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NITI Aayog

Overview of Battery Recycling Ecosystem: Stakeholder identification and perspective on Environment, Health & Safety aspects

NDC TRANSPORT INITIATIVE FOR ASIA

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The study was initiated given the high relevance in addressing the end-of-life management of the used Electric Vehicle batteries. We hope that the study will serve as a useful guideline for the stakeholders in the recycling domain to establish a safe and efficient EV battery recycling ecosystem.

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Abbreviations

AC	Alternate current
AST	Above ground safety tank
BIS	Bureau of Indian Standards
BMS	Battery management system
CPCB	Central pollution control board
CTE	Consent to establish
CTO	Consent to operate
DC	Direct current
DISCOM	Distribution company
EPR	Extended producer responsibility
EV	Electric vehicle
EV OEM	Electric vehicle original equipment manufacturer
GIIP	Good international industry practice
HV	High voltage
IFC	International Finance Corporation
ISO	International Organization for Standardization
LiB	Lithium-ion Battery

MOEFCC	Ministry of environment, forest, and climate change
NOC	No objection certificate
OHSAS	Occupational Health and Safety Assessment Series
PAH	Polycyclic aromatic hydrocarbon
PCB	Printed circuit board
PM	Particulate matter
PPE	Personal protective equipment
PWD	Public works department
SAE	Society of Automotive Engineers
SOP	Standard Operating Procedure
SPCB	State pollution control board
TPD	Tons per day
TSDF	Treatment storage and disposal facility
UIN	Unique Identification Number
UN	United Nations
UST	Underground safety tank
VOC	Volatile organic compounds

Introduction

Introduction

Context

India has outlined an ambitious target of 500 GW of in-country energy generation from non-fossil fuel sources by 2030 and achieve net zero by 2070[1]. These targets reaffirm India's commitment to work towards a low carbon emission pathway, while simultaneously endeavouring to achieve sustainable development goals. The Government has launched many schemes and programs to scale up India's actions on both adaptation and mitigation, and appropriate measures have been taken across many sectors, including water, agriculture, energy and enterprise, sustainable mobility and housing, waste management, circular economy, and resource efficiency, etc

Coupled with the challenges of recent years like severe air pollution, or growing impact of climate change, a large-scale shift from internal combustion vehicles powered by fossil fuels to electric vehicles (EVs) powered by clean, low carbon energy sources is the need of the hour.

However, with the escalating growth of EVs and associated battery production, the end-of-life management of the used batteries becomes a matter of utmost importance. Global EV battery demand increased by about 65% in 2022, reaching around 550 GWh, about the same level as EV battery production. The lithium-ion automotive battery manufacturing capacity in 2022 was roughly 1.5 TWh for the year, implying a utilisation rate of around 35% compared to about 43% in 2021.[1]. Rapid technological developments of battery chemistry and falling prices of battery raw materials (e.g., lithium) shall lead to dominance of lithium-ion batteries in the traction battery space. As per US Department of Energy's Vehicle Technical Office, there has been an 89% decline in the cost of lithium-ion battery pack from 2008 to 2022.

The growing demand can be met by either mining them (provided the country is rich in battery critical minerals) or by extracting them from batteries already placed on market once they reach their end of life. These recovered minerals shall be used to manufacture new batteries.

Increasing impetus toward reusing/refurbishing/repurposing traction batteries is critical for nations not having battery mineral reserves. Traction batteries can be utilized in second-life applications through refurbishing/ repurposing after they reach their end-of-first life. Upon reaching the end-of-second life, such batteries shall be further channelized for recycling and end-of-life disposal.

The entire flow of waste/used/spent batteries from various producers, consumers, collection agencies, refurbishers, waste management authorities after end of first life/ second life comprises the battery recycling ecosystem. A robust recycling ecosystem in a country can promote effective channelization of waste batteries for recycling.

[1] A step towards achieving India's long term goal of reaching net-zero by 2070. Retrieved from pib.gov.in/PressReleaseIframePage.aspx?PRID=1847812
[2] IEA's Global EV Outlook 2023. Retrieved from Global EV Outlook 2023: Catching up with climate ambitions (windows.net)

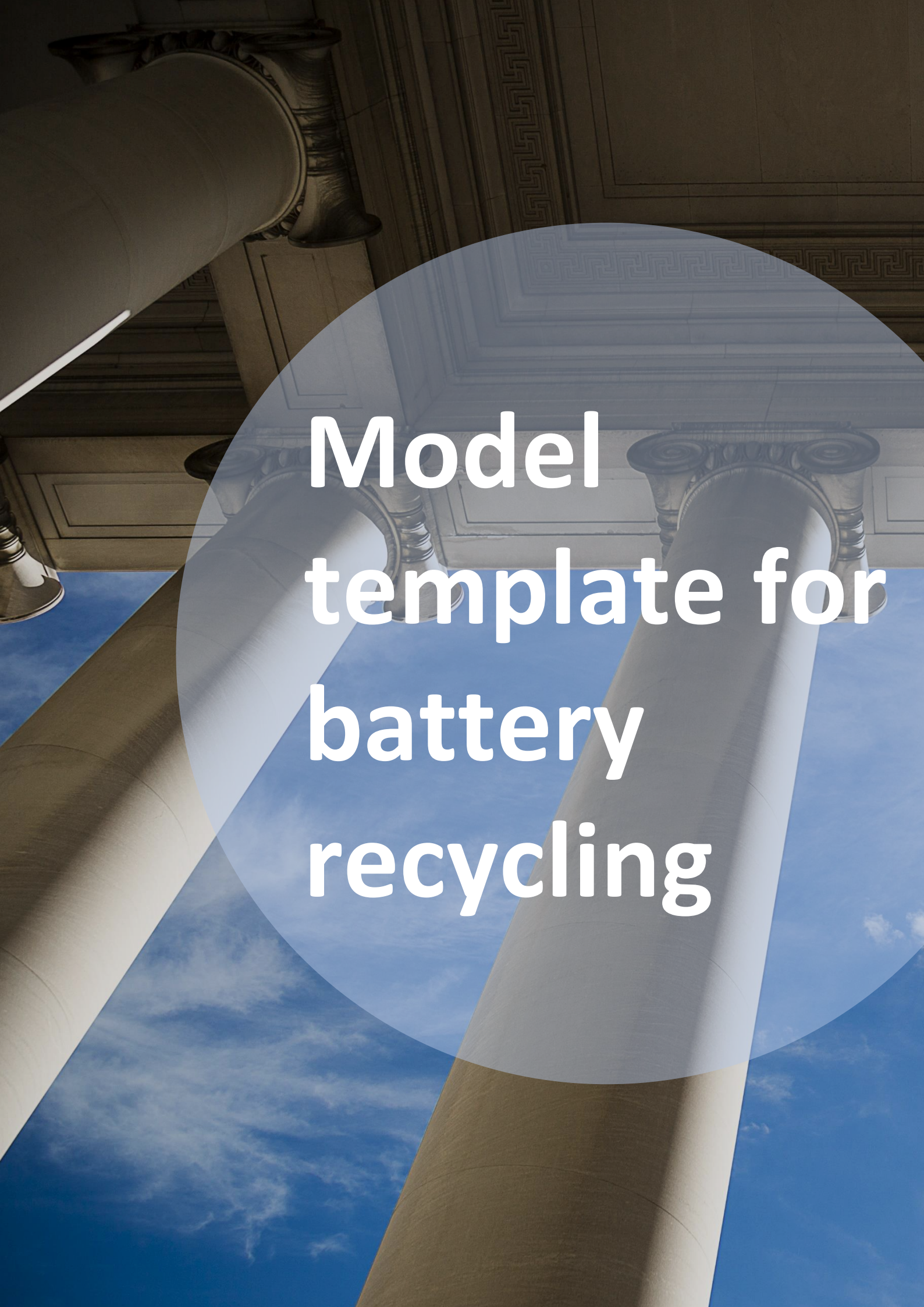
This document has been developed with the purpose of guiding new entities/individuals foraying into the battery recycling/refurbishing. The report aims to:

1. Help the entities in identifying various stakeholders in the ecosystem.
2. Inform about the various permissions required to set up a battery recycling/ refurbishing facility.
3. Identify the various risks involved throughout the ecosystem and suitable mitigation measures adopted in the industry. The entities can choose to adopt such measures or adopt different measures based on their business model.
4. Provide a Standard operating procedure to ensure safe handling of batteries to minimize battery incidents of any nature.

This document thus focuses on providing an overview of battery recycling ecosystem from the perspective of stakeholder identification, risk identification, and its mitigation measures. The report has three chapters:

- **Chapter 1**: **Model template document for battery recycling ecosystem** – It describes the various stakeholders involved in the ecosystem followed by their corresponding roles and responsibilities. Permissions required for establishing a battery recycling/refurbishing facility has also been covered in this chapter.
- **Chapter 2**: **Environmental Health and Safety Risk Screening Framework** – This chapter captures potential risks and their mitigation measures involved in individual steps of battery recycling
- **Chapter 3**: **Standard operating procedures** – This chapter lists out the various procedures to be followed during individual steps of battery recycling.

The intent of this report is to guide new entities in the battery recycling ecosystem in identifying various stakeholders and their corresponding roles and responsibilities, permissions required for setting up battery recycling/refurbishing facilities, risks and corresponding mitigation measures, and standard operating procedures for safe handling of batteries.



Model template for battery recycling

1. Model template document for battery recycling ecosystem

The battery recycling ecosystem consists of stakeholders such as consumers, dealers, producers, battery collection agencies, refurbishing facilities, and recyclers. The ecosystem encompasses the flow of batteries from consumers to recycling facilities through appropriate and defined channels. An effective battery recycling ecosystem can ensure higher collection rates of traction batteries and higher levels of extraction of critical minerals from spent traction batteries.

This model template has been developed to provide an overview of multiple stakeholders involved in the recycling ecosystem and the steps involved in establishing a recycling facility catering to traction batteries reaching their end-of-life.

1.1 Stakeholders in battery recycling ecosystem

The value chain contains stakeholders viz. producers, consumers, dealers, battery collection agencies, refurbishing facilities, recyclers, and disposal facilities. There are business level interactions amongst the mentioned stakeholders which are enabled by policy makers and regulators who shape up the ecosystem through various regulations and incentives. Some stakeholders can also be supported by financial institutions which provide necessary funding support for business growth.

Any consumer can deposit their waste batteries either to a dealer or a battery collecting agency. If the waste batteries are deposited to the dealers, they would be transported to battery collecting agencies. These collecting agencies may be operated individually or jointly by producers.

The waste batteries are transported from the battery collection agencies to either recycling or refurbishing facilities. In case the spent batteries are sent for refurbishment, the batteries and recyclable components not fit for refurbishment are further channelized for recycling. The waste batteries can also be directly sent to recycling facilities for dismantling, recycling, and end-of-life disposal.

The consumer can also choose to dispose-off the waste battery by depositing it to public waste management authorities. The public waste management authority can either carry out recycling and end-of-life disposal themselves or transport those batteries to registered recyclers for recycling and end-of-life disposal.

The steps mentioned are illustrated through a figure:

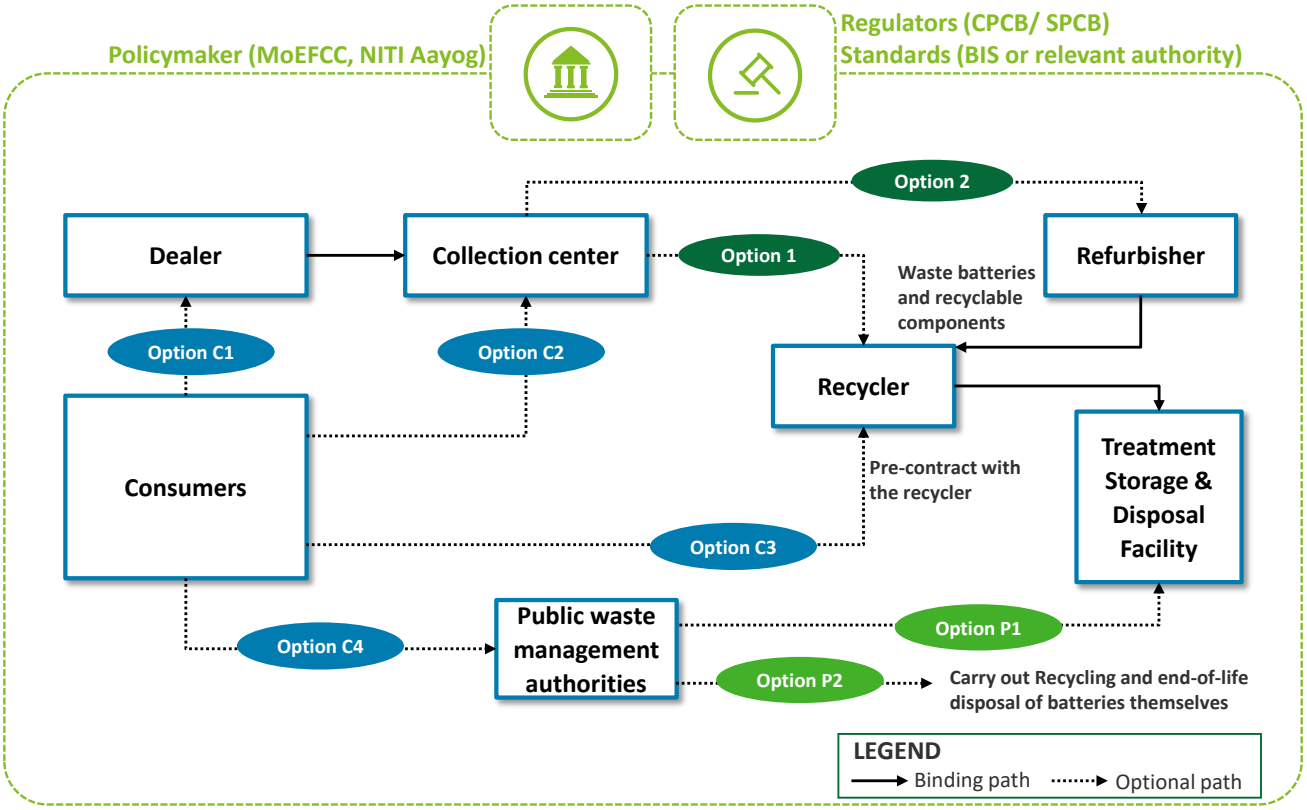


Figure 1: Stakeholders involved in battery recycling ecosystem

The ecosystem also houses other stakeholders. Policy makers such as MoEFCC and NITI Aayog are responsible for the launch of policies and devising incentives. Regulators like central and state pollution control boards ensure compliance with rules and regulations of the ecosystem. Authorities like BIS will also be responsible for releasing standards for efficient and safe handling of waste batteries and battery recycling.

Table 1: List of stakeholders in battery recycling ecosystem

Category		Stakeholders
	Waste feedstock generators	• Consumers
	Collection and transportation facilitators	• Dealer • Battery collection agencies • Producers[2] • Public waste management authorities • Refurbishing facilities
	Recycling and disposal	• Recycler • Public waste management authorities (optional) • Treatment storage and disposal facility (TSDF)

[2] As per Battery Waste Management Rules, 2022 producers may engage itself or authorize any other entity to collect spent batteries on its behalf.

Category		Stakeholders
	Policy and related enablers	• Central pollution control board • State pollution control board • Ministry of Environment, Forest, and Climate Change • NITI Aayog • Bureau of Indian Standards

There are some common responsibilities attached to the stakeholders in the ecosystem which are mentioned below:

Table 2: Common roles and responsibilities for stakeholders

Sl.	Activity	Battery collection agencies	Producer	Refurbisher	Recycler
1.	One time registration with concerned SPCB	✓	✓	✓	✓
2.	Development of IT system to record battery waste handled for scrutiny by SPCBs	✓	✓	✓	✓
3.	Annual/quarterly returns filing with SPCB		✓	✓	✓

Note: SPCB- State Pollution Control Board

The stakeholders are required to maintain adequate records in the centralized portal to be designed by CPCB as per the **Battery Waste Management Rules 2022**. Stakeholders will record the amount of waste batteries handled by them which is subject to scrutiny from the respective SPCBs. In the following sections of the section, we cover the roles and responsibilities of multiple stakeholder groups.

1.1.1 Waste feedstock generation

Waste feedstock generators for waste batteries refer to the users of traction batteries.

1.1.1.1 Consumers

The consumers entail individual EV owners, EV OEMS, battery swapping operators, and fleet operators. The roles and responsibilities of consumers are as follows:

- Consumers will ensure that they deposit spent batteries to dealers or battery collection agencies or public waste management authorities.
- Consumers will ensure that waste batteries are discarded separately from other forms of waste/domestic waste. Producers can incentivize consumers to deposit batteries at the dedicated

battery collection agencies by implementing battery buy back or deposit refund schemes as per Battery Waste Management Rules 2022.

- Consumers will ensure that the spent batteries are deposited in demarcated areas with the seller/dealer from whom the consumer had brought the battery or with entity engaged in collection/refurbishment/recycling/disposal in an environment friendly manner
- The consumers will ensure that they receive an invoice from the dealer for every spent battery sold

1.1.2 Collection and transportation facilitators

This part of the battery recycling ecosystem consists of dealers, battery collection agencies, producers, public waste management authorities and refurbishing facilities. The common roles and responsibilities of these stakeholders have been listed out in the table below:

Sl.	Activity	Dealer	Producer	Battery collection agencies	Public waste management authority	Refurbishing facilities
1.	One time registration with concerned State pollution control boards/MOEFCC	✓	✓	✓	✓	✓
2.	Ensure the collection of used batteries and channelize it for further disposal or recycling	✓	✓	✓	✓	✓
3.	Ensure used batteries collected are of similar type and specifications as new batteries sold	✓	✓	✓	✓	
4.	Ensure the safe transportation of the collected spent batteries to registered recyclers	✓	✓	✓	✓	✓
5.	Records regarding battery waste handled should be made available for scrutiny by concerned State pollution control boards or MOEFCC	✓	✓	✓	✓	✓
6.	Filing annual returns to the concerned State pollution control boards	✓	✓	✓	✓	

1.1.2.1 Dealers

Dealers refer to any entity involved in purchasing batteries from the producers, refurbishers or other dealers for wholesale or retail sale to consumers. Such dealers can be EV showrooms having an integrated service center with the required technical knowhow of handling waste batteries. Dealers will be responsible for collecting spent batteries from consumers. They will set up a demarcated area or box or bin (for e-2w and e-3w batteries) to collect spent batteries from consumers and then send these collected batteries to battery collection agencies.

Other than the primary role mentioned above, some other responsibilities of dealers are mentioned below:

- Ensure that the spent batteries collected are of **similar specifications and type** as compared to the new battery sold
- Ensure that tax is paid, and **an invoice is raised** for every spent battery received/ collected from consumer
- Ensure that the amount as per the take-back system or deposit refund scheme of the producer is **refunded back** to the consumer depositing battery waste
- Ensure that no damage is caused to the environment during the **storage** of the spent batteries by taking respective steps as mentioned in Annexure under **4.1.1 Storage of spent** batteries.
- Ensure **safe transportation** of the collected spent batteries to registered battery collection agencies or recyclers or producer by taking respective steps as mentioned in Annexure under **4.1.2 Transport of spent** batteries**.**
- **Submit details** of spent batteries collected to the concerned state pollution control board. Failure to furnish these rules shall lead to the cancellation of the registration granted to the dealers

1.1.2.2 Producers

Producers will be responsible for entry of new battery packs on to the market[3]. Producers refer to an entity which engages in:

- Manufacturing and selling batteries (including refurbished batteries)
- Selling of battery (including refurbished batteries) which are included in an equipment under a separate brand. The batteries may be manufactured by other manufacturers
- Importing batteries and equipment containing batteries

Producers also need to collect back the spent batteries via the dealers or by setting up battery collection agencies either individually or jointly. Some of the key roles and responsibilities of producers are as follows:

- Ensure the collection of hazardous waste generated during battery manufacturing and channelize it for further disposal or recycling
- Ensure that the new batteries are sold only to dealers, and OEMs which are **registered** with CPCB
- Ensure that waste generated from manufacturing is handled according to the provisions under **Hazardous and Other Wastes (Management and Transboundary Movement) Rules**, 2016
- Ensure that they have **Extended Producers Responsibility** for the batteries introduced in the market. They will fulfil recycling/refurbishment/end-of-life disposal obligations.
- Ensure that they chart out **Extended Producer Responsibility plan** for the batteries manufactured in the preceding/current financial year
- Meet the collection and recycling/refurbishment **targets** set forth by the government.
- Ensure that spent batteries are collected back as per the schedule against new batteries (except those sold to OEMs)
- **Set up battery collection agencies** either individually or jointly at different places for collection of spent batteries from consumers or dealers
- Ensure that they adhere to **labelling requirements** for waste batteries as per Battery Waste Management Rules, 2022

[3] Producers include battery manufacturers and battery sellers. Their responsibilities are similar as per Battery Waste Management Rules 2022. For example: Batteries may be manufactured by A and supplied to B for use in their EVs. Here A qualifies as the battery manufacturer and B as the seller. But handling battery waste becomes the obligation of B, provided it placed the battery on the market under its own brand.

