WRI INDIA

CONFERENCE PROCEEDINGS

Safety Management for EV Battery Reuse and Recycling in India

A SUMMARY OF EXPERT PERSPECTIVES

January 13, 2023 | New Delhi | Dr. Parveen Kumar and Pawan Mulukutla

BACKGROUND

WRI India hosted a panel discussion titled "Battery Safety for Reuse and Recycling" to discuss the current gaps in policies and regulations pertaining to the safety challenges that arise during the reuse and recycling of electric vehicle (EV) batteries. The panel also explored the development of safe pathways for the transition of batteries during their life cycle. This session was part of the "Global Electric Vehicle Battery Safety Forum" organized by the India Energy Storage Alliance (IESA). Experts on the panel (see the list of experts in Appendix A) discussed policies, standards, and regulations as well as the future course of action for a safer EV battery reuse and recycling ecosystem in India. The panel discussed the possible enabling actions required to ensure safety in the reuse and recycling phase of EV batteries.

The topics of discussion included the following:

- The status of testing and certification for a safe battery reuse and recycling ecosystem.
- Gaps in policies, regulations, and standards that can address the quality and safety concerns that arise during the life cycle of EV batteries.
- Possible changes that can be incorporated during the battery manufacturing process to make batteries safer during their first life, reuse applications, and recycling.
- The types of data required and the architecture of a data sharing system for safe life cycle management of EV batteries.
- Safety requirements during transportation, storage, inventory, and operation of retired EV batteries.

CONTENTS

DISCLAIMER: The contents of the conference proceedings reflect the views of the participants in the panel discussion on Battery Safety for Reuse and Recycling held in the Global EV Battery Safety Forum organized by the India Energy Storage Alliance (IESA), where WRI India was a session partner. The conference proceedings do not necessarily reflect the views of WRI India or other event partners. The content of the conference proceedings aims to faithfully reflect the conversations and content generated at the panel discussion, but for readability, some text has been edited.

INTRODUCTION

Globally, the growing EV market will create 1.2 million tons of recycling opportunities and more than 200 gigawatt-hour (GWh) of second-life utilization opportunities for retired lithium-ion batteries (LIBs) by 2030 (Willuhn 2019). When EV batteries degrade by 20–30 percent, they are no longer suitable for primary EV applications; however, the remaining 70–80 percent of the battery capacity is still suitable for second-life applications, which are stationary applications such as behind-the-meter, front-of-the-meter, telecommunications, data center backup services, renewable-energy-powered EV charging stations, and low-power EV applications. The end-of-life (EOL) recycling of these batteries needs to be planned in a safe, resource-efficient, and environment-friendly manner to alleviate the rising demand pressure on the critical metals used in battery manufacturing.

Safety features are one of the most critical requirements for LIBs, especially in EV applications (about 90 percent of the LIB market is going to be driven by EVs by 2030 [Gulia et al. 2022]). Multiple instances of fire hazards have occurred in LIBs during transportation in the EV use phase. However, these fire hazards are not only limited to first-life of EV applications. Such safety concerns are greater during post-EV applications, when batteries are considered for reuse and recycling. This is because the internal and external characteristics of EV batteries change significantly after completing several cycles in harsh conditions, leading to a reduction in primary safety characteristics—thus, these batteries need more careful handling. In the case of lead acid batteries (LABs), the recycling industry is currently dominated by informal players, who could enter the LIB battery reuse and recycling industry on a large scale. The lack of awareness in the informal sector of the safety considerations when handling these batteries may pose a big challenge to the safety of workers and the environment. The absence of safety considerations could lead to safety hazards in the reuse and recycling industry. In 2021, China restricted the use of refurbished EV batteries in large-scale energy storage applications due to several fire incidents in recycling facilities and energy storage facilities. Shen (2021) suggested that early adoption of refurbished EV batteries in energy storage applications in conjunction with the lack of technical standards was the primary cause of such fire accidents.

Following safety measures when handling LIBs is important for extended battery durability, the circular economy, and the safety of workers and of the environment. In India, early-phase retired EV batteries will soon be in the market, and their reuse and recycling potential will be explored. Current regulations and standards mainly deal with the safety of LIBs in EV applications. As we move toward a circular economy in the LIB ecosystem, safety measures for LIBs in post-EV applications will be critical. Stringent policies, regulations, and a standardization and certification ecosystem will make battery reuse and recycling safer and reduce accidents.

