to transform the batteries into nonflammable and non-explosive materials.

***NOTES***:

[1] Under this structure, the one possible major exception to "without any prior preprocessing" could occur with large format batteries (e.g., EV or energy storage batteries) that are physically discharged under resistance loading along with some level of post-discharging disassembly (e.g., out frame, battery management system... etc.). These systems are usually large enough to reasonably apply discharging protocols although the efficiency at discharging every individual cell within the modules is a concern. This is because in a battery pack, individual cells can have slightly different characteristics (capacity, internal resistance, etc.), which can lead to some cells being discharged more deeply than others, potentially reducing the overall system efficiency of the discharge process[131]. Also, battery management systems have been known to interfere with the efficiency of full discharge. This is because their purpose is to slow down or partially inhibit[132] the discharge process in order to minimize heat release and to optimize charging/discharging cycles for battery lifetime. An unexpected consequence of this, however, is that they can inhibit or limit full discharge.

[2] This section also assumes the waste EOL LIBs that are being packaged have previously been sorted to separate the non-lithium batteries from the lithium batteries, and the lithium-ion from the lithium-metal.

[3] It is also assumed, for reasons outlined below, that marine transit of waste "used" EOL lithium batteries, at all scales, will follow the Packing Group I requirements.

[131] B. Liu, S. Yin, J. Xu, 2016. Integrated computation model of lithium-ion battery subject to nail penetration. Appl Energy, 183, pp. 278-289.

[132] Technically, battery management systems can/are designed with undervoltage control mechanisms.

## Lithium-Ion Batteries

***General considerations.***

*Marine transit of lithium batteries.* When packaged to be shipped via marine transit, lithium batteries are classified as Class 9 dangerous goods and subject to the International Maritime Dangerous Goods (IMDG) Code regulations. The relevant UN packaging codes are UN3480 and UN3481. UN3480 applies to lithium-ion batteries not packed with or contained in equipment, while UN3481 applies to lithium-ion batteries packed with or contained in equipment. They are also subject to specific packaging requirements, including the use of UN performance-oriented packaging. The packing group for UN3480 (Lithium-ion batteries) is Packing Group II, indicating a medium degree of danger for the materials being shipped. In general, this means lithium batteries should be individually enclosed in non-metallic inner packaging to prevent short circuits and contact with other conductive materials. Classification as Packing Group II also requires that the packaging container holding the used "waste" EOL lithium batteries must be designed to withstand a higher level of impact and vibration compared to Packing Group III, but less than Packing Group I[133]. This means strong[134], reliable containers for safe[135] transport[136]. Finally, it must contain electrically non-conductive cushioning material to both reduce the propagation of heat or sparks from individual cells or batteries and to reduce damage if subjected to shocks (e.g., from dropping). The use of an absorbing cushioning material that can absorb leaked electrolyte is also a plus. ***NOTE***: While it is possible that larger batteries with a strong outer casing may have alternative packaging options, these are not assumed sufficiently standardized to develop policy around. Finally, the packaging must also be strictly labeled and marked along stringent requirements, including the use of a Class 9 lithium battery label.

*Marine transit of DDR lithium batteries.* With respect to the packaging of DDR lithium batteries for marine transit, Packaging Group I performance level[137] will be required to satisfy stricter demands for safe transportation and prevention of potential hazards like thermal runaway reactions[138]. In addition to requiring one DDR lithium battery per inner packaging, and only one inner packaging per outer packaging, this includes the requirement of fire suppressant packing material as well specially designed containers with thermal containment

[133] The Packing Groups are rated by the relevant "Drop Test"[133] – a test that must be conducted for the qualification of all packaging design types and performed periodically as specified in CFR 49[133]. For packing group II, for example, the drop height is 3.9 feet while for packing group I, the drop height is it 5.9 feet. Examples of strong, rigid outer packaging used include wood, fiberboard, or metal boxes or drums.

[134] i.e., rigid enough to resist punctures or tears and provide impact and crush protection to prevent damage to the waste EOL lithium batteries during transit.

[135] i.e., able to contain/prevent leakage in event of electrolyte spills during transit.

[136] Be clearly marked with the UN specification code and the packing group designation (e.g., X for PG I and Y for PG II).

[137] https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2023-03/DDR-brochure.pdf.

[138] DDR lithium batteries are also subject to additional packaging requirements, (see § 173.185(f)(1-4)).

capabilities—for example, steel drums with removable lids. ***NOTE***: It should be noted that these restrictions are a moving target and there is no law that requires the shippers or their insurance companies to ship DDR batteries in packaging that fall under DOT and IMDG regulations. Rather, it is likely that shippers or their insurers will simply refuse to ship any used "waste" EOL lithium battery labelled as DDR.

*Marine transit of used "waste" EOL lithium batteries from Hawai'i.* One of the biggest issues with respect to transporting used "waste" EOL lithium batteries from Hawai'i via marine transport is the inability to determine, with certainty, whether the used "waste" EOL lithium batteries are reasonably stable or DDR. Consider, for example, the case of used "waste" EOL EV lithium batteries. EV lithium batteries are aggregations of hundreds or thousands of individual cells all packed tightly within larger packs and larger casings. As such, evaluation of individual cells is impractical, if not impossible. More, due to the high energy density of individual battery cells, if just one battery cell undergoes a thermal runaway event, the likelihood it will propagate to adjacent and remaining cells is high, if not a certainty. And even though new and properly maintained EVs operate regularly without incident, increasing incidents of fires at sea that sink boats shipping new EVs is occurring[139]. Even more concerning is the fact that older EVs possess an even higher and legitimate risk of thermal runaway reactions due to factors such as aging and accumulated charge/discharge cycles. Moreover, there is always the significant risk with old and used EVs that they will have been subjected to an accident, exposure to water (floods), irregular charging cycles, or excess heat or other forms of damage before being added to the recycle stream. Finally, even if the technology existed to determine with complete certainty that a single individual battery cell is DDR, it is technically impossible, on any industrial waste-management scale, to test[140] them all prior to being packaged for shipment.

Because of these realities, and the significant risks associated with fires breaking out during marine transit, and the concomitant concern of shipping companies and their insurance agencies to carry the risk of transporting waste EOL lithium batteries, ***this analysis will assume that the best practice for marine transit of waste EOL lithium batteries, at all scales, will be to impose the Packing Group I requirements to all shipments of waste EOL lithium batteries***. In practice, this will be realized through the standardized use of steel drums with reusable lids. Exceptions to this standard, however, can include larger format lithium batteries (e.g., EV and home/commercial energy storage batteries, or those from utility scale parks) that have been professionally discharged (and even partially disassembled) by certified professionals. These can then be packed in other packaging materials that meet Packing Group I requirements.

[139] See, for example, the recent sinking of a cargo ship transporting new EV's off the coast of Alaska. https://www.nytimes.com/2025/06/25/us/alaska-cargo-ship-vehicles-sinks-pacific.html.
[140] At all scales.

The use of reusable steel drums as packaging material does carry some specific requirements, including:

- Every steel drum (as does any alternative packaging that fits under the exception defined above) must be checked and verified to be free from corrosion, contamination or other defects prior to its being filled and handed over for transport;
- Any steel drum which shows signs of weakening, with reference to the approved prototype cannot be used or shall be refurbished so that it can pass the tests required for the prototype;
- Any steel drum meeting Packing Group I standards must have done so by passing specific tests, with all testing conforming to the testing of an accepted prototype steel drum, e.g., shall be manufactured, reconditioned and tested under a quality assurance program which satisfies the competent authority (e.g., DOT); and
- The steel drums (and all other packaging meeting Packing Group I standards) shall bear markings which are durable, legible and readily visible, constituted by a sequence of symbols, letters and numbers[141].

***Requirements – Waste lithium-ion batteries.***

*Household, consumer and portable lithium batteries (small format, <100 Wh per battery).* Typically comprised of consumer and portable batteries, once sorted these small format batteries must be repacked into appropriately labeled[142] 5, 16, 55-gallon steel drums[143] co-packed with granular fire-retardant suppressant (2/3rd fire suppressant to 1/3 battery by volume).

*The following regulations apply[144]*: Standards for Universal Waste Management 40 CFR Part 273; HAR CHAPTER 11-273.1 (universal waste handlers), 49 CFR Lithium cells and batteries § 173.185 (c) (3), the International Maritime Dangerous Goods (IMDG) Code and the UN Manual of Tests and Criteria, specifically Section 38.3.

*What training is required?* While the training required is flexible (and can be influenced by insurance underwriters and/or State DOH regulators), some form of DOT dangerous goods training (or training from qualified or recognized stewardship programs, e.g., Call2Recycle) will be required[145].

[141] i.e., United Nations packaging symbol, Drum with removable head, packaging group, maximum gross mass in kilograms, carriage of solids, the State authorizing the allocation of the mark, the manufacturer of the Drum/container, and the year of manufacturing.
[142] Appropriately labeled meets Class 9 regulations for LIB 40 CFR Lithium cells and batteries § 173.185 (c) (3).
[143] Competent steel drums are assumed to be standard accepted practice for ocean vessel mode of transportation.
[144] By ground its DOT, by Air its IATA, by water its IMDG.
[145] Any stewardship program will provide the training for the format.

*NOTE*: Special permits can be obtained to allow a certain number of batteries above 100 Wh per battery. This is a benefit of having a stewardship program, letting local companies call in to learn of any special permits.

*e-bikes, e-scooters, weed eaters, leaf blower batteries (mid-format, 100<Wh/battery, <300 Wh for cells).* Typically comprised of e-bike, e-scooter, weed eater, leaf blower batteries, these mid-format batteries are not removed from the drums (16 gallon) there were brought in with, but rather generally repacked directly into a 55-gallon drums mixed with granular fire suppressant (1/3 battery to 2/3rd suppressant by volume).

***NOTE***: Exceptions are when the sources of the 16-gallons drums are not trusted (e.g., or there is a defect showing in the 16- gallon container) or they are not verified. Under this circumstance, the battery must be taken out, inspected, slipped into non-metallic bags, and then repacked into 55-gallon steel containers[146]. As described below, DDR batteries are packed individually into 5-gallon steel drums which can then be packed into 55-gallon drums.

*The following regulations apply*: Standards for Universal Waste Management 40 CFR Part 273; HAR CHAPTER 11-273.1 (universal waste handlers), 49 CFR, the International Maritime Dangerous Goods (IMDG) Code and the UN Manual of Tests and Criteria, specifically Section 38.3.

*What training is required?* DOT dangerous goods training from qualified providers such as recognized stewardship programs (e.g., Call2Recycle). All can provide the required training directly, or through a third party. Depending upon the quantity, a small or large waste transporter permit will be required. Also, hazmat training and potentially IMDG training.

*EV, home or commercial scale energy storage, portable power packs (large format, >300 Wh/battery).* Typically comprised of EV or home/commercial energy storage systems, these large format EV batteries are left in the same crate that they were transported in to the temporary storage facility (e.g., from a car dealership, home or commercial site). If brought in on pallet, however they must be put into a wooden crate (which needs to be reinspected every time reused).

[146] Although hard cardboard or metal lined with plastic will meet IMDG standards, in this analysis we are using steel drums to meet packing group 1 standards so as to meet expectations of insurance carriers that best practices are being followed across all scales.

*The following regulations apply*: Standards for Universal Waste Management 40 CFR Part 273; HAR CHAPTER 11-273.1 (universal waste handlers), 49 CFR Lithium cells and batteries § 173.185 (c) (3).

*What is the required training?* DOT dangerous goods training from qualified providers such as recognized stewardship programs (e.g., Call2Recycle). All can provide the required training directly, or through a third party. Also, hazmat training and potentially IMDG training. In the case where batteries are repackaged, high voltage training is needed.