- Ensure that used batteries collected are of **similar type and specifications** as compared to the new batteries sold
- Ensure that no damage is caused to the environment during the storage of spent batteries by taking respective steps as mentioned in Annexure under **4.1.1 Storage of spent** batteries**.**
- Ensure safe transportation from the battery collection agencies to the premises of the registered recycler by making necessary arrangements with the dealer and by taking respective steps as mentioned in Annexure under **4.1.2 Transport of spent** batteries**.**
- Ensure that the used batteries are sent for recycling only to **registered recyclers**
- Report any violation by the dealers to the State Board or the Ministry of Environment, Forests and Climate
- Develop methods to ensure **traceability of battery** during manufacturing, sales, use, recycling, and end-of-life.
- Ensure that they have an obligation regarding minimum use of **domestic recycled materials** in new batteries as per the targets prescribed by Battery Waste Management Rules, 2022
- In case the producer is a battery manufacturer, they have to ensure to assign an UIN (Unique Identification Number) to the batteries produced by them for ease of monitoring batteries across the value chain[4]

1.1.2.3 Battery collection agencies

Battery collection agencies will be responsible for setting up collection centers for collecting spent batteries from consumers or dealers or producers. The battery collection agencies will then send the collected spent batteries either to registered refurbishers or recyclers.

Some of the key roles and responsibilities of battery collection agencies are as follows:

- Ensure that the facilities are in accordance with the **standards or guidelines** prescribed by the central pollution control board
- Ensure that the battery waste collected is **stored in a secure manner** and no harm is caused to the environment till it is sent to the registered recycler by taking respective steps as mentioned under in Annexure under **4.1.1 Storage of spent** batteries**.**
- Ensure **verification** of spent batteries. Batteries containing residual charge should be sent by the collection agencies to organizations till these batteries get discharged completely
- Ensure that no damage is caused to the environment during **transportation** of the spent batteries by taking respective steps as mentioned in Annexure under **4.1.2 Transport of spent** batteries**.**

1.1.2.4 Public waste management authorities

Public waste management authorities generally include urban and rural local entities or agencies which are engaged on their behalf. They will be responsible for handing over the collected waste batteries to either producers or agencies acting on behalf of the producers.

Public waste management authorities may also hand over waste batteries to entities engaged in recycling/refurbishing/end-of-life disposal. Public waste management authorities differ from battery collection agencies in the aspect that such public waste management authorities may choose to carry

[4] The details of UIN are expected to be rolled out in upcoming guidelines for Battery Waste Management Rules 2022 to be published by the CPCB.

out recycling/refurbishing/disposal of waste batteries themselves. But in order to carry out recycling/refurbishing/disposal of waste batteries, they need to get registered with MoEFCC first.

1.1.2.5 Refurbishing facilities

Refurbishing facilities generally include entities involved in reconditioning, repairing, refurbishing, or repurposing of used/spent batteries for use in second-life applications. Battery collection agencies can transport spent batteries to refurbishing facilities. Refurbishing facilities carry out various processes to recondition, repair, refurbish or repurpose spent batteries. The waste batteries or recyclable components unfit for refurbishment are sent to recycling facilities to extract critical minerals and end-of-life disposal. Some of the key roles and responsibilities are as follows:

- **Strictly comply** with the terms and conditions of the registrations for recycling of spent batteries or guidelines prescribed by central pollution control boards
- Channelize spent/used batteries and recyclable components unfit for refurbishment to recyclers
- Ensure that no damage is caused to the environment during the **storage and transport** of battery waste through by taking respective steps as mentioned in **4.1 Annexure for model template document for battery recycling** facility**.**
- Ensure that waste generated from refurbishment is handled according to the provisions under **Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016**
- Ensure that other waste generated from refurbishment should be managed as per extant regulations such as **Plastic Waste management Rules, 2016, Solid Waste Management Rules, 2016, and E-waste Management Rules, 2016.**
- Make a system for maintaining the following records and furnishing quarterly returns
    - Details of waste battery collected including information on type of battery, details of entities which deposited waste batteries, quantity of waste batteries in number and weight
    - Details of waste batteries refurbished including type of battery, quantity of batteries refurbished in terms of number, total weight, total dry weight, and weight of battery materials recovered
    - Details of waste generated and disposed during refurbishment
    - Details of extended producer responsibility certificate including number of certificates issued for producers
- Ensure that they sell Extended Producer Responsibility certificates to producers in exchange for waste battery based on type and quantity of waste battery refurbished
- Ensure that they keep a record of transactions for EPR certificates and submit the same to central pollution control board while filing quarterly returns

1.1.3 Recycling, recovery of critical minerals and disposal

This part of the battery recycling ecosystem consists of recyclers and treatment storage and disposal facilities. The common roles and responsibilities of these stakeholders have been listed out in the table below:

Sl.	Activity	Recycler	Treatment storage and disposal facility
1.	One time registration with concerned pollution control boards	✓	✓

2.	Records regarding battery waste handled should be made available for scrutiny by concerned State pollution control boards or MOEFCC	✓	✓
3.	Ensure that no damage is caused to the environment during the dismantling, recycling, or disposal of battery waste	✓	✓
4.	Ensuring non-recyclable and non-recoverable components are sent to authorized or registered treatment storage and disposal facilities	✓	

1.1.3.1 Recyclers

The battery recycler will be responsible for recycling the spent batteries and recovering the precious metals from such batteries. Some of the key roles and responsibilities of recyclers are as follows:

- Develop **central recycling facilities** with adequate capacities in order to ensure effective and adequate pollution control
- **Strictly comply** with the terms and conditions of the registrations for recycling of spent batteries or guidelines prescribed by central pollution control boards
- Ensure that collected waste batteries are not landfilled or incinerated.
- Ensure that no damage is caused to the environment during the **storage and transport** of battery waste through by taking respective steps as mentioned in **4.1 Annexure for model template document for battery recycling** facility**.**
- Ensure that the recycling processes do not cause any **adverse effect** on health and environment by:
    - Using **non-conductive trays** to move battery packs
    - Taking precautions to **limit exposure** to electrolyte vapor
    - Covering all metal work surfaces **with an insulating material** and keeping the work area **clean and free of sharp objects** which may cause short-circuit or a fire hazard
    - Procuring **inspection tools** (rulers, callipers, etc.) which are either made from or **covered** with **a non-conductive material**
    - **Avoiding hot and humid conditions** and ensuring that batteries should not be placed in **direct sunlight, or in hot locations or on hot surfaces.**
- **Mark "Recycled"** on metal recovered by re-processing
- Ensure that the factions/materials which **cannot be recycled** in the facility such as electronics, thermoplastics (used to make battery casing) should be sent to **respective authorized recyclers** such as e-waste recyclers or plastic recyclers.
- Ensure that the **residue generated** during the recycling processes is **disposed** of in an authorized treatment storage disposal facility
- Ensure that waste generated from recycling is handled according to the provisions under **Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016**
- Ensure that other waste generated from recycling and battery handling should be managed as per extant regulations such as **Plastic Waste management Rules, 2016, Solid Waste Management Rules, 2016, and E-waste Management Rules, 2016.**
- Ensure compliance for **material-wise recovery** as per **Battery Waste Management Rules, 2022**[5]. Such records should be maintained and made available for inspection
- Make a system for maintaining the following records and furnishing quarterly returns

[5] This refers to recycling efficiency

  - Details of waste battery collected including information on type of battery, details of entities which deposited waste batteries, quantity of waste batteries in number and weight
  - Details of waste batteries recycled including type of battery, quantity of batteries recycled in terms of number, total weight, total dry weight, and weight of battery materials recovered
  - Details of waste generated and disposed during recycling
  - Details of extended producer responsibility certificate including number of certificates issued for producers
- Ensure that they sell Extended Producer Responsibility certificates to producers in exchange for waste battery based on type and quantity of waste battery recycled
- Ensure that they keep a record of transactions for EPR certificates and submit the same to central pollution control board while filing quarterly returns
- Ensure that they meet the materials recovery targets as set out in Battery Waste Management Rules, 2022.

1.1.3.2 Treatment storage and disposal facility (TSDF)

After the process of recycling, there are certain residual items which are hazardous in nature. Disposal facilities ensure that the residue received by them are properly handled and neutralized before they are put into landfills. After battery recycling, the hazardous waste will be transported to treatment storage and disposal facility player who will be responsible for receiving hazardous waste, storing hazardous waste, treating hazardous waste and their subsequent disposal.

1.1.4 Policy and related enablers

This part of the battery recycling ecosystem consists of pollution control boards, policymakers and standard enabling agency

1.1.4.1 Pollution control boards

India has a system of pollution control boards which operate both at state and center levels. The system enables wider monitoring at a state level with overarching center level policies.

1.1.4.1.1 Central pollution control board

Central Pollution Control Board will be responsible for monitoring the operational activity of the battery recycling facilities and State Pollution Control Board on a national level. Some of the key responsibilities of CPCB are as follows:

- **Registration and EPR:**
  - Ensure registration of producers
  - Ensure that EPR plan along with registration details of the producers is shared with the State Pollution Control Board
- **Regulation, standards, and guidelines:**
  - Prepare guidelines/ SOPs for environmentally sound procedures of waste battery collection, handling, transportation, storage, and recycling
  - Prepare guidelines for imposition of environmental compensation from recycling facilities or producers for not fulfilling their EPR obligations
- **Compliance:**

  - **Compile and publish data** received from state boards every year
  - Review the **compliance of rules** via period inspection and audit to ensure improvement in collection and subsequent recycling of spent batteries and appraise MoEFCC
  - Ensure that producers' registration is suspended or cancelled or impose environmental compensation upon failure to fulfil their EPR obligations
  - Publish list of producers who have failed to fulfil their EPR obligations
  - Generate and assign EPR certificates to recyclers based on fulfilment of recovery targets, weight of waste battery processed and geographical source of battery
- **Technology:**
  - Ensure review of technologies related to waste battery management and check their viability and feasibility in India.
  - Develop an online platform for exchange of EPR certificates between relevant stakeholders

1.1.4.1.2 State pollution control board

State Pollution Control Board will be responsible for monitoring the operational activity of the battery recycling facilities present in its respective jurisdiction. Some of the key responsibilities of SPCBs are as follows:

- **Registration:**
  - Ensure **one-time registration** of dealers
- **Compliance:**
  - Act as the prescribed authority and ensure compliance of the provision of the rules via periodic inspection and audit
  - Publish the list of entities which have not fulfilled their EPR obligations annually
  - File **annual compliance status report** to the central pollution control board
  - Compile and forward quarterly reports submitted by recyclers to central pollution control board and publish such reports
  - Ensure **periodic monitoring** of all recycling facilities

1.1.4.2 Policymakers

As an overarching body, policymaking bodies are responsible for creating a favourable market and ecosystem for battery recycling in the country. The policymakers may choose to do so by implementing policies, incentives or other measures which promotes battery recycling in the country such as:

- Launch such **policies/incentives/subsidies** like battery waste management rules (India) and Battery Stewardship scheme (Australia) to promote battery recycling in the country
- Policymakers could set up short-term (2025) and long-term (2050) battery waste recycling rates as well as rates of recovery of major battery materials
- **Draft rules and regulations/ standards/ guidelines** regarding battery recycling (including safety precautions). Such rules, regulations and guidelines could include offering recyclers rebates per kg to collect, sort and process the end-of-life batteries.
- Chart out the **roles and responsibilities** of the major stakeholders in the battery recycling ecosystem

The policymakers for the ecosystem would consist of MoEFCC, NITI Aayog, etc. as per the requirement of the industry from time to time. It is of utmost importance to have stakeholder buy-in for suggested policies and upgradation of the policies and guidelines with changing market dynamics. In addition, states may also choose to come up with suitable policies, incentives, and subsidies to further promote battery recycling in respective states. For instance, Uttar Pradesh has announced a capital interest subsidy of 50% per annum for five years on loan reimbursement to support battery recycling.

1.1.5 Standard enabling agency

Standards enable any industry to achieve superior quality of products and operating procedures. In the Indian context, Bureau of India standards (BIS) is the body responsible for releasing standards and guidelines to be adhered to in the battery recycling ecosystem. The standards so formulated should provide industry with the necessary room for innovation and at the same time it should be restrictive to ensure safety of the players involved throughout the recycling value chain. Agencies like BIS can take reference from international standards like SAE J3071 (battery recycling identification and cross contamination prevention guidelines) and SAE J2984 (recommended practices for transportation of battery systems for recycling) to develop relevant standards for prevalent Indian conditions to ensure an efficient battery recycling ecosystem.

1.2 Setting up a battery recycling facility

In order to set up a recycling facility, there are a few permissions and approvals required from various governing authorities. These permissions are categorized into three sub classes: **permissions related to land**, **permissions related to pollution control boards** and **other permissions** & **certificates**.

Figure 2: Flow diagram for permissions required for setting battery recycling facility

1.2.1 Land allotment

In order to set up a battery recycling facility an individual/entity must first identify a land. Generally, a recycler should require a minimum of 500 square meters of land to build a recycling facility of capacity of 1 Ton per day. Recyclers can opt for selecting a land/area of 2500 square meter if they wish to establish a recycling facility of 5 MT/day[6]. Battery recycling facilities are set up in land areas declared as red zones. Prior to land identification, the entity looking to set up a battery recycling facility can also conduct a **feasibility study and draft a detailed project report** to make an informed decision regarding the establishment of the battery recycling facility. Post the selection, there are a few documents required such as lease agreement, building plan approval, occupancy certificate and change of land use approval. This process has further been elaborated below:

Table 3: Approvals required for land allotment

Sl.	Approval/ permissions required
1.	**Lease agreement** with the landowner (for private lands) or from municipal development corporation (for public land)
2.	Permission and approval of the **site plans** from the municipal corporation department and Urban Development and Department of Panchayati Raj and Rural development
3.	**Occupancy certificate** required from local body/authority before occupying the site for opening battery recycling facility.
4.	The recycling facility must obtain permission for approval of change of land use for recycling purposes from Land Administration/ Municipal Corporation Department of the state

1.2.2 Pollution related certifications and clearances

After selecting the land and getting the approvals, the recycling facility needs to get approvals from the State Pollution Control Board. The battery recycling facility must submit requisite documents for obtaining approval from the State Pollution Control Boards. The various permissions required from the State Pollution control boards are listed below:

[6] Central pollution control board. Implementation Guidelines for E-Waste (Management) Rules, 2016. Retrieved from https://cpcb.nic.in/displaypdf.php?id=aHdtZC9HVUlERUxJTkVTX0VXQVNURV9SVUxFU18yMDE2LnBkZg==

Sl.	Permission/ certification type	Issuing authority	Requirements
1.	**Pollution No Objection Certificate**	State Pollution Control Board (shall conduct a legal check of the same)	• Factory license • Trade license • Proof of registration of the unit • Site plan layout • Compliance report of NOC • Satellite imagery of the project site • Completion certificate of the Effluent Treatment plant • Pan card (for partnership/company), ID and address proof of authorized person
2.	**Consent to establish/operate under the Air (Prevention & Control of Pollution) Act, 1981 & Water (Prevention and Control of Pollution) Act, 1974**	State Pollution Control Board	**Consent to establish:** • Installed capacity of the recycling facility (TPD) • Technical specifications of the control arrangements installed to control air pollution • Schematic diagram/building plans with machinery details • Total built up area • Project report with details of operation • Break up of water usage and water balance and details of effluent/sewage treatment plant • Detailed reports of Emission analysis • Nearest residential area and water body from the proposed site • Raw material list mentioning quantity per month • Details of Solid waste collection/ storage/ disposal facility **Consent to Operate:** • Break up of water usage and water balance • Project report with details of operation • Details of air pollution control measures • Raw material list mentioning quantity per month • Permission for ground water intake (if applicable) • Details of measures taken to reduce waste generated or for recycling and reuse • Wastewater analysis and emission analysis reports
3.	**Authorization under Hazardous and other Wastes**	State Pollution Control Board	• List of hazardous waste generated

(Management & Transboundary Movement) Rules, 2016	• Consent for Establishment under the Air (Prevention & Control of Pollution) Act, 1981 & Water (Prevention and Control of Pollution) Act, 1974 • Factory or trade license • Memorandum of association • Articles of association • Certification of incorporation (for company or LLP) • Layout plan • PAN card of the partnership/company

1.2.3 Other permissions and certifications

Apart from getting approvals for land, pollution and electrical connection, the individual/entity needs to get the following certificates/approvals for setting up a battery recycling facility:

Sl.	Permission and certification type	Issuing authority
1.	**Company Incorporation Certificate**	Ministry of Corporate Affairs.
2.	**Registration Certificate**	Granted by the District Industries Centre or any other governmental institution legalized in this context.
3.	**Validation of action plan**	Secretary in charge of Urban Development of the respective State or union territory
4.	**Approval for Installed Capacity of Battery Recycling**	District Industries Centre
5.	**Registration for battery recycling facility**	MoEFCC or an agency designated by it. The officer designated by MOEFCC, or any agency designated by it should decide on approval of the registration within 90 days of receipt of application.
6.	**No Objection Certificate (for fire)**	Directorate of Fire Services – Department of Home
7.	**Electricity connection**	DISCOM and Electrical Inspectorate Department
8.	**Water connection**	State Water Supply and Sewage Board/PWD division in the State

EHS Risk Screening

2. EHS risk screening framework

2.1 Introduction

Environmental Health and Safety management or EHS system refers to the implementation of rules, procedures focused on improving the safety of the workers and ensuring proper working environment around them. EHS processes are important for an organization to achieve its overall environmental goals. EHS processes minimize the harmful impact on the surrounding environment and improve safety of workers, ensure their wellbeing, and improves overall employee retention and productivity.

Organizations handling lithium-ion batteries at any stage of their operations need to be aware of the potential hazards and subsequent mitigation measures. Without proper controls, environmental and health risks could be significantly higher. Adoption of EHS management system could be critical in instilling confidence of investors, employees, and public officials in the recycling operations.

For this purpose, we have proposed an Environmental Health and Safety Risk screening framework which helps in -

- Eliminating or minimizing the potential for work-related injuries, fatalities, and occupational hazards
- Identifying and promptly controlling risks
- Supporting safe work environment
- Effectively dealing with incidents
- Orienting, training, educating, and supervising workers to handle and dispose batteries and battery waste
- First aid provisions (as per EHS Regulations)
- Ensuring incident investigations that meet minimum compliance requirements

The purpose of the EHS framework is to provide the refurbishers/recyclers of lithium-ion cells & battery packs with enough information to safely handle risks under normal and emergency conditions. Risks associated with every step and process have been listed and measures to resolve such risks have been proposed.

Caution must be taken while handling batteries specifically in the following stages: collecting the batteries from the end users, storage and transport of batteries, refurbishing, recycling, and end-of-life disposal. From an EHS perspective, personnel working in the recycling value chain of these batteries must be trained regarding all the safety aspects related to lithium-ion battery handling and their waste management. In addition, recycling and refurbishing centers must be equipped with necessary equipment to handle and investigate any emergencies and incidents related to lithium-ion batteries (LiBs).