SAFETY CHALLENGES ASSOCIATED WITH THE EV BATTERY REUSE AND RECYCLING ECOSYSTEM

Safety challenges in LIB reuse and recycling processes must be addressed, and the necessary precautions should be taken. Disregarding safety considerations may lead to various types of risks such as thermal runaway. The safety concerns involved in reuse and recycling of spent EV LIBs are discussed below, and Figure 1 maps the safety challenges involved in the circular economy.

Unorganized sector: The safety challenge in post-EV applications starts with the collection of retired batteries for reuse and recycling. The unorganized sector, which currently dominates the battery recycling market, has become a major concern for the safety of workers and of the environment because this sector does not adhere to safety guidelines. A system for data collection and sharing is needed that will help trace batteries from the cradle to the grave. The domination of the unorganized sector makes managing the data and the details of assets a major challenge for the sector.

Transportation and storage: Transportation and storage of LIBs is a major safety concern not only in India but globally as well. This safety concern becomes more acute when storing and transporting retired EV batteries. The lack of standards and safety measures for the storage and transportation of EV batteries makes the reverse logistics process unsafe and challenging.

Dismantling and refurbishment: Both reuse (refurbishment) and recycling entail dismantling of the battery. This dismantling involves mechanical processes that can potentially result in mechanical abuse of the battery and thermal runaway in the battery, thus creating a hazardous situation and a worker safety challenge.

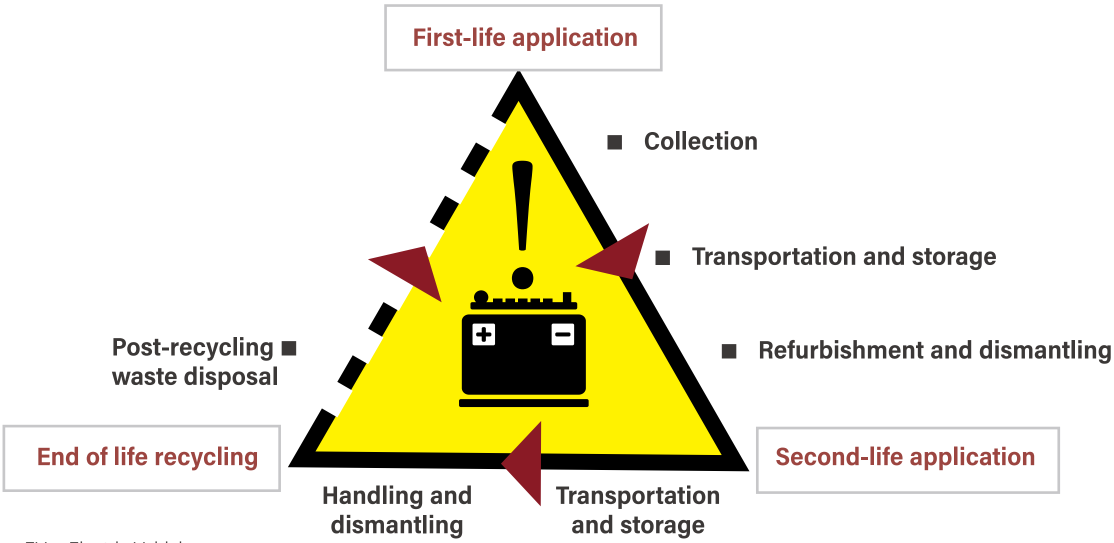
Human resources: The handling of LIBs needs a skilled workforce or automation during the entire process of refurbishment or recycling. Currently, India does not have enough skilled workers or any design standardization for the adoption of automation in reuse and recycling of LIBs, which makes the entire process inefficient.

Public awareness: There is a need to increase consumer confidence in buying refurbished or reused batteries. Because the battery goes through various phases in the first-life application, consumers have safety concerns about its second-life application. Raising the awareness of consumers and their confidence in the safety of second-life applications of batteries is a major challenge.

Gaps in policies and regulations: Currently, in India, only the Battery Waste Management Rules, address battery recycling. The second-life application potential of batteries is discussed in the Draft Battery Swapping Policy, which has not been implemented yet. Robust policies and regulations are needed because EV battery waste is going to increase significantly in the coming years.