Utility scale format. The permits and PPAs for IPPs require that they are responsible for the removal of used "waste" EOL energy storage systems. To date, all of these systems in Hawaiʻi are lithium-ion batteries. In the case of natural disasters, third parties may be brought in as deemed necessary by government authorities. These large-scale utility batteries are typically housed in battery banks. Prior to their transport, they will be fully discharged and subject to an appropriate level of disassembly prior to being appropriately packaged in wooden crates. Moreover, they will be professionally inspected for the presence of DDR battery packs.

*The following regulations apply*: Standards for Universal Waste Management 40 CFR Part 273; HAR CHAPTER 11-273.1 (universal waste handlers), 40 CFR Lithium cells and batteries § 173.185 (c) (3), the International Maritime Dangerous Goods (IMDG) Code and the UN Manual of Tests and Criteria, specifically Section 38.3.

*What is the required training?* DOT dangerous goods training from qualified providers such as recognized stewardship programs (e.g., Call2Recycle). All can provide the required training directly, or through a third party. Also, hazmat training and potentially IMDG training. In the case where batteries are repackaged, high voltage training is needed.

***Requirements – Waste DDR lithium-ion batteries.***

*Household, consumer and portable lithium batteries (small format, <100 Wh per battery).* Prior to transport to the ocean ship, the 5-gallon drums (if they were brought in that way) or other sources of DDR batteries must be repackaged into appropriately labeled 55-gallon drums before marine transport with fire suppressant (1/3 to 2/3$^{rd}$ ratio). In addition to the proper shipping name and other required markings, the outer packaging will have to be marked as appropriate[147]. Letters must be at least 12 mm (0.47 inches) high.

*The following regulations apply*: Standards for Universal Waste Management 40 CFR Part 273; HAR CHAPTER 11-273.1 (universal waste handlers), 40 CFR Lithium cells and batteries § 173.185 (c) (3), the International Maritime Dangerous Goods (IMDG) Code and the UN Manual of Tests and Criteria, specifically Section 38.3.

---

[147] e.g., "Damaged/defective lithium-ion battery" and/or "Damaged/defective lithium metal battery."

*What is the required training?* Full hazardous materials/dangerous goods training to ship lithium batteries by ground and vessel in compliance with 49 CFR and the IMDG Code. Also, full hazmat training is required.

*e-bikes, e-scooters, weed eaters, leaf blower batteries (mid-format, 100<Wh/battery, <300 Wh for cells).* The DDR batteries are kept in their respective 5 or 16-gallon tubes/containers before being repacked into a 55-gallon drums mixed with granular fire suppressant (1/3 battery to 2/3rd suppressant by volume). Each DDR battery should be in its own drum which can be shipped alone or after being further packed into the 55-gallon drum. Special permits are available that can give allowances.

*The following regulations apply*: Full hazardous materials/dangerous goods training to ship lithium batteries by ground and vessel in compliance with 49 CFR and the IMDG Code. Also, full hazmat training is required.

*What is the required training?* Full hazardous materials/dangerous goods training to ship lithium batteries by ground and vessel in compliance with 49 CFR and the IMDG Code. Also, full hazmat training is required.

*EV, home or commercial scale energy storage, portable power packs (Large format, > 300 Wh/battery).* The batteries must remain the specialized (fireproof) crate they arrived in at the temporary storage site.

*The following regulations apply*: Standards for Universal Waste Management 40 CFR Part 273; HAR CHAPTER 11-273.1 (universal waste handlers), 40 CFR Lithium cells and batteries § 173.185 (c) (3), the International Maritime Dangerous Goods (IMDG) Code and the UN Manual of Tests and Criteria, specifically Section 38.3.

*What is the required training?* Full hazardous materials/dangerous goods training to ship lithium batteries by ground and vessel in compliance with 49 CFR and the IMDG Code. Also, full hazmat training is required.

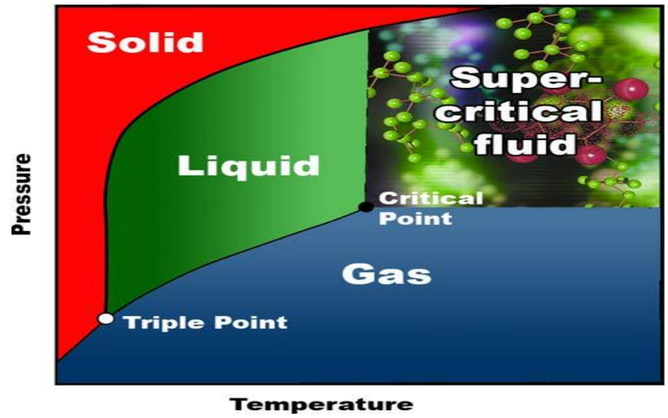
*Utility scale format.* As with non-DDR waste EOL lithium-ion batteries, DDR batteries at the utility scale will be handled by the IPP.

***Requirements – Waste lithium metal batteries.*** With the exception of format being different owing to grams classification, all else is applicable.

**Pros and Cons of Packaging "As Is"**

***Figure 18. Pros and cons of packaging of used "waste" lithium-ion batteries "as is" and without any deactivation pretreatment.***

| Pros | Cons |
| --- | --- |
| • No permitting, equipment, or processing needed.<br>• Provides a timeline to establish collection and routes of collection to scale into processing.<br>• Can use existing companies in operation on-island.<br>• Lower cost to entry—no significant land or capital development costs to build treatment facilities.<br>• Does not require hazardous waste processing permit? | • Does not address current concerns about transportation off-island.<br>• Must rely on manual labor for properly packaging batteries.<br>• Longer storage of batteries presents risk.<br>• Generally, requires packaging in 55-gallon steel drums—imposes a significant logistics hurdle in terms of obtaining and amassing large warehouse stores of these drums for local packaging.<br>• Runs risk of unexpected elevated temporary storage loads if a shortage of steel drums is realized, or a disruption in their shipping occurs.<br>• Highest risk in transit of options presented—leads to vulnerability in permissibility to ship, exposure to insurance cost/permissibility fluctuations, and/or implementation of more costly and stringent packaging requirements.<br>• Can require quite expensive packaging containers, especially with DDR batteries—this can encourage to mislabeling manifests (to achieve reduced costs) or illegal storage/dumping in Hawaiʻi (to avoid high costs).<br>• Uncertain future as to the permissibility of shipping—shippers are increasingly refusing to ship DDR batteries and older EV vehicles.<br>• Restrictions are only trending to be more aggressive and costly.<br>• Subject to uncertain insurance regulations and costs. |




# REQUIREMENTS – DEACTIVATION BY SUPERCRITICAL $CO_2$

## Deactivation Using Supercritical $CO_2$ (#7)

This section refers to the on-island deactivation of used "waste" EOL LIBs through application of supercritical $CO_2$[148]. This process does not shred or grind the batteries down to smaller "non-battery" components. In this sense, it is not a "treatment" applied to the batteries which simplifies the permitting process. Rather, this process leaves the batteries intact physically but fully deactivated after the lithium ion is bound or locked up in reactions with the carbon dioxide. The process also extracts and recovers the solvents.

### Overview

This technology has, currently, reactor designs for three scales: 4 liters, 10 liters, and 500 liters. All operating parameters are similar in terms of pressure and temperature. Prior to adding the batteries to the reactor (Figure 19 and 20), they must first be sorted by breachable[149] or non-breachable[150] battery type (Figure 20). Mixed cell geometries and chemistries can be processed together including; prismatic, pouch, and battery cells (Figure 19). Electric vehicle prismatic cells, for example, are breachable and can be put into that reactor without further processing. On the other hand, pouch cells are not breachable and must first be punctured. Once punctured, they can be added to the reactor. Any breachable battery cells can be added directly to the reactors (Figure 20). The non-breachable cells must be punctured prior to their addition to the reactors. Once the batteries have been added to the reactor, and the $CO_2$ has been added, the reactor temperature is raised to and maintained at 120°C for roughly 1 hour.

[148] S. E. Sloop, Patent No.: US 7.198.865 B2, 2007.
[149] Breachable type is defined as being permeable to the supercritical $CO_2$ fluid.
[150] Non-breachable type is defined as not being permeable to the supercritical $CO_2$ fluid.