There is a perceived knowledge gap on LiB safety aspects and there is an urgent need to educate all stakeholders, including the general public, first responders e.g., fire services, transporters, and governmental organizations. Therefore, EHS considerations are crucial. The EHS risk screening framework has been prepared for facilities dealing with batteries used in EVs for all vehicle segments and stationery storage applications.

This chapter focuses on capturing the possible risks in the end-of-life treatment of lithium-ion batteries from applications ranging from mobility and stationary storage

2.2 Approach

The risks associated in the recycling of lithium-ion batteries have been contextualized through the value chain. The broad illustration for the framework is provided below:

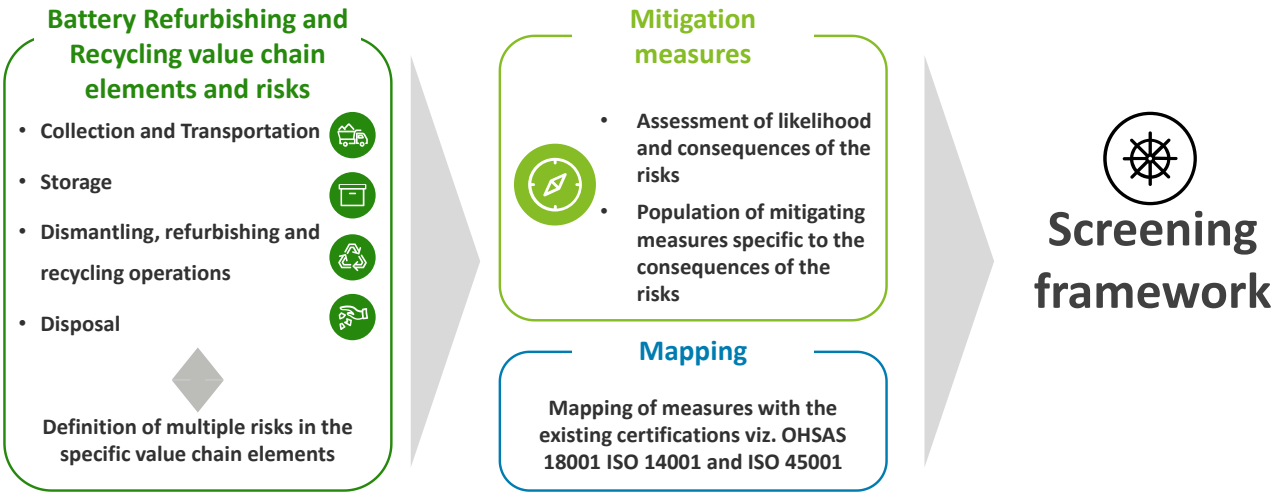


Figure 3: Approach for developing EHS risk screening framework

The risk matrix basis the likelihood and the consequences of events is shown below.

Table 4: Risk Matrix for the likelihood and consequences of events[7]

	Consequences (rating)		
	Low impact (1)	**Serious (2)**	**Catastrophic (3)**
Likelihood (rating)	**1**	**2**	**3**
	Risk score		
Remote (1)	1	2	3
Possible (2)	2	4	6
Probable (3)	3	6	9
LEGEND	Low risk	Moderate risk	High risk

[7] The Matrix has been developed by taking reference from the following documents:
SERI. The sustainable electronics reuse & recycling (R2) standard. Retrieved from https://sustainableelectronics.org/wp-content/uploads/SERI%20Manual%20v.%201.1%202022.12.15.pdf
ISO. Occupational health and safety management systems - ISO45001. Retrieved on 26th June 2023 from https://www.iso.org/standard/63787.html
IFC. EHS Guidelines. Retrieved on 26th June 2023 from https://www.ifc.org/wps/wcm/connect/29f5137d-6e17-4660-b1f9-02bf561935e5/Final+-+General+EHS+Guidelines.pdf?MOD=AJPERES&CVID=jOWim3p
Industry stakeholders were also consulted for risk mapping across the value chain.

The risk score is obtained by multiplying the likelihood and consequence scores. High risk activities must be addressed immediately and reviewed often to ensure control measures are accurate and adequate. Moderate and low risk activities are reviewed and addressed once all the high-risk activities have adequate control measures in place.

The consequence of risks across the value chain elements varies considering the preparedness of the stakeholders involved. For instance, an electrolyte leakage would be situation of lower criticality in the recycling facility itself compared to the same occurring during transportation in trucks.

The likelihood of the risks has been reached at by the consultations with industry players (recyclers) and internal deliberations of the working group. The sections that follow cover the risks and associated mitigating measures for all the value chain elements of recycling.

2.3 Risk mapping across the value chain

2.3.1 Collection and transportation

Upon reaching their end-of-life, batteries must be transported from retail and bulk consumers to the refurbishing/recycling facilities. The batteries usually move from the consumers to the battery collection agency (may be organized like dealers or unorganized like scrap collectors) and then they are moved to dismantlers and recyclers. In India, the battery dismantling is done by the recycling firms themselves.

The entire process of collection and transportation spans across a wide geography and multiple operators. Owing to the hazardous nature of lithium-ion batteries, operators must be trained and should have access to adequate equipment to ensure no damage is inflicted on the batteries during the processes. Safety regulations and supervision during these phases are critical to maintain the safety conditions. The most common procedures for moving the batteries in containers is road transportation in India[8]. The main concerns during this stage of the value chain are lack of proper insulation of battery terminals, protective material, and technical supervision to ensure no accidents take place from the waste batteries, and they are damage free.

2.3.1.1 Risks associated during collection and transportation

Key risks envisaged during collection and transportation are captured below:

- **Improper handling of batteries**
    - Mechanical damage, crushing or puncture damage to cells or battery packs, due to poor handling practices. Instances such as boxes or pallets being dropped or damaged by forklift accidents causing incidents like fire.
    - Direct exposure to battery materials (e.g., electrolyte fumes) in case the battery is damaged

- **Battery Fire**

[8] Industry insights

  - External heating of the cells due to a fire initially unrelated to lithium-ion battery packs can lead to release of electrolyte, short circuiting, and possibly cell thermal runaway that can result in a fire or explosions
  - Damaged high voltage batteries possess stranded energy which can lead to electric shock or thermal runaway and can cause battery fires
- **Inadequate training and awareness amongst employees**
  - Lack of training, education, and supervising guidance to collectors & transporters on safe work practices, lack of proper equipment in place
  - Lack of expertise, knowledge, and technical capability to process each type of electronic equipment, component, and material the collectors are accepting to recycle
  - Consumption of food and beverages while handling LiBs and in contaminated areas
  - Lack of procedures in place for identifying the type of vehicle to be used, training required to educate drivers regarding the risks involved in transporting batteries
  - Lack of information, awareness, and training of workers regarding past relevant incidents, internal or external to the organization, including emergencies, and their causes
  - Not ensuring that the contractors involved in the battery storage, collection & transportation operations are reputable and legitimate enterprises
  - Lack of knowledge, expertise, and trained personnel to handle high voltage batteries
- **Inadequate processes and procedures**
  - Lack of an EHS management system certified from an accredited body (ISO, OHSAS, certified professionals)
  - Non-maintenance of proper SOPs, records, and documents necessary to demonstrate the processes required during collection and transportation of lithium-ion batteries
  - Lack of SOPs to demonstrate the processes required to remove, collect & transport high voltage batteries, degraded/damaged batteries
  - Occupational risks like long work hours, victimization and bullying at workplace not allowing the workers to perform with safety
  - Not establishing a planned response to emergency situations, including the provision of first aid
  - Lack of a communication channel in place to ensure that OH&S information is communicated consistently and is reliable as per the process needs
  - Not ensuring the adoption of best transport safety practices across all aspects of battery collection operations
  - Absence of life and fire safety systems and equipment designed and installed in the vehicles used for transportation
  - Long work hours, victimization and bullying at workplace not allowing the workers to perform with safety[9]

2.3.1.2 Standard mitigation measures during collection and transportation

The mitigation measures for the stated risks are mentioned as follows:

[9] Only applicable in cases where recycler has its own collection and transportation service

Table 5: Risk mitigation measures during battery collection and transport

Mitigation measure	**Identifier[10]**	**Reference**
Avoid transporting batteries in metal boxes and tape terminals to prevent contact being exposed to short circuiting. Recommended option is putting the batteries in a clear plastic bag and placing them in a firm box (vermiculite) with good padding.	RMM1	R2; ISO 45001
Ensure that batteries are kept away from heat, isolated from device (if any), transported in an insulated container or padded bag to prevent shock if dropped or impacted. Temperature to be maintained between -20°C to 60°C	RMM2	ISO 45001
Do not transport or ship a fully charged battery. The recommended State of Charge (SoC) is 30% or less. If the battery SoC is above 30%, then discharge it using proper SOPs before transporting	RMM3	ISO 45001
Stacking of batteries should be avoided without protective barriers (insulators like honeycomb cardboard) between them	RMM4	R2
Provide operators with hazard information and training, appropriate PPEs for specific chemicals, channel for incident reporting and fair working environment	RMM5	R2, ISO 45001
Fire safety systems, heat sensors, alarms must be installed in the vehicles to prevent any fire related incidents	RMM6	ISO 45001
Specific measures and guidelines emphasizing safety aspects among drivers like requirement of license, limits for trip duration and checking overtiredness, planning to avoid dangerous routes and times of day, installation of speed regulation devices and procedure to monitor vehicle fitness to be ensured	RMM7	ISO 45001
Ensure responsibility and accountability for the prevention of work-related injury and ill health, as well as the provision of safe and healthy workplaces and activities	RMM8	ISO 45001
Ensure anonymity and safeguarding workers from reprisals when reporting incidents, hazards, risks**,** and opportunities	RMM9	R2
Provide proper documentation and communication (considering diversity aspects) regarding relevant information like location of PPEs inventory, evacuation plan, etc. to respond to emergency situations in a sound manner	RMM10	R2, ISO 45001
Provide information and train workers regarding past relevant incidents, internal or external to the organization, including emergencies, and their causes	RMM11	ISO 45001
Ensure that the requirements of facility's OH&S management system are met by the contractors and their workers	RMM12	ISO 45001
Communicate and provide relevant information regarding evacuation plan to contractors, emergency response services, government authorities and	RMM13	R2

[10] RMM stands for Risk Mitigation Measure. Identifiers have been provided against each of the mitigation measures due to their applicability across the value chain for risks and easy aggregation of the framework in large.

Mitigation measure	Identifier[10]	Reference
the local community needed to prepare for and respond to emergency situations.		
Implement management controls (audits, procedures, inspections, communications, training, and drills) to address residual risks that have not been prevented or controlled through engineering measures.	RMM14	R2, ISO 45001
Provide written SOPs for all the processes, evacuation procedures in case of high voltage & degraded batteries, emergencies arising during transportation and handling of batteries	RMM15	IFC EHS Guidelines
Label containers regarding the hazardous chemicals present inside them for appropriate handling	RMM16	R2, ISO 45001
Train operators involved in the removal, collection & transportation of high voltage & degraded batteries to ensure minimum injuries and damage to workers and the public	RMM17	IFC EHS Guidelines

Mitigation measures such as RMM2, RMM3, RMM5, RMM6, RMM11, RMM17 have also been covered as a part of standard operating procedure guidelines in section 0.

The mitigation measures are in line with the fact that the lithium-ion batteries can come from multiple sectors viz. consumer electronics, electric vehicles, etc. The informal/ unorganized sector is highly involved in the collection and transportation segment of the value chain; proper governance mechanism with standard operating procedures (SOPs) must be in place to ensure minimization of any risk event.

2.3.1.3 Risk profiling and mitigation measures mapping in collection and transportation

The matrix shown below captures the broad risks and the mitigation measures for them.

Table 6: Risk profiling & mitigation measures mapping matrix in collection and transportation

Risk	Likelihood (A)	Consequences (B)	Risk score C = A*B	Mitigating measures
Improper handling of batteries	2	3	6	RMM1, RMM2, RMM3, RMM4, RMM17
Battery fire	2	3	6	RMM2, RMM3, RMM5, RMM6, RMM11, RMM13, RMM17, RMM18
Inadequate training and awareness amongst employees	2	3	6	RMM5, RMM7, RMM10, RMM11, RMM13, RMM9, RMM17
Inadequate processes and procedures	2	2	4	RMM8, RMM12, RMM14, RMM15, RMM16, RMM17, RMM10

2.3.2 Storage

The storage of the battery is the act of keeping the battery in a specific place for use in the future for any operation. The batteries can be stored at the battery collection agencies, at OEMs site waiting to be transported by road or ship, at the port or at the recycling site, waiting to be dismantled.

The storage sites should be safe places with restricted access to reduce the probability of shock or other external aggression occurrence. It is also important to assure that during the storage phase the temperature of the environment external to the battery system and modules is lower than the maximum recommended by the manufacturer.

2.3.2.1 Risks associated with storage

Storing Li Ion battery in a safe and secured place is critical as improper storage can be very harmful to the humans and environment. Storage of the battery possess various risks including thermal runaway, unsuitable environmental conditions etc. which can lead to explosions and fire. Common storage risks include:

- **Risk of fire from batteries**
  - HV (high voltage) battery coming into close contact with flammable substances
  - Thermal runaway in batteries/ modules/ cells
  - Reaction of leaked electrolytes with nearby entities can cause huge fires

- **Emission of hazardous gases**
  - Fire, smoke emanating from batteries/ modules/ cells
  - Irritating fumes caused by off-gassing
  - Lack of ventilation in storage area
  - In case of battery damage, leaked electrolytes can react with nearby substances and emit harmful gases

- **Improper procedures & handling of batteries in storage area**
  - Sharp objects in the storage area that might puncture sleeve of batteries/ modules/ cells
  - Storage area temperature not optimal (15 – 30°C) for li-ion batteries
  - Placement of storage area near a collection, or a containment structure connected to municipal wastewater/stormwater collection system
  - Local soil corrosion and water contamination due to installation of USTs
  - No SOPs in place for operating and filling of underground safety tanks (USTs), above ground safety tanks (ASTs) and other equipment used by workers
  - Injuries to personnel due to inadequate training to remove waste materials from tanks, vessels, processing equipment or contaminated land
  - Not ensuring that the contractors involved in the battery storage operations are reputable and legitimate enterprises
  - Long work hours, victimization and bullying at workplace not allowing the workers to perform with safety

- **Inadequate access control to storage facility**
  - Setting up of warehouse/ facility in a highly populated area

- Access to storage area by unauthorized personnel
- Battery storage area if used for other operational activities can cause disturbance in the stored batteries

- **Unavailability of emergency response measures**
  - Not establishing a planned response to emergency situations, including the provision of first aid
  - Unavailability of heat sensors, fire detection & alarm system, and absence of safety systems to prevent accidents
  - No provisions on incident reporting and investigation to identify the reasons responsible for the occurrence of mishap

2.3.2.1.1 Standard mitigation measures during storage

The mitigation measures for the stated risks are mentioned as follows:

Table 7: Risk mitigation measures during storage

Mitigation measure	Identifier	Reference
Store batteries in a dry and well-ventilated place at room temperature or lower. While batteries can be used safely between -20 and 60 °C, it is strongly suggested to avoid storing them at a temperature that is close to the upper or lower range	RMM18	ISO 45001
Store lithium-ion batteries on floors which are made up of concrete, metal, or ceramic or any non-flammable material and in a reserved area. If batteries are placed in stacks, ensure proper insulation and protective layer between the stacks.	RMM19	ISO 45001
Have a fire detector in the storage area and a class ABC or CO2 fire extinguisher nearby the storage area. For large Li-ion battery fires use foam extinguisher containing CO2, powder graphite, ABC dry chemical, or sodium carbonate.	RMM20	R2, ISO 45001
Ensure storage area is free of sharp objects and tools which can puncture battery outer casing	RMM21	R2
Provide adequate training, awareness & frequent mock drills to employees to prepare for emergency situations	RMM22	ISO 45001
Ensure facility is located away from highly populated area, municipal/stormwater streams, and the feedstock storage away from the main operations area	RMM23	IFC EHS Guidelines
Ensure a proper communication channel for consistent and reliable OH&S information flow in case of emergencies	RMM24	IFC EHS Guidelines
Provide appropriate security arrangements to ensure access of only authorized personnel in facility premises	RMM25	ISO 45001
Provide SOPs for filling and operating USTs and ASTs to check their overfilling and leakages	RMM26	IFC EHS Guidelines

Mitigation measure	Identifier	Reference
Ensure portable spill containment and clean-up equipment on site and provide relevant trainings for the equipment deployment	RMM27	IFC EHS Guidelines

Mitigation measures such as RMM18, RMM19, RMM20, RMM22 have also been covered as a part of standard operating procedure guidelines in section 0

2.3.2.2 Risk profiling and mitigation measures mapping in storage

The matrix shown below captures the broad risks, their criticalities, and the mitigation measures for them.

Table 8: Risk profiling and mitigation measures mapping matrix in storage

Risk	Likelihood (A)	Consequences (B)	Risk score C = A*B	Mitigating measures
Risk of fire from batteries	2	3	6	RMM18, RMM19, RMM20
Emission of hazardous gases	2	2	4	RMM2, RMM3, RMM19, RMM20, RMM21, RMM27
Improper procedures & handling of batteries in storage area	1	3	3	RMM4, RMM21, RMM22, RMM23, RMM26, RMM27
Inadequate access control to storage facility	1	1	1	RMM24, RMM25
Unavailability of emergency response measures	2	3	6	RMM12, RMM13, RMM15, RMM16, RMM17, RMM22

2.3.3 Dismantling, refurbishing, and recycling operations

Once spent batteries are collected, they are sent to dismantling facilities. Dismantling/ disassembly of EV batteries involve breaking down of the battery to cell or module level post which those cells and modules are sent to recycling facilities.

EV batteries are major source feedstock and dismantling of EV LiBs from automotive applications is complex due to a wide variety of the battery designs, presence of flexible components like cables, and potential dangers caused by high voltage and the chemicals contained in the battery cells. All these factors must be considered when planning for the dismantling process(es).