Gaps in testing and standards: For the life-cycle safety of batteries, a rigorous battery testing ecosystem is necessary. Battery testing along with the required standards will ensure safe and proper utilization of post-first-life battery applications. Currently, in India, standard norms such as AIS-156 and AIS-038 ensure the safety of batteries in electric vehicles. Similar standards also need to be implemented in or extended to refurbished batteries to increase consumer confidence in their adoption and promote safe recycling practices in the industry.

FIGURE 1 | Safety challenge mapping of post-first-life application of EV battery



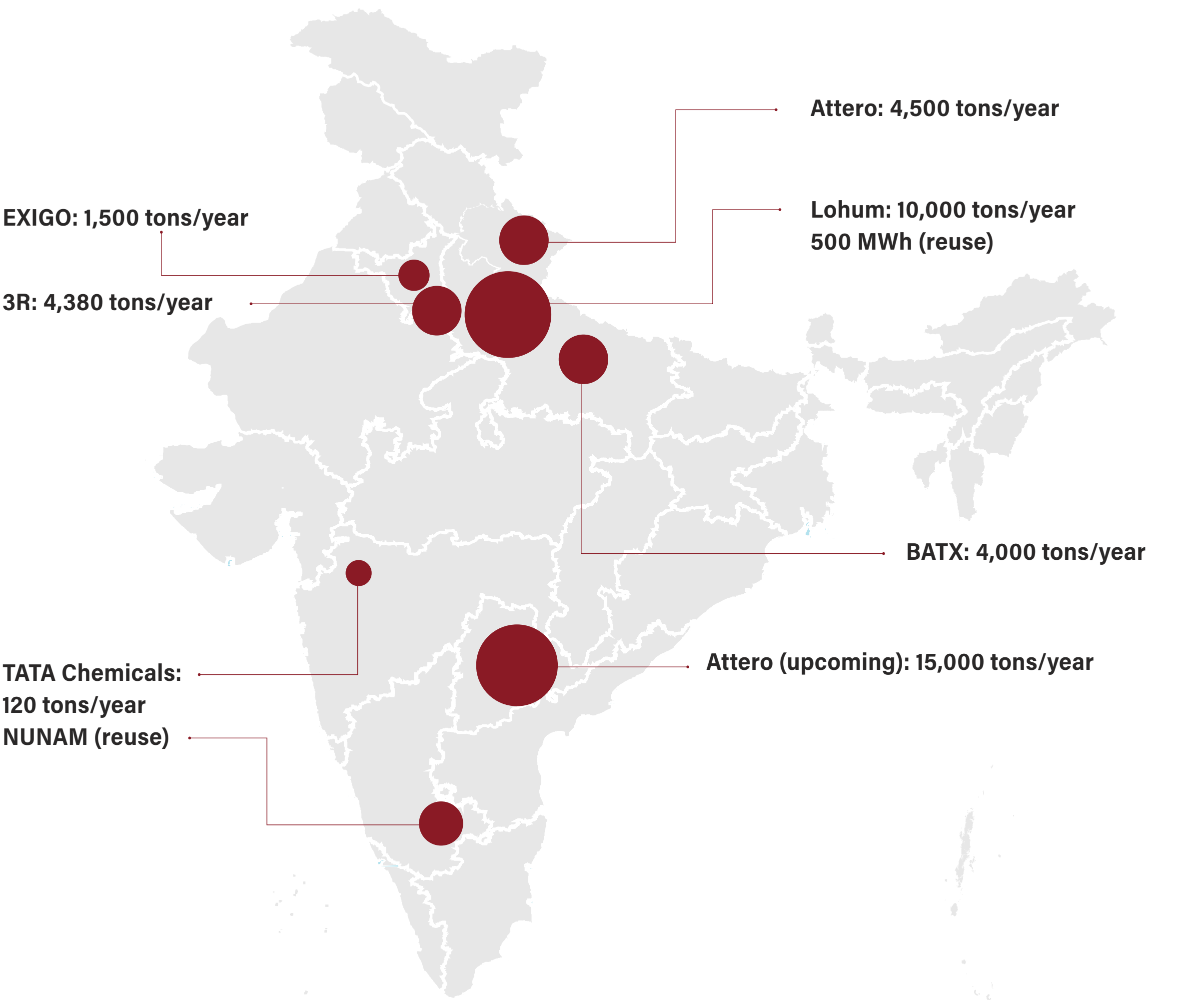
Notes: EV = Electric Vehicle.
Source: Developed by WRI India.

