INTERNATIONAL SOLAR ALLIANCE

SUNRISE
Solar Upcycling Network for Recycling, Innovation & Stakeholder Engagement

Battery Recycling Guidelines for ISA Member Countries:

Advancing Circular Battery Value Chains



About ISA

The International Solar Alliance (ISA) is an inter-governmental alliance of over 120+ countries that is working to increase sustainable deployment of solar energy technologies and to support its Member Countries in improving their energy access, energy security, and facilitating energy transition towards low-carbon economies. To achieve its objective, the ISA publishes knowledge products that support data collection, dissemination along with analysis and insights on solar and related value chains across its Member Countries.

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Foreword



The global energy transition is entering a decisive phase, with batteries emerging as a cornerstone of clean energy systems, electric mobility, and energy storage worldwide. As global battery demand crosses 1.5 TWh and continues to accelerate, the sustainability of battery value chains—particularly at its end of life—has emerged as a defining challenge for the coming decade. In ISA member countries, deployment of battery systems far exceeds the recycling infrastructure and regulatory framework needed. To overcome this gap is both an environmental imperative and a strategic opportunity as waste batteries comprise of valuable critical minerals including lithium, cobalt, nickel, and copper- resources necessary for energy security.

The report Battery Recycling Guidelines for ISA Member Countries: Advancing Circular Battery Value Chains responds directly to this need. It details how countries can transition from their current linear “take-make-dispose” battery ecosystems to circular value chains that decouple growth in the batteries and energy storage sector from excessive resource consumption, environmental degradation, and exploitation of vulnerable and economically disadvantaged groups. Drawing on global learnings experience, the report analyses policy approaches, and business models that support safe, traceable, and economically viable battery end-of-life management.

A key outcome of the report is a set of battery recycling guidelines developed for ISA member countries. These guidelines are benchmarked to global standards and best practices, and are agnostic to battery chemistry, type, and application. These guidelines promote a shared stakeholder responsibility model that brings together key network actors and stakeholders including regulators, producers, and recyclers, and consumers, and emphasize the need to enforce clearly defined roles, standards, and robust traceability tools across battery lifecycle. Circular design and systems thinking form the basis of these global guidelines as they encourage stakeholders to act in a coordinated and synergistic manner across the entire value chain and battery lifecycle, allowing for a more sustainable and resilient growth.

The global guidelines developed are informed by practical, on-the-ground insights and strengthened by expert inputs from international consultation reaffirming the need for aligned regulatory frameworks, formalized collection systems, regional aggregation models, and digital tools to enable scale, safety, and compliance—particularly in emerging markets.

ISA remains committed to supporting its member countries in translating these insights into action. By advancing globally aligned yet context-sensitive recycling guidelines, this report aims to support policy development, capacity building, and cross-country cooperation for circular battery ecosystems. It serves as both a practical reference and a call for collective action to ensure that the batteries powering the clean energy transition today do not become the waste challenge of tomorrow.

Project Background

Countries are reducing their dependence on fossil fuels by expanding their energy portfolio to include renewable energy sources such as solar and wind among others. As the world moves towards supporting clean energy transitions and achieving net zero targets, the demand for batteries including those for electric vehicles (EV) and for energy storage systems has increased significantly. Energy from renewable sources creates its own challenges - that of maintaining a continuous, uninterrupted energy supply and stable energy grid - this necessitates the use of energy storage systems (ESS). ESSs support grid stability and congestion management by capturing excess energy during periods of high production and releasing it during periods of high consumption. In scenarios where battery uptake is reduced, solar power adoption also reduces, reliance on coal and natural gas continues, fossil fuel import costs continue to increase, target to achieve emission reduction stalls, and the 1.5 °C climate target becomes unattainable [1]. Given their importance and recent technological advancements in achieving cost efficiency, battery energy storage systems (BESS) have become an integral part of clean energy planning frameworks across the globe [2].

As of 2024-25, global installed solar PV capacity surpassed 1.86TW while global demand for both EV and energy storage batteries exceeded 1.5TWh [3]. This has, in turn, increased dependence on scarce and geographically concentrated primary raw materials and critical minerals including lithium, nickel, cobalt, and graphite used to manufacture solar panels, batteries, and other renewable technologies. This increase in uptake of clean energy technologies has led to a new challenge and a resource opportunity– that of end-of-life management of solar PV systems, batteries, and other clean energy technologies. For countries, especially in emerging markets, where demand for renewable technologies exceeds the regulatory environment to support management of renewable energy value chains, it is important to reduce dependence on imports of scarce primary resources, insulate from global supply and price shocks, strengthen domestic supply of critical minerals, and minimize the environmental impact of new waste streams.

To support the same, the International Solar Alliance (ISA) has launched **SUNRISE — the Solar Upcycling Network for Recycling, Innovation & Stakeholder Engagement** — as a global platform to implement activities to support solar PV and battery waste management as part of its Technology Roadmap & Policy Pillar. By bringing together governments, industries, innovators, recyclers, and other key network actors, the SUNRISE platform aims to enable ISA Member Countries build a circular solar future—where every solar panel and battery is designed, deployed, and recovered responsibly, ensuring maximum material reuse, economic value, and environmental protection. To support such efforts and build sustainable battery value chains, the International Solar Alliance (ISA) has developed this report titled ***Battery Recycling Guidelines for ISA Member Countries: Advancing Circular Battery Value Chains.*** These guidelines developed for its member countries are chemistry-agnostic and globally benchmarked, rooted in shared stakeholder responsibility, and aim to pave the way for a sustainable, circular, and resource-secure global battery ecosystem.

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List of Abbreviations

ACC	Advanced Chemistry Cell
AGM	Absorbent Glass Mat
BaaS	Battery as a Service
BWMR	Battery Waste Management Rules
BESS	Battery Energy Storage System
BTM	Behind The Meter
C&I	Commercial & Industrial
CES	Customized Energy Solutions Ltd
CPCB	Central Pollution Control Board
CTE	Consent To Establish
CTO	Consent To Operate
DGFT	Directorate General of Foreign Trade
DPP	Digital Product Passport
DST	Department of Science & Technology
DoD	Depth of Discharge
DRC	Democratic Republic of Congo
EFB	Enhanced Flooded Battery
EoL	End of Life
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
ESG	Environmental, Social & Governance
ESS	Energy Storage System
EU	European Union
EV	Electric Vehicle
FLA	Flood Lead Acid
GHG	Greenhouse Gas
GOI	Government of India
GIS	Geographic Information System
GST	Goods & Services Tax
HSN	Harmonized System of Nomenclature
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
IEA	International Energy Agency
IRR	Internal Rate of Return
ISA	International Solar Alliance
LFP	Lithium Ferro Phosphate
LiB	Lithium-ion Battery
LMB	Lithium Metal Batteries
LMFP	Lithium Manganese Iron Phosphate
LMO	Lithium Manganese Oxide
LTO	Lithium Titanate Oxide
METI	Ministry of Economy, Trade and Industry
MIIT	Ministry of Industry & Information Technology
MoEFCC	Ministry of Environment, Forest & Climate Change
MoRTH	Ministry of Road Transport & Highways
MSDS	Material Safety Data Sheet
NiCd	Nickel Cadmium
NCA	Lithium Nickel Cobalt Aluminium Oxide
NDIR	Non-Dispersive Infrared
NEDO	New Energy and Industrial Technology Development Organization
NMC	Nickel Manganese Cobalt
NPV	Net Present Value
O&M	Operations & Maintenance
OECD	Organisation for Economic Co-operation & Development
OEM	Original Equipment Manufacturer
PCS	Producer Compliance Scheme
PLI	Production Linked Incentive
PPE	Personal Protective Equipment
PPP	Public Private Partnerships
PRO	Producer Responsibility Organisation
RaaS	Recycling as a Service
RCM	Reverse Charge Mechanism
RE	Renewable Energy
RCRA	Resource Conservation & Recovery Act
RPRA	Resource Productivity & Recovery Authority
RTE	Round Trip Efficiency
SoH	State of Health
SLA	Sealed Lead Acid
SOP	Standard Operating Procedure
TOC	Total Organic Carbon
TPA	Tonnes Per Annum
TRL	Technology Readiness Level
USA	United States of America
VRFB	Vanadium Redox Flow
ZBRF	Zinc-Bromine Redox Flow


ENERGY STORAGE

Introduction

Over the past decade, battery technologies have advanced significantly from the early lead-acid batteries to today's prevailing lithium-ion batteries (LiBs), with innovations such as solid-state batteries now on the horizon. As of 2024, lithium-ion batteries account for over 40% of the global battery market by material share, significantly surpassing lead-acid technology, which are now primarily limited to legacy and cost-sensitive use cases. Figure below shows a clear rise in lithium-ion battery dominance across all applications, including electric vehicles (EV), energy storage systems (ESS), and consumer electronics, displacing lead-acid and other chemistries between 2015 and 2030.