2.3.3.1 Risks associated with dismantling, refurbishing & recycling operations

Currently, dismantling is a highly manual process in the country due to the unavailability of standardized battery packs and modules. The risk level increases with increase in manual interventions. The key risks in the process include:

- **Improper handling of batteries**
    - Leakage of chemicals, e.g., of the electrolyte, due to mechanical damage

  - Emission of electrolytes fumes during battery dismantling and shredding (part of the recycling process)

- **Battery fire**
  - High voltage in the batteries

- **Inadequate training and awareness amongst employees**
  - Improper training of the dismantling process leading to strains, musculoskeletal injuries, struck by object, electroshock
  - Lack of information, awareness, and training of workers regarding past relevant incidents, internal or external to the organization, including emergencies, and their causes

- **Inadequate safety measures during dismantling process**
  - Missing of process safety information and safety data sheets to handle specific hazardous materials
  - Exposure to battery electrolyte and chemicals
  - Lack of appropriate waste specific personal protective equipment while dismantling
  - Long work hours, victimization and bullying at workplace not allowing the workers to perform with safety
  - Shopfloor is uneven, not in level and skiddy; no markings for safe area to walk and emergency exits
  - No adequate natural and artificial lighting in the operations area
  - Unavailability of labelling and markings according to national and internationally recognized requirements and standards
  - Injuries due to unavailability of temporary fall protection measures in elevated work surfaces

- **Inadequate processes and procedures**
  - Lack of an EHS management system certified from an accredited body to plan and manage the environmental, health, and safety aspects of the plant operations
  - No clearly documented SOPs and safety parameters for the processes (start-up, normal operations, temporary operations, emergency shutdown, emergency operations, normal shutdown, and start-up following a normal or emergency shutdown or major change), evacuation response and hazard mitigation
  - No provision of a quality assurance plan for equipment, maintenance materials, and spare parts required in day-to-day operations
  - Not assessing the potential risks from forces of nature (earthquakes, floods, tsunamis etc.) while selecting the location of the facility
  - No provisions to monitor working at heights & confined spaces, vibrations, temperature, and noise level on the shopfloor
  - Spillage and release of uncontrolled toxic materials outside designated containers
  - Not ensuring that the contractors involved in the handling, treating, and disposing of hazardous waste are reputable and legitimate enterprises
  - Damage to the battery pack, cells and the battery casing while removing the Battery management system (BMS)
  - Over-discharging of batteries because of Battery management system (BMS) failure which may lead to internal damage to electrolyte surface or short circuits

- **Disposal of hazardous waste and gases**
  - No provisions of collection of data and information about the processes generating waste and waste streams in existing facilities, and the non-availability of infrastructure to manage waste in an environmentally sound manner
  - No procedures for stringent waste segregation to prevent the mixing of non-hazardous and hazardous waste at the facility
  - Not using specially trained personnel to identify and remove waste materials from tanks, vessels, processing equipment or contaminated land

- **Emergency preparedness**
  - Not establishing a planned response to emergency situations, including the provision of first aid, and not providing adequate training to prepare for such response
  - No provisions of audible alarms such as fire bells, sirens, vehicle mounted speakers etc. to alert the nearby community in case of emergencies
  - Not installing a back-up system for communications on-site with off-site resources, such as fire departments, in case of emergency when normal methods won't work
  - Facility not having a robust emergency preparedness plan which includes all the elements pertaining to administration, roles and responsibilities, emergency resources, business continuity and contingency

2.3.3.2 Standard mitigation measures for risks during recycling, refurbishing and dismantling operations

The mitigation measures for dismantling operations are mostly related to the operational aspects of the process. They are summarized below:

Table 9: Risk mitigation measures during dismantling and operations

Mitigation measure	Identifier	Reference
Complete discharging of battery before dismantling	RMM28	R2
Provide mechanisms, time, training, and resources necessary for workers consultation and participation for the prevention of accidents in the facility	RMM29	ISO 45001
Ensure actions to achieve EHS, OH&S objectives getting integrated into the organization's business processes	RMM30	IFC EHS Guidelines
Prepare a spill control, prevention, and countermeasure plan as a specific component of their Emergency Preparedness and Response Plan	RMM31	IFC EHS Guidelines
Implement management controls and SOPs (procedures, inspections, communications, training, and drills) to address residual risks that have not been prevented or controlled through engineering measures.	RMM32	R2, ISO 45001
Prepare a quality assurance plan for equipment, maintenance materials, and spare parts required in day-to-day operations	RMM33	ISO 45001
Assess potential risks from forces of nature (earthquakes, floods, tsunamis etc.) while selecting the location of the facility to be ensured	RMM34	IFC EHS Guidelines
Provide measures for safe working at heights & confined spaces, vibrations, temperature, and noise level on the shopfloor	RMM35	ISO 45001

Mitigation measure	Identifier	Reference
Collect data and information regarding processes generating waste and existing waste streams in facility and ensure stringent rules for environmentally safe disposal of segregated waste	RMM36	R2
Adopt stringent waste segregation procedures to prevent mixing of hazardous and non-hazardous chemicals & wastes	RMM37	R2, ISO 45001
Ensure stringent procedures for the selection of vendors and contractors	RMM38	IFC EHS Guidelines
Install audible alarms such as fire bells, sirens, vehicle mounted speakers etc. to alert the nearby community in case of emergencies	RMM39	ISO 45001
Adopt appropriate dust suppression measures such as applying water or non-toxic chemicals to minimize dust from vehicle movements	RMM40	ISO 45001

Mitigation measure RMM28 has also been covered as a part of standard operating procedure guidelines in section 0.

2.3.3.3 Risk profiling and mitigation measures mapping during dismantling

Table 10: Risk profiling and mitigation measures mapping matrix in dismantling and operations

Risk	Likelihood (A)	Consequences (B)	Risk score C = A*B	Mitigating measures
Improper handling of batteries	2	2	4	RMM28, RMM29, RMM32, RMM35
Battery fire	2	3	6	RMM20, RMM21, RMM28
Inadequate training and awareness amongst employees	2	2	4	RMM5, RMM10, RMM11, RMM29, RMM30
Inadequate safety measures during dismantling process	1	3	3	RMM29, RMM31, RMM32
Inadequate processes and procedures	2	2	4	RMM16, RMM32, RMM33, RMM35, RMM38, RMM40
Emission of hazardous waste and gases	2	2	4	RMM37, RMM38
Emergency preparedness	2	3	6	RMM12, RMM15, RMM16, RMM22, RMM24, RMM29, RMM31

2.3.4 Air pollution

Damaged LiBs in landfills causes fires, which produce a mixture of toxic gases and smoke. The smoke usually consists of polycyclic aromatic hydrocarbons (PAHs),94–96 dioxins/furans, volatile organic compounds (VOCs), heavy metals, polychlorinated biphenyls, or organochlorine pesticides and finally, particulate matter (PM). Some of the harmful gases, such as CO, SO2 or H2S are also generated with burning of batteries.

2.3.4.1 Risks associated with air pollution

Some of the common air pollution specific risks from recycling processes are:

- **Hazardous emissions**
    - Hazardous emissions in environment like CO, SO2, N2O, H2S etc.
    - High PM 2.5 & PM 10 levels in surrounding area
    - Health issues like respiratory infections, heart diseases and lung cancer for people living in nearby areas
    - Air pollution from the above-mentioned substances can lead to environmental issues like acid rain, haze, ozone depletion, eutrophication, crop damage, global climate change etc.
    - Practice of not designing the stack height[11] for emissions from battery-related facilities in accordance with Good International Industry Practice (GIIP). Further annual stack emissions are not tested specifically in the unorganized sector.

2.3.4.2 Standard mitigation measures for risks related to air pollution

The mitigation measures to accommodate the process related emissions are as follows:

Table 11: Risk mitigation measures related to air pollution

Mitigation measure	Identifier	Reference
Preventing fires or preventing uncontrolled fires related to battery waste	RMM41	ISO 45001
Treatment of fumes before disposing in environment (gas treatment equipment installation) and setting stack height as per GIIP and annual stack emission testing	RMM42	ISO 14001
Use of mist spray to keep down dusts, especially during and prior to loading or other handling procedures	RMM43	IFC EHS Guidelines
Use of flue gas treatment system for control of acid gases, particulate matter, and other air pollutants	RMM44	IFC EHS Guidelines

2.3.4.3 Risk profiling and mitigation measures mapping for air pollution

Table 12: Risk profiling and mitigation measures mapping matrix related to air pollution

Risk	Likelihood (A)	Consequences (B)	Risk score C = A*B	Mitigating measures
Hazardous emissions	2	2	4	RMM41, RMM42, RMM43, RMM44

[11] Stack height – A stack is a type of chimney or a similar structure which is used to exhaust combustion product gases (flue gases) in the atmosphere. Stack height refers to the height of the chimney from base to the top.

2.3.5 Waste disposal in landfills

The management of spent LiBs and waste generated during recycling process incorporates disposal as the last step. The local disposal routes depend on national legislation and regulations, recycling capacities, collection systems and type of waste generated.

The main sources of emissions from landfills are surface dust, landfill gases (e.g., biogas), leachate and fires. Buried LiBs, which may be holding a charge and contain flammable electrolytes, may trigger, amplify, and prolong landfill fires. Landfill fires caused by small LiBs are a major emerging problem. Accurate prediction of the ignition potential of LiBs is challenging, as spent batteries will have various compositions, States of Health (SoH) and charge (SoC); besides, it is likely that cells, modules, and packs will be dumped and landfilled.

In landfills, batteries may be damaged during compacting and hence ignite either immediately or after burial. In the latter case, serious fires could result due to surrounding flammable materials and existing methane in the landfill environment.

2.3.5.1 Risks associated with process waste disposal

The waste generated from recycling is usually sent to TSDFs (Treatment, storage, and disposal facilities) for proper treatment prior to putting them in the landfills. If not sent to proper TSDFs, the following risks emanate:

- **Emission of hazardous gases**
  - Landfill gases, surface dust
  - Fires generating toxic emissions
  - Hazardous emissions in environment like CO, SO2, NO2, H2S etc.
  - High PM 2.5 & PM 10 levels in surrounding area
- **Groundwater contamination**
  - Heavy metals penetration to ground
  - Leachate migration from the landfill to the ground water
- **Inadequate monitoring and compliance of EHS norms**
  - Proximity of landfill to residential, recreational, agricultural, natural protected areas, or wildlife habitat and areas prone to scavenging wildlife, also to surface water sources
  - Improper division the landfill into different cells to separate wastes with different properties
  - No record maintenance of the wastes received, including sources and quantity
  - Lack of procedures for closure of cells (divided basis waste filled) for workers
  - Lack of adequate protective equipment & clothing for workers

2.3.5.2 Mitigation measures for improper waste disposal

Table 13: Risk mitigation measures to handle improper waste disposal

Mitigation measure	Identifier	Reference
Install groundwater monitoring wells outside the landfill perimeter at locations and depths sufficient to evaluate whether leachate is migrating	RMM45	IFC EHS Guidelines

Mitigation measure	Identifier	Reference
from the landfill into the uppermost groundwater unit and periodically monitor them		
Monitor landfill gases via installation of landfill gas collection system and treat them before discharging into the environment	RMM46	IFC EHS Guidelines
Consider EHS impact of long-term operation and maintenance of the landfill in the system design	RMM47	IFC EHS Guidelines
Consider proximity of landfill site to residential, agricultural, and natural protected areas and to surface water sources	RMM48	IFC EHS Guidelines
Regularly sample boreholes surrounding the landfill to monitor for the migration of landfill gas	RMM49	IFC EHS Guidelines
Divide the landfill into different cells to separate wastes with different properties	RMM50	IFC EHS Guidelines
Maintain proper records of the wastes received, including sources, and quantities	RMM51	IFC EHS Guidelines
Install a liner system, consisting of two or more liners with a leachate collection system above and between the liners, to prevent migration of wastes out of the landfill	RMM52	IFC EHS Guidelines
Provide waste transport workers with protective clothing, gloves, respiratory face masks and slip-resistant/hard soled shoes	RMM53	ISO 45001
Equip collection vehicles and landfill equipment with audible reversing alarms and visible reversing lights	RMM54	ISO 45001

2.3.5.3 Risk profiling and mitigation measure mapping for process waste disposal

Table 14: Risk profiling and mitigation measures mapping matrix for waste disposal

Risk	Likelihood (A)	Consequences (B)	Risk score C = A*B	Mitigating measures
Emission of hazardous gases	2	2	4	RMM41, RMM43, RMM44, RMM46, RMM48, RMM49
Groundwater contamination	1	3	3	RMM45. RMM48, RMM52
Inadequate monitoring and compliance of EHS norms	2	2	4	RMM47, RMM50, RMM51, RMM53

2.4 EHS risk screening framework

A consolidated view of the risks and associated mitigation measures is provided below:

Table 15: Consolidated EHS Risk Screening framework

Value chain element	Risk	Likelihood (A)	Consequences (B)	Risk score C = A*B	Mitigating measures
Collection and Transportation 	Improper handling of batteries	2	3	6	RMM1, RMM2, RMM3, RMM4, RMM17
	Battery fire	2	3	6	RMM2, RMM3, RMM5, RMM6, RMM11, RMM13, RMM17, RMM18
	Inadequate training and awareness amongst employees	2	3	6	RMM5, RMM7, RMM10, RMM11, RMM13, RMM9, RMM17
	Inadequate processes and procedures	2	2	4	RMM8, RMM12, RMM14, RMM15, RMM16, RMM17, RMM10
Storage 	Battery Fire	2	3	6	RMM18, RMM19, RMM20
	Emission of hazardous gases	2	2	4	RMM2, RMM3, RMM19, RMM20, RMM21, RMM27
	Improper procedures & handling of batteries in storage area	1	3	3	RMM4, RMM21, RMM22, RMM23, RMM26, RMM27
	Inadequate access control to storage facility	1	1	1	RMM24, RMM25
	Unavailability of emergency response measures	2	3	6	RMM12, RMM13, RMM15, RMM16, RMM17, RMM22
Dismantling and operations 	Improper handling of batteries	2	2	4	RMM28, RMM29, RMM32, RMM35
	Battery fire	2	3	6	RMM20, RMM21, RMM28
	Inadequate training and awareness amongst employees	2	2	4	RMM5, RMM10, RMM11, RMM29, RMM30
	Inadequate safety measures during dismantling process	1	3	3	RMM29, RMM31, RMM32

Value chain element	Risk	Likelihood (A)	Consequences (B)	Risk score C = A*B	Mitigating measures
	Inadequate processes and procedures	2	2	4	RMM16, RMM32, RMM33, RMM35, RMM38, RMM40
	Disposal of hazardous waste and gases	2	2	4	RMM37, RMM38
	Emission of hazardous waste and gases	2	2	4	RMM12, RMM15, RMM16, RMM22, RMM24, RMM29, RMM31
	Emergency preparedness	2	3	6	RMM28, RMM29, RMM32, RMM35
Air Pollution	Hazardous Emissions	2	2	4	RMM41, RMM42, RMM43, RMM44
Waste disposal 	Emission of hazardous gases	2	2	4	RMM41, RMM43, RMM44, RMM46, RMM48, RMM49
	Groundwater contamination	1	3	3	RMM45. RMM48, RMM52
	Inadequate monitoring and compliance of EHS norms	2	2	4	RMM47, RMM50, RMM51, RMM53

High category risks are mostly placed out of the recycling facilities. The organized players have to obtain CTO (Consent to Operate) which takes care of the processes in the plant. However, with the high dependence for collection and storage on the unorganized sector, the development of suitable regulations towards driving batteries directly to the organized players is required.

2.5 Consolidated mitigation measures

Table 16: Consolidated mitigation measures

Mitigation measure	Identifier[12]	Standards referred
Avoid transporting batteries in metal boxes and tape terminals to prevent contact being exposed to short circuiting. Recommended option is putting the batteries in a clear plastic bag and placing them in a firm box (vermiculite) with good padding.	RMM1	R2; ISO 45001
Ensure that batteries are kept away from heat, isolated from device (if any), transported in an insulated container or padded bag to prevent shock if dropped or impacted. Temperature to be maintained between -20°C to 60°C	RMM2	ISO 45001
Do not transport or ship a fully charged battery. The recommended State of Charge (SoC) is 30% or less. If the battery SoC is above 30%, then discharge it using proper SOPs before transporting	RMM3	ISO 45001
Stacking of batteries should be avoided without protective barriers (insulators like honeycomb cardboard) between them	RMM4	R2
Provide operators with hazard information and training, appropriate PPEs for specific chemicals, channel for incident reporting and fair working environment	RMM5	R2, ISO 45001
Fire safety systems, heat sensors, alarms must be installed in the vehicles to prevent any fire related incidents	RMM6	ISO 45001
Specific measures and guidelines emphasizing safety aspects among drivers like requirement of license, limits for trip duration and checking overtiredness, planning to avoid dangerous routes and times of day, installation of speed regulation devices and procedure to monitor vehicle fitness to be ensured	RMM7	ISO 45001
Ensure responsibility and accountability for the prevention of work-related injury and ill health, as well as the provision of safe and healthy workplaces and activities	RMM8	ISO 45001
Ensure anonymity and safeguarding workers from reprisals when reporting incidents, hazards, risks, and opportunities	RMM9	R2

[12] RMM stands for Risk Mitigation Measure. Identifiers have been provided against each of the mitigation measures due to their applicability across the value chain for risks and easy aggregation of the framework in large.

Mitigation measure	Identifier[12]	Standards referred
Provide proper documentation and communication (considering diversity aspects) regarding relevant information like location of PPEs inventory, evacuation plan, etc. to respond to emergency situations in a sound manner	RMM10	R2, ISO 45001
Provide information and train workers regarding past relevant incidents, internal or external to the organization, including emergencies, and their causes	RMM11	ISO 45001
Ensure that the requirements of facility's OH&S management system are met by the contractors and their workers	RMM12	ISO 45001
Communicate and provide relevant information regarding evacuation plan to contractors, emergency response services, government authorities and the local community needed to prepare for and respond to emergency situations.	RMM13	R2
Implement management controls (audits, procedures, inspections, communications, training, and drills) to address residual risks that have not been prevented or controlled through engineering measures.	RMM14	R2, ISO 45001
Provide written SOPs for all the processes, evacuation procedures in case of high voltage & degraded batteries, emergencies arising during transportation and handling of batteries	RMM15	IFC EHS Guidelines
Label containers regarding the hazardous chemicals present inside them for appropriate handling	RMM16	R2, ISO 45001
Train operators involved in the removal, collection & transportation of high voltage & degraded batteries to ensure minimum injuries and damage to workers and the public	RMM17	IFC EHS Guidelines
Store batteries in a dry and well-ventilated place at room temperature or lower. While batteries can be used safely between -20 and 60 °C, it is strongly suggested to avoid storing them at a temperature that is close to the upper or lower range	RMM18	ISO 45001
Store lithium-ion batteries on floors which are made up of concrete, metal, or ceramic or any non-flammable material and in a reserved area. If batteries are placed in stacks, ensure proper insulation and protective layer between the stacks.	RMM19	ISO 45001
Have a fire detector in the storage area and a class ABC or CO2 fire extinguisher nearby the storage area. For large Li-ion battery fires use foam extinguisher containing CO2, powder graphite, ABC dry chemical, or sodium carbonate.	RMM20	R2, ISO 45001
Ensure storage area is free of sharp objects and tools which can puncture battery outer casing	RMM21	R2

Mitigation measure	Identifier[12]	Standards referred
Provide adequate training, awareness & frequent mock drills to employees to prepare for emergency situations	RMM22	ISO 45001
Ensure facility is located away from highly populated area, municipal/stormwater streams, and the feedstock storage away from the main operations area	RMM23	IFC EHS Guidelines
Ensure a proper communication channel for consistent and reliable OH&S information flow in case of emergencies	RMM24	IFC EHS Guidelines
Provide appropriate security arrangements to ensure access of only authorized personnel in facility premises	RMM25	ISO 45001
Provide SOPs for filling and operating USTs and ASTs to check their overfilling and leakages	RMM26	IFC EHS Guidelines
Ensure portable spill containment and clean-up equipment on site and provide relevant trainings for the equipment deployment	RMM27	IFC EHS Guidelines
Complete discharging of battery before dismantling	RMM28	R2
Provide mechanisms, time, training, and resources necessary for workers consultation and participation for the prevention of accidents in the facility	RMM29	ISO 45001
Ensure actions to achieve EHS, OH&S objectives getting integrated into the organization's business processes	RMM30	IFC EHS Guidelines
Prepare a spill control, prevention, and countermeasure plan as a specific component of their Emergency Preparedness and Response Plan	RMM31	IFC EHS Guidelines
Implement management controls and SOPs (procedures, inspections, communications, training, and drills) to address residual risks that have not been prevented or controlled through engineering measures.	RMM32	R2, ISO 45001
Prepare a quality assurance plan for equipment, maintenance materials, and spare parts required in day-to-day operations	RMM33	ISO 45001
Assess potential risks from forces of nature (earthquakes, floods, tsunamis etc.) while selecting the location of the facility to be ensured	RMM34	IFC EHS Guidelines

Mitigation measure	Identifier[12]	Standards referred
Provide measures for safe working at heights & confined spaces, vibrations, temperature, and noise level on the shopfloor	RMM35	ISO 45001
Collect data and information regarding processes generating waste and existing waste streams in facility and ensure stringent rules for environmentally safe disposal of segregated waste	RMM36	R2
Adopt stringent waste segregation procedures to prevent mixing of hazardous and non-hazardous chemicals & wastes	RMM37	R2, ISO 45001
Ensure stringent procedures for the selection of vendors and contractors	RMM38	IFC EHS Guidelines
Install audible alarms such as fire bells, sirens, vehicle mounted speakers etc. to alert the nearby community in case of emergencies	RMM39	ISO 45001
Adopt appropriate dust suppression measures such as applying water or non-toxic chemicals to minimize dust from vehicle movements	RMM40	ISO 45001
Controlling fires related to battery waste	RMM41	ISO 45001
Treatment of fumes before disposing in environment (gas treatment equipment installation) and setting stack height as per GIIP and annual stack emission testing	RMM42	ISO 14001
Use of mist spray to keep down dusts, especially during and prior to loading or other handling procedures	RMM43	IFC EHS Guidelines
Use of flue gas treatment system for control of acid gases, particulate matter, and other air pollutants	RMM44	IFC EHS Guidelines
Install groundwater monitoring wells outside the landfill perimeter at locations and depths sufficient to evaluate whether leachate is migrating from the landfill into the uppermost groundwater unit and periodically monitor them	RMM45	IFC EHS Guidelines
Monitor landfill gases via installation of landfill gas collection system and treat them before discharging into the environment	RMM46	IFC EHS Guidelines
Consider EHS impact of long-term operation and maintenance of the landfill in the system design	RMM47	IFC EHS Guidelines

Mitigation measure	Identifier[12]	Standards referred
Consider proximity of landfill site to residential, agricultural, and natural protected areas and to surface water sources	RMM48	IFC EHS Guidelines
Regularly sample boreholes surrounding the landfill to monitor for the migration of landfill gas	RMM49	IFC EHS Guidelines
Divide the landfill into different cells to separate wastes with different properties	RMM50	IFC EHS Guidelines
Maintain proper records of the wastes received, including sources, and quantities	RMM51	IFC EHS Guidelines
Install a liner system, consisting of two or more liners with a leachate collection system above and between the liners, to prevent migration of wastes out of the landfill	RMM52	IFC EHS Guidelines
Provide waste transport workers with protective clothing, gloves, respiratory face masks and slip-resistant/hard soled shoes	RMM53	ISO 45001
Equip collection vehicles and landfill equipment with audible reversing alarms and visible reversing lights	RMM54	ISO 45001

SOP for battery recycling

3. Standard operating procedures

3.1 Introduction

Lithium-ion batteries used in EVs reach their end-of-first life when their SOH decreases to ~80%. Such batteries can be sent for reuse in second-life applications, if fit, or else they are sent for recycling. After reaching end-of-second life, the spent batteries shall be sent for recycling. The flow of such batteries after the end of first life/second life require close coordination amongst multiple stakeholders to ensure their safe handling. Additionally, certain procedures have to be followed to ensure maximum waste battery feedstock to the recycling facilities which would get translated to maximized recovery of critical battery minerals.