MARKET ANALYSIS FOR SAFETY DURING REUSE AND RECYCLING OF EV BATTERIES

LIB reuse and recycling market footprint in India

In India, the battery recycling industry can be divided into the unorganized and organized sectors. Out of all the retired LIBs available as of 2020, 70 percent of the phased-out LIBs are either dumped in landfills or not received by the organized or unorganized sector for recycling. Twenty percent is recycled in the unorganized sector, out of the remaining 30 percent, 5 percent is recycled in the organized sector, and 5 percent is exported for recycling (Gattu et al. 2022). Although recycling of LIBs has begun in India, most of the black mass recovered from LIBs is still shipped outside India for further processing to get battery-grade raw material. Indian companies such as Attero recycle with 98 percent (Anand 2022) efficiency through their patented technology and are capable of extracting battery-grade raw materials such as lithium, cobalt, nickel, graphite, and manganese from the recycled black mass. Similarly, Lohum, through its patented technology Metelec™, recycles LIBs without producing any waste (Team AutoStory 2023). However, recycling players such as SungEel and TES-AMM (EVreporter 2019) in collaboration with international recyclers are exporting the black mass after mechanically disintegrating LIBs. Figure 2 shows some key players involved in LIB reuse and recycling within India along with their capacities.

FIGURE 2 | Selected Li-ion battery reuse and recycling players and their capacities



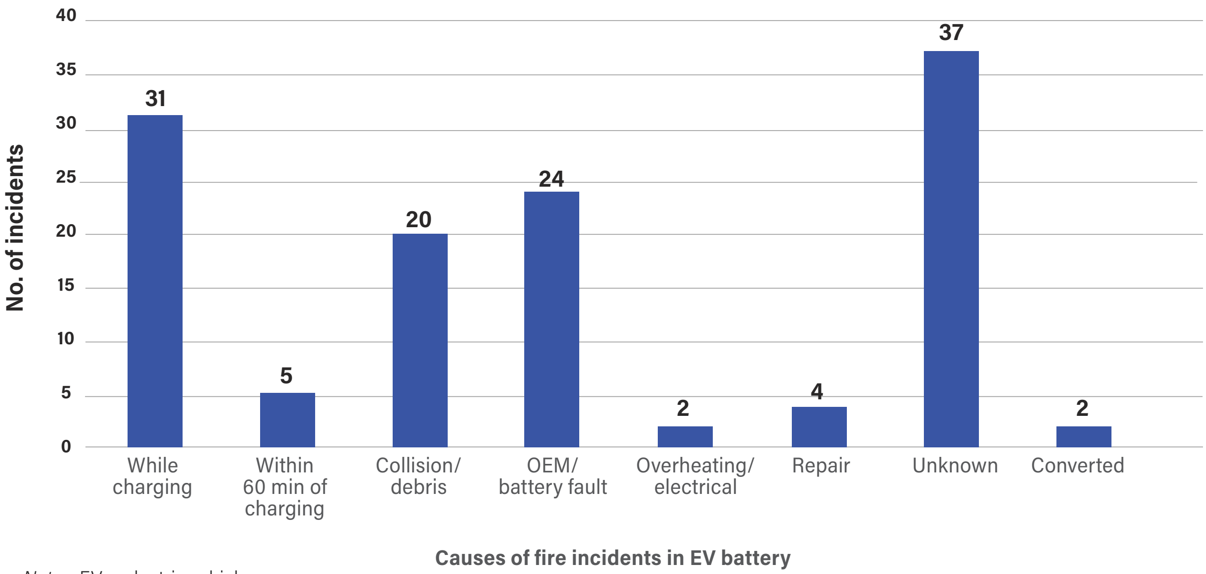
DISCLAIMER: This map is for illustrative purposes and does not imply the expression of any opinion on the part of WRI India concerning the legal status of any country or territory or concerning the delimitation of frontiers or boundaries.
Sources: Author-generated map, compiled by WRI India.

Currently, the Indian battery recycling industry is dominated by players from the unorganized sector, which collects the majority of the retired batteries. This sector consists of itinerant collectors, scrap dealers, and informal smelters, who sell the recycled material to local battery manufacturers or assemblers, who in turn sell the product to retailers. The organized sector handles the flow of batteries from end consumers to recycling plants through well-defined channels such as registered recyclers, battery manufacturers, or battery vendors. Although worker and environmental safety norms are strictly followed throughout the recycling and disposal of collected batteries in the organized sector, this is not true of the informal smelters.