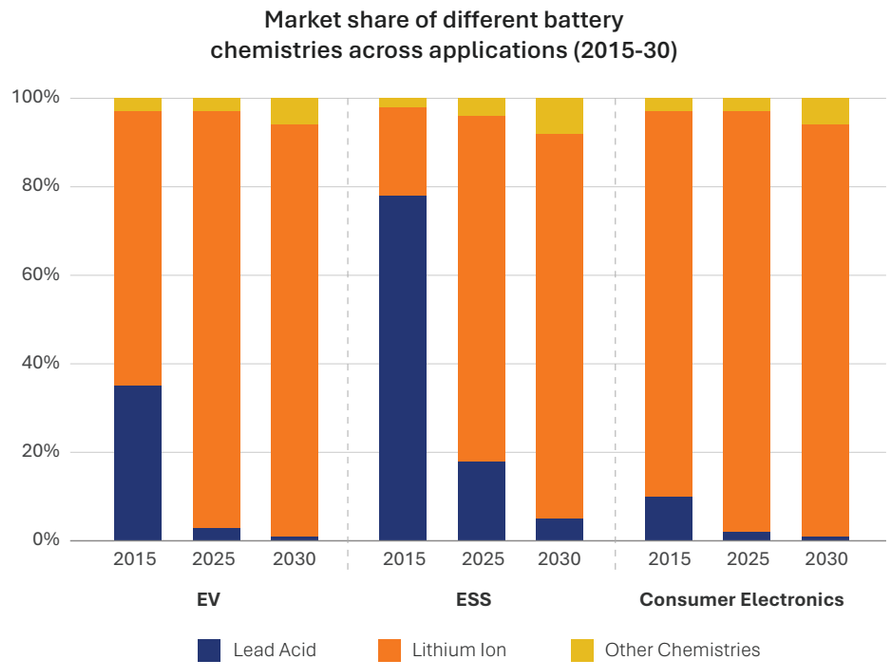


Figure 1: Trend in Market Share of Various Battery Chemistries across Applications from 2015-2030[1] [4]

Compared to lead-acid batteries, lithium-ion batteries store much more energy for their weight (120-180 vs. 30-50 Wh/kg energy density), last longer (3,800-4,000 vs. 300-400 cycles), and use around 90% of their energy repeatedly without harm (DOD-Depth of Discharge 90%), making them more efficient and cost-effective over time. LFP (Lithium Iron Phosphate) batteries are relatively safe (very high thermal stability) and efficient (about 95% round-trip efficiency meaning longer life and less frequent replacements which reduces replacement cost), making them popular for EV and stationary energy storage applications. Currently, Nickel Manganese Cobalt (NMC), Nickel Cobalt Aluminum (NCA), and Lithium Cobalt Oxide (LCO) - constitute the majority of cobalt based chemistries in lithium-ion battery production [5], [6]. However, emerging trends indicate a shift towards batteries with reduced cobalt content, driven by concerns over cost, supply chain risks,

[1] CES analysis- compiled from projections from various reports and validated through industry stakeholder interviews



and sustainability [7]. On the other hand, lead-acid batteries are heavier, shorter-lived, and more toxic, leading to less use in energy storage. Technologies like LTO (Lithium Titanate Oxide) are more expensive (relative to LFP) provide higher cycle life but are low in energy density. LMO (Lithium Manganese Oxide) is lower in price but also low in energy density. LFMP (Lithium Manganese Iron Phosphate) while incorporating manganese provides higher energy density, operates at higher voltage, and provides better thermal stability and safety features at the same time as being more cost-effective as compared to LFP thereby emerging as an improved alternative to LFP batteries. Sodium-ion technology is moving from R&D to commercial scale production in 2026. They have good energy density, moderate power density (25-45 W/kg), stable operating temperature (65°C), and lower toxicity further bolster its widespread adoption in solar storage, offering a cost-effective, durable, and environmentally preferable solution over lead-acid and other battery types [8].

Batteries in Solar

Lithium-ion batteries: with their compact size, high efficiency, and long lifespan of 10-15 years, are the most common type of solar battery used for both residential and commercial solar systems.

Lead-acid batteries: while cheaper than lithium-ion batteries, lead-acid batteries have a short lifespan of 3-5years, are less efficient, and have increased size and mass but are still a viable option for those on a budget or situated in areas with off-grid solar systems [9].

Saltwater batteries: are an emerging, environmentally friendly technology, still in its development stage. These batteries use abundantly available materials like saltwater to store energy. While they also have a long lifespan, they are not as efficient or as widely available as lithium-ion batteries [10].

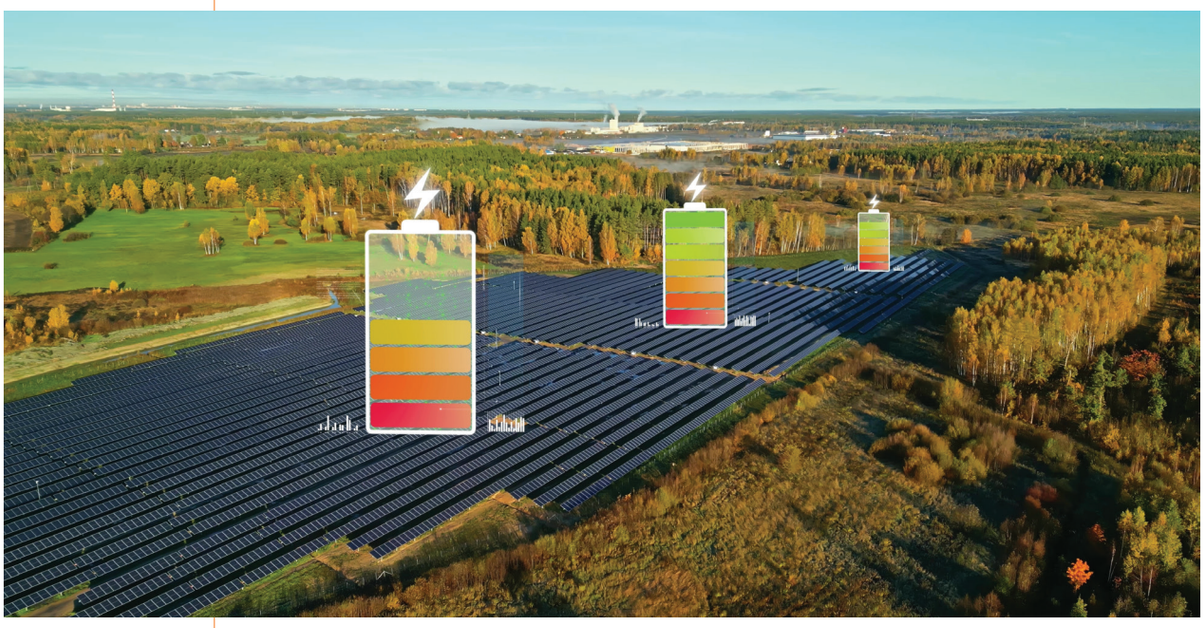
Flow batteries: use two electrolytes that flow through the system to store energy. While expensive and still less common than lead-acid or lithium-ion batteries, they are scalable and can store large amounts of energy [11].

Cobalt-intensive batteries (NMC and NCA) and lithium-ion batteries such as LCO dominant today's global battery production. Their high energy density and widespread suitability in applications ranging from electric vehicles (EVs) to energy storage systems account for over 55% of lithium-ion battery cathode materials as of 2025 [12]. Motivated by economic factors and ethical concerns related to cobalt mining and supply chain security, the industry is now witnessing a shift towards batteries with lower cobalt content.

LFP batteries with increased safety profile, lower costs, and long cycle life have become the dominant battery chemistry in China despite having lower energy density as compared to cobalt-rich batteries [13]. This regional prevalence of LFP in China contrasts with North American and European battery markets, where cobalt-rich NMC and NCA batteries dominate however, these regions are also seeing a shift to cobalt-reduced battery chemistries with higher nickel and lower cobalt levels such as seen in the NMC811 variants.

Constantly evolving battery chemistries influence material recovery strategies, environmental impacts, and economic viability of recycling technologies across regions and therefore necessitate dynamic recycling and resource recovery frameworks that can support management of changing battery chemistries at the end of their useful life. This is particularly important because while older, lead-acid batteries benefit from a mature and effective recycling ecosystem, newer lithium-ion and other emerging battery technologies do not. Emerging batteries with varying chemistries present new challenges being more hazardous in nature and with higher potential for thermal incidents and therefore demand more focused attention. Further, growing interest in repurposing end-of-life batteries for second life applications including stationary applications (solar-powered microgrids and off-grid systems), introduces additional concerns regarding safety, traceability, battery state of health, and overall performance.

At the end of their life, spent batteries disposed improperly in landfills pose significant environmental health and safety risks to humans and ecosystems including soil and water contamination and air pollution. With increasing battery demand, global retired battery volumes available for recycling are projected to reach ~314 GWh by 2030, while in India, retired battery volumes can reach anywhere between 84-115 GWh in the same year [14]. To sustainably manage such large volumes of waste batteries at country and regional levels, robust frameworks are needed to strengthen reverse logistics and ensure better end-of-life battery management.




Power
Silver Technology
63Ah
012 | 12V | 63Ah | 600A
Power indicator
POWER FOR EVERY START

End-of-Life Pathways for Batteries: Reusability Assessment and Recycling Technologies

Battery end-of-life value chain comprises of a series of critical stages that, if properly implemented, ensure sustainable management of spent batteries. Starting from collection and transport, sorting, reuse, recycling, material recovery to residual waste management, at each stage specific activities, stakeholder, and operational frameworks can maximize use, material recovery, minimize environmental impact, and uphold safety and regulatory compliance. Below details all the steps of battery waste management.



Collection & Logistics

01

- Aggregation from EVs, ESS, and consumer electronics by OEMs, dealers, or Producer Responsibility Organisations (PROs).
- Global collection efficiency averages 40–45% for LIBs (IRENA, 2024). India's target under Battery Waste Management Rules (2022) is 63% by 2027 - Establish decentralized collection hubs with IoT-enabled reverse logistics. Enforce EPR policies with digital traceability systems such as Battery Aadhaar and the Battery Passport

Sorting & Diagnostics

02

- Chemistry/form factor classification; State-of-Health (SoH) diagnostics via digital tools.
- Blockchain-based Battery Passport IDs and AI-driven SoH analytics enable safe sorting and classification (Global Battery Alliance, 2023; IRENA, 2024).
- Deploy AI/ML-assisted SoH diagnostics and blockchain traceability. Follow IEC 62933 and UL 1974 standards for safe handling and data management.

Second-Life Reuse / Repurposing

03

- Repurposing batteries with >70% remaining capacity for stationary storage, microgrids, and telecom applications.
- The global second-life LiB market is projected to exceed USD 10–11 billion by 2030, growing at a ~28% CAGR (BloombergNEF, 2023; IDTechEx, 2024).
- Develop certified refurbishment and testing centers for second-life deployment. Focus reuse in microgrid, renewable integration, and telecom tower applications.

Pre-treatment & Dismantling

04

- Discharging, dismantling, and separating cells/modules/casings; removal of electrolytes and plastics.
- UL 1974 and IEC 62933 outline safety protocols for discharge, fire prevention, and worker safety (UL, 2023; IEC, 2022).
- Implement robotic disassembly and fire-resistant facility design. Conduct certified safety training for workers.

Recycling / Material Recovery

05

- Mechanical, hydrometallurgical, and pyrometallurgical recovery of Li, Ni, Co, Cu, Al, Mn, and graphite.
- Recovery efficiency: >95% for Co and Ni, 70–90% for Li (IRENA, 2024). Regional trends - pyro/hybrid preferred in India & China; hydrometallurgy dominant in EU & North America
- Develop regional recycling clusters via PPP models. Use hybrid recycling for chemistry-specific optimization. Integrate mechanical + chemical pre-treatment for higher yield.