*Figure 19. Supercritical $CO_2$ pretreatment of LIBs.*

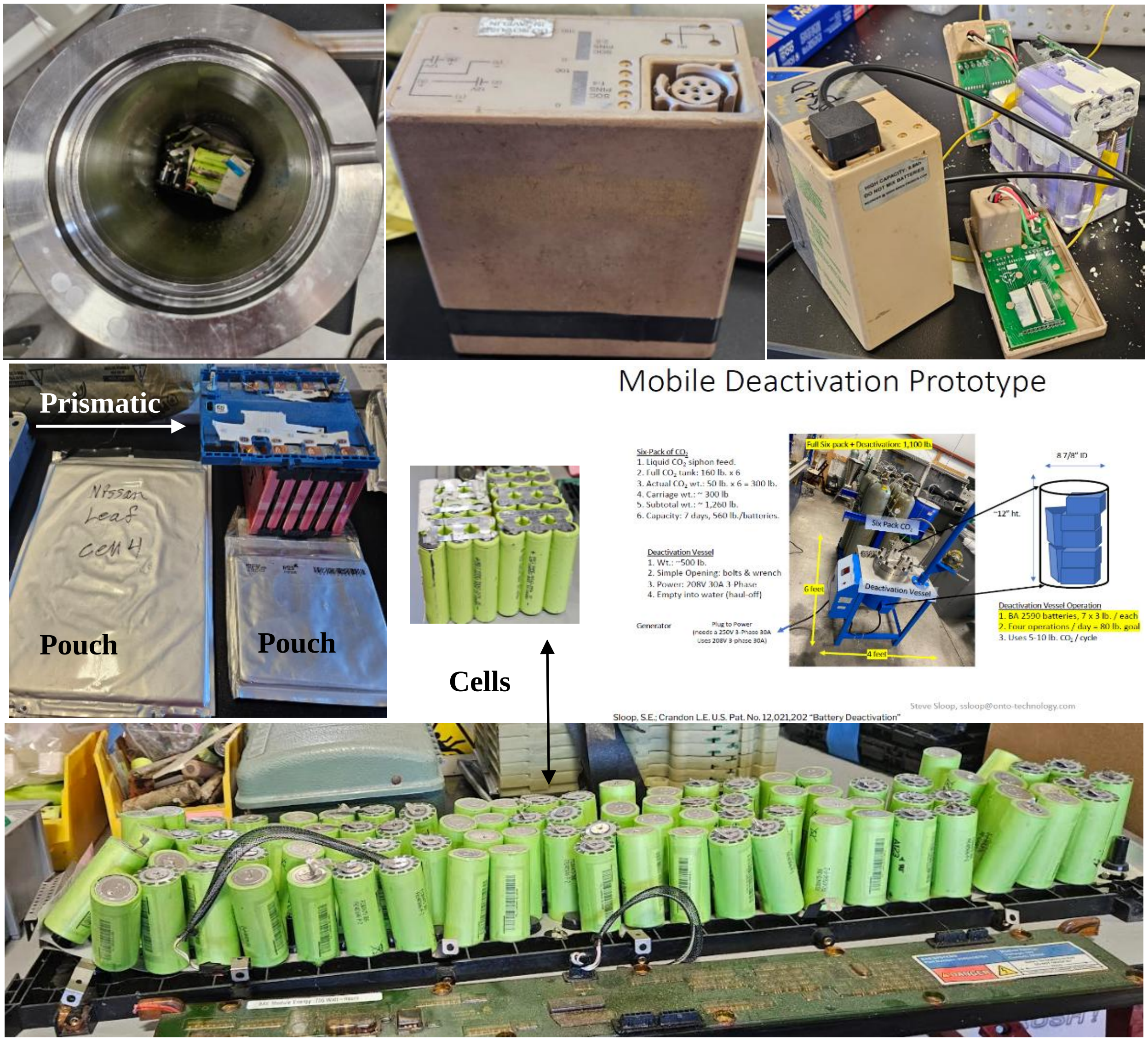
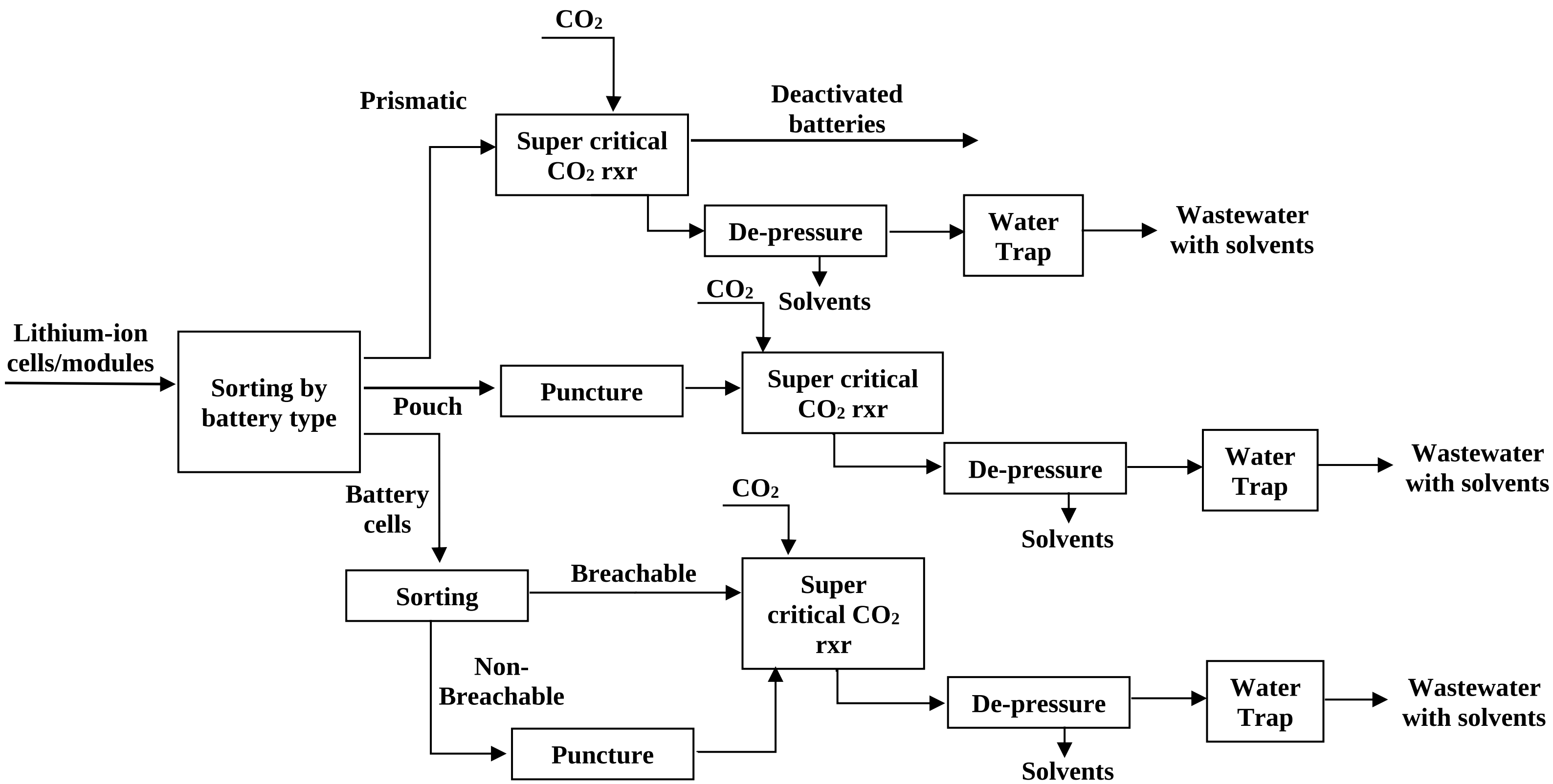


*Figure 20. Process flow diagram for supercritical $CO_2$ treatment of LIBs.*



Upon completion, the supercritical $CO_2$ is then released through a larger expansion or de-pressuring reactor/tube for the purpose of depressurizing the supercritical $CO_2$ to gaseous $CO_2$ at atmospheric conditions before passing through a water trap. The majority of the solvents within the batteries condense out of solution and are captured or collected using a collection tap located on the bottom of the de-pressuring reactor/tube. Any solvents remaining in the gas phase are then captured in a water trap through which the exiting $CO_2$ gas must pass before its discharge to the environment[151].

The requirement of puncturing non-breachable battery cells is to ensure complete deactivation. This will require, beforehand, experimental verification of breachability brand by brand—determining which brand of batteries are breachable (or not) is a trial-and-error exercise. As such, any new battery format will need to be tested. Those batteries that need to be breached will also come in many shapes and formations. This will require various approaches to breach the various packaging methods used to enclose the batteries[152]. For example, battery cells contained within an EV casing will need to be approached differently than individual cells or those that are in pouches. Ideally, the batteries should be punctured within the supercritical $CO_2$ reactor chamber after sealing but currently no prototypes are being tested, let alone approaching commercial use.

***Permits.*** The deactivation process was allowed for use in Hawai‘i for site demonstrations with review by Hawai‘i Department of Health, Environmental Protection Agency, Hazardous Waste Program Managers, and compliance officials from the U.S. Army Garrison-Hawai‘i and MCB Hawai‘i. Three questions were addressed positively:

1. Is a hazardous waste permit required for the activity? No
2. Can the generator of hazardous waste be treated on-site? Yes
3. Is the treatment process legitimate and viable? Yes

***Energy.*** Modeling indicates 3.5 kwh /kg battery feed. This translates to \$241/ton feed based upon a \$0.07 cost per kWh for electrical heating of ten 10L vessels for processing 75 tons per year.

***Carbon dioxide ($CO_2$).*** The weight ratio of $CO_2$ to LIBs processed (lb./lb.) is roughly the same with scale (i.e. 0.5 for 4-liter, 10 liter and 500-liter reactors). This equates to roughly 4 lbs. $CO_2$ per 8 lb. of batteries deactivated (4-liter reactor), 12.5 lb. $CO_2$ per 25 lb. of batteries deactivated (10-liter reactor), or 550 lb. $CO_2$ per 1,100 lb. of batteries deactivated (500-liter reactor). On a larger scale (e.g., 500-liter), the $CO_2$ is expected to be recycled so the ratio will decrease to roughly 0.25. Also, in general, $CO_2$ loss to carbonate formation is negligible. For reference a standard 50-pound $CO_2$ cylinder holds approximately 50 pounds of liquid $CO_2$. In terms of cost, the mainland price of bulk $CO_2$ can be between \$0.27 and \$0.45 per pound. Assuming the $CO_2$ shipped to

[151] Or capture vessel for its recycle and reuse.
[152] This combination of battery and its housing is often termed “appliances” and has many forms, from military battery modules deployed in field, battery tool modules, and even batteries enclosed in phones or tablets.

Hawai‘i the higher estimate of $0.45 is taken, yielding a crude estimate of $247 to process 550 lb. of used “waste” EOL lithium batteries.

***Requirements – Waste lithium-ion.***

*Household, consumer, and portable lithium batteries (small format).* So long as the cells and battery modules are permeable to gasses, there are no strict preprocessing requirements prior to placement within the reactor chamber. While it is recommended to discharge the batteries prior to their addition, those that have not been fully discharged and/or are damaged, defective, or recalled *can be* processed given that the pressure vessel is able to withstand the explosions. Moreover, the heat generated during explosions can aid in the evolution of heat that raises the temperature within the vessel such that supercritical conditions are maintained. Used “waste” lithium-ion batteries that are enclosed/packaged in impenetrable casings, however, will need to be punctured in such a manner as to so allow the $CO_2$ to penetrate.

*The following regulations apply*: Operating a supercritical $CO_2$ ($sCO_2$) reactor involves several regulations, primarily focused on ensuring safety and preventing environmental damage. These include regulations related to containment, pressure limits, and emergency procedures, as well as environmental regulations regarding $CO_2$ emissions and waste. Specifically, pressure vessel certification (i.e., SME Boiler and Pressure Vessel Code (BPVC)).

*What is the training required?* Standardized training on pressure vessel operation as well as standard hazmat training for batteries.

*e-bikes, e-scooters, weed eaters, leaf blower batteries (mid-format).* Similar to consumer and portable batteries, as long as the battery format can be penetrated by the $sCO_2$, there are no strict requirements of pretreatment. While it is recommended to discharge the batteries, those that have not been fully discharged and/or are DDR *can be* processed given that the pressure vessel is able to withstand the explosions. Moreover, the heat generated can aid in the evolution of heat that raises the temperature within the vessel such that supercritical conditions are maintained with lower energy input. Used “waste” lithium- batteries that are enclosed in impenetrable casings will need to be disassembled such that the individual cells are penetrable by the $sCO_2$. As with the consumer and portable batteries are also encased in materials that are not penetrable by the $sCO_2$, they will likewise need to be punctured in such a manner as to allow the $sCO_2$ to penetrate.

*The following regulations apply*: Operating a $sCO_2$ reactor involves several regulations, primarily focused on ensuring safety and preventing environmental damage. These include regulations related to containment, pressure limits, and emergency procedures, as well as environmental regulations regarding $CO_2$ emissions and waste. Specifically, pressure vessel certification (i.e., SME Boiler and Pressure Vessel Code (BPVC)).

*What is the training required?* Standardized training on pressure vessel operation as well as standard hazmat training for batteries.

*EV, home or commercial scale energy storage, portable power packs (large format).* So long as the pressure vessel (e.g. 500 liter) is designed to hold the size of the EV or ESS used "waste" lithium battery this method can be applied. Given the energy density of batteries in this format, it is recommended to pace the EV or energy storage system battery through a discharge cycle prior to it being fed into the reactor as a whole piece. However, increasingly, EV manufacturers are applying designs that fully encase the entirety of battery modules into a total casing that have been fabricated in such a manner as to severely hinder their disassembly and penetration by the supercritical $CO_2$. This fact will impose the need to disassemble the battery casing to remove or reveal the internal battery cells for puncturing.

*The following regulations apply*: Operating a $sCO_2$ reactor involves several regulations, primarily focused on ensuring safety and preventing environmental damage. These include regulations related to containment, pressure limits, and emergency procedures, as well as environmental regulations regarding $CO_2$ emissions and waste. Specifically, pressure vessel certification (i.e., SME Boiler and Pressure Vessel Code (BPVC)).

*What is the training required?* Standardized training on pressure vessel operation as well as standard hazmat training for batteries.

*Utility scale.* Utility scale system will need to be disassembled into a large format beforehand in order to fit into the relatively small 500-liter reactor. Once disassembled, the process for large format batterie applies.

***Requirements* – *Waste DDR lithium-ion.*** For the purpose of processing used "waste" DDR EOL lithium batteries, there are no deviations from the procedures stated above except for the fact that any method used to puncture the cells beforehand will need to be modified to ensure safety measures countering explosions and fires as appropriate for DDR batteries.

*Household, consumer and portable lithium batteries (small format, <100 Wh per battery).* No specials exceptions are required other than those described above for this format. The process can accommodate DDR batteries alongside non-DDR batteries.

*The following regulations apply*: Operating a $sCO_2$ reactor involves several regulations, primarily focused on ensuring safety and preventing environmental damage. These include regulations related to containment, pressure limits, and emergency procedures, as well as environmental regulations regarding $CO_2$ emissions and waste. Specifically, pressure vessel certification (i.e., SME Boiler and Pressure Vessel Code (BPVC)).

*What is the training required?* Standardized training on pressure vessel operation as well as standard hazmat training for batteries.