Fire hazards in EV batteries

In EVs, fire incidents due to battery failure are well known. These fire incidents are not limited to EV applications (the primary application); there is a significant risk of fire incidents due to thermal runaway in the battery during reuse and recycling, especially in the dismantling phase, where mechanical abuse of the battery may give rise to such hazards. These incidents are rare because the LIB reuse and recycling industry is in the nascent stage. Over time, such incidents could become more frequent as the number of retired EV batteries increases, unless suitable safety measures are instituted. Figure 3 shows the incidence of fire accidents in the various phases of LIB use.

FIGURE 3 | Global incidence of EV battery fires by cause (2010 -2023)



Notes: EV = electric vehicle.
Source: EV Fire Safe 2023.

Precautions need to be taken not only in the reuse and recycling activity but also while handling (storage and transportation) spent batteries. Improper handling of spent batteries can cause a fire hazard if proper precautions are not taken. In the United States and Canada, waste batteries caused 317 fire incidents in 2020, 367 incidents in 2021, and 390 incidents in 2022 in waste and recycling facilities (Quinn 2023). Because LIB reuse and recycling is an emerging industry in India, proper safety measures must be instituted to prevent such hazards.

These safety measures need to be implemented strictly along with interventions in the form of policies, regulations, and standardization processes. Along with regulatory interventions, some technological interventions in the battery manufacturing process can further ensure the safety of the battery pack. One possible technical intervention in the battery manufacturing process is the inclusion of fire-resistant material in the battery pack design. Thermal conductivity and material density are two important criteria for selecting a fire-resistant material for an EV battery. Materials such as ceramic sheets and mica sheets can be used in the cell bottom and lid to restrict fire propagation. For pouch cells, compression pads can be used to restrict cell swelling. Currently, aerogel and lightweight encapsulating foam are used by General Motors and Tesla, respectively, in their battery packs to prevent fire hazards (Grom 2022).

Status of policies and regulations for safe LIB reuse and recycling

Various policies and regulations have been implemented by international organizations and governments for the safety of batteries in the reuse and recycling phase. For example, the labeling requirement in LIB batteries for basic information about the battery is useful for both reuse and recycling purposes and is currently mandated by Europe, the United Kingdom, the United States, China, and India. Similarly, dismantling is a major activity in reuse and recycling, and safety measures for it are mandated by only the United Kingdom and China. Table 1 shows the policies and regulations of various countries for ensuring the safety of LIBs in the reuse and recycling phase.

TABLE 1 | Policies and regulations of various countries for ensuring reuse and recycling safety

COUNTRY	PHASE	POLICY/REGULATION	ACTION
Europe	Labeling	New EU battery policy	Labeling complying with ADR norms or any other labeling indicating the presence of hazardous material
	End of first life		SoH data and battery passport
	Other		Prohibits disposal to the environment
United Kingdom	Dismantling	Waste battery and accumulator regulations	Details procedure for dismantling battery
	Storage and transportation		Safe and environment-friendly transport
United States	Labeling	AB 2832	Information regarding type of material and electrode
China	Labeling	GB/T34014-2017	Unique labeling of battery
	Reuse	NEA	Mandatory compliance with safety evaluations
			Regular evaluation of battery and emergency plan
	Storage	GB 18599-2016	Safe storage of waste power battery
		GB/T33598-2017	Storage management standard
	Dismantling		Dismantling standard
	Packaging and transport	WB/T 1061-2016	Safe transportation and packing
Korea	Reuse	KBIA	Second-life battery grading evaluation
India	Storage and transportation	Battery Waste Management Rule 2022	CPCB is developing guidelines for storage and transportation
	Post-processing		Disposal according to Hazardous Waste Management Rule 2016

Notes: ADR = Accord Dangereux Routier; CPCB = Central Pollution Control Board; SoH = State of Health; KBIA: Korea Battery Industry Association; NEA: National Energy Administrator.
Source: Authors' analysis.

Battery testing and standards for safety

Stringent testing and standards are necessary for a safe battery reuse and recycling ecosystem. Various national and international testing standards are already available. These safety tests and standards are designed to ensure that the risk of safety accidents in certified LIBs is low in specified kinds of thermal runaway induction and expansion situations.