Refining & Material Processing

06

- Purification and conversion of recovered metals into cathode/anode precursors.
- Recycled materials could meet up to 30% of global cathode metal demand by 2030 (IEA, 2024).
- Establish closed-loop supply contracts between recyclers and gigafactories. Enforce recycled-content mandates under frameworks like the EU Battery Regulation (2023/1542).

Reintegration & Market Use

07

- Verified supply of recycled-content materials to battery and component manufacturers.
- The EU Battery Regulation (2023) mandates minimum recycled content by 2031: 16% Co, 6% Ni, and 6% Li (European Commission, 2023).
- Implement carbon-credit incentives, public procurement policies, and eco-labeling for products using verified recycled materials. Promote consumer-return incentives.

Waste Residue Management

08

- Neutralization, vitrification, and compliant disposal of non-recoverable residues under hazardous waste rules.
- Proper residue management mitigates heavy metal leakage and GHG emissions (IRENA, 2024). India's Hazardous and Other Wastes (Management and Transboundary Movement) Rules (2016, amended 2022) disposal (MoEFCC, 2022).
- Ensure national hazardous waste rules compliance. Adopt LCA-based monitoring for emissions tracking. Integrate social safeguards by formalizing informal-sector roles.

Figure 2: Stepwise Battery Recycling Process for LiBs

Echelon and Cascading Utilizations: Repurposing Spent Batteries for second-life applications

Electric vehicles (EVs) require batteries with large capacity to reduce range anxiety associated with EV uptake. Therefore, once EV batteries drop to 80% of their initial capacity, they are considered end-of-life batteries [15]. The 80% State of Health (SoH) cutoff for primary EV service leaves these batteries suitable for repurposing through redesign and refurbishing. Repurposed batteries can serve in secondary applications including renewable energy integration, telecom towers, and stationary storage devices with operational lifespan of 5-8 additional years [16]. Second-life batteries, being 50-70% cheaper compared to new batteries, present a significant cost advantage and are economically more viable [13].

Echelon utilization presents pathways for battery reuse by systematically assessing and redeploying end-of-life batteries in lesser energy demanding applications to maximize their value. Through echelon utilization batteries' entry into the recycling phase is systematically delayed which reduces resource extraction pressures and environmental footprints [17]. Batteries are successively deployed across various tiers of application, each with progressively lower performance requirements. This multi-stage reuse framework ensures resource circularity and optimizes the overall lifespan of batteries [18].

Battery's state of health (SoH) diagnostic is key in determining its end-of-life and in classifying them according to their residual performance, ensuring safety, and suitability across various second-life uses. AI-driven diagnostics and digital tracking facilitate SoH evaluations, fostering safe and efficient integration into echelon utilization framework [19]. below presents the criterion to determine spent battery reusability.

The deployment of batteries through echelon utilization minimizes and delays waste output and decreases the demand for primary raw materials while extending the batteries functional utility thereby contributing to development of sustainable battery management ecosystems.

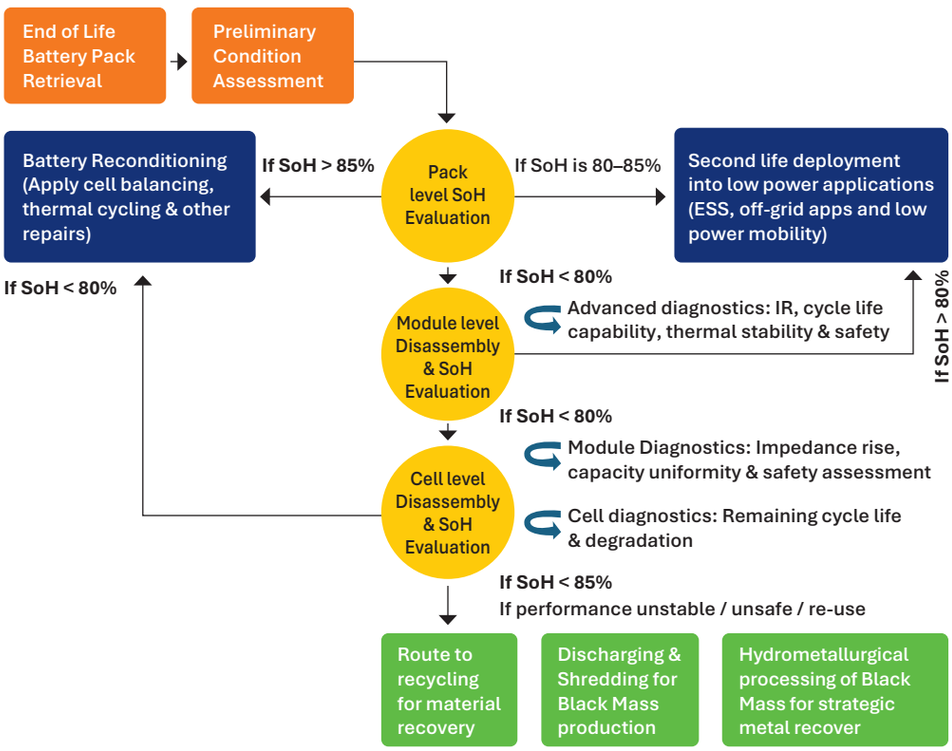


Figure 3: Determination of Waste Battery Reusability for Lithium-ion batteries

Recycling different spent battery chemistries and recycling technologies

Different lithium-ion battery chemistries necessitate tailored recycling technologies for optimal resource recovery and environmental performance. Currently, three main recycling methods are employed, given in the table below. Table 1 provides an overview of various recycling technologies and their characteristics.

Table 1: Different battery recycling technologies and outputs

Pyrometallurgy	Hydrometallurgy	Direct Recycling
Smelts' batteries at~1500°C to produce a metal alloy containing Co, Ni, Cu, Fe. **Li and Mn** end up in slag; Li may be further recovered. **Output:** Metal ore / alloy	Uses **leaching, separation, and solvent extraction** to purify battery metals Recovers **Li, Ni, Mn, and Co** as battery-grade compounds. **Output**: Battery-grade materials	Retains and restores **cathode active material (CAM)** for reuse in new batteries. Avoids full breakdown into elemental metals. Still in **R&D phase** **Output:** Cathode Active Materials
Purity: ~96% Cobalt, ~98% **Lithium;** Recovery: ~95% for Co, Ni, Mn,	**Purity:** ~99% Lithium & Cobalt, ~98% Copper; **Recovery**: ~95% for Co, Mn, Ni and 80% for Li.	**Recovery Rate:** Still emerging, high potential
Advantages: Scalable, processes diverse battery types	**Advantages**: High recovery rates, less energy use, environmentally friendlier	**Advantages**: Low energy, preserves cathode structure
Disadvantages: Highly energy-intensive, generates toxic gases	**Disadvantages**: Generates liquid waste, chemically and water intensive	**Disadvantages**: Limited commercial readiness, complex process



Battery recycling technologies vary by region, reflecting predominant chemistries produced and consumed locally. In China, lithium iron phosphate (LFP) batteries dominate production due to their safety and cost advantages. Recycling facilities here predominantly employ pyrometallurgical processes, which are more economically viable for LFP given its low cobalt content and lower chemical reagent needs, making hydrometallurgical methods less attractive [19], [21], [22], [23]. In contrast, regions like Europe and North America, where cobalt-rich NMC and NCA batteries are prevalent, favour hydrometallurgical recycling for higher recovery rates of lithium, cobalt, and nickel. Hybrid approaches combining pyrometallurgy and hydrometallurgy are gaining traction to optimize recovery efficiency and minimize environmental impact, accommodating diverse battery chemistries efficiently [24].

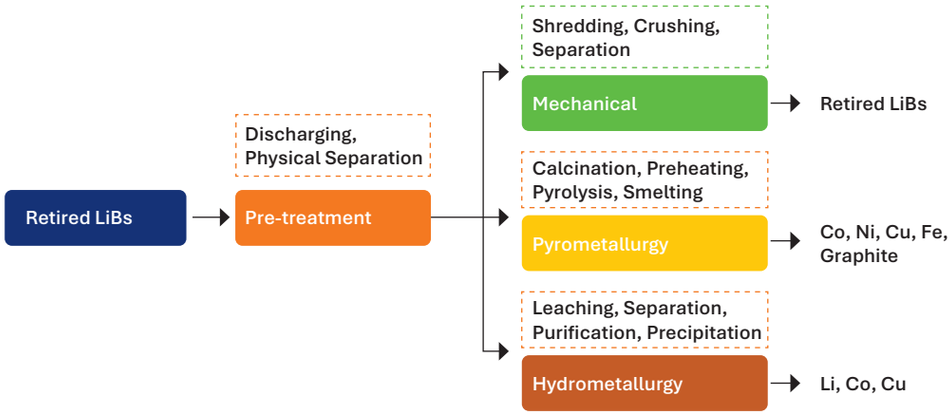


Figure 4: Treatment of retired batteries with different recycling technologies


EV STATION

Waste Collection Models and EPR Collaborations in Battery End-of-Life Management

Advancements in battery chemistries and in recycling technologies on their own cannot solve the increasing battery waste management problem and need the presence of enabling policies and regulations, scalable waste collection systems, and commercially viable business models to support battery waste management. A key policy tool in supporting development and implementation of waste management ecosystem is extended producer responsibility (EPR). EPR assigns legal responsibility to producers and OEMs to collect and recycle the batteries they produce at its end-of-life. It is adopted in many countries across the globe however its application varies by country and region. In countries where EPR is well-established including the EU, Japan, and India, adopting EPR has played a key role in formalizing battery waste streams, supporting compliance through oversight, and implementing funding mechanisms. Figure below illustrates the EPR Framework for Battery Waste Management.