*e-bikes, e-scooters, weed eaters, leaf blower batteries (mid-format, 100<Wh/battery, <300 Wh for cells).* No specials exceptions are required other than those described above for this format. The process can accommodate DDR batteries alongside non-DDR batteries.

*The following regulations apply*: Operating a $sCO_2$ reactor involves several regulations, primarily focused on ensuring safety and preventing environmental damage. These include regulations related to containment, pressure limits, and emergency procedures, as well as environmental regulations regarding $CO_2$ emissions and waste. Specifically, pressure vessel certification (i.e., SME Boiler and Pressure Vessel Code (BPVC)).

*What is the training required?* Standardized training on pressure vessel operation as well as standard hazmat training for batteries.

*EV, home or commercial scale energy storage, portable power packs (Large format, > 300 Wh/battery).* No specials exceptions are required other than those described above for this format. The process can accommodate DDR batteries alongside non-DDR batteries.

*The following regulations apply*: Operating a $sCO_2$ reactor involves several regulations, primarily focused on ensuring safety and preventing environmental damage. These include regulations related to containment, pressure limits, and emergency procedures, as well as environmental regulations regarding $CO_2$ emissions and waste. Specifically, pressure vessel certification (i.e., SME Boiler and Pressure Vessel Code (BPVC)).

*What is the training required?* Standardized training on pressure vessel operation as well as standard hazmat training for batteries.

*Utility scale format.* Any utility scale system will need to be disassembled into a large format beforehand in order to fit into the 30-liter reactor.

### Pros and Cons of Deactivation by Application of Supercritical $CO_2$

*Figure 21. Pros and cons of deactivation of used "waste" lithium-ion batteries via application of supercritical $CO_2$.*

| Pros | Cons |
|---|---|
| • Not regarded as "treatment" of batteries from regulatory point of view.<br>• Can be downscaled to support smaller transportable stations.<br>• Has been rigorously reviewed for demonstration in Hawai'i.<br>• Reactor will contain explosions and propagation of heat.<br>• Relatively simple system to build.<br>• Low energy deactivation.<br>• Low-cost materials consumption with $CO_2$ use for battery deactivation.<br>• Batch process can be matched with existing batch packaging efforts.<br>• Scalable to meet generator requirements >1 ton/day. This increases the efficacy of the labor put into discharging and packaging batteries for deactivation rather than shipping.<br>• Multi-ton-per-day scalability is feasible; however, this is not meant to replace a shredder.<br>• Shredding per ton of batteries produces an equal mass of hazardous materials whereas deactivation eliminates hazardous material.<br>• Deactivated material can be shipped to any pyrometallurgical and/or hydrometallurgical processors providing options for the best price on battery chemistries. On the other hand, shredding creates black mass that can only be refined with hydrometallurgy. Black mass is currently processed by pyro processes in EU and Asia. | • The batchwise nature of this technology can limit throughput.<br>• Need to puncture some battery types to promote penetration of supercritical $CO_2$ is problematic for large scale processing.<br>• High energy input required per battery processed.<br>• $CO_2$ input required to process batteries.<br>• Uncertain about commercial scalability and cost.<br>• Puncturing batteries may be considered treatment requiring permitting.<br>• General uncertainty about the process due to lack of knowledge.<br>• Uncertain about the sizing of equipment for larger packs and battery modules.<br>• Maintenance and spare parts—unknown.<br>• Shredding per ton of batteries produces an equal mass of hazardous materials.<br>• Does DOT recognize deactivated batteries by this technology as deemed safe for shipment?<br>• Concerns around viability to scale. |

## REQUIREMENTS – CRUDE SHREDDING

### Crude Shredding (#7)

**Overview**

This section refers to the on-island crude shredding of waste EOL LIBs to smaller "non-battery" components that are no longer explosive or flammable and are thus safe to transport by marine transit[153]. These batteries will arrive to the shedder after visible verification of non-DDR status and after having been sorted to ensure separation from non-LIBs.

Although promising as a pre-shipping treatment, the shredding lithium batteries requires special attention be paid to safety and environmental concerns due to the risks of fire, explosions, and the release of toxic materials[154]. Specifically, lithium batteries are generally considered hazardous materials and are classified as Class 9 Miscellaneous Hazardous Materials by DOT due to their potential for fire and explosion. Also, certain metals and minerals, specifically metal and mineral concentrates, are classified under UN 3077, which designates them as "Environmentally Hazardous Substances, Solid, not otherwise specified (N.O.S.)". This classification identifies them as having a potential toxic threat to marine life, even if they don't fall under other dangerous goods classifications. Materials classified under UN 3077, generally cannot be shredded with standard procedures and will likely require specific handling and disposal methods due to their potential environmental hazard. For this reason, the shredder design needs to take into account containment of the byproducts of the shredding process. One method currently employed to facilitate this is shredding under a nitrogen positive environment[155]. This is usually accomplished through use of feed hopper. Also, as in the norm at operational facilities, the shredding should be

[153] They will still be classified as hazardous waste, however. That said, if the end products are shredded down to the point the pieces are no longer classified as batteries, which includes no voltage potential, there flammability and explosion capacity are vastly diminished.
[154] Marcelo Oliveira, Bárbara Abreu and Henrique Costa. 2024. Shredding of Lithium-Ion Batteries: Overview and Industrial Perspective. In (Hosam M. Saleh and Amal I. Hassan) Waste Management for a Sustainable Future - Technologies, Strategies and Global Perspectives. DOI: 10.5772/intechopen.1008229
[155] https://www.recyclingproductnews.com/article/38741/new-bhs-sonthofen-shredders-process-hazardous-materials-in-a-protective-nitrogen-atmosphere.

supervised by trained professionals using specialized equipment to ensure the safety of the process and proper handling of the hazardous materials.

Shredding lithium batteries also requires special attention be paid to safety concerns[156]. In the processing of post-consumer waste EOL lithium batteries, dry shredding has a significant fire issue, because a lot of batteries will not be properly discharged and thus have excess stored energy. The shredding process unleashes that energy by creating short circuits within the batteries as they are penetrated by conductive teeth. This short circuiting of lithium batteries immediately generates large amounts of heat that catalyzes the degradation of internal solvents that leads to their rapid combustion in the presence of atmosphere oxygen. As such, shredder design should account for both heat generation and the explosivity of the solvents in the presence of oxygen. Also, and similar to the containment of hazardous materials, the shredder should be supervised by trained professionals using specialized equipment to ensure the safety of the process and proper handling of the hazardous materials.

There are techniques being trialed in industry to reduce/contain the heat release. For example, common practices currently in play to avoid undo heat generation include prior discharge of batteries (if and when possible)[157], calcination pretreatment, cryogenic pretreatment, and/or shredding under water. These will be discussed in more detail below.

***Land required per kg of waste EOL processed (including temporary storage and sorting).*** For the process designed at Ecobat's Arizona plant, the base land requirement for smallest size plant that wet shreds the lithium-ion batteries to a crude black mass and plastic byproduct, is roughly 10 acres per 3000 tons processed per year. This size plan can be expanded to a rough maximum of 5,000 tons per year[158].

> ***NOTE***: It is not expected that this base amount of land would be significantly reduced for a plant that solely shreds the batteries to a crude shred. The reason for this is that the added machinery to shred the crude shred does not significantly take up floor space or add to the ancillary equipment and waste stream processing equipment already in place to execute the crude shred.

***Energy (as electricity) required per kg of waste EOL processed.*** For the process designed at Ecobat's Arizona plant, the base energy requirement for smallest size plant (10 acres, 3,000 tons

[156] Marcelo Oliveira, Bárbara Abreu and Henrique Costa. 2024. Shredding of Lithium-Ion Batteries: Overview and Industrial Perspective. In (Hosam M. Saleh and Amal I. Hassan) Waste Management for a Sustainable Future - Technologies, Strategies and Global Perspectives. DOI: 10.5772/intechopen.1008229
[157] Brine discharge en masse (mix of forms, consumer electronic batteries) is super ineffective (water proofing, degradation of electrical connections).
[158] As per discussion with Travis Hesterberg, Vice President Research and Development, Ecobat.

per year) that completes the crude shredding of lithium-ion batteries to a crude black mass and plastic byproduct, is estimated to be roughly 0.37 kwh/kg product (battery) processed.

> ***NOTE***: This estimate will rise with plant expansion, it should rise not too substantially if the plant is expanded to process up to 5,000 tons per year owing to the fact that much of this energy load is dedicated to pre-existing unit operations that would take on the added flows.

***Water required per kg of waste EOL processed.*** All total Ecobat's operating system operates as "water negative" owing to the water contained in the crude filter cake black mass[159]. In other words, the wastewater generated from Ecobat's process is contained (and ultimately shipped) in the filter cake of crude black mass produced at the plant with the water in the wet shredder is recycled through the treatment towers.

***NOTES***:

[1] The amount of water flowing through the closed loop recycling system when processing 3000 tons per year is roughly 25 gallons per minute, closed loop.

[2] Technically the use of the word "closed loop" is not correct as wastewater produced by the process is ultimately taken away in the crude black mass filter cake that is shipped to another processing plant (that extracts and recovers high value metals from the crude black mass).

[3] The filter cake is a "crude" black mass. Although safe to ship, the filter cake is considered a "crude" product because it needs further treatment before it is fully prepared for higher level recycling operations[160] that recover the high value metals.

***Emissions (with description) to atmosphere per kg of waste EOL processed.*** For the process designed at Ecobat's Arizona plant, the base emission load for smallest size plant (10 acres, 3,000 tons per year) that completes the crude shredding of lithium-ion batteries to a crude black mass and plastic byproduct, is estimated to be roughly 0.21 kg $CO_2$/kg product (battery) processed.

***Emissions (with descriptions) to standing/flowing bodies of water per kg of EOL processed.*** As described above, Ecobat's system does not produce wastewater. The water used in the wet shredder is both recycled but also a fraction of it is lost to the crude filter cake that is processed at another plant. As such, Ecobat's process does not release wastewater to the local environment but rather produces a crude black mass filter cake that is transported by truck or rail to recycling plant.

***How much land needs to be between shredder and surrounding infrastructure to be safe?*** There aren't specific, universally mandated standards for the amount of empty land required around lithium-ion battery shredder plants. However, safety and environmental regulations, including

[159] As per discussion with Travis Hesterberg, Vice President Research and Development, Ecobat.
[160] Generally, some form of pyrometallurgy and hydrometallurgy.

those from OSHA, the EPA, and local authorities, play a crucial role in determining the distance from other facilities and sensitive areas. These regulations address fire safety, hazardous material storage, and environmental protection.

***What type of fire suppression systems are required?*** Sprinkler systems for the building are expected at a minimum[161]. That said, a combination of fire suppression systems directly applied to the shredder is recommended, including water mist systems, and potentially aerosol suppression or inert gas systems. Water mist is preferred for its ability to cool the battery and prevent re-ignition, while aerosol and inert gas systems can offer rapid suppression and are suitable for areas with restricted access or where water damage is a concern.