TABLE 2 | International standards that can be adapted for battery testing in reuse and recycling

STANDARD SYSTEM	STANDARD CODE	STANDARD FULL NAME	YEAR	STANDARDS SERIES	APPLICATION SCOPE	TECHNICAL CHARACTERISTICS
SAE	SAE J2464-2009	Electric and Hybrid Vehicle Rechargeable Energy Storage System Safety and Abuse Testing	Released in 1999, revised in 2009	SAE J1715 SAE J1739 SAE J1950 SAE J2344	Battery pack and battery system	Security requirements
UN	UN38.3	United Nations Manual on Hazardous Materials Transport Tests and Standards, Part 3, Section 38.3	2015	n/a	Battery cell, module, and pack	Security requirements
ISO	ISO 16750–2	Road Vehicles - Environmental Conditions and Testing for Electrical and Electronic Equipment - Part 2: Electrical Loads	2010	ISO 16750–1 ISO 16750–3 ISO 16750–4 ISO 16750–5	Battery cell, module, and pack	Reliability and safety test specifications
IEC	IEC 62660–2-2010	Secondary Lithium Ion Cells for the Propulsion of Electric Road Vehicles – Part 2: Reliability and Abuse Testing	2010	IEC 62660 –3-2016 IEC 60068–2-2 IEC 62133–2012	Battery cell	Reliability and safety test specifications
UL	UL 2580–2010	Battery Safety Standards for Electric Vehicles	2013	UL 1642–2009 UL 2054–2009	Battery cell, module, pack, and system	Requirements for electrical performance, environmental suitability, and safety

Notes: n/a = not applicable.
Source: *Chen et al. 2021.*

In India, testing standards for the safety of new batteries can be extended for the safety of refurbishment or recycling of batteries. Organizations such as the Automotive Research Association of India (ARAI) and the International Centre for Automotive Technology (ICAT) perform these tests for safety evaluation.

TABLE 3 | Indian standards suitable for battery testing in reuse and recycling

STANDARD SYSTEM	YEAR	STANDARDS	TECHNICAL CHARACTERISTICS
AIS	2016	AIS 048	Safety requirements of traction battery
	2020	AIS 156	Vibration test Thermal shock and cycling test Mechanical drop test for removable REESS Mechanical shock Fire resistance External shock circuit protection Overcharge protection Over-discharge protection Over-temperature protection

Notes: AIS = Automotive Industry Standard; REESS = rechargeable energy storage system.
Source: Pandya 2022.

Timely assessment of LIBs is important because it ensures safety and provides better economic value throughout the lifespan of the battery. Along with these safety assessments, remaining useful life (RUL) testing is necessary for reuse in the appropriate application. Similarly, for safe recycling, residual power/ residual capacity testing can be considered.

GROUP DISCUSSION OUTCOMES

The webinar explored the following themes:

- Safety standards and regulations needed during battery reuse and recycling.
- The importance of the battery design for a smooth reuse and recycling process.
- The need for standardizing assessment, testing, and certification of retired EV batteries.
- The role of data logging and a robust data analytics system in decision-making during reuse and recycling of EV batteries.

Key lessons and entry point for action

Battery pack design for safe reuse and recycling

EXPERTS' INPUTS: The current structure of the battery packs makes it hard for the battery to be dismantled for reuse and recycling. The structure and design of the battery packs needs to be simplified considering potential reuse and dismantling as a feature, without compromising the safety aspects. The batteries retiring from EV applications in the early phase will pose a major challenge in the reuse stage because these batteries were not manufactured considering their potential second-life application. Therefore, the stakeholders have to take responsibility for the safety of these early-stage batteries if they are used in second-life applications or considered for recycling. It is necessary to ensure that battery packs are designed keeping repurposing in mind during the manufacturing stage itself. This can be achieved by adopting standards serving the common purpose of safe reuse and recycling with a minimum set of criteria. However, hard standardization in pack design will no longer work in the current scenario as battery pack development is at a nascent stage, and continuous innovations are occurring in cell design. For a safe and financially feasible recycling ecosystem, in addition to recycling-friendly battery pack design, collaborative R&D is needed for a suitable recycling technology that can be applied irrespective of the material content and cathode chemistry.

ENTRY POINTS FOR ACTIONS: Although the cost factor of the battery is important in terms of EV adoption, the safety features of batteries should not be compromised. Batteries should be designed prioritizing safety considerations in accordance with the available standards. The use of some fire-resistant material in the battery pack needs to be mandated for the battery safety throughout the primary application, the subsequent reuse application, and recycling. For safety and efficiency, some baseline standardization can be set while maintaining sufficient scope for innovation.