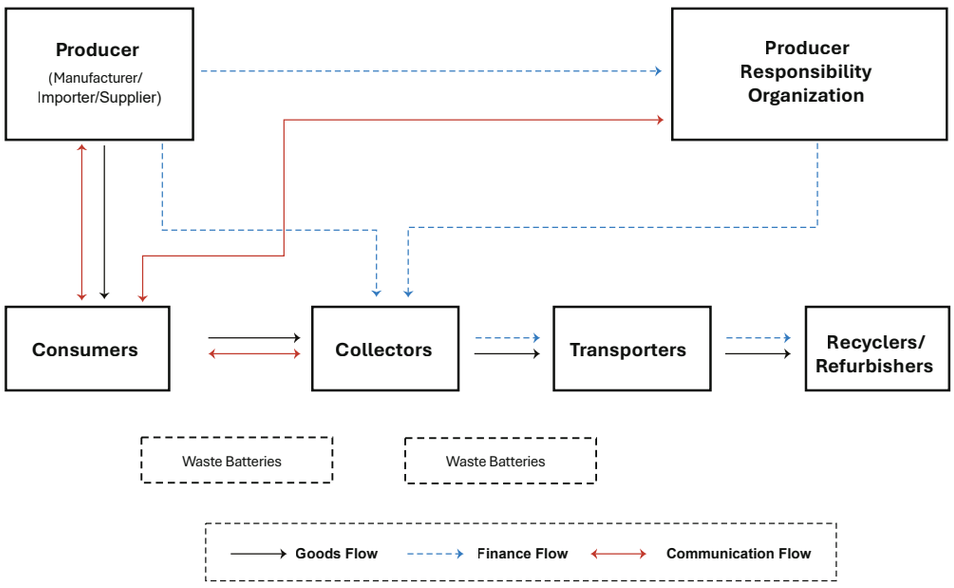


Figure 5: EPR Framework for Battery Waste Management

Waste collection models vary globally, shaped by regulatory frameworks, infrastructure, stakeholder engagement, producer responsibility, and market maturity [25],[26]. Typical models are discussed in Table 2 below.

Table 2: Opportunities and challenges of various spent battery collection & recycling models

Battery collection & recycling models	**Description**	**Prominent Regions**	**Commercial Feasibility**	**Key Enablers and Challenges**
In-house OEM Recycling/ Producer managed collection	Battery producers or original equipment manufacturers (OEMs) collect their own batteries from the market and recycle them in-house.	EU, China, South Korea	Moderate to High	Ensures accountability, material control but needs traceable logistics, high upfront cost and volume dependence
Battery Buy-back	OEMs or recyclers purchase used batteries from consumers at a nominal rate.	US, India	Low	Low consumer awareness and high logistics costs
Retail Take-Back Model	Consumers return spent batteries to retail drop-off points or service centers.	Japan, US	Moderate – High	Convenient for users; success depends on retail participation and awareness.
Municipal / Public Collection	Local authorities organize public collection sites and coordinate with recyclers.	EU member states	Moderate	Expands are made but need funding and alignment with EPR schemes.
Deposit-Refund / Incentive System	Consumers pay a small deposit refund upon return of used batteries.	Nordic countries (pilot)	Moderate	Effective behaviorally but complex to administer.
Recycling Service Model	Specialized companies offer recycling services to battery OEMs and fleet operators.	US, China, EU	Low-Moderate	Shared Infrastructure, consistent waste inflow, high upfront cost, volume dependence
Toll Recycling	Recyclers charge a fixed fee for processing batteries, and the recycled or semi-recycled materials are then handed over to the owners.	Japan, South Korea	Low	Difficult to ensure quality and efficiency
Battery as a Service	Operators lease or exchange batteries, primarily in light electric vehicles, enabling them to track battery usage and collect them for recycling at the end of their life.	China, Taiwan, India	Low-Moderate	Battery tracking, achieving operational scale, and maintaining chemistry uniformity
Aggregator, informal network - Informal Recycling	Informal collectors aggregate spent batteries for resale. Unregulated recycling by informal/ unauthorized recyclers	South Asia, Africa	Low	Wide reach and robust network but environmental and health risks along with traceability issues.

In Europe and North America, companies such as Ford, BMW, and Volvo developed closed-loop recycling systems by partnering with Redwood Materials and Northvolt recyclers thereby ensuring re-entry of recovered materials into the supply chain. Such collaborations to support material recovery also reduces dependence of raw materials and stabilizes input costs for gigafactories [7]. Countries mandated by EPR policies such as China, have firms that operate integrated production-recycling ecosystems. CATL, BYD, and GEM operate in-house recycling allowing for traceable value chains and improved recovery efficiency. In countries such as India with emerging ecosystems, public-private partnerships (PPPs) between original equipment manufacturers (OEMs), producers, and recyclers (such as Attero and Lohum) allow companies to meet Battery Waste Management Rules (2022) collection and recycling targets. To make waste management financially viable, EPR is supported by producer-pays mechanisms, advance recycling fees (ARFs), and deposit-refund schemes that internalize recycling costs instead of passing them onto the consumer. Revenue from recovery of materials such as lithium, cobalt, and nickel provide additional income streams. In mature markets such as in the EU, EPR credits are combined with recycled-content mandates under EUs regulation 2023/1542.

Need for globally aligned regulatory frameworks

Batteries, especially new and emerging batteries, rely on critical raw materials such as lithium, cobalt, and nickel – that are scarce and unevenly distributed. While 58% of the global lithium reserves are found in South America, half of cobalt is found in the Democratic Republic of Congo, and 22% of the world's nickel reserves are in Indonesia, the processing of these materials is dominated by China that refines over 60-70% of the world's cobalt, lithium, and nickel and produces 90% of battery-grade graphite [27], [28]. Such global concentration of critical materials and their processing creates supply-chain risks for countries, especially emerging economies, without secure and stable access to these resources. Recently with the US imposing tariffs of up to 100% on Chinese EVs and batteries, the EU investigating subsidy practices, and China restricting export of critical materials such as graphite and gallium – there is a tightening and politicization of critical mineral flow and disruption of the global batter supply chain [29], [30]. As countries adopt renewable energy sources along with EVs, the demand for critical minerals will accelerate steeply. Between 2020-2022 lithium prices alone rose by over 400% and its demand is expected to increase 40 times by 2040, while that of cobalt and nickel will rise 20-25 times, which can lead to price volatility in the coming years [31].

In the presence of global supply shocks and price volatility, sustainable management of batteries at their end-of-life becomes imperative. Currently however, the massive flow of e-waste from major exporting countries and regions like the US, the EU, and Japan to China, Southeast Asia, including India, and Central Africa, highlights significant challenges and missed opportunities due to the lack of formal recycling and resource recovery practices [32]. Much of the e-waste trade takes place informally or is undocumented and entails reuse, refurbishment, and unsafe recycling practices that do not capture the full value of the waste. Globally, 62 million tonnes of e-waste was generated in 2022 and is expected to rise to 82 million tonnes by 2030 however, only 1% of the global rare earth demand is being met by e-waste recycling, further emphasizing the need for formal recycling systems and technologies [33]. To implement the same, globally aligned policies and regulatory frameworks are needed that can support harmonization of standards, promote equitable resource recovery, and enable knowledge sharing across regions. In the section below, globally relevant policies supporting battery recycling and waste management ecosystems are reviewed and best practices, implementation models, and regulatory frameworks are discussed.


ENERGY
STORAGE

Global Policies Supporting Battery Recycling Ecosystem

Globally, the Basel Convention, country-wise battery waste management regulations, and more recent policies on critical mineral security highlight the focus towards circular economy, energy security, and environmental sustainability. While the stringency, scope, and maturity of policies and their implementation varies across regions, there are converging drivers shaping the landscape.

Countries including the European Union, along with India, China, Japan, Canada, the United States, and the United Kingdom represent the most advanced frameworks, with legally enforceable Extended Producer Responsibility (EPR) obligations, clear collection and recycling targets, and mechanisms to encourage material recovery. This section provides a summary of policy frameworks governing battery waste management globally while **Annexure 1** gives a detailed table of comparative analysis of global battery/e-waste regulations conducted across various countries in Europe, Asia, North and South America.

Europe: The Benchmark for Structured and Ambitious Regulatory Frameworks

The European Union stands as a global benchmark with its comprehensive EU Battery Regulation (2023/1542) that harmonizes the battery value chain from design through end-of-life management. This regulation integrates:

- **EPR:** Mandatory take-back schemes and recycling financing for producers ensure accountability.
- **Collection Targets:** These include ambitious goals such as achieving 63% collection of portable batteries by 2027 and 73% by 2030, along with targets specific to light means of transport batteries.
- **Material Recovery Requirements:** Recyclers must achieve minimum recovery percentages of critical materials—such as 90% recovery of cobalt, copper, lead, and nickel and 50% for lithium by 2027—which rise further by 2031.
- Black mass is considered as a hazardous waste in the EU, which tightens its trans-boundary movement and allows for resource recovery, supply chain resilience, and critical minerals security. To support the same, BASF is now operating the largest black mass refinery plant in Schwarzheide, Germany, with processing capacity of 15000 tonnes per annum that is about 40,000 EV batteries annually. The plant using hydrometallurgical methods, is achieving high purity and yields while reducing carbon footprints and fostering circularity [34] [35].
- **Purity and Yield Standards:** These are necessary to guarantee the usability of recycled battery material, ensuring that lithium-ion batteries contain a minimum recycled content of cobalt, lead, lithium, and nickel, reinforcing circularity.
- **Battery Passports and Traceability:** The regulation mandates digital documentation enabling full lifecycle traceability, aiding enforcement and consumer awareness.

Europe's approach, backed by strong enforcement and funding initiatives, demonstrates measurable progress and provides a replicable blueprint for other regions [36].

China: Leading with Detailed Standards and Industrial Integration

China has rapidly evolved into a global leader through comprehensive regulatory mandates and industrial integration:

The government enforces detailed purity and impurity limits for black mass (the intermediate product concentrated from battery recycling), such as iron below 0.5%, copper ≤ 0.5%, and aluminum ≤ 1%, ensuring recycled materials meet high-quality benchmarks.

A whitelist system supports formal recycling with QR-code enabled traceability is imposed, mandating every stage of recycling—from collection to processing be monitored for quality and environmentally sound recovery.

Standards such as GB/T-45203-24 provide technical specifications, quality parameters, and usage classifications specifically for black mass used in lithium-ion batteries. [37]

Collection targets set for lead-acid batteries were 40% by 2020 and 70% by 2025, supported by an extensive network of collection points and processing plants despite some underutilization due to feedstock shortages.

China's approach reflects a systemic commitment to environmental protection, industrial policy alignment, and circularity.