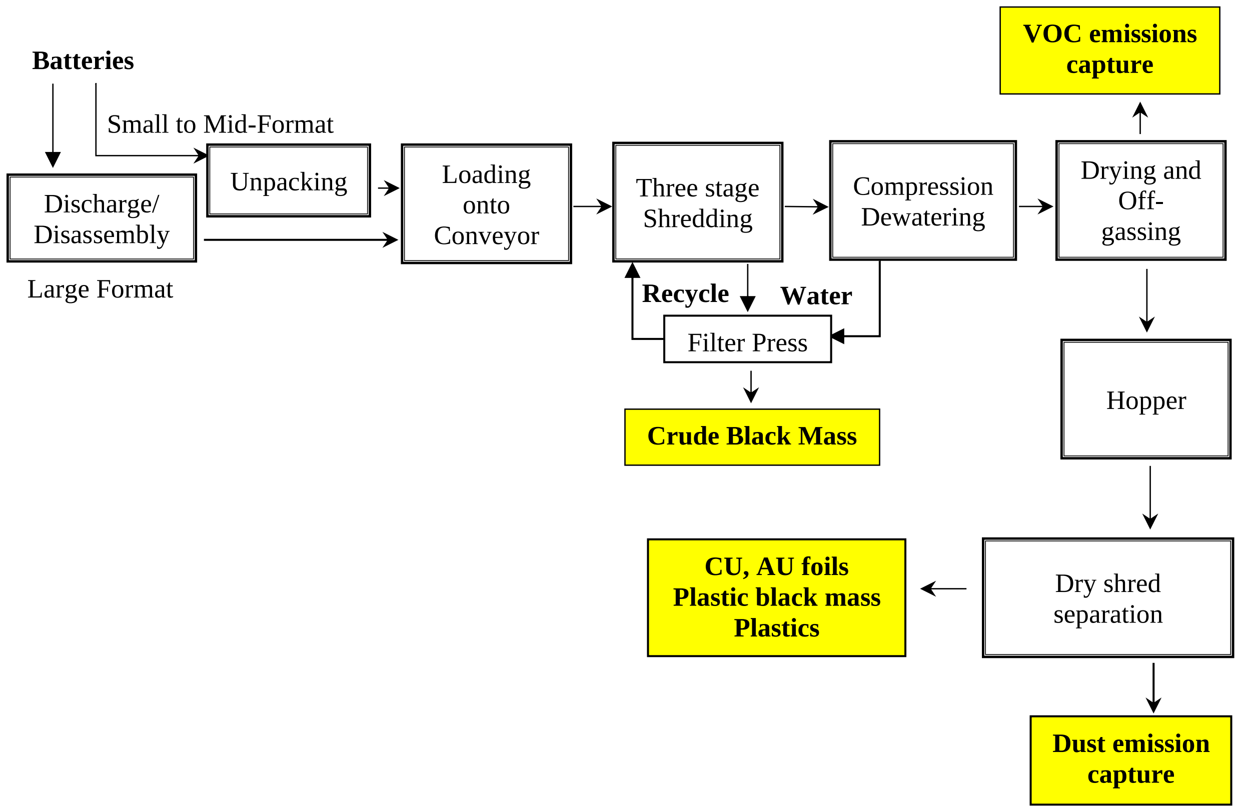
***What kind of monitoring systems are required?*** Thermal imaging cameras linked to a water system can be utilized. Proper packaging and storage are also important mitigation steps that need to be utilized.

**Process Flow Diagram**

A very general high level process description of the shredding process is outlined in the process flow diagram below (Figure 22). Initially, the lithium batteries should be discharged as much as practically possible. Next, the batteries are loaded via a conveyor into a feed hopper and then into the shredder where they are broken down into smaller not battery parts which must then be degassed under heated vacuum to remove any leftover flammable electrolytes. After shredding, the mixture of the shredded battery and wet solution is processed to separate the dissolved material from the remaining components. To minimize discharge to the environment, the water is recycled through a filter press to separates out solids (residual black mass). This crude wet black mass is now prepped for more sophisticated recycle operations to extract and purify high value metals (i.e., cobalt, nickel). Not shown are standing tanks that the recycled water is passed through to allow for solids settling and cooling. The pressed water is then reused. Also, the air stream in the heated auger is pumped out and to a water scrubber to capture and additional air borne particulates (including a residual black mass).

[161] Consider other tools like Fire Rover or FPS FIKE water system.

*Figure 22. Generic process flow diagram for wet shredding process.*




## Unit Operations

### *Discharge/Disassembly*

*Discharge.* With the exception of having a particularly large shredder, large format lithium-ion batteries are generally discharged and disassembled prior to being fed into the shredder. Both steps also reduce heat evolution/explosion hazards during the shredding process. Discharging removes stored energy, reducing the risk of short circuits, explosions, or fires that could occur if the battery is shredded while still fully charged. Ideally, batteries are discharged to 30% or less, with 20% being the safest threshold. This step can increase acceptable loading rates (to the shredder) but at the expense of increasing the number of personnel needed to front-end their disassembly. Depending upon the size of the shredder, some level of disassembly may be required simply to permit the battery to fit. ***In this analysis, it is assumed that in Hawai'i, the preferred mechanism will be to use shredders that require the discharge and disassembly of large format batteries.***

There are two primary mechanisms to discharge lithium batteries: physical or chemical. In physical discharge, the battery electrodes are connected through a physical resistor. In chemical discharge, the battery electrodes are connected through a liquid conductive medium, typically through submersion in a salt solution. Of the two, physical discharge is the most efficient although far more cumbersome. Moreover, physical discharge is difficult to apply across all battery formats (especially small formats) and nearly impossible to practically achieve in any industrial setting. Chemical discharge, by contrast, is easier to execute but more inefficient owing to corrosion of electrodes during the exposure to salts, leading to reduce or inefficient discharge. Soaking also produces a contaminated saline solution that is difficult to purify before its reuse. ***In this analysis, it is assumed that in Hawai'i, the preferred mechanism will be physical discharge.***

*Disassembly.* Once discharged, large format lithium-ion batteries are disassembled before fed into the crude shredder, primarily to improve the purity and value of the recovered materials[162]—disassembly can help prevent the encapsulation of valuable materials during shredding, which increases the difficulty of downstream recovery of the high value metals[163]. Also, large format batteries bring (with them) a lot of additional low to non-value materials (plastics, battery management system electronics) that can damage the shredder blades or clog up the augers that move the shredded materials through the linked shredders. Finally, the disassembly of large format batteries into smaller modules permits control over the size and energy density (of batteries) being fed into the shredder as a function of time—a concept very important to the control/mitigation of undue heat evolution.

***NOTE***: Large format batteries will add a higher operational cost burdens due to the increased handling requirements they impose, including their initial disassembly.

***Unpacking.*** In order to process the lithium batteries, they must first be transported to the shredding facility in compliance with DOT regulations and the expectations of the insurance underwriters. In general, this comprises small format batteries being delivered in 55-gallon steel drums filled with fire retardant suppressant (at a 2-part suppressant to 1-part battery by volume ratio) with larger format batteries being delivered on wooden pallets. While the unpacking and handling of the larger format batteries (affixed to pallets) is addressed in the section on Disassembly (above), the smaller format batteries must first be removed from the 55-gallon drums and separated from the fire suppressant packing material. In a continuous operation, this either requires personnel to personally unload each drum or to have them use forklifts to load the open drums onto a large mechanical shaker/sieve that separates the suppressant packing material from the lithium batteries remain.

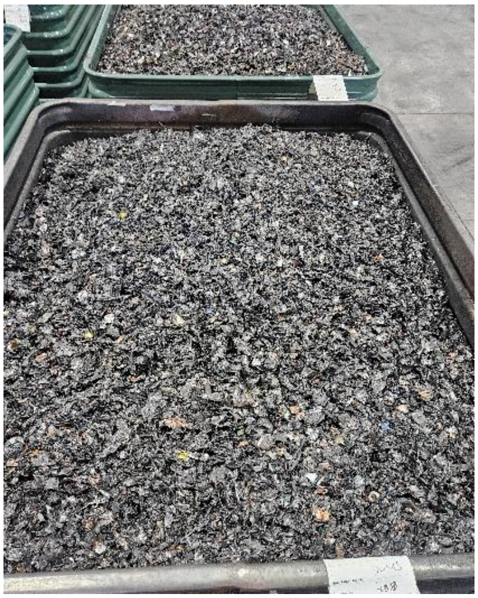
---

[162] Wu, S.; Kaden, N.; Dröder, K. A Systematic Review on Lithium-Ion Battery Disassembly Processes for Efficient Recycling. *Batteries* 2023, *9*, 297.
[163] Copper, Nickel, Cobalt.

***Loading.*** After unpacking, the batteries are fed to the shredder through a double airlock compartment that maintains a nitrogen gas atmosphere above the shredder blades[164]. The process generally comprises a conveyor belt that moves the batteries up an incline towards the opening of a feed hopper coupled to the airlock system that isolates the shredding chamber from the external environment, further enhancing safety[165]. A double airlock mechanism is often preferred and used. For individual cells or in battery packs are collected off Oʻahu, the waste "used" EOL lithium batteries will first need to be removed from 55-gallon drum containers prior to being loaded onto the conveyor belt.

***Crude Shredding.*** Although the shredding process of LIBs is effectively a size reduction operation that enables the subsequent separation of components, in terms of this analysis the application of a shredder to the preprocessing waste EOL LIBs is recognized for its ability to reduce the batteries to smaller "non-battery" fragments that are no longer flammable and explosive, thus making them safer to transport by marine shipping (Figure 23)[166]. Once delivered to a recycler, the crude shred will be further processed into finer and coarser fractions, ultimately producing a black mass which is further subjected to pyrometallurgical and/or hydrometallurgical methods to extract high value metals.

***Figure 23. Output from crude shred of lithium-ion batteries[167].***



[164] Even in a wet shredder, a portion of the shredder blades must sit above the water in order to capture and pull-down batteries encased in plastics that float.
[165] At this point, although removed from their steel drums and separate from the fire-retardant suppressant, the batteries are still enclosed in the plastic sealers/bags they were enclosed in when initially discarded for recycling.
[166] It is noted, however, the crude shred remains a hazardous material and must be handled during shipping as such.
[167] Source: Ecobat

The primary or crude shredding stage grinds the intact battery cell or module into smaller particle sizes that are no longer batteries. Crude shreds are typically achieved using shaft or rotor shredders[168,169], although more stages of shredding/crushing are often employed to maximize the disaggregation of active materials (i.e., black mass) from their respective copper and aluminum sheets. The crude shred is often termed "primary shredding" while these additional unit operations are often referred to as "secondary shredding."

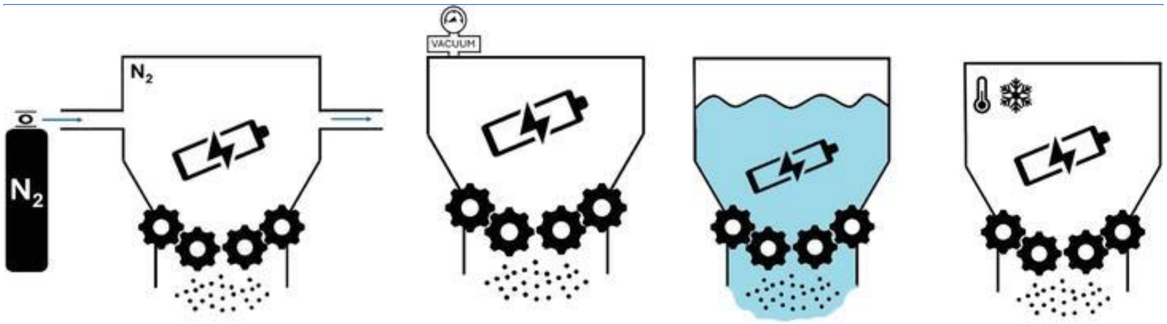
For initial crude shredding, the general consensus is to use four-shaft crushers, although other types of crushers are also employed to some extent. The size and number of shafts, the spacing between them, their geometry, and the material used in their construction are key design criteria to ensure good performance and proper maintenance of the shredder over time. These features will need to be evaluated before installing a crude shredder and their specification will be influenced by the expected battery formats to be processed. Key design criteria include crushing speed, the maximum allowable size of the battery/module, and whether it is intended to crush modules or whole batteries. The decision on the latter must be coordinated with the design of the preceding sorting/disassembly unit operations.

*Shredder operational types.* Crude shredders come in a variety of operational modes, most of which are designed to reduce the threat of inhouse fires and explosions. To that end, the majority of shredding processes strive to reduce the event of ignition or explosion by introducing an inert nitrogen atmosphere to reduce the oxygen content of the surrounding atmosphere. Variations on this approach include operation under vacuum or other inert gases. Additionally, some processes use fluids to maximize heat dissipation and minimize contact with oxygen, with the advantage of simultaneously leaching the conductive salt. In this analysis, four shredding formats have been identified: *inert shredding*, *vacuum shredding*, *wet shredding*, and finally *cryogenic shredding* (Figure 24).