Battery refurbishing followed by recycling process involve storage, handling, and transport of batteries amongst different stakeholders. Lithium-ion batteries have the potential of catching fire and cause severe injury. There should be guidelines in place which promote safe handling, storage, transport, refurbishing/repurposing, recycling, and disposal of such batteries.

The intent of this document is to collate standard operating procedures regarding a safe lithium-ion battery recycling ecosystem

3.2 Background

Battery recycling includes the flow of batteries from the end consumers to the recycling plant through appropriate and defined channels, such as battery aggregators. Collection of the batteries is also done by the battery manufacturers or electric vehicle OEMs themselves. Once these batteries are collected, they shall be transported either to battery refurbishing/repurposing plants or directly to recycling facilities.

When waste batteries are repurposed, they can be used in second-life applications till they reach the end-of-second life. They shall then be sent for recycling and disposal. The materials extracted from the batteries through several recycling processes is further sold to industries or battery manufacturer.

The overall value chain of battery recycling can be summarized in **six process steps**:

3.3 SOP for operating traction battery recycling and refurbishing facility

Taking cue from the guidelines and standard operating procedures defined by regulators globally, and India's Battery Waste Management Rules, 2022 and E-Waste Management Rules, 2016[13], the SOP for an efficient battery recycling system has been drafted. In addition to the global and domestic guideline references, industry inputs were also captured while drafting the SOP. The SOP has been prepared for batteries used in EVs for the following segments: e-2W, e-3W, and e-4W.

[13] And subsequent amendments

3.3.1 Stage 1: Planning

Recycling being a downstream activity relies heavily on other entities for ensuring a steady flow of waste batteries. The recycler does not have much visibility regarding the quantum of spent battery feedstock channelized to them. The recycler can undergo a planning stage for the purpose of having greater visibility of quantum, and type of feedstock which shall be channelized to the recycler. The planning stage involves the battery collection agencies (as set up by the OEMs, dealers, or recycling facilities) collecting various information from the consumers such as EV OEM/ battery refurbisher/ fleet operator, or the OEM regarding the battery.

With lithium-ion batteries, value recovered highly depends on the chemistry of feedstock owing to the varying concentration of critical minerals. Hence, it is critical to ensure that the recycling facilities undergo adequate planning for setting up a supply chain of waste batteries to their facilities. With adequate planning, the recycler can adjudge the quantity, type, and cost of the feedstock. Thereby, the recyclers can estimate their revenue based on their recycling efficiency for different types of feedstocks. This can help recyclers in inventory planning (for waste battery feedstock and chemicals) and overall business planning.

From a refurbisher's perspective, obtaining high energy density lithium-ion batteries (like NMC) ensures that the facility has higher output for the same mass of batteries. Obtaining such lithium-ion batteries through supply chain planning can enable refurbishers to maximize feasibility of business.

A Unique Identification Number should be assigned to each battery during the manufacturing phase along with a QR code. Information such as name of battery manufacturer, battery chemistry, internal resistance, round-trip efficiency, self-discharging rate of the battery at the time of manufacturing can be associated with the UIN. The battery recycler can then simply scan the QR code or enter the UIN into the portal of the CPCB to access the stored information. This will help the recyclers/refurbishers in sampling and grading batteries.

Note: These recommendations may not be directly required as a part of SOP; however, such information will ensure an efficient battery recycling ecosystem.[14]

3.3.1.1 Asset identification

1	Information such as **type, chemistry, size, weight, form, shape, and serial number** of the battery must be gathered by the battery collecting agency
	This is desired as having information on type, chemistry, size, weight, form, shape, serial number etc. helps in planning collection and transportation of the spent batteries. For e.g., if the batteries are heavy then forklifts for lifting them could be arranged beforehand, also type of vehicle for transportation could be decided in advance

[14] The chemistries of batteries and visibility of battery specification/parameters across their life cycle shall be driven by future guideline released by MoEFCC

2	Chemical information such as **type, and chemistry** of the battery must be gathered by the battery collecting agency
	Gathering information regarding type and chemistry of the battery can help in determining the further course of action by battery recyclers. For ex, for a LCO battery, the recycler needs to carry out processing for extraction of Lithium and Cobalt and not for other metals like Nickel.

3	**Agreements** with refurbishing facilities to provide necessary feedstock
	The feedstock for refurbishing facilities may consist of some batteries which do not have potential for second life. Such batteries have to be channelized to recyclers for extracting battery minerals and plastics.

3.3.2 Stage 2: Collection and segregation/ sorting

The first stage of the entire battery recycling ecosystem in India is – collection of spent or used batteries. Globally, automobile manufacturers or battery OEMs are responsible for collecting the spent batteries from the EV owners. In India, the responsibility of collecting the batteries from EV owners falls on the battery producer/manufacturer. The producer may choose to engage itself or authorize any other entity/agency such as a dealer/retailer[15] for collecting spent batteries. The producer/manufacturer may further authorize the logistics partner and/or recycler to transport batteries to the recycling/refurbishing facility. The other entities involved in collection of waste batteries are importers, assemblers[16], reconditioners, and several public waste management authorities. battery collecting agency can refer to any stakeholder who collects batteries (dealer of EV or battery OEMs, aggregator or charging points or swapping stations). All such entities which are responsible for collecting waste batteries should follow the below guidelines to ensure safe battery handling.

3.3.2.1 Guidelines for collection from consumers/ OEMs

1	Precautions should be taken to avoid the **dropping** of batteries while collection from consumers. Non-conductive trays can be used along with push carts to avoid the same.
	Dropping batteries can rupture or break or crack battery casing. This can allow moisture or oxygen to enter the battery and oxidize lithium (in li-ion batteries) in the battery which can lead to an exothermic reaction. This can lead to fires or explosion of the battery. Further dropping of batteries may lead to overcharging, overheating or shock which can also give rise to exothermic reactions.

[15] The battery waste management rules 2022 suggests that a producer may engage itself or authorize any other entity for collection, recycling or refurbishment of Waste Battery. However, it is the Producer's obligation to meet the Extended Producer Responsibility targets. .
[16] Importers and assemblers can use their wide dealer network to collect waste batteries from multiple segments and consumer categories

2	Spent batteries or battery waste can weigh up to 900 kg and may be categorized as volumetric and non-volumetric. The consumers shall be provided **a box, bin, or a demarcated area** for collecting battery waste.
	Battery waste should be collected separately as recycling these batteries gives us access to critical minerals. Disposing batteries in trash will put high pressure on the long-term supply of raw materials for battery manufacturing and disrupt supply. *Additionally, if spent batteries are disposed of in trash, it may become damaged or crushed during transport or from sorting and processing equipment and create a fire hazard.* *Disposal in solid waste landfill can lead to various contaminants leaking into the soil damaging the environment. Hence spent batteries must be collected separately to ensure proper treatment and recycling to extract key minerals and minimize damage to the environment.*
3	The bins or boxes which collect used batteries must be **resistant to the electrolyte** of the battery.
	To prevent the reaction of battery electrolyte with the surface of the bins or boxes. Battery electrolyte of some batteries can be corrosive and may dissolve or react with several materials, which could lead to a hazard. Hence, the box/bin should be resistant to the electrolyte of the battery and should also prevent the leakage of electrolytes to the environment in case of electrolyte loss
4	The bins or boxes should not be filled to a **level greater than the height** of its sides.
	Filling battery collection bins to a level greater than height of its sides can lead to batteries accidently dropping off which can cause overheating, overcharging or shock to the batteries leading to an exothermal reaction. Such events could cause fire hazards.
5	The bins or boxes should be placed at positions which is **well ventilated, dry, and sheltered** from the weather. All battery collection rooms shall be naturally or forced ventilated. Minimum amount of air exchanges should be ensured to keep the battery collection room safe.
	Certain batteries can release gases such as hydrogen (lead acid batteries) and other potentially explosive gases. Hence, collection boxes should be kept in well ventilated areas to ensure the diffusion of such gases to prevent accumulation of mixtures which could be explosive. Additionally, lithium is extremely sensitive to moisture and high temperatures, hence care should be taken to ensure that the batteries are kept in a dry environment and are adequately sheltered from the weather.

	*To ensure proper ventilation a **wall mounted axial type extract fan** with back draught **dampers** can be used. It should be mounted as high as possible in the collection rooms.*

6	**Hydrogen gas** from battery rooms shall be **extracted or ventilated to a safe area**, i.e., outdoors or to an area where the gas will always dissipate into the atmosphere without possible danger of the gas accumulating in any part of that area.

7	Batteries should be **placed in stacks** to avoid bumping or knocking over of batteries (for volumetric).
	Keeping batteries in stacks makes them stable and prevents bumping or knocking over of batteries which could damage them.

3.3.2.2 Guidelines for sorting

1	The battery collecting agency should identify various **properties of the batteries** to accurately sort them.
	The physical size, weight, and surface identifiers need to be analysed in different combinations to carry out sorting of batteries according to their chemistry before sending out to recycling facilities.

2	**Manual sorting** should be carried out according to their chemistries, condition (based on visual inspection to identify damage)
	Manual sorting involves separating out the unwanted materials which end up along with the spent batteries. Manual sorting shall also involve segregating already damaged batteries from otherwise spent batteries. Such batteries shall be transported in special containers as covered in 3.3.3.4 Guidelines for transport of damaged, defective, or recalled Lithium-Ion batteries

3.3.2.3Safety guidelines

1	It should be ensured that batteries are **not damaged** during collection process or in the battery collection agencies.

	Damaged batteries could leak electrolytes, overheat, overcharge or release electrolyte vapor which could create a hazard. In some cases, it could lead to internal short circuits resulting in cell venting or explosion.
2	Batteries should not be kept in an environment which might lead to **fire or explosion** of batteries
	Exposure to moisture or direct sunlight or high temperatures could lead to fire or explosion of batteries. Additionally, the presence of other spent batteries in the vicinity could cause a chain reaction thereby causing a large explosion or fire hazard putting the lives of people nearby at risk.
3	It should be ensured that **heavy objects** are not placed on boxes which collect used lithium-ion batteries
	Placing heavy objects on boxes containing spent battery packs could lead to crushing or puncturing the cell case. Severe damage could further lead to internal short circuit resulting in cell venting or explosion.
4	**Firefighting provisions** such as liquid nitrogen fire extinguishers or ordinary fire extinguishers and sand, dry ice, blankets, should be present in each battery collection agency/other stakeholders involved in battery collection.
	Firefighting provisions should be present in battery collection agencies to ensure isolation of fire to prevent chain reaction which could lead to a major hazard.
5	To prevent the short circuit of batteries when in battery collection agencies, each battery pack must be fully enclosed in **inner packaging made of non-conductive material/ contact with other battery packs**, devices or conductive materials should be prevented.
	Short circuit of batteries could result in swelling, rupturing, fire, or explosion of batteries. Hence measures such as ensuring no contact with metal objects, preventing spent battery abuse, etc. should be taken.
6	The battery collecting agency should have **trained personnel** for handling batteries in case of any incident.

	Trained personnel are well accustomed to handling procedures and dangers of exposure in case of a battery incident. Correct handling of battery incidents can reduce the risk of fire and/or explosion.

3.3.2.4 Guidelines for collection of damaged, or defective Lithium-Ion batteries

Damaged or defective lithium-ion batteries have the potential for producing a dangerous evolution of heat, fire, or short circuit. Hence ensuring safety during collection of such batteries is essential. The following guidelines need to be followed to ensure safe collection of such batteries:

1	Damaged or defective lithium-ion batteries **should not be placed in the same collection box/bin** with other spent batteries. A dedicated area or boxes/bins must be kept aside for collecting such batteries. The bins/boxes must be kept in well-ventilated areas.
	Damaged or defective lithium- ion batteries can release gases, heat, or cause a battery fire. Such incidents can be handled in isolation. If placed along with other spent batteries, such incidents could easily spread thereby causing a mishap. *Care should be taken by consumers as well to ensure that damaged or defective lithium-ion batteries are not placed in trash.*

2	Damaged or defective lithium-ion should be placed in a **non-flammable material** such as **sand or another chemically inert cushioning material** for short-term.
	Damaged or defective lithium- ion batteries can release gases, heat, or cause a battery fire. Hence, to control such incidents, the damaged or defective batteries should be placed in a non-flammable material such as sand.

3	The battery collecting agency should have **trained personnel** for identifying damaged or defective batteries.
	Trained personnel should be able to identify a damage or defective battery via a visual inspection. The trained personnel are well accustomed to handling procedures and dangers of exposure in case of a battery incident. Correct handling of battery incidents can reduce the risk of fire and/or explosion.

4	All personnel should wear **proper PPE (gloves, eyewear, apron, shoes)** while **collecting or handling** damaged and defective batteries.

	Damaged or defective lithium- ion batteries can leak electrolyte. Hence, to protect the personnel collecting or handling such batteries from exposure, it is deemed essential to wear PPE

5	Immediate arrangements must be done to transport such batteries to registered recyclers/refurbishers for further testing and end-of-life disposal.

3.3.3 Stage 3: Transportation

Transportation is involved in multiple stages in the Indian battery recycling ecosystem. Dealers / battery refurbishers/ battery recyclers are responsible for transport of waste batteries or battery components respectively. Certain guidelines are supposed to be followed by dealers to ensure safe transportation of spent batteries.

3.3.3.1 General guidelines

1	The **battery terminals** need to be protected while being transported by covering battery terminals with molten wax/battery packs must be securely cushioned to prevent shifting/securely attach packaging covers with sufficient strength to protect battery terminals
	Protection of battery terminals is important during transportation to prevent short circuiting during transportation. Also shifting of batteries could loosen or reorient battery terminals in such a way which could cause short circuit and hence should be prevented.

2	Lithium-ion battery packs transported by ground (road or railway) need not have a limit on the state of charge. But lithium-ion batteries shipped by aircraft or vessels must be discharged below **30% of state of charge.** The waste batteries should only be transported by agencies or shippers which have contracts for transporting hazardous materials/dangerous good services.
	Batteries need to be below 30% state of charge if shipped by aircraft or vessel to reduce the likelihood of a thermal event and provide an additional layer of security. Ideally, using air services for recalling batteries for recycling should be avoided for safety reasons and is prohibited in many countries.

3	During transport of lithium-ion battery packs, it should be ensured that **uninsulated connections** should not be in contact with other objects (short circuit)
	Uninsulated connection when in contact with certain objects like metals could lead to short circuit which might escalate to a thermal event during transport.

4	While transporting the lithium-ion battery packs, it should be ensured that the battery packs are not placed near any **heat source/extreme temperatures** (strong light/ sun/ machinery)
	As lithium-ion batteries are sensitive to extreme temperatures, presence of a heat source nearby might lead to a thermal runaway or overheating which could lead to a fire or explosion. To prevent fire, any device with installed batteries must not turn on while in transport. Switches which can accidentally be activated should be protected. Devices like flashlights or rechargeable drills can generate a dangerous amount of heat if accidentally activated. Similarly, care should be taken to not place batteries near any cold surface or source.
5	Precautions should be taken to avoid the **dropping** of lithium-ion battery packs.
	Dropping batteries can rupture or break or crack battery casing. This can allow moisture or oxygen to enter the battery and oxidize lithium (in li-ion batteries) in the battery which can lead to an exothermic reaction. This can lead to fires or explosion of the battery. Further dropping of batteries may lead to overcharging, overheating or shock which can also give rise to exothermic reactions.
6	It should also be ensured that spent batteries are sent only to **registered recyclers/ refurbisher**
	Registered recyclers/ refurbisher are required to submit annual records regarding receipt, source, quantity, and metal yield of spent batteries available for inspection to the concerned state pollution control board. They are also responsible for strictly complying with the terms and conditions of the registrations for reprocessing and/or recycling of spent batteries. Hence, sending spent batteries to registered recyclers/ refurbisher promotes a safe battery recycling ecosystem.
7	Batteries should be **marked** with international recycling sign or **"not for first use"**
	These signs on the packaging or on the transport vehicle will indicate that these batteries are not meant for first use to ensure that batteries are first reprocessed before being sent either for second use of recycling.
8	All employees involved in the shipment, including preparation for shipment must be trained according to **hazmat employee training requirements**
	Hazmat employee training requirements must include general awareness/familiarization training, function-specific training, safety training, security awareness training and in-depth security training

3.3.3.2 Guidelines for packaging during transport

1	The battery packs should be secured with outer packaging to prevent **excessive movement** during the transport by using a non-combustible and **non-conductive cushioning material.** The packaging must also include an acid or alkali-proof liner or supplementary packaging which must have adequate seals and sufficient strength to prevent electrolyte fluid leakage during spillage.
	Excessive movement of batteries could trigger accidental activation or short circuit or heating. Hence, the packaging must ensure minimal movement of such batteries.
2	An overpack to **consolidate several packages** may be used. The overpack must be marked with the word "overpack" and labelled with the appropriate lithium battery handling label.
	Individual packages in the overpack must comply with the necessary requirements such as limitations on the net battery weight or pass through the 1.2-meter drop test, as applicable.
3	The **original packaging or suitable plastic container** should be ideally used for transporting batteries. Further each package containing battery packs must be marked with recycling sign to indicate that these packages are being sent for recycling.
	The original packaging provided by the manufacturer ensures that the battery is protected from environmental factors (humidity), battery terminals do not get in contact with one another, and battery terminals don't touch any metal object.
4	Lithium-ion batteries must be packaged such that **short circuit is prevented** while transporting.
	Short circuit of batteries could result in swelling, rupturing, fire, or explosion of batteries. Hence measures such as ensuring no contact with metal objects, preventing spent battery abuse, etc. should be taken while transporting batteries.
5	The batteries must be packaged in such a way to **avoid contact** with other devices or **conductive materials** or fluids such as **acid, or water** and provide shelter against weather (rain).
	This could cause short circuit of the batteries and lead to fire or explosion of the batteries.