This model highlights the importance of enforceable quality standards alongside collection mandates and advanced industrial infrastructure to support waste management and resource recovery [38], [39],[40].

Japan: Emerging Industrial Capacity Amid Evolving Regulation

Japan's regulatory landscape for battery recycling is less prescriptive compared to Europe and China but shows strong industrial momentum:

While specific black mass regulations are still under development, the Japanese Ministry of Economy, Trade, and Industry (METI) has set clear targets for the establishment of domestic recycling infrastructure to support black mass resource recovery by 2030.

Leading industry players like Sumitomo Metal Mining are expected to operationalize lithium-ion battery recycling plant in Ehime Prefecture by mid-2026 with processing capacity on 6000-7000 tonnes per year, the plant will be processing battery waste from 60,000 electric vehicles [41]. Japan emphasizes technological innovation and circular economy integration, positioning itself for more formal regulatory frameworks aligned to industrial progress [42].



United States: Controlled Hazardous Waste Management and Second-Life Standards

In the United States of America, battery recycling is chiefly regulated under the Resource Conservation and Recovery Act (RCRA), which governs hazardous waste:

- Handling and shredding of batteries (to produce black mass) are restricted to licensed RCRA facilities, ensuring environmental safety by operating under strict hazardous waste rules.
- While USA is advancing its battery stewardship programs, there are no explicit national standards yet issuing purity or yield targets comparable to the EU or China.
- The country leads globally in the development and adoption of standards for second-life battery applications, prominently the UL 1974 certification for repurposed battery safety and performance, and voluntary IEC standards for energy storage system interoperability and safety (IEC 62660, IEC 62933). These standards provide a benchmark for establishing safety standards, and performance along with certification requirements to ensure reliable use of repurposed batteries in stationary storage and other secondary applications.

  The U.S.A is actively strengthening federal guidelines on lithium-ion battery waste management, with the Environmental Protection Agency working toward a dedicated universal waste category for lithium-ion batteries [43].

India: Ambitious EPR, Weak Purity Enforcement

India's Battery Waste Management Rules (2022) impose strong EPR-based collection targets (EV/portable: 90% by 2026–27; industrial: 60%) and recovery obligations (Li: 80%, Co/Cu/Ni/Pb: 95% by 2031). Yet, lack of enforcement of harmonized purity/yield leads to inconsistent classification of black mass in trade, sometimes exported under HS codes for mixed salts or cobalt powder. Instead of capturing the full value of waste, this leads to leakages of critical minerals and resources out of the country. While the rules are ambitious on paper, enforcement challenges remain. This along with lack of infrastructure, policy alignment, and regulatory clarity undermine compliance [44], [45], [46]

Canada and Australia: Building Collection Infrastructure with Voluntary to Mandated Progress

Canada and Australia currently operate with evolving regulatory frameworks emphasizing collection network expansion:

Canada's collection rates for portable batteries are increasing through voluntary programs like Call2Recycle Canada, although there are no nationwide mandatory material recovery targets. Different provinces have varied requirements, with emerging Extended Producer Responsibility (EPR) schemes.

Australia operates an industry-led Battery Stewardship Scheme (B-cycle) under voluntary arrangements with growing collection rates, reporting ~73% recovery of collected materials with over 5,000 drop-off points. However, no mandatory purity standards or black mass rules exist. Legislation for mandatory EPR is expected in New South Wales by 2025, signalling a move toward stronger governance.

Both countries are investing in industrial capacity and research to support sustainable recovery in anticipation of future regulation [47], [48].

Emerging Economies: Patchy Enforcement

Colombia: Mandates EV battery collection, rising to 65% by 2044, but lacks recovery purity standards [49].

Peru and Brazil: Frameworks exist, but battery-specific mandates are poorly defined; black mass infrastructure is minimal [50], [51].

South Africa: EPR rules under NEMWA (2020) cover lifecycle obligations, with penalties (up to 15 years imprisonment), though technical standards remain weak [52].

Nigeria: Introduced full lifecycle EPR in 2024, but lacks explicit recovery or purity benchmarks, and compliance is low despite significant fines and sanctions in place [53].

Turkey: Aligning with the EU Battery Regulation, with collection targets (63% by 2027; 73% by 2030) and recovery goals (Li: 50% by 2027, 80% by 2031). Black mass regulation remains limited, but EU alignment indicates future convergence [54].

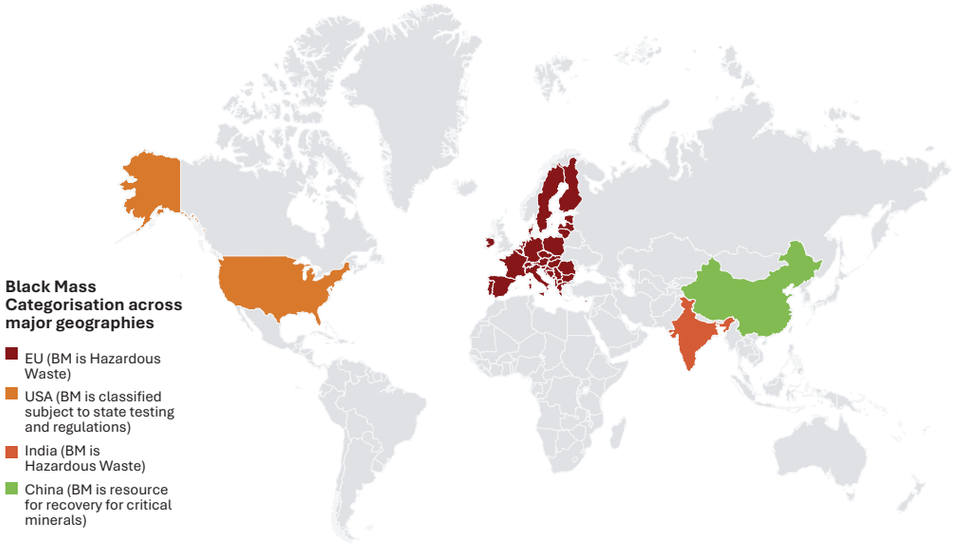


Figure 6: Global Categorization of Black Mass across major geographies

As can be seen in the figure above and from global policies analyzed, Europe and India categorize the resource rich black mass as hazardous. In Europe, hazardous waste follows tightened trans-boundary movement allowing for resource recovery while in India it is exported under HS codes for mixed salts or cobalt powder, leading to loss of critical minerals [55]. In North America (USA) only designated RCRA facilities can process EOL batteries to black mass stage, which is an intermediate material sent for metals recovery (refining) or use in new products [56]. Only in China is the black mass considered resource rich and recoverable item, with the country coming out with GB/T-45203-24 standards detailing technical specifications for recycled black mass for Li-Ion batteries and GB/T 6284 for Testing and Appearance Requirements for Black Mass [37].

Overall, while mature economies such as China, Germany, and the EU drive advanced material recovery standards and robust policy frameworks that combine efforts from upstream producers to integrate traceability, achieve recycling targets, and support technology deployment—many emerging economies and developing regions require enhanced regulatory clarity, enforcement capacity, and incentives that bring stakeholders together. Closing these gaps is crucial for ensuring that global battery recycling delivers on environmental and supply chain sustainability goals, especially with rising volumes of lithium-ion batteries entering end-of-life stages worldwide.

The International Solar Alliance (ISA) as an intergovernmental organization supporting transition to a low-carbon future and setting-up sustainable solar projects with focus on Least Developed Countries (LDCs), Small Island Developing States (SIDS), and other emerging economies plays a crucial role in bringing key stakeholders and network actors from across the battery value chain, especially manufacturers and producers, together to support robust reverse logistics and recycling ecosystems that, as can be seen in the case-study presented in the next chapter, are dependent on stakeholder collaborations and support through Extended Producer Responsibility (EPR) policy implementation.




Lithium Ion Battery
Maintenance Free
IMPORTANT: NOT SERVICEABLE
DO NOT OPEN
Lithium Ion Battery
12.8 Volt 100Ah



Lithium-ion Battery Recycling in the Global South: India case-study

With the rising volume of end-of-life batteries and growing policy momentum toward circularity in the battery value chain, understanding the financial feasibility of recycling infrastructure has become critical. This section evaluates the cost economics of establishing a lithium-ion battery (LiB) recycling facility in India - to provide a practical reference for policymakers and investors to understand the capital and operational requirements of such infrastructure, thereby supporting informed decision-making for scaling battery recycling in emerging markets.

The analysis focuses on 3 capacities – 1000 TPA, 5,000 TPA and 10,000 TPA of the recycling plant. Facilities with capacities below 5,000 TPA are typically commercially sub-scale due to high unit capital costs, lower equipment utilization, and limited material throughput. The 5,000 TPA and 10,000 TPA configurations were therefore selected to represent commercially viable and scalable plant sizes that align with projected EoL battery availability in India over the next decade, while capturing economies of scale in capital deployment, reagent consumption, and energy use.

Hydrometallurgical technology is considered, as it is currently the most commercially preferred due to its high recovery efficiency (up to 95%), lower energy consumption, and capability to selectively extract critical raw materials like lithium, cobalt, and nickel.

Three feedstock compositions are considered to reflect market heterogeneity:

100% LFP (Lithium Iron Phosphate)

100% NMC (Nickel Manganese Cobalt)

Mixed chemistry feedstock, comprising **15%** LCO, **50%** LFP, and **35%** NMC.

The financial model assumes a 15-year plant life with capacity utilization getting ramped up from 30% to 60%, in line with prevailing industry benchmarks. The key assumptions used in this analysis, such as capital investment, O&M costs, electricity tariffs, and recovery rates, are detailed in Table 3 below. These assumptions underpin financial outputs, such as the Internal Rate of Return (IRR) and Net Present Value (NPV), to assess project viability.