---

[168] Diekmann J, Sander S, Sellin G, et al. Crushing of Battery Modules and Cells BT. In: Kwade A, Diekmann J, editors. Recycling of Lithium-Ion Batteries: The LithoRec Way. Cham: Springer International Publishing. 2018. pp. 127-138.
[169] Diekmann J, Sander S, Sellin G, et al. Material Separation BT. In: Kwade A, Diekmann J, editors. Recycling of Lithium-Ion Batteries: The LithoRec Way. Cham: Springer International Publishing. 2018. pp. 207-217.

*Figure 24. Different technologies to shred a lithium-ion battery: (a) inert, (b) vacuum, (c) wet, and (d) cryogenic.*



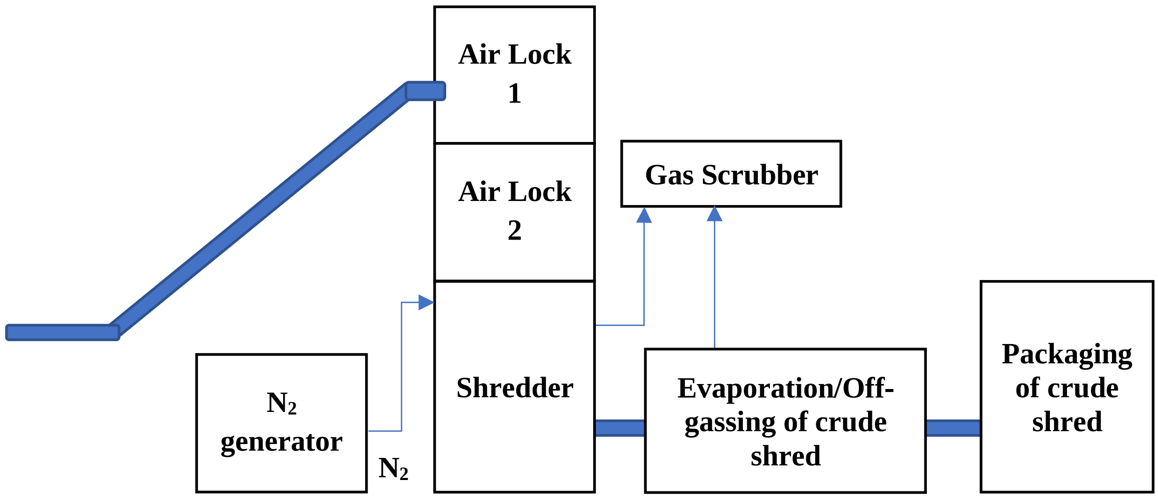

(a) (b) (c) (d)

*Inert shredding*. Inert shredding is a process that shreds the waste lithium batteries under a nitrogen atmosphere (Figure 24a, 25). Nitrogen ($N_2$) is a non-reactive molecule under standard conditions and its presence provides as inert atmosphere that enhances the overall safety by minimizing the amount of atmospheric oxygen, which reduces the probability of reactions with the solvents as they decompose at elevated temperatures, thus reducing fire ignition and explosion[170]. With inert shredding, an important factor is that the oxygen concentration in both the shredding and drying chambers should be kept below 3%[171,172]. As described previously, the batteries are fed through an intermediate airlock (usually two) that separates the external air atmosphere (21% oxygen) from the crusher atmosphere (<3% oxygen with the remainder being inert di-molecular nitrogen). Airlock systems also help to prevent/mitigate the escape of dust or fumes[172]. Airlock systems can be designed to accommodate continuous flow (through constant purging with $N_2$ gas) or batch operation wherein the shredding equipment is kept airtight during shredding (and after $N_2$ purge) through use of air-tight gate valves with optimal sealing (Figure 25). One advantage to using a continuous purge of $N_2$ is to prevent the accumulation of flammable and toxic gases that will accumulate during the evaporation of the electrolyte, which can be particularly relevant when shredding batteries that contain low flash point solvents such as dimethyl carbonate (DMC) and ethyl methyl carbonate (EMC).

[170] During the shredding process short circuits occur in the batteries which leads to rapid evolution of heat. At the higher temperatures the solvents begin to degrade into products that are very reactive with oxygen.
[171] Diekmann J, Sander S, Sellin G, et al. Crushing of Battery Modules and Cells BT. In: Kwade A, Diekmann J, editors. Recycling of Lithium-Ion Batteries: The LithoRec Way. Cham: Springer International Publishing. 2018. pp. 127-138.
[172] Diekmann J, Sander S, Sellin G, et al. Material Separation BT. In: Kwade A, Diekmann J, editors. Recycling of Lithium-Ion Batteries: The LithoRec Way. Cham: Springer International Publishing. 2018. pp. 207-217.

After shredding, the shredded materials are dried under exhaust suction to remove any residual toxic electrolyte and volatile organic compounds (VOCs) adhered to the products of the crude shred that collect at the bottom of the mechanical shredder[173].

*Figure 25. Generic process flow diagram for dry shredder.*



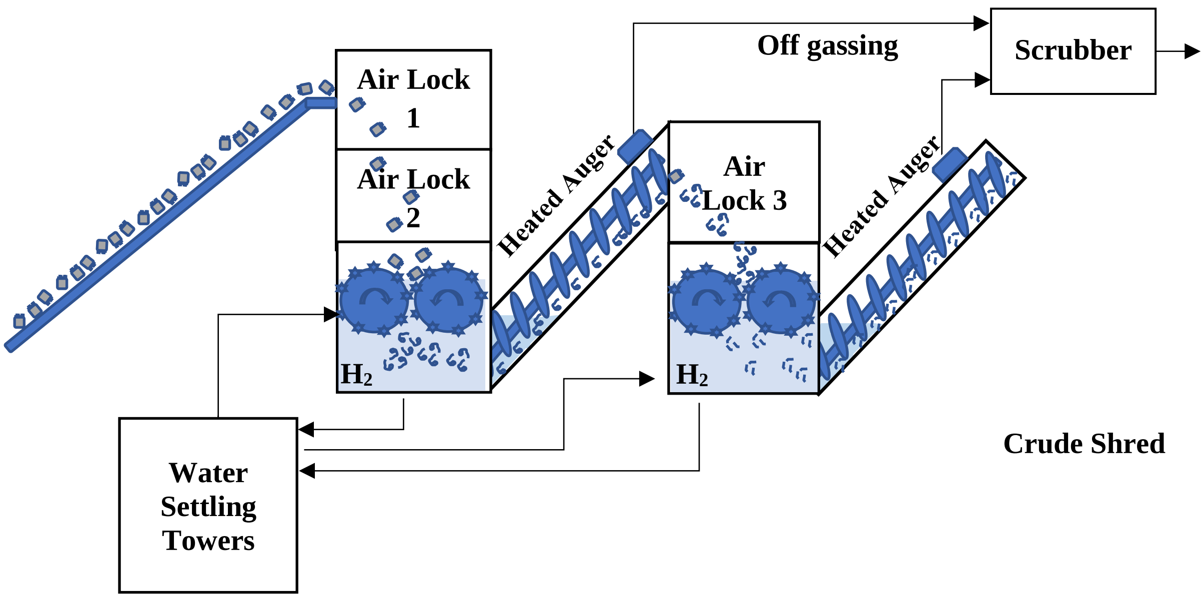

Finally, since the maximum allowable oxygen concentration is relatively high compared to the concentration of commercial nitrogen gases, the operator can choose from different techniques for nitrogen generation, benefiting from local production. There are three technologies for nitrogen purification: membrane separation, Pressure Swing Adsorption (PSA), and conventional distillation[174,175].

*Wet shredding*. Wet shredding of lithium-ion batteries involves reducing battery packs to smaller granules in a water-filled chamber to suppress sparks and prevent fires, while also enabling density-based material separation—lighter materials like plastics and separators float, while heavier materials including the black mass sink. The use of liquids helps to minimize the risk of explosions and fires during the shredding process. Specifically, the liquid acts as a barrier between the fuel (decomposing solvents) and the oxidizer (oxygen in the atmosphere) while also mitigating the effects of heat released during the shredding

[173]Roy et al., 2022. Green Recycling Methods to Treat Lithium-Ion Batteries E-Waste: A Circular Approach to Sustainability. Advanced Materials. 34, 2103346.
[174]Omega Air d.o.o. Ljubljana. Nitrogen and oxygen production. 2023. Available from: https://www.omega-air.si/news/news/nitrogen-and-oxygen-production [Accessed: November 28, 2023].
[175]Van MG. How a nitrogen generator works: PSA vs. Membrane separation technology. 2023. Available from:https://www.ecscorrosion.com/blog/how-a-nitrogen-generator-works [Accessed: November 28, 2020].

stage[176]. Wet shredding also reduces dust formation that could otherwise pollute the surrounding atmosphere and reduce black mass recovery yields due to losses in dust, as there is less tendency for dust to become airborne given that it is wet[176]. If water is used, a heated[177] screw auger can be used to separate out the solids from the water. If a solvent is used, various separation methods, such as filtration and subsequent distillation, can be used to recover the DMC to be reused in the process. In many cases, a second or third shredder can be linked into the unit operation train to further reduce the parti le size of the shredded battery components. A general schematic of a crude shred unit operation is presented in Figure 26.

*Figure 26. Generic process flow diagram of wet shredder unit operation.*




In general, there are two fluids of interest as a medium for wet shredding: water and organic solvents, in particular, a low-boiling-point solvent typically found in the electrolyte could be used, such as DMC or EMC, which could increase the efficiency of the leaching of conductive salt ($LiPF_6$)[178]. These solvents would necessarily have an affinity for both the conductive salt and the high-boiling-point solvents present in the electrolyte, such as

[176] Sattar A, Cooper L, Dowson M, et al. Considerations in lithium-ion battery recycling. 2023. Available from: https://warwick.ac.uk/fac/sci/wmg/business/transportelec/wmg_-_considerations_in_lithium-ion_battery_recycling.pdf
[177] The heating helps to evaporate off any residual solvents and water.
[178] From a technical standpoint, using DMC in wet shredding appears to be the best option. Since DMC is used in the composition of electrolytes, it likely has a greater affinity for the conductive salt as well as for other organic solvents, such as EC (ethylene carbonate), which is known to be difficult to remove from black mass without using high temperatures. Therefore, extraction with DMC would result in a purer black mass, free of conductive salt and high-boiling-point solvents.

ethylene carbonate (EC) and propylene carbonate (PC). However, from an operational standpoint, this process requires additional safety measures, as DMC is an inherently flammable liquid, and its inhalation should be avoided due to its volatile nature. Indeed, no literary evidence was found of a shredding application involving an organic solvent. For these reasons, water is the solvent of choice in wet shredding, although it can be advantageous to add salts to facilitate the dissipation of any residual electricity in the battery. For example, salts like sodium hydroxide, calcium hydroxide, or even lithium hydroxide can be used to give the liquid a pH of 8 or higher—basic solutions prevent the acidification of the water, as any leached acid (from the punctured battery cell) will be immediately neutralized[179]. There are several safety considerations, however, that must be addressed when water is used due to the degradation of the conductive salt and associated secondary reactions that produce hydrogen[180]. The associated costs of treating the contaminated water must also be considered.

Overall, wet shredding offers a safe and efficient method for the preprocessing of lithium-ion batteries to a crude product of small fragments or crude black mass (for the next step that recovers the high value metals) while suppressing fires, enabling separation of materials, and reducing dust generation while posing some challenges like effluent treatment and potential corrosion. Although this process is beginning to gain some industrial traction, several disadvantages are associated with it, including the necessary treatment of the effluents generated during the process and the potential formation of hydrogen due to the interaction between the aqueous effluent and metal foils, especially aluminum[181].