6	**UN approved boxes or barrels** (200L or 400 Kg palette box) used for packaging must be first filled with **10 cm layer of dry sand** (lithium-ion) or vermiculite (other batteries). Then stacks or layers of batteries can be placed. On top of the batteries additional layer of 10 cm dry sand or vermiculite should be added. Extra **sand or vermiculite** must be added if the battery is damaged, swollen or leaking. The distribution of weight should be as follows: Sand – 1/3 and Battery – 2/3. Care should be taken to not mix damaged and non-damaged batteries.[17] Each UN-approved barrel should be labelled stating category 1, 2, or 3. • Category 1: Undamaged batteries. Battery chemistry/technology must be mentioned • Category 2: Damaged, swollen, or leaking batteries. Battery chemistry/technology must be mentioned. • Category 3: Devices with swollen batteries. Battery chemistry/technology must be mentioned.

3.3.3.3 Guidelines for transport vehicles

1	The transport vehicle must be **well ventilated, provide shelter from the weather** and easily accessible if a fire breaks out.
	Transport vehicle should be kept in well ventilated to ensure the diffusion of such gases to prevent accumulation of mixtures which could be explosive. Additionally, lithium-ion batteries are extremely sensitive to moisture and high temperatures, hence care should be taken to ensure that the batteries are adequately sheltered from the weather.
2	The vehicle should have a satisfactory level of **security.** Also, the logistics partner must apply **geotagging** on packages to enable geographical **tracking** of batteries.
	The batteries which are being transported should only be accessible to trained people.
3	Appropriate **fire-fighting equipment** such as ordinary fire extinguisher or sand must be carried in the vehicle in case a battery catches fire while transporting.
	Firefighting provisions should be present in transport vehicle to ensure isolation of fire in case of a thermal event.

[17] Industry Stakeholder discussion

4	All drivers must be **trained** in spill and emergency response. They must also be aware of the Hazardous Waste Management Rules for batteries as well.
	In case of an emergency during transport, appropriate support may not arrive quickly. Hence to ensure proper handling of such incidents and prevent further escalation, the drivers must be given training on how to handle batteries.

5	Logistics partner must have **dedicated vehicles** (similar to oil tankers) for transport of batteries
	Having a dedicated vehicle will ensure enhanced safety during transportation of spent batteries; this will significantly reduce the possibility of any hazard while transporting

3.3.3.4 Guidelines for transport of damaged, defective, or recalled Lithium-Ion batteries

Damaged lithium-ion batteries which are identified by manufacturers as being defective, have the potential for producing a dangerous evolution of heat, fire, or short circuit. Such batteries should be transported only via highways, rails, or vessels. Additionally, the following guidelines should be followed to ensure safe transport of such batteries:

1	Each battery must be placed **in individual, non-metallic inner packaging or a container** which should completely enclose the battery pack. This package must further be enclosed by another leak-proof exterior package.
	This ensures isolation of the damaged/defective lithium-ion batteries.

2	The **container** should be **closed, structurally sound, compatible with battery contents**. The container should lack any evidence of leakage, spillage or damage which could cause leakage in foreseeable conditions.
	Leakage of the battery contents or electrolytes from the container could react with nearby objects or other batteries which can cause a hazard. Hence, it should be ensured that the container is compatible with the battery electrolyte and can contain electrolyte loss.

3	The **inner packaging** must also be surrounded by non-conductive, non-combustible, and cushioning material having absorbent capabilities.
	This is done to prevent accidental activation, short circuiting, or battery fires during transportation.

4	The boxes or drums or **outside packaging** containing damaged lithium-ion batteries should be marked with an indication that the package contains a **"defective/damaged lithium-ion battery"**
	This enables identification of damaged batteries by recycling facilities who then shall send these batteries for disposal post examination.

5	Transport of batteries showing evidence of **leakage of materials** characterized as **hazardous waste** should be managed as fully regulated hazardous waste. Appropriate **eye wear and gloves** must be used, and the battery must be removed from the vicinity and placed in a clear plastic bag and placed securely in an electrolyte resistance packaging.

3.3.4 Stage 4: Storage

The batteries are transported by dealers to battery collecting agencies where these batteries are stored before being transported to refurbishing/ recycling facilities.

3.3.4.1 General guidelines

1	The lithium-ion batteries should be stored at **~40% of their rated capacity**.
	Lithium-ion batteries become unstable when not stored at proper levels of state of charge.

2	The **optimal storage temperature** should be maintained (at or below 35° C)
	The ideal temperature (considering Indian conditions) to store lithium-ion batteries should be 30-35° C. Exposure to higher temperatures can cause thermal runaway or overheating which could lead to a fire or explosion.

3	**Heavy objects** should not be stacked on top of boxes containing lithium batteries packs.
	Placing heavy objects on boxes containing spent battery packs could lead to crushing or puncturing the cell case. Severe damage could further lead to internal short circuit resulting in cell venting or explosion.

4	Battery packs should be **stored** in their original containers.

	The original packaging provided by the manufacturer ensures that the battery is protected from environmental factors (humidity), battery terminals do not get in contact with one another, and battery terminals don't touch any metal object.

3.3.4.2 Guidelines for storage area

1	The battery packs should be stored in a **well ventilated and dry area**. The cells should be stored in an isolated area and far from combustible materials.
	Certain batteries can release gases such as hydrogen (lead acid batteries) and other potentially explosive gases. Hence, collection boxes should be kept in well ventilated areas to ensure the diffusion of such gases to prevent accumulation of mixtures which could be explosive. Additionally, lithium is extremely sensitive to moisture and high temperatures, hence care should be taken to ensure that the batteries are kept in a dry environment and are adequately sheltered from the weather.
2	**A reserved area** should be designated only for storing lithium-ion batteries which should be a cool and dry place far from heat sources and high-tension cables or transformers.
	As lithium-ion batteries are sensitive to heat, presence of a heat source nearby might lead to a thermal runaway or overheating which could lead to a fire or explosion. High tension cables or transformers may also pose danger if kept near batteries.
3	The ideal **surface** for storing lithium-ion batteries is **concrete, ceramic, metal, or any non-flammable material**. But it must be ensured that the batteries do not touch each other.
	Concrete, ceramic, and metal are fire-resistant and would not act like fuel if there is a fire due to any incident. This prevents the fire from spreading quickly ensuring that the batteries in the vicinity do not catch fire.
4	Batteries should not be stored on the floor especially in vessels which may encounter **seawater.** Care should also be taken to not store batteries on the floor especially in water-logged areas or coastal areas.
	The seawater could react with lithium forming lithium hydroxide and hydrogen (flammable). It could corrode or damage the internal safety devices in the battery and cause the battery to overheat, rupture, leak or ignite.

5	**Excessive quantities** of battery packs should **not be allowed** to **accumulate** in any storage area.

3.3.4.3 Safety guidelines

1	Batteries should always be **stowed** carefully to avoid accidental damage, flooding, discharging, or short circuiting.

2	Batteries should never be left **unattended** at a place where it can be damaged by anyone.

3	The storage area should have a **fire detector** and a class ABC or CO_2 fire extinguisher in the storage area.
	Due to external or internal conditions, the battery might short circuit or catch a fire. Hence, it is necessary to have a fire detector which could alert the personnel in the storage area. Proper handling of such situations could reduce the risk of explosion.

4	A lithium-ion battery **fireproof safety bag** or any other fireproof container should be used to store the lithium-ion batteries if it catches fire.
	Such fireproof safety bags provide passive fire protection and contain the thick smoke and toxic gases if the battery catches fire.

5	Storage area must be equipped with appropriate **fire extinguishers, emergency kits, protective eye wear, gloves, gas masks and an extraction unit** to aid during a fire hazard or if toxic gas flows into the storage area
	If the battery is damaged during the dismantling process, the electrolyte could cause fire or emit toxic gases. Hence adequate measures should be taken to ensure safety of worker if such an event occurs.

3.3.5 Stage 5: Repurposing/refurbishing

The spent batteries are transported to registered refurbishers by collection agencies. The spent batteries packs undergo testing (for sorting and grading process) before dismantling. Post dismantling, the components are sent for refurbishing or reprocessing. The refurbishers need to follow certain guidelines to ensure safe handling of batteries. Post refurbishing, the batteries rendered as spent along with other battery components (not required for refurbishing/repurposing) shall be sent to battery recyclers for recycling and end-of-life disposal.

3.3.5.1 General guidelines

1	The refurbishers should ensure that the refurbishing/repurposing and dismantling processes do not have any **adverse impact** on the **health of personnel involved or on the environment**
	Refurbishing involves many risks such as battery overheating, short circuit, cell venting, electrolyte loss, etc. which could pose a risk towards the personnel working or the environment. Hence, such risks should be mitigated by developing guidelines, employee training programmes and timely process audits to identify gaps.
2	Battery waste from dismantling and refurbishing/reprocessing should also be **segregated** into electronics, metal with iron, battery modules, and residual materials by refurbishers.
3	Post segregation, the refurbishers/repurposers should also send the battery waste to **register recyclers** for recovering precious materials
	Refurbishing and repurposing facilities have process discards (i.e., batteries which cannot be reused). The batteries/ modules which are rejected must be sent to CPCB (Central Pollution Control Board) registered battery recyclers.
4	Only **trained personnel** should carry out the dismantling and refurbishing processes. During the processing of such batteries, **fireproof safety bag** or any other fireproof container should be used to store the lithium-ion batteries if it catches fire.
	There are various safety hazards like short circuits during cell opening which can lead to thermal runaway, health issues arising due to chemical compounds in the battery and damaging samples due to improper treatment. Hence, only personnel trained adequately with dismantling processes must carry out refurbishing.
5	Battery systems constructed using repurposed cells, modules and battery packs must be tested and ensured that they meet the **end use battery requirements**
6	Refurbisher should maintain **records and file quarterly returns** regarding the information on the following: • Quantity of used batteries collected or received from producers/entities • Refurbished/repurposed quantities • Hazardous waste generated after refurbishment • Disposal of such waste as per extant rules

3.3.5.2 Guidelines for information collection and analysis

1	All available **information on the battery** should be **gathered**.

Information required includes the following:

- *Battery markings, schematic, specifications, construction, configuration, and chemistry*
- *Any literature or BMS information available on the first life of the battery pack*
- *Reason for retirement and end of first life reaching date*
- *Battery fault/breakdown/abnormal conditions and maintenance records*
- *Storage condition after battery is removed from vehicle*

Such information should be documented as it can be useful for determining state of health of the battery.

2	All available **information on the modules and cells** should be **gathered**.

Information required includes the following:

- *Manufacturer, date of manufacture, part number, markings, rating, specifications, and other available literature*
- *Module construction, configuration, contents, and schematics*
- *Cell chemistry, weight, dimensions, cell specification sheet and ell construction*
- *Safety test data, certifications*

Such information should be documented as it can be useful for determining state of health of the module or cell.

3	The repurposer should **record** all **information** available from **BMS**

Information required includes the following:

- *Manufacturer, date of manufacture, BMS specifications regarding voltage, current and temperature protection, etc.*
- *Communication protocols, CANBUS message schemes, variables*
- *Data regarding BMS software update regarding battery safety during service*
- *Schematics, algorithms, markings, board layout and information on use, installation, operation, programming, and maintenance*

3.3.5.3 Guidelines for disassembly and inspection

1	**Visual inspection** of the battery pack should be carried out by the refurbisher

	Visual inspection involves inspecting if there is any visible damage in the battery pack. If any visible damage is identified, such battery packs should be sent in for review in accordance with repurposer/refurbisher's procedure for rejection.
2	The battery packs must be **discharged** before the dismantling process is initiated. The standard technique for discharging battery packs is by using **static or dynamic resistance** in form of an electronic load.
	The residual charge could harm the workers if certain workstations depend on manual dismantling.
3	Various elements of the battery pack (protective casing, power electronics, BMS, system covers, etc.) need to be removed in order to **obtain the battery modules**
	The main aim of the dismantling process is to get modules/cells from the battery pack which are then sent to registered refurbishers.
4	**Voltage measurements** should be done before or during the dismantling process
	Voltage measurements are done to see if it lies within the nominal range specified by the manufacturer. Voltage measurements could also indicate a blown fuse or completely discharged batteries.
5	**Temperature measurements** must also be done by the means of a **heat scan**
	This is done in order to check if the battery temperature is more than the ambient temperature which could be an indication of overheating, instability, short circuit, etc.
6	**Modules/cells** must be gradually removed from the battery pack
	Modules and cells are gradually removed to reduce the voltage for safe processing. Ultimately all the cells are removed.
7	**Visual inspection** to check if there is any visible damage to the **cells or other components.**

If any visible damage is identified, such battery packs should be sent in for review in accordance with repurposer/refurbisher's procedure for rejection. Visible damage could be as follows:

- *Electrolyte leakage, coolant leakage, traces of burning, or other physical damage*
- *Frayed, damaged wiring, damaged insulation, PCB damage, isolation system damage, damaged HV bus*
- *Damaged casing or enclosure or structure, loose connections*

3.3.5.4 Testing for sorting and grading process

1	Repurposers must have a system for **grading** battery packs, modules, or cells.
	The repurposers must have a criterion for grading cells. It is recommended that they use a 6-sigma limit[18] for specifications such as: Open circuit voltage, capacity, internal resistance, mass, dimensions, etc.
2	**Incoming open circuit voltage measurements** must be carried out on the battery packs, modules, and cells.
	Battery packs, modules and cells below the minimum voltage limit should be rejected for refurbishing or repurposing and thereby sent for disposal
3	**Incoming high isolation voltage check** must be carried out on the battery packs, modules, and cells.
	Insulation resistance test is carried out for both the terminals with dead metal parts separately. The measurement is carried out using a DC voltage of 500 V after an interval of 60 seconds. The measured insulation should be at least: 100Ω/V for AC circuit or 500 Ω/V for ac circuit. Devices not meeting this criterion shall be rejected for reuse.
4	**Capacity check** must be carried out on the battery packs, modules, and cells.
	Battery packs, modules, and cells shall be fully charged under ambient room temperature. After 1-4 hours the battery pack, module, or cell shall be discharged (constant current). Capacities of the pack, cell, or module shall be recorded and compared with available data or manufacturer rating. Devices not meeting the criteria shall be rejected for reuse.

[18] As per UL1974

5	**High internal resistance check** must be carried out on the battery packs, and modules.

- *The battery packs or modules are first charged to full capacity and then rested for 30 mins to 4 hours.*
- *The battery packs or modules are then discharged at constant current I_1 for a specified duration T_1 (till capacity falls to 80-90% SoC). The discharge voltage V_2 is recorded.*
- *The battery packs or modules are then discharged at a constant current $I_2 = 5I_1$ for a duration of 1-10 seconds. The discharge voltage V_2 is recorded.*
- *The resistance is calculated, $R = (V_1 – V_2) / (I_1 – I_2)$.*
- *The battery packs or modules shall be further discharged until they reach 20% SoC. The battery packs or modules shall be rested for 30 mins – 4 hours and then internal resistance should be measured*
- *The internal resistance so measured should meet the criteria set by the repurposer or rejected for reuse*

6	The **BMS controls** and **protection components** must be checked

BMS data (including error messages) should be reviewed to determine if the BMS can be used for repurposing/refurbishing. Out of specification limits indicators may lead to the battery being unfit for repurposing.

7	**Discharge/cycle test** must be carried out on the battery packs, modules, and cells.

Battery packs, or modules, or cells shall be charged and discharged for at least 1 cycle at ambient room temperature. The voltage, current and temperatures must be monitored during the process. Devices not meeting the criteria shall be rejected for reuse

8	**Self-discharge test** must be carried out on the modules and cells.

The modules and cells shall be charged to full capacity and stored in a controlled environment at ambient room temperature for at least a day. The open circuit voltage shall be recorded at specific time period of 5 mins, 1 hour and 24 hours. Devices not meeting the criteria shall be rejected for reuse.

9	**Performance and safety characterization** of the cell must be recorded.

The repurposer should have a program for long term data collection of aged cell samples which can be representative of the cells actually sent for repurposing/refurbishing.

3.3.5.5 Guidelines for safety

1	Batteries should be **completely discharged** during dismantling process. The standard technique for discharging battery packs is by using **static or dynamic resistance** in form of an electronic load.
	This ensures that there is no charge flowing when batteries are dismantled which could lead to electrocution if proper precautions are not taken by personnel.
2	All the tools used for the dismantling and refurbishing battery packs need to be **electrically isolated.**
	Tools should be electrically isolated in order to ensure the protection of people dismantling and refurbishing the battery.
3	All personnel should wear **gloves, shoes, and safety glasses** during the dismantling and refurbishing processes
	Gloves and safety glasses ensure protection to skin and eyes if the electrolyte or battery acid splashes or leaks.
4	Adequate **floor cover** (acid/electrolyte resistant) must be ensured in the work area where batteries are dismantled
	This should be done in order to prevent damage to the floor in the event of an accidental spillage of electrolyte or battery acid onto the floor.
5	Workstation must be equipped with appropriate **fire extinguishers, emergency kits, gas masks and an extraction unit**
	If the battery is damaged during the dismantling process, the electrolyte could cause fire or emit toxic gases. Hence adequate measures should be taken to ensure safety of worker if such an event occurs.
6	Battery dismantling or cell opening should not be carried out in **hot or humid conditions.**

	Battery dismantling in hot or humid air could result to hazards such as fire as certain batteries are sensitive to temperature and moisture and react with moisture to produce flammable gases such as hydrogen which could cause a fire.

7	Equipment for static discharge must be installed **outside the working area** to ensure removal of static charge from individual personnel post handling batteries

8	The repurposing/refurbishing facilities should have a **controlled environment** for storage, handling and testing the batteries in accordance with the repurposer/refurbisher's specifications
	Controlled environment could refer to ambient temperature and humidity which should be monitored and recorded hourly by the repurposer or refurbisher.

3.3.6 Stage 6: Recycling and disposal

The spent batteries are transported to registered recyclers by collection agencies or where the spent batteries are first dismantled or by battery refurbishers. Post dismantling the battery components are sent for recycling or reprocessing of waste batteries. At times, the manufacturers, or consumers such as EV OEMS, battery swapping operators, and fleet operators directly send the spent batteries to registered recyclers. The recyclers also need to follow certain guidelines to ensure an efficient battery recycling ecosystem. Post recycling, the remaining materials are sent for disposal to end-of-life disposal facilities.

3.3.6.1 General guidelines

1	**Hot and humid conditions** should be avoided. Furthermore, batteries should not be placed in direct sunlight, or in hot locations or on hot surfaces.
	Lithium is extremely sensitive to moisture and high temperatures; hence care should be taken to ensure that the batteries are not exposed to hot and humid conditions.

2	**Burning, overheating, disassembling, short-circuiting, soldering, puncturing, crushing or otherwise mutilating batteries packs** should be avoided
	Burning, overheating, short-circuiting, soldering, puncturing, crushing or mutilating battery packs may lead to cell venting, battery fire or explosion. Hence such acts should be avoided.

3	Batteries should not be put in **contact** with **conductive materials, strong oxidizers, water, seawater, and strong acids**.

4	Different types of batteries should not be **mixed.**
	Batteries with different chemistries cannot be recycled in similar processes. Hence batteries should not be mixed at recycling facilities.

5	The recyclers should ensure that the dismantling and recycling processes do not have any **adverse impact** on the **health of personnel involved or on the environment**
	Dismantling and recycling involves many risks such as battery overheating, short circuit, cell venting, electrolyte loss, etc. which could pose a risk towards the personnel working or the environment. Hence, such risks should be mitigated by following proper guidelines.