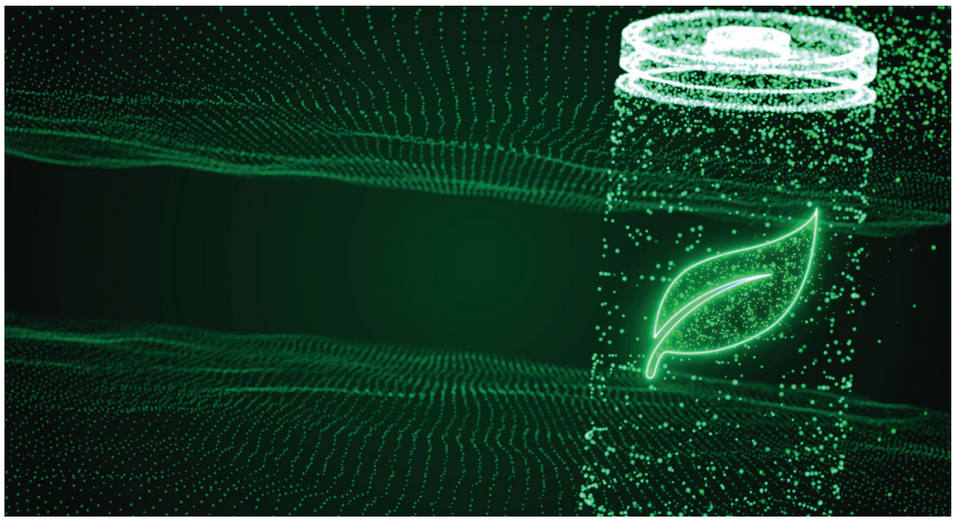


Table 3: Assumptions for Setting up a LiB Recycling Plant in India[2]

Technology	Hydrometallurgy
Capacity	1000 TPA, 5000 TPA, 10KTPA
Life of Plant	15 years
Capacity Utilization Factor	30% to 60% (Steady State)
O&M Cost	1% of CapEx
Electricity Price	INR 9/kWh
Debt to Equity	70:30
Return on Equity	13%
Interest Rate	9%

Based on the assumptions highlighted in the table above, capital and operating expenditure have been calculated. The various cost components of a LiB recycling plant are listed in Table 4 below for 3 capacities – 1000 TPA, 5,000 TPA and 10,000 TPAwhile Table 5 shows operating expenditures for different feedstock chemistries particularly between Nickel Manganese Cobalt (NMC), Lithium Iron Phosphate (LFP) batteries, and mixed feedstock, which represent the predominant chemistries entering end-of-life streams. As summarized in Table 5, a comparative analysis of cost structures highlights significant variations in chemical reagent usage, recovery yields, and by-product value recovery, which collectively influence the overall process economics and profitability of recycling facilities.

Table 4: Total Capital Cost Calculation for recycling plant[3]

Capital Component	1KTPA (INR Cr)	1KTPA (Mn USD)	5KTPA (INR Cr)	5KTPA (Mn USD)	10KTPA (INR Cr)	10KTPA (Mn USD)
Land & Building	4.7	0.5	19.0	2.2	38.1	4.4
Plant & Machinery	12.5	1.4	62.5	7.3	125.0	14.4
Other Equipment	4.1	0.5	10.5	1.2	17.5	2.0
Other Costs	3.0	0.35	6.0	0.7	9.0	1.0
Total Capex Cost	24.3	2.8	98.0	11.4	189.6	21.8

[2] Source: input collected from industry players
[3] Source: Input collected from industry players

Table 5: Operating Costs to Run a LiB Recycling Plant[4]

OPEX Components	NMC	LFP	Mixed Feedstock
Raw Materials (Feedstock) (INR Crore/Ton)	0.02	0.011	0.018
Labour (INR Crore/Ton)	0.00066	0.00066	0.00066
Energy (INR Crore/Ton)	0.00046	0.00046	0.00046
Chemicals, Solvents (INR Crore/Ton)	0.01	0.0068	0.01
Transportation (INR Crore/Ton)	0.004	0.004	0.004
Total (INR Crore/Ton)	0.035	0.023	0.033

Different lithium-ion chemistries have different metal recovery rates. As provided in Table 6, NMC chemistry offers significant recycling value due to their high content of critical metals, including cobalt, nickel, and manganese. With recovery efficiencies ranging from 70% to 95%, the process yields substantial quantities of metal salts per ton of battery material. This makes NMC battery recycling particularly attractive from both a resource recovery and economic standpoint. LFP batteries on the other hand do not contain cobalt, copper, or aluminum and instead are composed of lithium, iron, phosphorous, graphite, copper, and aluminum. LFP recovery efficiencies also range from 70-95%.

For India, the feedstock composition is assumed to be a mixed chemistry stream, comprising approximately 15% LCO, 50% LFP, and 35% NMC batteries, reflecting the prevailing and anticipated composition of its end-of-life battery market. The table 6 gives the recovery of metals from mixed feedstock along with the EPR floor prices set by the Central Pollution Control Board (CPCB) for each recovered metal. For calculating EPR revenue (Table 6), the floor prices fixed by India's Central Pollution Control Board have been considered. These have been fixed for each metal that is recovered from battery recycling.

Table 6: Metal Recovery from Mixed Feedstock and EPR floor price set by CPCB

Metal/Mineral	Metal recovered from recycling mixed chemistry feedstock (Kg/ton of spent battery)	EPR floor price (INR/kg pure metal recovered)
Cobalt	90	166
Nickel	47	166
Lithium	21	720
Manganese	32	166
Copper	138	81
Aluminium	109	36
Graphite	119	0
Iron	105	36

[4] Source: Input collected from industry players

NMC battery recycling offers a higher economic value due to the presence of critical and high-value metals, such as cobalt and nickel, yielding greater returns per ton despite higher processing costs. In contrast, LFP batteries are more cost-effective to recycle, yielding substantial quantities of materials such as copper, aluminium, iron and lithium, albeit with lower market value. While NMC recycling is revenue-driven, LFP recycling supports sustainability and resource recovery at lower operational complexity.

The output from the financial model indicates that a recycling plant can generate an estimated revenue of INR 0.53 crores per ton of spent NMC battery recycled, driven by high-value metals such as cobalt and nickel. In comparison, LFP battery recycling yields around INR 0.193 crores per ton of spent LFP battery recycled, based on the recovery of lithium, iron, and copper. In case of mixed feedstock (15% LCO, 50% LFP, 35% NMC), the revenue generated per ton of recycled spend batteries is approximately INR 0.34 crores. These values are indicative and based on prevailing average market prices for recovered metals, which are subject to periodic fluctuations.

The model for 100% LFP plant indicates that the project will remain financially unviable in the absence of EPR support or capex subsidy. When EPR support and 20% capex subsidy are provided, LFP recycling attains a decent IRR of 8-9% at above 80% utilization of capacity. NMC recycling on the other hand manages to attain bankable rates of IRR even in absence of these supporting policy mechanisms at capacity utilization of 60% and above.

In conclusion, the financial viability of a LiB recycling plant is closely tied to composition and quality of the spent battery feedstock, material recovery efficiency and operational costs. While NMC-based recycling offers higher revenue potential due to the recovery of valuable metals, the feedstock is also costlier and involves significantly higher processing costs. LFP recycling, on the other hand, is more cost-efficient but yields lower revenue due to presence of a smaller number of recoverable high value metals. A successful recycling operation will ultimately depend on optimizing process economics, securing consistent and good quality feedstock supply, and aligning with evolving regulatory and sustainability frameworks.

Lithium-ion battery recycling: India's worst, base, and best-case scenario

A sensitivity analysis was undertaken to evaluate the influence of key policy and operational variables namely EPR support, capital subsidy, taxation on feedstock, and plant capacity utilization on the Project IRR and Equity IRR of recycling facilities with processing capacities of 1,000 TPA, 5,000 TPA, and 10,000 TPA. The analysis considers three scenarios namely— best case, base case, and worst case, to capture potential variations in market and policy conditions. Across all scenarios, the feedstock composition is assumed to be a mixed chemistry stream, comprising approximately 15% LCO, 50% LFP, and 35% NMC batteries, reflecting the prevailing and anticipated composition of the end-of-life battery market in India. This assumption provides a representative basis for financial assessment, given the increasing dominance of LFP and NMC chemistries in EV and stationary storage applications. All other techno-economic parameters and cost assumptions remain consistent with those outlined in the preceding sections.

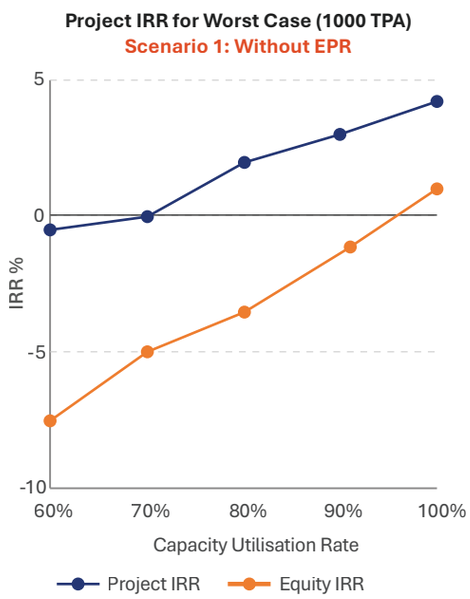
Worst Case – Plant Processing capacity 1000 TPA only, GST on feedstock 18%

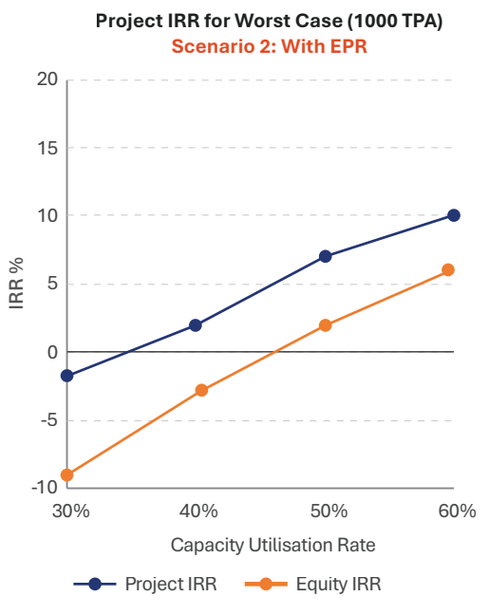
In this scenario, the Project IRR and Equity IRR have been modelled across a capacity utilization range of 30% to 100%, under the assumption of an EPR support framework that ensures a floor price for recovered metals. The impact of capital subsidy has not been considered in this case, as such incentives are typically extended only to facilities with a processing capacity of 5,000 TPA or higher.

The results indicate that, with EPR support, the project attains a bankable IRR when plant utilization exceeds 60%, reflecting the positive influence of stable revenue streams from recovered materials. In contrast, without EPR support, the project achieves only a 4% IRR even at full capacity utilization (100%), underscoring the dependence of financial viability on policy-backed price mechanisms.