*Vacuum shredding*. Vacuum shredding comprises shredding the lithium batteries under vacuum as a means to minimize the total amount of oxygen present (and, in fact, all gases) within the shredding chamber, whether they are combustible, oxidizing, or inert. Operating below 100 mbar is considered safe, preferably around 5 mbar[182], since at such low pressure the quantity of oxygen and other gases is negligible. Additionally, because the evaporation occurs as the battery is shredded, shredding under vacuum reduces or eliminates the need for the post shredding evaporation step required with shredding under nitrogen atmosphere—as discussed previously, drying is the slowest step of the process. According to manufactures, about 80% of the electrolyte is removed during the shredding stage, which

[179] Biedermen CJ, Ton TG, Lovell MJ, et al. Apparatus for separating materials recovered from batteries. WO2022246570A1. 2022.
[180] i.e., the presence of hydroxide salts could trigger another secondary reaction that produces hydrogen, as in the case of a reaction with LiOH or any hydroxide salt used.
[181] Sattar A, Cooper L, Dowson M, et al. Considerations in lithium-ion battery recycling. 2023. Available from: https://warwick.ac.uk/fac/sci/wmg/business/transportelec/wmg_-_considerations_in_lithium-ion_battery_recycling.pdf.
[182] Von Loeper B, Hanisch C. Method for recycling components of electrochemical energy stores, and recycling devices therefore. WO2023165780A1. 2023.

is higher than in inert gas technology. One hurdle to apply vacuum shredding in industrial practice is the need to maintain the vacuum tightness with prolonged continuous operation over many production years. Because of this, vacuum shredding is currently not prevalent on an industrial scale, although it does have the advantage of vastly improving the evaporation rate of solvent released during the shredding process.

*Cryogenic shredding*. Cryogenic shredding is a methodology that involves lowering the temperature of the lithium batteries to be shredded using dry ice, liquid carbon dioxide, or liquid nitrogen, prior to their introduction into the shredder. This has the effect of significantly reducing the risk of thermal runaway reactions during the dry shredding process which improves safety during recycling. This process utilizes the principle that freezing the electrolyte prevents the movement of lithium ions as the shredder teeth rip apart (and short circuit) the battery, thereby eliminating heat generation and preventing the potential for fire and explosion. The process begins with the dismantling of larger batteries and crushing them in a cryogenic environment using liquid nitrogen, until the batteries reach -195°C[183]. This method is highly effective when a large number of batteries need to be crushed. It also makes the external plastic casing hard and brittle, facilitating the crushing process. Studies show that penetration tests on frozen batteries indicate no significant difference in safety at temperatures of -80°C or lower. Starting from -73°C, the temperature gradually begins to rise, reaching—21°C, where thermal runaway occurs, likely due to the melting points of the electrolyte components and the resulting increased mobility of lithium ions[184]. The post evaporation step is still needed, however, before the shredded bits can be safely packed for marine transit.

On the down side, it is necessary to consider subsequent stages as the frozen electrolyte will eventually melt and could cause a short circuit in the shredded material. To mitigate this issue, companies include a step where the shredded material is immersed in water. Unfortunately, this loses the advantages of this method and introducing the disadvantages associated with wet shredding.

A summary of the pros and cons to these shredder types is given below.

---

[183] McLaughlin W, Adams TS. Li reclamation process. US5888463. 1999

[184] Sunderlin et al., 2023. Effects of cryogenic freezing upon lithium-ion battery safety and component integrity. Journal of Energy Storage. 63:107046.

*Figure 27. Pros and cons for the shredding operational types (wet, vacuum, inert, and cryogenic).*

| Method | Advantages | Disadvantages |
|---|---|---|
| **Wet Shredding** | • Easier to scale up than dry inert shredding methods.<br>• Allows harmful chemicals to be neutralized.<br>• Increasing safety by deterring thermal runaway—since the recyclable Li-ion battery material does not readily absorb water, it can be used to cool the materials and quash incipient fires.<br>• Glues or gels also tend to float so can be easily handled in a wet recycling system.<br>• A wet system can capture VOCs in the water, which can be filtered, so air filtration can be simple with just a scrubber and charcoal filtration.<br>• Wetting can minimize the formation of airborne dust, which can be a concern in dry shredding processes.<br>• Wet shredding is considered the only technique that effectively removes the conductive salt from the black mass.<br>• Wet shredding uses liquids to deactivate the battery cells, eliminating the need for inert gas or vacuum systems for oxygen control.<br>• Effectively removes the conductive salt from the black mass. | • The process generates effluents (waste liquids) that require treatment, adding complexity to the recycling process.<br>• Hydrogen is generated if aluminum is present.<br>• Addition of alkali reagent to water increases costs.<br>• Alkali ions can be corrosive to process equipment.<br>• No electrolyte recovery is possible.<br>• Additional cost of effluent treatment.<br>• Involves several separate stages that must be sufficiently integrated by an experienced manufacturer.<br>• Presents challenges related to effluent treatment and potential hydrogen formation.<br>• The shredded material stream contains some black mass, leading to a decrease in process yield, potentially accounting for 3-7% of the black mass.<br>• The necessary treatment of the effluents generated during the process and the potential formation of hydrogen due to the interaction between the aqueous effluent and metal foils.<br>• Wastewater generated during wet shredding requires treatment to remove any contaminants, such as electrolytes and other dissolved substances.<br>• In some cases, especially with the interaction of the aqueous effluent and metal foils, there is a risk of hydrogen formation.<br>• The resulting lye, contaminated with hydrofluoric acid, can corrode steel components at the plant.<br>• Disposal of the resulting residue presents a sustainability challenge. |

| Method | Advantages | Disadvantages |
|---|---|---|
| **Vacuum Shredding** | • Electrolyte drying should be faster; unlike the nitrogen method, vacuum shredding already occurs under conditions that promote the evaporation of major electrolyte compounds, such as dimethyl carbonate, meaning the drying process begins as soon as the crushing starts.<br>• Avoids high consumption of nitrogen compared to inert shredding.<br>• Cheaper to operate than using inert gas.<br>• Can be coupled with a vacuum extraction unit to evaporate and condense electrolyte carbonates.<br>• Relatively mature technology is used in other recycling operations.<br>• Because the evaporation is faster and occurs as soon as the battery is shredded, it should decrease significantly the total process time—as discussed previously, drying is the slowest step of the process. According to manufactures, about 80% of the electrolyte is removed during the shredding stage, which is higher than in inert gas technology.<br>• Faster removal of electrolyte, as the shredding is done under vacuum.<br>• The electrolyte residue is expected to have a cleaner profile. Depending on the degree of purity, this could facilitate the valorization of this residue, a topic that has not yet been fully developed in the industry.<br>• Savings on nitrogen, as in this case, only the vacuum pump requires nitrogen for protection.<br>• Reduces nitrogen consumption and holds promise. | • Only suitable for batch processing, making it difficult to scale up<br>• Safety not as high as shredding in an inert atmosphere.<br>• Not suitable for shredding charged cells.<br>• Vacuum shredding of lithium batteries is a technique that has not yet been implemented on an industrial scale; although, there are clear advantages that could in the future raise interest in this technology.<br>• Yet to be used industrially. |

| Method | Advantages | Disadvantages |
|---|---|---|
| **Inert Shredding** | • Mature technology is used in recycling of other flammable material.<br>• Semi-continuous shredding is possible with right feeding mechanism.<br>• Inert gas crushing is the most prominent type of crushing in the industry, with the highest number of recyclers and equipment suppliers at present.<br>• Safe and mature technology is widely adopted by several recyclers and has the highest number of suppliers. | • Every battery cell must be discharged—there is no practical or certain way of knowing if all the cells are fully discharged.<br>• Batteries are placed in a salt solution for several weeks to discharge, but this is messy, requires excessive space, and produces a chemical effluent that must be properly disposed.<br>• More expensive than vacuum shredding in utilities.<br>• May need inert conveyance line post-shredding to avoid fires/explosions.<br>• Not suitable for shredding charged cells and modules.<br>• Can still pose environmental challenges, including the potential for airborne dust and VOCs.<br>• Typically require the disassembly of packs or modules and discharge of the individual battery cells before further processing and can be at risk of thermal events.<br>• Disassembly is difficult—battery manufacturers are now increasingly filling their packs and modules with a glue-like gel as a safety precaution, to keep the case together in case of damage from a collision or drop. However, this makes battery disassembly even more complex. Even the companies that manufacture them have no method of disassembly.<br>• The variety of batteries that must be dismantled from packs and discharged can make a dry system prohibitive from a cost and return on investment standpoint.<br>• All battery packs are built differently, so there is no single method for discharge.<br>• Treating or separating these airborne materials is more difficult as well as more costly and dangerous—you have to filter, scrub, and thermal oxidize them (battery electrolyte and VOCs) off.<br>• High nitrogen consumption. |
| **Cryogenic Shredding** | • Increases the recovery of valuable components.<br>• Low energy consumption in the shredding phase.<br>• Low temperatures.<br>• Safe technology. | • Expensive reagents used.<br>• Only suitable for batch processing, making it difficult to scale up.<br>• Environmental problems from disposal.<br>• Faces several limitations for industrial application. |

***Requirements - Waste lithium-ion.***

*Household, consumer and portable lithium batteries (small format).* Cells and batteries must be removed from steel drum containers and can remain in their plastic coverings, but should be separated from packing insulation. The shredding equipment must be designed to mitigate fire and explosion hazards, often requiring explosion-proof features and an inert gas or fluid system to prevent runaway thermal reactions. The "wet" shredding process itself is a safety measure to prevent ignition.

*The following regulations apply*: Shredding is a treatment process that can only be performed at a designated "destination facility," not by a universal waste handler. When batteries arrive at a destination facility for recycling, they are no longer managed under the Universal Waste Rule and are subject to full RCRA hazardous waste regulations.

*What is the training required?* Employees must be trained in the risks of lithium battery materials and on how to handle them safely. The facility must have clear procedures for fire and other emergencies, and all personnel must be trained on safety measures. Proper PPE must be provided to and used by all employees involved in the shredding process.

*e-bikes, e-scooters, weed eaters, leaf blower batteries (mid-format).* Similar to consumer and portable batteries, batteries in this format must be removed from the steel containers they were packed in and separated from packing insulation. It is recommended to discharge the batteries prior to loading them into the shredder. To the highest degree possible, batteries at this scale should be separated from the protective coverings (e.g. military batteries encased in protective plastic molds). The shredding equipment must be designed to mitigate fire and explosion hazards, often requiring explosion-proof features and an inert gas or fluid system to prevent runaway thermal reactions. The "wet" shredding process itself is a safety measure to prevent ignition.

*The following regulations apply*: Shredding is a treatment process that can only be performed at a designated "destination facility," not by a universal waste handler. When batteries arrive at a destination facility for recycling, they are no longer managed under the Universal Waste Rule and are subject to full RCRA hazardous waste regulations.

*What is the training required?* Employees must be trained in the risks of lithium battery materials and on how to handle them safely. The facility must have clear procedures for fire and other emergencies, and all personnel must be trained on safety measures. Proper PPE must be provided to and used by all employees involved in the shredding process.

*EV, home or commercial scale energy storage, portable power packs (large format).* Batteries in this format should be disassembled and separated from their housing (e.g., steel casing, battery management systems... etc.). This reduces the stress on the shredding teeth, provides a downs stream product that is easier to separate. If the shredder is smaller scale, it also allows a lower energy density fed to the shredder and thus reduces heat generation. To minimize fire risk, batteries at this scale should be fully discharged before shredding. This neutralizes the battery's energy and reduces the danger of an ignition event during the shredding process.