6	Battery waste after dismantling and recycling should be **segregated** into electronics, metal with iron, battery modules, and residual materials by recyclers
	The battery waste should be segregated by recyclers and sent to respective authorized recyclers

7	All the tools used for the dismantling of battery packs need to be **electrically isolated.**
	Tools should be electrically isolated in order to ensure the protection of people dismantling the battery.

8	Adequate **floor cover** (acid/electrolyte resistant) must be ensured in the work area
	This should be done in order to prevent damage to the floor in the event of an accidental spillage of electrolyte or battery acid onto the floor.

3.3.6.2 Guidelines for inspecting spent batteries at recycling facility

1	Batteries should always be **inspected** for any signs of damage.
	Damaged batteries could leak electrolytes, overheat, overcharge or release electrolyte vapor which could create a hazard. In some cases, it could lead to internal short circuits resulting in

	cell venting or explosion. Such batteries should be sent for disposal. Hence, before recycling batteries should be inspected for any sort of damage.
2	While removing batteries from their original packages for inspection, they should be arranged in order to prevent **shorting**.
3	All inspection tools (rulers, callipers, etc.) should either be made from or covered with a **non-conductive material**.
	If the inspection tools are made from conductive materials or metals, current could pass through the material and electrocute personnel if precautions are not taken. Hence, all such inspection tools should be made from or covered with non-conductive material.
4	Post inspection, the battery pack should be returned to its **original container** if possible.
	The original packaging provided by the manufacturer ensures that the battery is protected from environmental factors (humidity), battery terminals do not get in contact with one another, and battery terminals don't touch any metal object. This ensures that external factors don't damage the batteries post inspection.
5	The **open circuit voltage (OCV)** of the cell should also be measured. The nominal OCV for individual cell's chemistry should be present on the manufacturer's data sheet or printed on the label.
	An OCV of 0.0 volts indicates complete discharge of the battery. 0.0 volts could also indicate a blown fuse. Hence, the battery should be checked for blown fuses and internal short circuits to ensure that 0.0 volts indicate complete discharge of the battery.
6	**Dented batteries** with dented cells should be sent for disposal irrespective of the status of electrolyte leakage.
	The denting of edges or sides of such batteries have higher likelihood of developing an internal short circuit in the long run.

3.3.6.3 Guidelines for handling batteries at recycling facility

1	All **metal work surfaces** should be covered with an insulating material. It should be ensured that the **work area is clean and free of sharp objects.**

	Covering metal work surfaces with an insulating material will ensure that current doesn't pass through the work surface which otherwise could harm workers. Sharp objects which could puncture the insulating sleeve of individual batteries.
2	**Forcing batteries** into battery holders or other types of housing should be avoided.
	It could lead to deformation of the battery causing an internal short circuit. At times forcing the battery into the housing can crush the terminal cap putting the entire battery structure and internal components at risk. This can cause cell venting. Hence, before inserting the cells into any type of housing they should be checked for proper fit.
3	Freeing of a battery from the housing should not involve the use of **excessive force.**
	Use of excessive force to free the battery from house could crush the terminals or damage or rupture the battery.
4	Battery packs should only be moved in **non-conductive carrying trays in push carts.**
	Moving batteries in non-conductive carrying trays will ensure that current does not pass through the trays and prevent short circuiting of batteries as well. This also reduces the chances of batteries being dropped, hence preventing physical damages. Using push carts also reduces the chances of dropping the battery packs significantly.
5	Wearing **safety glasses and gloves** when handling batteries.
	Safety glasses and gloves protect against battery acid which is extremely corrosive and can cause severe burns to the skin or eyes if it comes in contact with them.
6	Battery system or modules should not be opened without prior **training and permissions.**
	Trained personnel are well accustomed to handling procedures and dangers of exposure in case of a battery incident.
7	Equipment for static discharge must be installed **outside the working area** to ensure removal of static charge from individual personnel post handling batteries

3.3.6.4 Operating procedure for dismantling at recycling facility

1	The battery packs must be **discharged** before the dismantling process is initiated. The standard technique for discharging battery packs is by using **static or dynamic resistance** in form of an electronic load.
	The residual charge could harm the workers if certain workstations depend on manual dismantling.
2	Various elements of the battery pack (protective casing, power electronics, BMS, system covers, etc.) need to be removed in order to **obtain the battery modules**
	The main aim of the dismantling process is to get modules/cells from the battery pack which are then sent to registered recyclers.
3	**Voltage measurements** should be done before or during the dismantling process
	Voltage measurements are done to see if it lies within the nominal range specified by the manufacturer. Voltage measurements could also indicate a blown fuse or completely discharged batteries.
4	**Temperature measurements** must also be done by the means of a **heat scan**
	This is done in order to check if the battery temperature is more than the ambient temperature which could be an indication of overheating, instability, short circuit, etc.
5	**Modules/cells** must be gradually removed from the battery pack
	Modules and cells are gradually removed to reduce the voltage for safe processing. Ultimately all the cells are removed.
6	After dismantling, the **battery cells** which show **no deviation** from the **ambient temperature** should be packed again, and the residual charge in the cell must be measured. They should be safely stored until they are sent to registered recyclers
7	**Battery cells** which show **a deviation** from the **ambient temperature** must be stored in a specially secured area after measuring the residual charge in the cell. They should be monitored constantly until they are sent to registered recyclers

	A deviation from the ambient temperature could indicate overheating, instability, or short circuit which could lead to a fire. Hence, they must be securely stored separate from the other cells to prevent fire and ensure other cells are not damages.

3.3.6.5 Emergency protocols to be followed at recycling facility

1	During an emergency, all **personnel should be evacuated from the area**. The area should also be secured to prevent the entry of unnecessary personnel.
	During emergency situations, batteries could catch a fire or explode. Electrolyte vapours are also dangerous and exposure to such vapours could harm the workers. Hence evacuation of all the personnel is a necessity.
2	**Bridge or emergency response teams** shall be notified immediately.
	Emergency response team are responsible for handling emergency situations like battery fire or hot battery. Personnel in the emergency response team would have adequate training as well. Hence, notifying them immediately can help in minimizing damage.
3	Prior to evacuation of the area, the presence of an **external short circuit** must be quickly determined. If present, the external short circuit must be removed immediately.
	External short circuit could result in cell venting, battery fire or explosion and will escalate the situation. Hence, if possible, it should be quickly determined and removed.
4	The battery pack must be carefully placed into the **emergency sand container** to **isolate the thermal event**. While doing so, the personnel must wear **gloves, impact helmets with impact resistant face shields and eyewear** to contain it. The area should remain evacuated until the battery pack has been cooled to room temperature
	Sand can be used to extinguish battery fires. Hence, placing the battery in an emergency sand container, will extinguish the fire and isolate it as well to ensure minimal damage. Sometimes the hot battery may release electrolyte vapor, or splash acid. Hence, gloves and eyewear should be used as protection.
5	Due to the absence of metallic lithium in a lithium-ion battery, **ordinary extinguishing agents** can be effective in extinguishing the fire.

6	The **battery pack must be removed** from the work area after it has cooled down to the room temperature. While doing so, the personnel should wear appropriate **personal protective equipment**. All the other hot battery packs shall also be disposed of as **hazardous waste**.

7	Only trained and qualified personnel should attempt at **fighting the fire** involving lithium-ion battery pack.

8	All precautions should be taken to **limit exposure** to the **electrolyte vapor**
	Exposure to electrolyte vapor could cause corneal damage and irreversible eye damage along with serious health effects. Hence it should be ensured that no one is exposed to electrolyte vapor.

9	**First aid provisions** must be made available in the recycling facilities. All the personnel in the recycling facilities should be given **first aid training** to aid in the event of a battery hazard

The risks mitigation measures and standard operating procedure guidelines provided in the report are a ready reckoner for various stakeholders in the industry to ensure minimal risk and safe battery handling respectively.

An entity planning to set up a battery recycling/refurbishing facility can choose to adopt the mitigation measures and operating guidelines. The entity may however identify other mitigation measures and operating procedures and choose to adopt them based on their business model.

Annexure

4. Annexure

4.1 Annexure for model template document for battery recycling facility

4.1.1 Storage of spent batteries

Sl.	Entity	Activity
1.	**Dealer**	• Lithium-ion batteries should be stored at **~40% of their rated capacity**[19] and at **optimal storage temperature** (at or below 35° C) • Storing the battery packs in their original containers at **well ventilated and dry places** far from combustible materials • Using surface made up of **concrete, ceramic, metal, or any other non-flammable material to** store waste batteries • Installing **fire detector, class ABC or CO_2 fire extinguisher, emergency kits, protective eyewear and gloves, and fireproof safety bag or container** (to store the waste batteries if they catch fire)
2.	**Producer**	• Ensuring that batteries are stored at **~40% of their rated capacity** at an optimal storage temperature (at or below 35°C) • Ensuring that battery packs are stored in well **ventilated and dry** areas far from combustible materials • Concrete, ceramic, metal, or non-flammable surface to be designated for storing lithium-ion batteries • Ensure the use of the international recycling sign on the spent batteries
3.	**Battery collection agency**	• Batteries are stored at **~40% of their rated capacity** at an **optimal storage temperature** (at or below 35° C) • Battery packs are stored in **well ventilated and dry area**s far from combustible materials • **Concrete, ceramic, metal, or non-flammable surface** to be designated for storing lithium-ion batteries
4.	**Refurbishing facilities**	• Ensuring that batteries are not put in **contact** with conductive materials, strong oxidizers, sea water, water, and strong acids • Ensuring that battery packs are stored in a **well ventilated and dry area** far from combustible materials • Storing Lithium-ion batteries at ~**40% of their rated capacity** and at **optimal storage temperature** (at or below 35° C) • Ensuring that battery packs are not placed near a **heat source or extreme temperatures**
5.	**Recyclers**	• Ensuring that batteries are not put in **contact** with conductive materials, strong oxidizers, sea water, water, and strong acids • Ensuring that battery packs are stored in a **well ventilated and dry area** far from combustible materials

[19] Industry Stakeholder discussions

	• Storing Lithium-ion batteries at ~**40% of their rated capacity** and at **optimal storage temperature** (at or below 35°C) • Ensuring that battery packs are not placed near a **heat source or extreme temperatures**

4.1.2 Transport of spent batteries

Sl.	Entity	Activity
1.	**Dealer**	• **Packaging** the waste batteries in a way to avoid contact with other conductive materials • For example, using **UN approved barrels** which must first be filled with 10 cm of dry sand (for li-ion batteries) or vermiculite (for other batteries). The waste batteries can then be filled in layers or stacks. Additional 10 cm layer of sand or vermiculite must further be added if the battery is damaged, swollen or leaking. • **Protecting battery terminals** during transport by covering them with **molten wax and non-conductive cushioning material** to prevent movement and securely attaching packaging covers • Ensuring that battery packs are not placed near a **heat source or extreme temperatures**
2.	**Producer**	• Packaging the waste batteries in a way to avoid contact with other conductive materials • Using **UN approved barrels** which must first be filled with 10 cm of dry sand (li-ion batteries) or vermiculite (other batteries). The waste batteries can then be filled in layers or stacks. Additional 10 cm layer of sand or vermiculite must further be added if the battery is damaged, swollen or leaking. Although such methods of packaging spent batteries is not prevalent in India, it is followed by international battery recycling players. • **Protecting battery terminals** during transport by covering them with molten wax and non-conductive cushioning material to prevent movement and securely attaching packaging covers • Ensuring that battery packs are not placed near a heat source or extreme temperatures
3.	**Battery collection agency**	• **Packaging** the waste batteries in a way to avoid contact with other conductive materials • For example, using **UN approved barrels** which must first be filled with 10 cm of dry sand (li-ion batteries) or vermiculite (other batteries). The waste batteries can then be filled in layers or stacks. Additional 10 cm layer of sand or

		vermiculite must further be added if the battery is damaged, swollen or leaking. • Protecting **battery terminals** during transport by covering them with **molten wax and non-conductive cushioning material** to prevent movement and securely attaching packaging covers • Ensuring that battery packs are not placed near a **heat source or extreme temperatures**
4.	**Refurbishing facilities**	• Ensuring that batteries are not put in **contact** with conductive materials, strong oxidizers, sea water, water, and strong acids • **Packaging** the waste batteries in a way to avoid contact with other conductive materials • Using **UN approved barrels** which must first be filled with 10 cm of dry sand (li-ion batteries) or vermiculite (other batteries). The waste batteries can then be filled in layers or stacks. Additional 10 cm layer of sand or vermiculite must further be added if the battery is damaged, swollen or leaking. • Protecting **battery terminals** during transport by covering them with **molten wax and non-conductive cushioning material** to prevent movement and securely attaching packaging covers • Ensuring that battery packs are not placed near a **heat source or extreme temperatures**
5.	**Recyclers**	• Ensuring that batteries are not put in **contact** with conductive materials, strong oxidizers, sea water, water, and strong acids • **Packaging** the waste batteries in a way to avoid contact with other conductive materials • Using **UN approved barrels** which must first be filled with 10 cm of dry sand (li-ion batteries) or vermiculite (other batteries). The waste batteries can then be filled in layers or stacks. Additional 10 cm layer of sand or vermiculite must further be added if the battery is damaged, swollen or leaking. • Protecting **battery terminals** during transport by covering them with **molten wax and non-conductive cushioning material** to prevent movement and securely attaching packaging covers • Ensuring that battery packs are not placed near a **heat source or extreme temperatures**

4.2 Annexure for EHS risk screening framework

4.2.1 Accreditation bodies for EHS systems

Sl.	Certification Authority	Certification	Detail
1	Occupational Health and Safety Assessment Series (OHSAS)	OHSAS 18001	This certification sets out good practices required for occupational health and safety for all kind of organisations. It also helps to eliminate or minimize operational risks and hazards. The last updated version of this standard was published in 2007. The standard has been discontinued from March 2021 and replaced by ISO 45001.
2	International Organization for Standardization (ISO)	ISO 14001, ISO 45001	ISO 14001 sets out guidelines to improve the environmental performance of any organization. It helps organisations in achieving the intended outcomes of their environmental management system (EMS) and to fulfil its compliance obligations. The standard was last updated in 2021. ISO 45001 is related to occupational health and safety and aims to reduce work related illness, injuries, and fatalities. It is designed to replace OHSAS 18001 by March 2021. ISO 45001 focuses more on why the hazard happens whereas OHSAS 18001 focused on post hazard solutions.
3	Sustainable Electronics Recycling International (SERI)	R2	“Responsible Recycling practices for Use in Accredited Certifications Programs” (R2) sets out practices to address the operational and environmental challenges in electronics recycling and repair. In 2008, the first set of R2 Practices were released. The first major revision occurred in 2013 and a second upgrade (R2v3) happened in 2020.

4.3 Annexure for standard operating procedure for battery recycling

4.3.1 Review of Indian operational guidelines for battery recycling ecosystem

The general process of battery recycling ecosystem has been shown in the figure below:

Figure 4: Flow diagram for general process of battery recycling ecosystem

4.3.1.1 Stage 1: Collection (by dealers)

The first stage of the entire battery recycling ecosystem in India the collection of spent or used batteries. Although, globally, automobile manufacturers or battery OEMs are responsible for collecting the spent batteries from the EV owners, in India, the dealers are responsible or collecting the batteries on behalf of the manufacturers or producers. The dealers should follow the below guidelines to ensure safe battery handling.

Sl. No.	Guidelines	Reference documents
1.	The dealer shall provide a box, bin, or a demarcated area to consumers for collecting battery waste	• Battery Waste Management Rules 2022
2.	The dealer can also collect battery waste from consumers through take back system on behalf on the producer	• Battery Waste Management Rules 2022
3.	The dealer should ensure that the used batteries collected are of similar type and specifications as compared to the new batteries provided in return	• Battery Waste Management Rules 2022
4.	Dealers should ensure that storage of batteries during the collection phase should not cause any damage to the environment	• Battery Waste Management Rules 2022
5.	Dealers should maintain records of the battery waste handled/ collected and submit to concerned State Pollution Control Board	• Battery Waste Management Rules 2022
6.	Battery collection agencies can be set up individually or jointly at various places for collection of spent batteries from consumers	• Battery Waste Management Rules 2022
7.	The dealer should refund the amount in accordance with the take back system or Deposit Refund Scheme of the producer to the consumer who deposits the battery	• E-Waste Management Rules, 2016
8.	Dealers should also file annual returns for buyback of spent batteries	• Battery Waste Management Rules 2022

4.3.1.2 Stage 2: Transportation (by dealers)

Transportation is involved in multiple stages in the Indian battery recycling ecosystem. Dealers both are responsible for transporting waste batteries or battery components respectively. Certain guidelines are supposed to be followed by dealers to ensure safe transportation of spent batteries.

Sl. No.	Guidelines	Reference documents
1.	The dealer should ensure **safe transportation** of collected spent batteries to registered battery collection agencies or registered recyclers	• Battery Waste Management Rules 2022 • E-Waste Management Rules, 2016
2.	The dealer should also ensure that no **damage** is caused to the environment while transporting the stored batteries to battery collection agencies or recyclers	• Battery Waste Management Rules 2022E-Waste Management Rules, 2016
3.	The dealers should ensure that spent batteries are sent only to recyclers which are **registered**	• Battery Waste Management Rules 2022
4.	Batteries should be marked with **international recycling sign**	• Battery Waste Management Rules 2022

4.3.1.3 Stage 3: Storage

The batteries are transported by dealers to battery collection agencies where these batteries are stored before being transported to recycling facilities. These battery collection agencies are set up by manufacturers, producers, importers, or assemblers. These battery collection agencies can be set up either individually or jointly by manufacturers, producers, importers, or assemblers. These battery collection agencies need to follow certain guidelines to ensure safe handling of batteries.

Sl. No.	Guidelines	Reference documents
1.	It should be ensured by battery collection agencies that the battery waste collected is stored securely until it is sent to registered recycler	• Battery Waste Management Rules 2022 • E-Waste Management Rules, 2016
2.	While storage it should be ensured that no damage is caused to the environment	• Battery Waste Management Rules 2022 • E-Waste Management Rules, 2016
3.	Records of the battery waste handled by battery collection agencies should be maintained and made available for scrutiny by State Pollution Control Boards	• Battery Waste Management Rules 2022 • E-Waste Management Rules, 2016
4.	Battery collection agencies should also be registered with State Pollution Control Board	• Battery Waste Management Rules 2022
5.	The battery collection agencies should be in accordance with standards and guidelines prescribed by Central Pollution Control Board	• Battery Waste Management Rules 2022 • E-Waste Management Rules, 2016

4.3.1.4 Stage 4: Recycling

The spent batteries are transported to registered recycling facilities by collection agencies where the spent batteries are first dismantled. Post dismantling, the components are sent for recycling. At times, the manufacturers, or consumers such as EV OEMS, battery swapping operators, and fleet operators directly send the spent batteries to registered recyclers. The recyclers also need to follow certain guidelines to ensure an efficient battery recycling ecosystem.