Assessment, testing, and certification of retired EV batteries

EXPERTS' INPUTS: The internal resistance (IR) of the battery increases as the battery ages. Using the battery after 70–80 percent state of health (SoH) raises safety concerns for EV applications. Before removing a battery for use in other applications, its RUL needs to be checked. The data for the quality of cells in the battery pack must be checked through the battery management system (BMS). A set of assessment criteria with which the battery pack must comply needs to be prepared for each application, and the ideal second-use application must be fixed accordingly. These batteries need to be labeled clearly as refurbished batteries, and they must be prohibited from being used in applications other than for their intended use. It is beneficial for battery manufacturers and the reuse and recycling ecosystem to retire batteries at the right time because it ensures safety and a good buyback value. It is necessary to decide at which point to shift from first life to reuse, and then from reuse to recycling. A large amount of data is required to determine this optimal point, which will provide the highest salvage value for the battery. The data from each cell of the battery pack plays an important role in the decision-making process before recycling or reuse and can be obtained with current technology. Battery packs and cells must be reconditioned before they are used in second-life applications, depending on the intended application. Cell manufacturers recommend that if the IR increases beyond a certain limit, safety dictates that the cell should not be used for any kind of application. To ensure safety, a robust BMS and the necessary testing infrastructure are needed for second-life applications and recycling of these battery packs. A self sustaining BMS containing data from each cell serves as the backbone for safety in the battery pack's entire life cycle. The BMS can also help build a mechanism in which it will perform a self-assessment and decide when the battery is ready for second-life applications and recycling. The SoH, IR, and calendar aging need to be considered when thinking about the safety in battery reuse and recycling. Data logging is needed to understand the state of the cells and the battery pack from the beginning.

ENTRY POINTS FOR ACTIONS: Proper assessment and testing of the battery is needed before it can be moved from first life to second life or recycling. Proper testing and certification needs to be done by testing centers with common sets of standards to evaluate the performance of the battery by assessing its chemistry and data throughout its life. Testing and certification would be critical in terms of safety to develop customer confidence in reused or refurbished batteries in secondary applications. Multidisciplinary and decentralized testing and certification infrastructure must be developed for streamlining the future requirements.

Safety during storage, transportation, and dismantling

EXPERTS' INPUTS: High-power batteries are sensitive to external environmental conditions. All types of LIBs can be damaged when temperatures are too high (above 55°C). External heat sources (open flames, heaters) can also accelerate failure in cells with defects or those that have been damaged due to other causes. The number of EVs continues to increase; therefore, safer logistics and storage systems are needed for the batteries sourced from these EVs. If these batteries are segregated at the source after assessing their vulnerability with the help of BMS data, a relatively safer battery reuse and recycling ecosystem can be developed.

ENTRY POINTS FOR ACTIONS: For the safe storage and transportation of retired EV batteries, they must be packed in a system having heat insulation, leak resistance, stabilization or shock proofing, and appropriate labeling. Safe packaging and transportation of these batteries requires special containers along with robust procedures such as prior informed consent (PIC). Guidelines need to be mandated for the storage of LIBs in the appropriate ecosystem.

Regulation and standards for a safe reuse and recycling ecosystem

EXPERTS' INPUTS: Safety should be the paramount consideration not only in the first life but throughout the battery's life, from the primary application to reuse and recycling. In terms of existing norms and regulations, India currently has the AIS 156 standard, which ensures that the battery will be roadworthy if it adheres to the standard for the first-life and post-first-life applications. Among the UL standards, UL-1973 and 1974 cover repurposing. The AIS Phase 2 standard includes data logging, which is essential for safety during reuse and recycling. The cost of the data should be included in the reuse and recycling process. Stringent implementation of the existing AIS standards, battery recycling regulations, and timely issuance of battery swapping regulations is the current need for a safe reuse and recycling ecosystem. The introduction of regulations similar to the battery passport system of the UK will provide end-to-end traceability and will ensure that the battery does not end up in the unorganized sector, which poses a major safety risk in the handling of LIBs.

ENTRY POINTS FOR ACTIONS: The reuse and recycling industry should be considered a revenue-generating industry instead of a cost-centric industry. Large investments in technology are needed for the safe collection, transportation, and management of retired LIBs. Strict implementation of safety regulations and standards is also needed. Because of the nascent stage of the industry, innovative business models and government schemes are needed to ensure the proper and safe functioning of the reuse and recycling sector.