Feedstock procurement remains the largest cost driver within the operating expenditure structure, further burdened by an 18% tax on spent Li-ion batteries. This significantly compresses margins, particularly at lower utilization levels.

Overall, the analysis suggests that **a 1,000 TPA Li-ion battery recycling facility is economically unviable in the absence of an EPR-backed price support mechanism. Even under the EPR regime, the project becomes financially sustainable only beyond 70% capacity utilization, highlighting the critical importance of both policy support and operational efficiency in ensuring commercial viability**





Base Case – Plant Processing Capacity 5000 TPA, GST on feedstock 18%

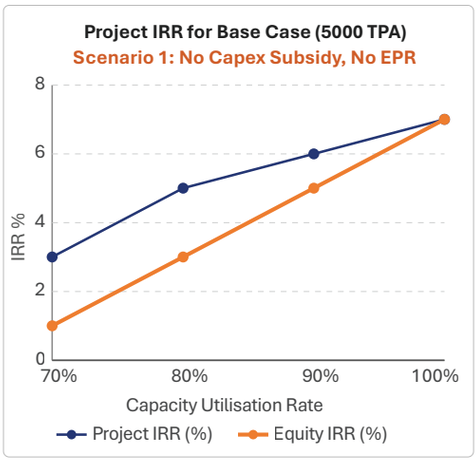
In this scenario, the Project IRR and Equity IRR were evaluated across a capacity utilization range of 30% to 60%, under the assumption of an EPR support regime that guarantees a floor price for recovered metals. The analysis also incorporates the impact of capital subsidy, which is typically extended only to projects that scale their processing capacity to 5,000 TPA or above.

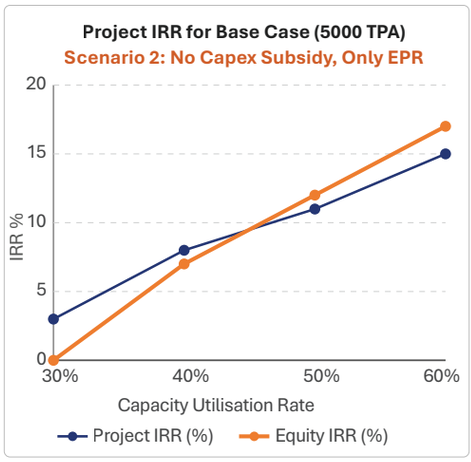
The results indicate that, in the absence of both EPR support and capital subsidy, the project fails to achieve a bankable IRR, even at 100% capacity utilization. When EPR support is absent, but a 20% capital subsidy is applied, Project IRR improves modestly to around 9% at full utilization. This suggests that, without EPR support, a capital subsidy in the range of 25–30% would be necessary to make the project financially viable.

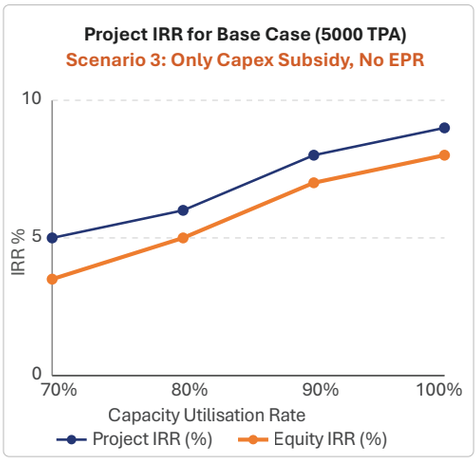
Conversely, when EPR support is introduced but capital subsidy is withdrawn, the project achieves a competitive IRR of approximately 15% at 60% utilization, primarily due to improved revenue certainty and recovery value. The combined presence of both EPR support and capital subsidy yields the most favorable outcome, with the Project IRR reaching around 17% at 60% utilization.

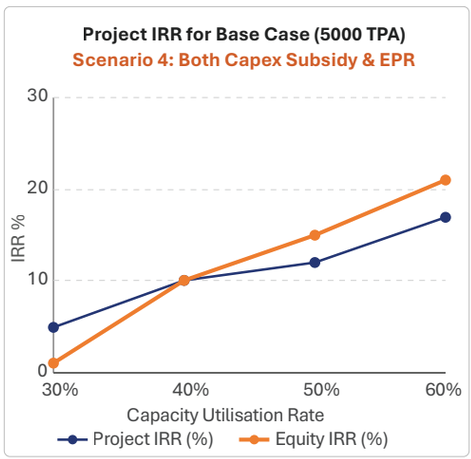
Across all cases, the cost of feedstock (spent Li-ion batteries) remains a dominant component of operational expenses, further exacerbated by the 18% GST levy on waste batteries.

A key conclusion from this analysis is that EPR support exerts a stronger influence on project and equity returns than capital subsidy, as it directly enhances EBITDA margins by stabilizing recovered metal revenues and reducing market price risk.









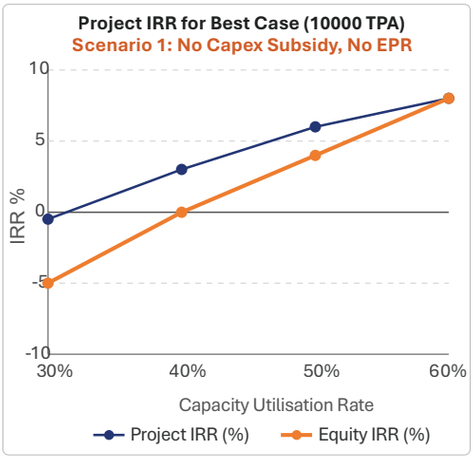
Best Case – Plant Processing Capacity 10,000 TPA, GST on feedstock 5% only

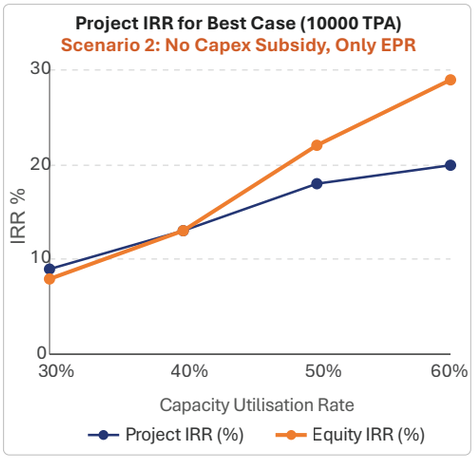
In this scenario, the Project IRR and Equity IRR were assessed across a capacity utilization range of 30% to 60%, under the assumption of an EPR support regime that guarantees a floor price for recovered metals. The analysis also considers the impact of capital subsidy, which is typically extended only to projects with a processing capacity of 5,000 TPA and above.

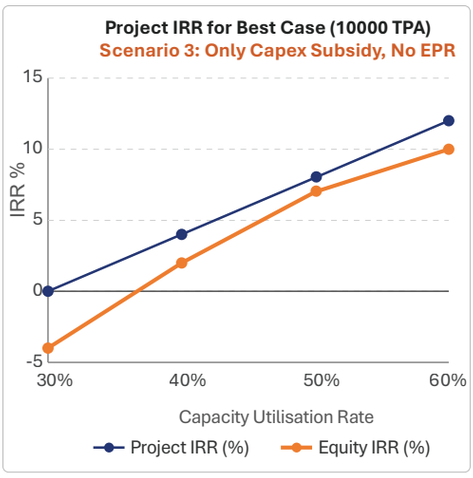
The results indicate that without EPR support or capital subsidy, the project achieves a bankable IRR only when utilization exceeds 60%, underscoring the importance of scale and efficiency. When EPR support is absent, but a 20% capital subsidy is introduced, the project attains a Project IRR of approximately 10% at 60% utilization. Conversely, when EPR support is provided but capital subsidy is withdrawn, the project achieves a competitive IRR of around 17% at 50% utilization, highlighting the strong revenue stability benefits associated with EPR-linked price assurance.

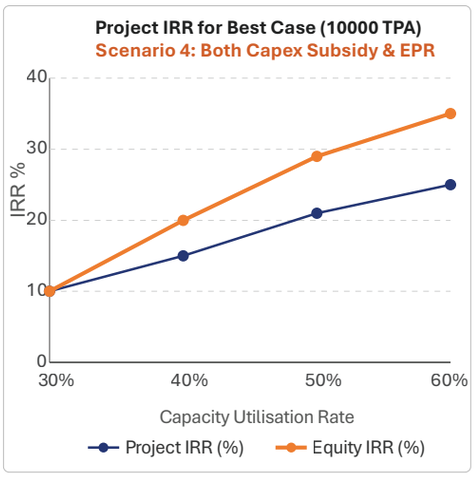
Under the combined presence of both EPR support and capital subsidy, the project attains a competitive IRR of 15% even at 40% utilization, reflecting the synergistic effect of policy incentives and scale-driven cost optimization.