Sl. No.	Guidelines	Reference documents
1.	Recyclers should be registered with MoEFCC or an agency which has been designated by MoEFCC	• Battery Waste Management Rules 2022 • E-Waste Management Rules, 2016
2.	The recyclers should strictly comply with the terms and conditions of registration or with the standards or guidelines prescribed by the Central Pollution Control Board	• Battery Waste Management Rules 2022 • E-Waste Management Rules, 2016
3.	Recyclers should mark “Recycled” on metals recovered after re-processing of spent batteries	• Battery Waste Management Rules 2022
4.	The recyclers should maintain records of receipt of used batteries, sources, quantities, and metal yield after recycling batteries. Such records should also be made available by the recycler to State Pollution Control Board for inspection	• Battery Waste Management Rules 2022 • E-Waste Management Rules, 2016
5.	Recyclers should also be responsible for creating public awareness through publications, advertisements, posters, etc. regarding hazards of heavy metals and obligation of customers to return spent batteries to registered dealers or at designated battery collection agencies	• Battery Waste Management Rules 2022
6.	Recycling facilities should ensure that the dismantling and recycling processes do not cause any adverse effect on health of personnel or environment	• E-Waste Management Rules, 2016
7.	Recyclers should also ensure that the materials or fractions which cannot get recycled in the facility shall be sent to respective authorized recyclers	• E-Waste Management Rules, 2016
8.	The residue generated during recycling process of spent batteries shall be disposed of in an authorized treatment storage facility	• E-Waste Management Rules, 2016
9.	Recycling facilities which operate without proper authorization will be considered as causing damage to the environment	• E-Waste Management Rules, 2016

4.3.2 Review of internationally adopted operational guidelines for battery recycling ecosystem

There are multiple options adopted globally to address waste batteries management from a recycling perspective. The two options are shown below:

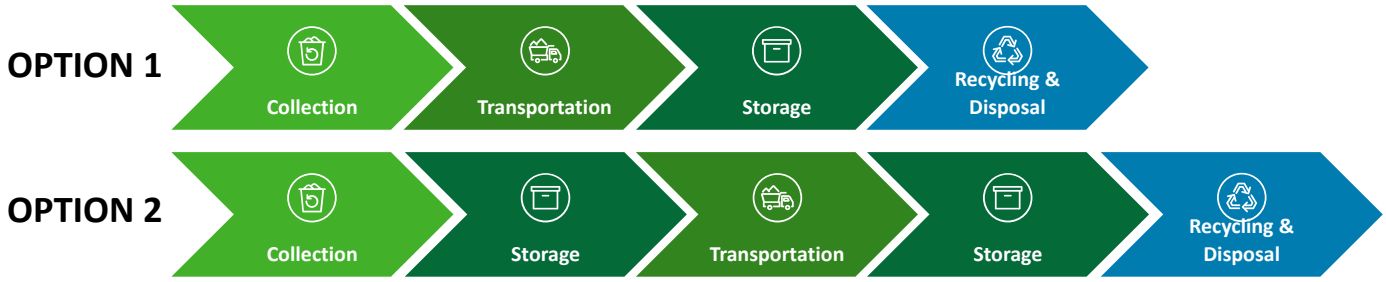


Figure 4: Flow diagram depicting multiple options adopted globally to address waste batteries management from a recycling perspective

Particulars	Option 1	Option 2
Details	• Option 1 can be preferred in cases where, the collection agencies/dealers can generate enough volume of feedstock for battery recyclers in frequent intervals. Since such centers can achieve minimum order quantities sooner, their need to store batteries isn't dire. • It is also applicable for cell manufacturing facilities which generate scrap. Such scrap can be sent to recycler on a regular basis, thereby eliminating the need for storage.[20]	• Preferred when, the collection agencies/dealers cannot generate enough volume of feedstock frequently. Thereby, battery collection agencies need to store such batteries for a period of time till they reach minimum order quantity and send it to recyclers for further processing
Pros	• Collection agencies/dealers are not liable for storing batteries • Recyclers are well versed with safe handling procedure of batteries. Hence, number of battery incidents may decrease	• This model allows for effective channelization of batteries in countries where the market of battery recycling is still nascent • Involvement of multiple stakeholders can ensure higher collection targets
Cons	• Since battery recycling market is still nascent, feedstock generation through spent battery collection won't result in high volumes. Thereby, dealers need to develop capabilities for storing spent batteries.	• Many stakeholders are involved in this model. Thereby, the liability of safely handling batteries is shared amongst different stakeholders. This increases the risk of battery incidents

[20] As per industry standards and stakeholder consultations, production scraps range from 5 to 30% (typically 10%) in lithium-ion battery cell manufacturing (Prescouter, State of Battery Recycling Report)

4.3.2.1 Reference documents/ guidelines

Sl. No.	Reference documents	Year
1.	International Air Transport Association **(International)**	2022
2.	Agreement Concerning the International Carriage of Dangerous Goods **(ADR) (International)**	2021
3.	Guidelines for transport - **Australian Battery Recycling initiative (Australia)**	2018
4.	Safety requirements for transport of Lithium batteries	2017
5.	Lithium-ion Battery Safety Guidance by **Massachusetts Institute of Technology (USA)**	2017
6.	Li-ion Battery safety and handling guideline by **Aved Electronics Incorporated (USA)**	2015
7.	Lithium Battery Safety, Handling, and Storage by **Antarctic Support Contract (USA)**	2015
8.	The recycling scheme for compact rechargeable batteries in Japan – under the **Act on the Promotion of Effective Utilization of Resources (JAPAN)**	2014
9.	Hazardous Materials: Transportation of Lithium Batteries by **Pipeline and Hazardous Materials Safety Administration (USA)**	2014
10.	Lithium Battery Safety Procedure by **Woods Hole Oceanographic Institution**	2011

4.3.2.2 Stage 1: Battery collection

The first stage of the entire battery recycling ecosystem is the collection of spent or used batteries. Globally, automobile manufacturers or battery OEMs are responsible for collecting the spent batteries from the EV owners. Due to the volatile nature of lithium batteries, it is suggested that the following guidelines are met to ensure safety of the EV owners as well as the personnel working in battery collection agency.

4.3.2.2.1 Collection from consumers

Sl. No.	Guidelines	Reference documents
1.	**Mixing** of different types of batteries should be avoided while collecting from consumers	• Lithium Battery Safety Procedure by Woods Hole Oceanographic Institution (2011)
2.	Precautions should be taken to avoid the **dropping** of batteries while collection from consumers	• Lithium Battery Safety Procedure by Woods Hole Oceanographic Institution (2011)
3.	The **bins or boxes** which collect used batteries must be resistant to the electrolyte of the battery	• Agreement Concerning the International Carriage of Dangerous Goods (2021)
4.	The **bins or boxes** should not be filled to a level greater than the height of its sides	• Agreement Concerning the International Carriage of Dangerous Goods (2021)
5.	The **bins or boxes** should be placed at positions which is well ventilated, dry and shelters from the weather	• Agreement Concerning the International Carriage of Dangerous Goods (2021)

4.3.2.2.2 Collection from automotive OEMs

Sl. No.	Guidelines	Reference documents
1.	It should be ascertained that the batteries are **classified**	• Hazardous Materials: Transportation of Lithium Batteries by Pipeline and Hazardous Materials Safety Administration (2014)
2.	While collecting battery packs from automotive OEMs, **mixed loading of different batteries** should be prohibited	• Hazardous Materials: Transportation of Lithium Batteries by Pipeline and Hazardous Materials Safety Administration (2014)
3.	The battery collection agencies should also furnish the **information and data regarding collection** in a traceable form and, if necessary, the required transport documents and accompanying documents such as authorizations, approvals, notifications, certificates, etc. should also be provided	• Hazardous Materials: Transportation of Lithium Batteries by Pipeline and Hazardous Materials Safety Administration (2014)
4.	The **packaging** used for batteries should be approved and suit the carriage of the batteries concerned and should bear the marks prescribed by the UN	• Agreement Concerning the International Carriage of Dangerous Goods (2021)
5.	Comply with the requirements on the **means of dispatch and on forwarding restrictions**	• Agreement Concerning the International Carriage of Dangerous Goods (2021)

4.3.2.2.3 Safety aspects

Sl. No.	Guidelines	Reference documents
1.	It should be ensured that batteries are **not damaged** in the battery collection agencies	• Lithium Battery Safety Procedure by Woods Hole Oceanographic Institution (2011)
2.	Batteries should not be kept in an environment which might lead to **fire or explosion** of batteries	• Lithium Battery Safety Procedure by Woods Hole Oceanographic Institution (2011)
3.	It should be ensured that **heavy objects** are not placed on boxes which collect used lithium-ion batteries	• Lithium Battery Safety Procedure by Woods Hole Oceanographic Institution (2011)
4.	**Firefighting provisions** should be present in each battery collection agencies	• Lithium Battery Safety Procedure by Woods Hole Oceanographic Institution (2011)

Sl. No.	Guidelines	Reference documents
5.	Measures should be taken to prevent the **short circuit of batteries** when in battery collection agencies	• Lithium Battery Safety Procedure by Woods Hole Oceanographic Institution (2011)
6.	The battery collection agency should have **trained personnel** for handling batteries in case of any incident	• Lithium Battery Safety Procedure by Woods Hole Oceanographic Institution (2011)

4.3.2.3 Stage 2: Transporting batteries

After collection of lithium-ion batteries by EV OEMs or battery collection agencies, they are transported to recycling facilities. While transporting, during certain conditions lithium-ion batteries can overheat and ignite in certain conditions. Hence while transporting lithium-ion batteries, certain guidelines need to be followed to ensure the safety of personnel involved.

4.3.2.3.1 Physical aspects

Sl. No.	Guidelines	Reference documents
1.	The **battery terminals** need to be protected while transporting batteries.	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
2.	Lithium-ion battery packs must **have state of charge less than 30%** of their rated capacity while being transported	• International Air Transport Association (2022)
3.	During transport, it should be ensured that the **uninsulated connections** should not be in contact with other objects.	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
4.	The batteries should not be stored near any **heat source** (strong light, sun, machinery, etc.)	• Guidelines for transport - Australian Battery Recycling initiative (2018)
5.	Precautions must be taken to avoid the **dropping of batteries** during transport.	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)

4.3.2.3.2 Transport vehicle and driver

Sl. No.	Guidelines	Reference documents
1.	The transport vehicle must be **well ventilated**, provide shelter from the weather and easily accessible if a fire breaks out	• Guidelines for transport - Australian Battery Recycling initiative (2018)
2.	The vehicle should have a satisfactory level of **security** to ensure that only trained people have access to the used batteries being transported	• Guidelines for transport - Australian Battery Recycling initiative (2018)

Sl. No.	Guidelines	Reference documents
3.	The driver should not choose such routes which can increase the risks of damage to the storage containers	• Guidelines for transport - Australian Battery Recycling initiative (2018)
4.	Appropriate fire-fighting equipment must be carried in the vehicle in case a battery catches fire while transporting	• Guidelines for transport - Australian Battery Recycling initiative (2018)
5.	All drivers must be trained in spill and emergency response	• Guidelines for transport - Australian Battery Recycling initiative (2018)

4.3.2.3.3 Packaging

Sl. No.	Guidelines	Reference documents
1.	The battery packs should be secured with outer packaging to prevent excessive movement during the transport by using a non-combustible and non-conductive cushioning material or through the use of tightly closed plastic bag.	• Agreement Concerning the International Carriage of Dangerous Goods (2021)
2.	The packages should be marked “LITHIUM BATTERIES FOR RECYCLING”	• Agreement Concerning the International Carriage of Dangerous Goods (2021)
3.	The original packaging or suitable plastic container should be used for transporting batteries.	• Agreement Concerning the International Carriage of Dangerous Goods (2021)

4.3.2.4 Stage 3: Storage

The proper storage of lithium-ion batteries is essential for reducing risk of fire and/or explosion and ensuring safe handling of batteries. Inadequate storage area or conditions could lead to lithium-ion battery fires. While spontaneous fires in lithium-ion batteries are rare, internal short circuits could lead to a chain of reactions leading to a fire. Type of cell design, temperature, chemistry, state-of-charge, and length of storage period are a few factors which pose a higher risk of fire in the storage area. The guidelines mentioned below if correctly followed could reduce the risk of fire and/or explosion of stored batteries.

4.3.2.4.1 Physical aspects

Sl. No.	Guidelines	Reference documents
1.	The lithium-ion batteries should be stored at ~40% of their rated capacity.	• Li-ion Battery safety and handling guideline by Aved Electronics Incorporated (2015)
2.	The optimal storage temperature should be maintained (at or below room temperature 60 – 75 ° F).	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)

Sl. No.	Guidelines	Reference documents
3.	Heavy objects should not be stacked on top of boxes containing lithium batteries packs as it could lead to crushing or puncturing the cell case. Severe damage could further lead to internal short circuit resulting in cell venting or explosion	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
4.	Battery packs should be stored in their original containers	• Li-ion Battery safety and handling guideline by Aved Electronics Incorporated (2015) • Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)

4.3.2.4.2 Storage area

Sl. No.	Guidelines	Reference documents
1.	The battery packs should be stored in a well ventilated and dry area. The cells should be stored in an isolated area and far from combustible materials. The depleted cells should be stored in an area separate from fresh cells	• Li-ion Battery safety and handling guideline by Aved Electronics Incorporated (2015) • Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015) • Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
2.	A reserved area should be designated only for storing lithium-ion batteries which should be a cool and dry place far from heat sources	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
3.	The ideal surface for storing lithium-ion batteries is concrete, ceramic, metal, or any non-flammable material. Batteries can also be stored in a metal cabinet (similar to chemical storage cabinet). But it must be ensured that the batteries do not touch each other	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
4.	Batteries should not be stored on the floor especially in vessels which may encounter seawater	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
5.	Excessive quantities of battery packs should not be allowed to accumulate in any storage area	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)

4.3.2.4.3 Safety

Sl. No.	Guidelines	Reference documents
1.	Batteries should always be **stowed** carefully to avoid accidental damage, flooding, discharging, or short circuiting	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
2.	Batteries should never be left **unattended** at a place where it can be damaged by anyone	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
3.	The storage area should have a **fire detector** and a class ABC or CO_2 fire extinguisher in the storage area	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
4.	A lithium-ion battery **fireproof safety bag** or any other fireproof container should be used to store the lithium-ion batteries. Manufacturer recommendations should be followed on fireproof bags for knowing details regarding their correct usage. Buying cheap fireproof bags should be avoided due to their lower effectivity.	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)

4.3.2.5 Stage 4: Operational guidelines for recycling facilities

The major causes of failure of lithium-ion batteries are accidental short circuits causing overheating, circuit damage, fire and/or explosion. Such hazards associated with secondary cells can be minimized by following the guidelines as mentioned below:

4.3.2.5.1 Physical aspects

Sl. No.	Guidelines	Reference documents
1.	**Hot and humid conditions** should be avoided when the battery is fully charged. Furthermore, batteries should not be placed in direct sunlight, or in hot locations or on hot surfaces.	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
2.	**Burning, overheating, disassembling, short-circuiting, soldering, puncturing, crushing or otherwise mutilating batteries packs** or cells should be avoided	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
3.	Batteries should not be put in **contact** with conductive materials, strong oxidizers water, seawater, and strong acids.	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
4.	Different types of batteries or old and new batteries should not be **mixed**.	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
5.	Battery packs or cells should not be exposed to any other **voltage sources** apart from those that meet the exact criteria defined by the battery pack/cell specification.	• Li-ion Battery safety and handling guideline by Aved Electronics Incorporated (2015)

4.3.2.5.2 Inspection

Sl. No.	Guidelines	Reference documents
1.	Batteries should always be **inspected** for any signs of damage	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)
2.	While removing cells from their original packages for inspection, they should be arranged in order to prevent **shorting**. The cells should not be **stacked or scattered**. The cells should further be placed only in **non-conductive carrying trays** which should have individual compartments for individual cells.	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
3.	All inspection tools (rulers, callipers, etc.) should either be made from or covered with a **non-conductive material**.	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015) • Li-ion Battery safety and handling guideline by Aved Electronics Incorporated (2015)
4.	Post inspection, the cell should be returned to its original container if possible	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
5.	The **open circuit voltage (OCV)** of the cell should also be measured. The nominal OCV for individual cell's chemistry should be present on the manufacturer's data sheet or printed on the cell label. An OCV of 0.0 volts could indicate a blown fuse. In the absence of fuses in the circuit, 0.0 volts could also indicate complete discharge	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
6.	**Dented batteries** with dented cells should be sent for disposal irrespective of the status of electrolyte leakage. The denting of edges or sides of such batteries have higher likelihood of developing an internal short circuit in the long run.	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)

4.3.2.5.3 Handling batteries

Sl. No.	Guidelines	Reference documents
1.	All **metal work surfaces** should be covered with an insulating material. It should be ensured that the **work area is clean and free of sharp objects** which could puncture the insulating sleeve of individual cells.	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
2.	If the **solder tabs or leads** need to be shortened only one lead or solder tab should be cut at a time. Cutting both the leads should be avoided as it could short the cell.	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
3.	**Forcing cells** into battery holders or other types of housing should be avoided as it could lead to deformation of the cell causing an internal short circuit. At times forcing the cell into the housing can crush the terminal cap putting the entire battery structure and internal components at risk. This can	• Li-ion Battery safety and handling guideline by Aved Electronics Incorporated (2015)

Sl. No.	Guidelines	Reference documents
	cause cell venting. Hence, before inserting the cells into any type of housing they should be checked for proper fit	
4.	Freeing of a battery from the housing should not involve the use of **excessive force**	• Li-ion Battery safety and handling guideline by Aved Electronics Incorporated (2015)
5.	Battery packs should only be moved in **non-conductive carrying trays**. This will ensure reduction in short circuit of cells; cells being dropped and other physical damages.	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
6.	Wearing **safety glasses** when handling batteries.	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
7.	Battery system or modules should not be opened without prior **training and permissions**	• Lithium-ion Battery Safety Guidance by Massachusetts Institute of Technology (2017)

4.3.2.5.4 Emergency procedures

Sl. No.	Guidelines	Reference documents
1.	During an emergency situation, all **personnel should be evacuated from the area**. The area should also be secured to prevent the entry of unnecessary personnel	• Li-ion Battery safety and handling guideline by Aved Electronics Incorporated (2015)
2.	**Bridge or emergency response teams** shall be notified immediately	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
3.	Prior to evacuation of the area, the presence of an **external short circuit** must be quickly determined. If present, the external short circuit must be removed immediately.	• Li-ion Battery safety and handling guideline by Aved Electronics Incorporated (2015)
4.	The battery pack must be carefully placed into the **emergency sand container** in order to **isolate the thermal event**. While doing so, the personnel must wear **gloves and eyewear** to contain it. The area should remain evacuated until the battery pack has been cooled to room temperature	• Li-ion Battery safety and handling guideline by Aved Electronics Incorporated (2015)
5.	Due to the absence of metallic lithium in a lithium-ion battery, **ordinary extinguishing agents** can be effective in extinguishing the fire	• Li-ion Battery safety and handling guideline by Aved Electronics Incorporated (2015)
6.	The **battery pack must be removed** from the work area after it has cooled down to the room temperature. While doing so, the personnel should wear appropriate personal protective equipment. All the other hot battery packs shall also be disposed of as hazardous waste.	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)

Sl. No.	Guidelines	Reference documents
7.	Only trained and qualified personnel should attempt at **fighting the fire** involving lithium-ion battery pack	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)
8.	All precautions should be taken to **limit exposure** to the **electrolyte vapor**	• Lithium Battery Safety, Handling, and Storage by Antarctic Support Contract (2015)

4.3.3 Reference documents/guidelines

Sl. No.	Reference documents	Year	Ref
1.	Battery Waste Management Rules by **Ministry of Environment, Forest, and Climatic Change (India)**	2022	access here
2.	International Air Transport Association **(International)**	2022	access here
3.	Agreement Concerning the International Carriage of Dangerous Goods **(ADR) (International)**	2022	access here
4.	Guidelines for transport - **Australian Battery Recycling initiative (Australia)**	2018	access here
5.	Safety requirements for transport of Lithium batteries	2017	access here
6.	Lithium-ion Battery Safety Guidance by **Massachusetts Institute of Technology (USA)**	2017	access here
7.	Li-ion Battery safety and handling guideline by **Aved Electronics Incorporated (USA)**	2015	access here
8.	Lithium Battery Safety, Handling, and Storage by **Antarctic Support Contract (USA)**	2015	access here
9.	The recycling scheme for compact rechargeable batteries in Japan – under the **Act on the Promotion of Effective Utilization of Resources (JAPAN)**	2014	access here
10.	Hazardous Materials: Transportation of Lithium Batteries by **Pipeline and Hazardous Materials Safety Administration (USA)**	2014	access here
11.	Lithium Battery Safety Procedure by **Woods Hole Oceanographic Institution**	2011	access here
12.	Repurposing of Lithium-ion batteries by **Battery Consortium (Singapore)**	2021	access here
13.	Creating a Safe Second Life for Electric Vehicle Batteries: UL1974 by **Underwriters Laboratory (USA)**	2018	access here

Notes

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