*The following regulations apply*: Shredding is a treatment process that can only be performed at a designated "destination facility," not by a universal waste handler. When batteries arrive at a destination facility for recycling, they are no longer managed under the Universal Waste Rule and are subject to full RCRA hazardous waste regulations.

*What is the training required?* Employees must be trained in the risks of lithium battery materials and on how to handle them safely. The facility must have clear procedures for fire and other emergencies, and all personnel must be trained on safety measures. Proper PPE must be provided to and used by all employees involved in the shredding process.

*Utility scale.* Utility scale systems will need to be disassembled into large format beforehand in order to fit into the shredder.

***Requirements - Waste DDR lithium-ion.*** For the purpose of processing used “waste” DDR EOL lithium batteries, there are no deviations from the procedures stated above except for the fact that upon entrance to the facility the DDR batteries must be stored separately and in specially designed fire restricting containers.

**Pros and Cons of Deactivation by the Wet Shredding Process**

***Figure 28. Pros and cons of deactivation of used “waste” lithium-ion batteries via application of crude wet shredding.***

| Pros | Cons |
|---|---|
| • Can be built as small as 2000 TPA and then scaled up as needed.<br>• Commonality of equipment means that maintenance and parts are widely available.<br>• Can be easily achievable with off-the-shelf components.<br>• Subject matter experts available for consulting.<br>• Material output is known and acceptable to consumers.<br>• Access to global markets for products from Hawai‘i (assuming regulatory compliance). | • Requires hazardous waste processing permit.<br>• Scale sensitive. Profit margins are very tight and highly dependent upon market timing. Can rapidly over capitalize (build too big a plant) and go upside down on profits very fast).<br>• Air control equipment must control off gassing and odors produced from processing.<br>• Agree with cons above as Hawai‘i has small volumes of batteries and processing scaling will be paramount.<br>• Crude shred must be refined enough for material output to be acceptable to consumers. |

| Pros | Cons |
| --- | --- |
| • Can have continuous processing eliminating risk of storage of batteries.<br>• Other outputs can generate revenue (copper, precious metals, aluminum).<br>• Avoids shipping used batteries from Hawaiʻi.<br>• Development of a public/private partnership may expedite siting and permitting. | • Water may be an issue, but usually net negative.<br>• Permitting may be lengthy and incredibly costly.<br>• Operational placement may be problematic and costly (land, buildings, etc.).<br>• May need bigger wet shred operation for EV sized batteries and modules.<br>• Biological risk due to possible inhalation of gases and vapors during crushing or drying, such as electrolyte compounds or degradation products of the conductive salt with water and organic compounds.<br>• Biological risk due to possible inhalation of black mass dust resulting from the transport, sieving, and packaging of black mass.<br>• Fire risk during crushing and drying due to the presence of flammable compounds in the electrolyte composition.<br>• Explosion risks in certain scenarios if chemicals are not properly contained and handled. |

## DISCUSSION

Located in the middle of the Pacific Ocean, largely dependent upon ocean shipping, and working under a mandate to expand and accelerate renewable resource development by 2035[185], the state of Hawai‘i is facing an oncoming crisis with respect to the flow of used "waste" EOL lithium-ion batteries in all formats entering the waste stream. Exasperating this crisis is the reality that LIBs share a concerning similarity to military bombs: they both release a tremendous amount of stored energy very rapidly. While such explosions are a dangerous malfunction and not the intended function of lithium batteries, their pervasive distribution at all scales and formats within every facet of our community, coupled with high ignorance of their proper treatment, use, and disposal, nonetheless imposes significant risk to Hawai‘i's population and economy. Indeed, warning signs are already appearing in: the refusal of many local salvagers to accept EVs[186]; tow truck drivers increasing reluctance to take on and tow abandoned/damaged EVs[187]; the increasing occurrence of fires in refuse vehicles[188], at transfer stations[189], and refuse processing facilities (H-Power)[190]; and the appearance of fires at homes containing e-bikes, e-scooters, and energy storage systems[191]. Moreover, the recent surge of fires on-board ocean-going vessels have catalyzed a recent decision by Matson[192] and Alaska Marine Lines[193] to forbid the shipment of new EV vehicles, let alone used EOL EVs. The shipping giant Mediterranean Shipping Company (MSC) has explicitly stated that it will not transport used or damaged lithium-ion batteries in ocean containers[194]. Meanwhile, CMA CGM has banned shipment of electric and hybrid vehicles older than seven years[195].

---

185 https://governor.hawaii.gov/main/governor-green-reinforces-commitment-to-renewable-energy/.
186 Personal communications and, for example, https://www.kitv.com/news/dead-batteries-from-electric-vehicles-in-hawaii-find-dead-ends/article_92426e58-3279-11ee-8f25-3b6dbd36030e.html.
187 Personal communications.
188 https://www.youtube.com/watch?v=45UXxT4BUr0.
189 Personal communications.
190 Personal communications and, for example, https://www.hawaiinewsnow.com/2024/07/16/ems-5-men-treated-smoke-inhalation-2-alarm-fire-h-power-plant/.
191 https://youtu.be/vgEFEZd9mEE?si=h1c6GGkMxfS35fJD.
192 https://subscriber.politicopro.com/article/eenews/2025/08/05/hawaiian-shipper-stops-ev-deliveries-because-of-battery-fires-00492913.
193 https://alaskapublic.org/news/public-safety/2025-08-20/alaska-marine-lines-will-no-longer-ship-electric-vehicles-due-to-fire-risk.
194 https://www.icetransport.com/blog/can-i-ship-lithium-batteries-in-an-ocean-container.
195 https://www.cma-cgm.com/assets/public/pdf/Client%20advisory%20Booking%20Guidelines%20for%20EVHEV%20cars%20%20General%20forms%20of%20vehicles%20CCAI467081123.pdf.

Additionally, even when it is possible to ship lithium batteries (and equipment containing them), the restrictions are only getting tighter and the costs (to ship) only higher[196]. The presence of any quality statewide stewardship structure that increases public and business access to readily accessible and cost-effective disposal solutions will only help to reduce these and all other concerns.

Three potential remedies to the overall dilemma of expanding volume of used "waste" EOL LIBs generated in Hawaiʻi were explored. In the first, used "waste" EOL lithium batteries are not physically treated by any method other than to package and ship them directly to mainland recyclers. In the second, the used "waste" EOL lithium batteries are deactivated using treatment by supercritical $CO_2$ prior to packaging and shipping them directly to mainland recyclers. In the third, the lithium batteries are deactivated by wet shredding them to an inert crude black mass that is then shipped directly to mainland recyclers. For all three, the physical requirements of each method are provided in great detail. When evaluating these pathways, the following attributes were weighted: (i) the ability to reduce the overall cost of disposal at large scale; (ii) fit to the existing education/commercial expertise of Hawaiʻi's local work force; (iii) tolerance/acceptance of stewardship structure/treatment methods to insurance underwriters and shipping companies; (iv) the adaptability of design to other waste stream products in the event of new battery technologies entering the market; (v) the ability to capture/process over 95% of *all* used "waste" EOL lithium batteries produced in Hawaiʻi regardless of format; (vi) ease of access to/or integration with existing waste management businesses in Hawaiʻi; and (vii) the likelihood to reduce the illegal storage, abandonment, dumping, and/or misleading manifest declarations[197].

Of the three methods reviewed, the one most easily accessible to the public, most practical to implement at a large scale, and most likely to minimize insurance risk was the wet shredding operation[198]. The key advantages supporting the wet shred option included (but were not limited to): (i) modularity that supports easy repurposing and redesign; (ii) scalability that allows for expansion or contraction based upon market demand; (iii) production of an inert crude black mass this is both safe for marine transport[199] and readily acceptable to a variety of mainland recycle operations; and (iv) relative cost competitiveness at large scale. The other two options considered were (i) deactivation by exposure to supercritical carbon dioxide and (ii) straight packaging of the used "waste" lithium batteries without any pretreatment. These were found less completive at a large scale owing to one or more of the following factors: (i) higher capital and/or operating costs;

---

[196] https://www.iims.org.uk/transporting-li-ion-batteries-identifying-and-addressing-the-risks/.

[197] All of which could become unacceptably high, both to the shipping companies and to the insurance industry that covers ***all*** facets of exposure to lithium-ion batteries in the state.

[198] Not considered by the working group was treatment option centered around crushing that was developed by the EPA and colleagues to address the DDR lithium batteries produced by the Lahaina fires. Despite many basic similarities to wet shredding, at the time of this report this was considered too immature in terms of development for a requirements study.

[199] With the obvious recognition that the crude black mass must be packaged to avoid risk of spillage to the environment.

(ii) a lack of de-escalating risk during marine and/or land transport; (iii) a lack of successful demonstration/implementation at commercial scale; and (iv) a perceived lack of scalability relative to the volumes used "waste" EOL lithium batteries expected to be generated in Hawaiʻi. That being said, the working group strongly noted that despite the heavier requirements of the additional treatment/shipping pathways, it could still make sense for certain private businesses to pursue either of the other two (and even others) on a case-by-case basis. For example, the supercritical $CO_2$ pathway was considered suited for niche applications of smaller feedstocks on outer islands or to handle particularly difficult DDR batteries, such as after fires. Part of the reasoning for this was recognition of Hawaiʻi's unique geography of five separate islands, each with different levels of waste streams and technological/shipping/transporting capacity.

The insurance requirements of each treatment pathway were also examined and found to be extensive and important to consider when developing policy. Currently, it is the responsibility of all participations in the logistic train that handle the used "waste" EOL lithium batteries to indecently purchase their own insurance, despite the fact their rates can be impacted by the actions of other participants in the logistical pathway. It was also found that the insurance requirements are heavily influenced by the treatment pathway. For example, the use of a wet shred operation to reduce used "waste" EOL lithium batteries to a crude inert black mass (this is safe for marine transport[200]) could dramatically minimize insurance risk and thus cost, while purchasing insurance for those using the pathway of simply packaging "as is" could become so costly and complex that it would encourage unacceptably high levels of illegal/inappropriate storage, abandonment, dumping, and/or misleading manifest declarations. Also, the complexity and burdensome nature of insurance purchase for all participants in the logistic train were highlighted. In particular, insurance underwriters were found likely to not only put onerous demands on business to identify their exposure to used "waste" EOL lithium batteries, but also to include information on that from all downstream participants who feed them the batteries.

In addition, three frameworks of stewardship structures, each of which would manage and fund the collection, on-island transport, on-island temporary storage, on-island sorting, on-island treatment (by *any* of the three processes considered above), and off-island shipment to mainland recyclers were reviewed. Several factors were identified that influenced the need for a state-independent stewardship structure: (i) the complexity of the logistic train and the large number of active players therein; (ii) the requirement of insurance for each player in the logistic train along with the extensive nature of insurance requirements and concerns of underwriters; and (iii) the growing concern of shippers and their insurers to not only ship used "waste" EOL lithium batteries but also their ability to provide this service at low cost. While a detailed analysis of the requirements for each stewardship structure will be provided in a forthcoming report[201], the stewardship structure determined to possess the most potential was a state sanctioned non-

[200] Provided, of course, the crude black mass is properly contained to avoid spillage to the environment.
[201] Expected to be completed by Spring 2026.

government aligned professional responsibility organization that can/will oversee a broad portfolio of public/private efforts to manage the capture and processing of the entire spectrum of lithium batteries. This model (Model C in our analysis) has the authority to manage: (i) private businesses that manage of the collection and transport of their own used "waste" EOL lithium batteries to mainland recyclers; (ii) manufactures who pay into the stewardship structure under EPR type laws/agreements; and (iii) a privately run but publicly funded facility that tracks the collection, on-island transport, temporary storage, sorting and pretreatment and/or packaging of all remaining used "waste" EOL lithium batteries in all formats. It was also strongly felt that the stewardship structure should be funded from a number of avenues including (but not limited to) a combination of EPR laws, advanced disposed fees at the time of purchase, taxes/registration fees, and tipping fees.