Worker and environmental safety

EXPERTS' INPUTS: To prevent accidents and mitigate potential hazards during the reuse and recycling process, it is crucial to ensure the safety of workers and of the environment. Only the organized sector can help achieve this. A transparent incentive mechanism for battery exchanges can be developed by the industry to restrict the unorganized sector. Skill development in the workforce is necessary to ensure the safety of workers. In various skill development institutions such as the Industrial Training Institutes, training on safety risks and precautionary measures should be given in collaboration with the industry. Safety is not just for human beings; the safety of the environment is equally important. Due to the lack of awareness of battery handling and the shortage of skilled workers, ensuring the safety of workers and of the environment is a major challenge.

ENTRY POINTS FOR ACTIONS: To ensure worker safety, skill development workshops should be conducted in collaboration with the industry in various training institutions. The organized sector should collaborate with the automobile service sectors and develop a transparent mechanism where a customer can enjoy incentives in exchange for EV batteries. Such incentives will help ensure the success of the organized sector.

NEXT STEPS

- Safety and performance standards should be implemented for all battery packs rather than standardizing the design of battery packs at the nascent stage of EV adoption, as this would stifle innovation by manufacturers.
- R&D needs to be conducted on technology innovation in priority areas such as an efficient and smart BMS for batteries, artificial intelligence (AI)-enabled battery data collection and analysis methods to identify hazardous conditions during first- and second-life applications, and the development of cost-effective and efficient fire-resistant material for EV batteries.
- RUL assessment criteria for battery packs need to be developed using a method that utilizes BMS, SoH, and IR data to grade (rank) different cells of a battery pack to simplify decision-making related to reuse and recycling applications.
- The required regulations and standards should be implemented to ensure safety during the second-life application of retired EV batteries, and a robust testing and certification ecosystem should be established to ensure consumer safety.
- To minimize the transportation and storage of LIBs in the diverse environmental conditions of India, which exacerbates safety hazards, the usage of second-life applications and recycling of LIBs needs to be prioritized within the boundaries of the state where the LIBs were first used.
- Because LIB fire hazards are not limited to EVs but also affect other consumer electronics devices, the safety risks of LIBs and the safety precautions to be followed when handling them must be included in the curriculum of skill development institutions. Also, academia–industry collaborations are required to organize workforce skill development programs on LIB safety risks and precautions.

APPENDIX A

LIST OF EXPERTS

Mr. Rohan Singh Bais, Founder and CEO, Ziptrax Cleantech Private Limited

Dr. Rashi Gupta, Founder and Managing Director, Vision Mechatronics Private Limited

Mr. Akshay Kashyap, Managing Director, Greenfuel Energy Solutions Private Limited

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LIST OF ABBREVIATIONS

AIS: Automotive Indian Standard

BMS: Battery Management System

CPCB: Central Pollution Control Board

EOL: End of Life

EV: Electric Vehicles

ESAI: Energy Storage Association of India

IEC: International Electrotechnical Commission

IR: Internal Resistance

ISO: International Organization for Standardization

LAB: Lead Acid Battery

LCO: Lithium Cobalt Oxide

LFP: Lithium Iron Phosphate

LIB: Lithium-Ion Battery

NMC: Nickel Manganese Cobalt Oxide

OEM: Original Equipment Manufacturer

PIC: Prior Informed Consent

RUL: Remaining Useful Life

R&D: Research and Development

SAE: Society of Automotive Engineers

SoH: State of Health

UL: Underwriters Laboratories

UN: United Nations

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ABOUT WRI INDIA

WRI India, an independent charity legally registered as the India Resources Trust, provides objective information and practical proposals to foster environmentally sound and socially equitable development. The India Resources Trust has a license from WRI to use the trademark "WRI India." Our work focuses on building sustainable and livable cities and working towards a low carbon economy. Through research, analysis, and recommendations, WRI India puts ideas into action to build transformative solutions to protect the earth, promote livelihoods, and enhance human well-being. We are inspired by and associated with World Resources Institute (WRI), a global research organization with more than 1,000 experts around the world. World Resources Institute began in Washington, DC, in 1982 to provide cutting edge analysis to address global environment and development challenges. WRI spans more than 60 countries, with offices in Brazil, China, Europe, Mexico, India, Indonesia, and the United States. In all these locations, WRI works with government, business, and civil society to drive ambitious action based on high-quality data and objective analysis.

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