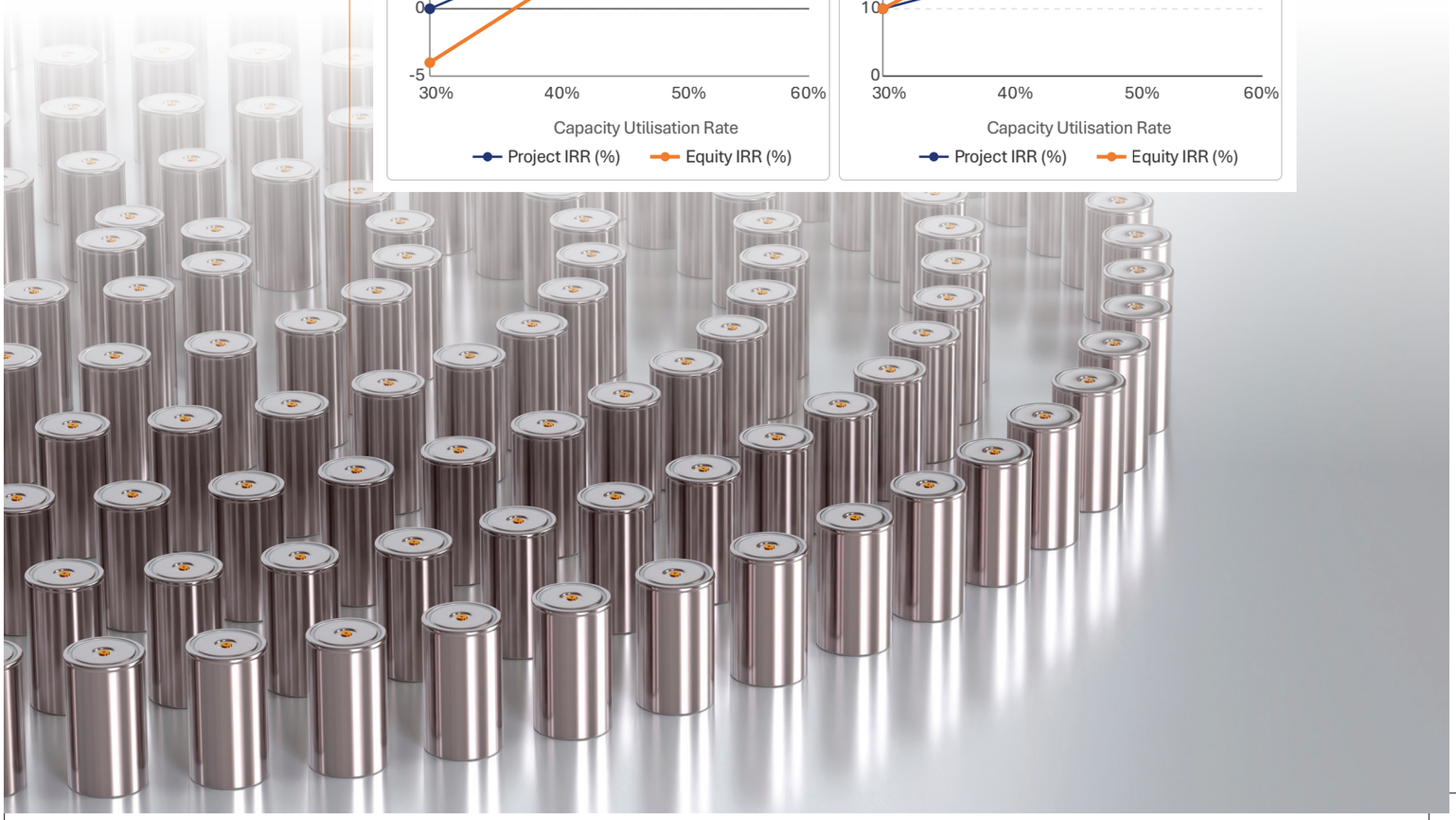
The analysis reaffirms that **EPR support has a more substantial impact on both Project and Equity IRR compared to capital subsidy, it directly improves EBITDA margins by stabilizing metal recovery revenues and mitigating market price volatility. The higher profitability observed in this case is attributed to the larger operational scale and the reduced tax rate of 5% on feedstock (spent Li-ion batteries), which significantly lowers input costs relative to smaller-scale facilities.**











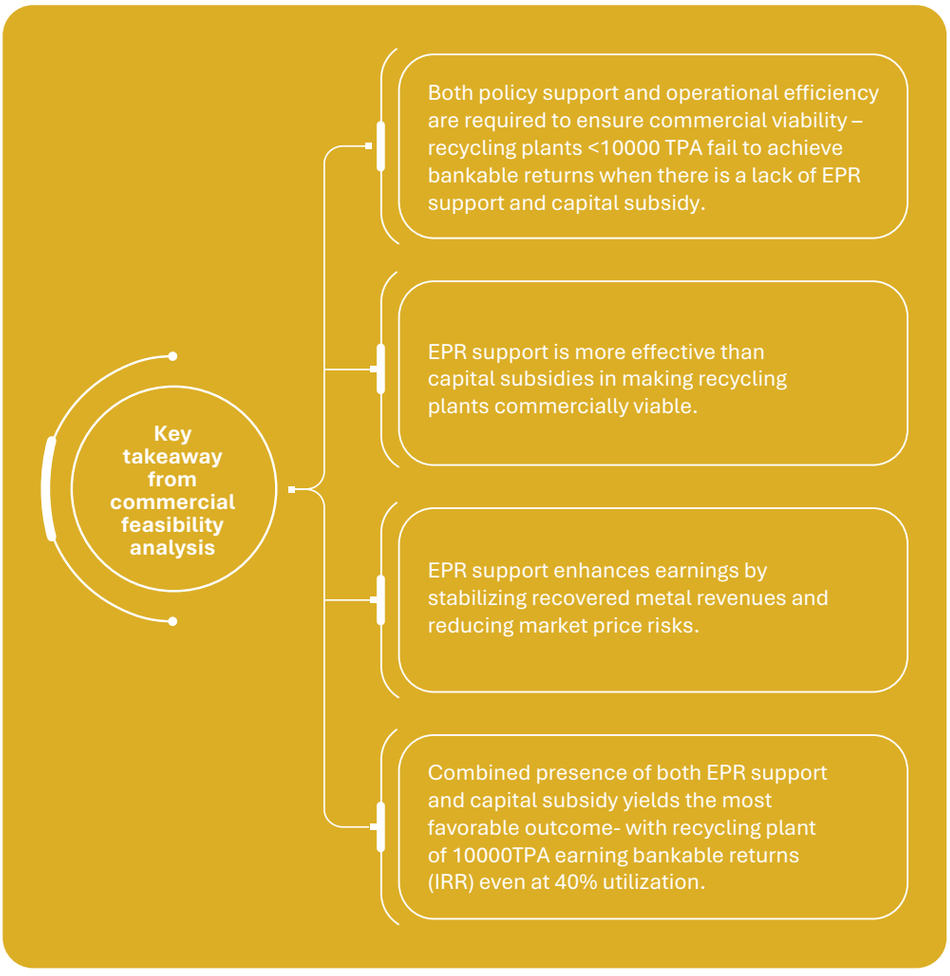


In conclusion, the financial analysis demonstrates that the financial viability of lithium-ion battery (LiB) recycling plants in India is highly sensitive to both operational scale and the policy environment. While hydrometallurgical recycling remains the most commercially preferred technology due to its high recovery efficiency and lower energy intensity, the associated capital and operating expenditures are substantial.

At smaller scales (e.g., 1,000 TPA), the economics are constrained by diseconomies of scale, high feedstock costs, and limited revenue potential, making such plants unviable without strong policy support. Financial returns improve significantly with capacity expansion to 5,000–10,000 TPA, where process optimization and material recovery volumes enable a more favorable cost structure.

The sensitivity analysis further indicates EPR support—particularly in the form of a floor price mechanism for recovered metals—has the most pronounced positive impact on project viability. In its absence, even with 100% utilization, projects struggle to achieve a bankable IRR. Conversely, when EPR support is present, bankable returns are achieved at moderate utilization levels (50–60%), underscoring the importance of stable policy-backed price signals.

While capital subsidies also improve returns, their impact is secondary to that of EPR incentives, as they primarily reduce upfront capital intensity rather than improving ongoing profitability.



In conclusion, **the establishment of a sustainable and financially attractive LiB recycling ecosystem in India will require a combination of policy-driven revenue assurance mechanisms (EPR credits or floor prices), fiscal incentives for capacity scaling, and rationalized taxation of waste batteries. These measures, together with investments in collection logistics and process innovation, are essential to enable economically viable, large-scale recycling infrastructure that supports India's transition toward a circular and resource-secure battery value chain.**


BATTERY
ENERGY
STORAGE

Battery Recycling Guidelines for ISA Member Countries: Advancing Circular Battery Value Chains

Battery Recycling Guidelines proposed are based on global policy review and best practices. They are complemented by inputs from industry, battery association, and regulatory bodies to address identified policy gaps in the current global regulatory frameworks and on-ground practices. Guidelines detailed below take elements of Extended Producer Responsibility (EPR) for battery waste management and e-waste, as shown in figure 7, and propose a collective responsibility model that includes state regulators, waste producers, recyclers and consumers. The guidelines are agnostic to battery chemistry, type, and application.



Collection Responsibility
Producers must ensure collection from consumers and industrial users



Authorized Facilities
Collected batteries must be sent to authorized refurbishers or recyclers



Collection Infrastructure
State agencies, municipal bodies, and district-level authorities can establish collection systems



Material Recovery Targets
Mandates re-use of recovered materials in new battery production



Defined Responsibility
Producers are assigned collection, recycling, and re-use targets



Producers Registration
Producers, recyclers, and second-life manufacturers to register with relevant authorities



Financial Responsibility
Producers are responsible for all costs associated with waste management



Recordkeeping & Annual Reporting
Producers, recyclers, and second-life manufacturers to submit annual reports



Eco-friendly Design
Encourages producers to design batteries with longer lifespans



EPR Credit Trading
Recyclers generate credits for compliance with EPR requirements



Consumer Awareness
Producers to conduct campaigns for informing consumers about collection programs



Audit and Transparency
Regulatory authorities may conduct audits and publish compliance reports

Figure 7: Key Components of EPR for Battery Waste Management

1. Establishing (waste) Definitions, Roles and Stakeholder Responsibilities, and EPR obligations

The success of battery waste management, second-life re-use, and recycling depends on key network actors and stakeholders along the value chain working together towards a shared goal of extending the useful life and resource recovery. Current ambiguity in definition leads to confusion over who fulfills extended producer responsibility (EPR) obligations for battery waste management. Is the responsibility of producer assigned to original equipment manufacturer (OEM), cell manufacturer, pack assembler, importer, or all the above. Overlap in responsibilities of stakeholders between primary battery producer and second- life battery manufacturers - makes it unclear to determine who is accountable for battery waste management in its second life. ***There is a need to move forward with market-based identity of stakeholders whereby second-life battery manufacturers become responsible producers incentivised to support primary producer in fulfilling EPR obligations.***

Definition of spent battery or battery waste to be all inclusive for end-of-life batteries, including spares and components, and off-specific batteries. Definition of 2nd life batteries and refurbished batteries to disclose with labelling the change in or addition of the stakeholders involved, the use case or battery specifications of the refurbished/ recycled battery.

Labelling for 2nd life batteries to include:

Product Condition {refurbished, certified pre-owned, factory remanufactured} along with information on "Original Parts" vs. "Third-Party Parts Installed",	Performance & testing status {functionality, components replaced/ repaired, standards, testing date
Actors involved {OEM, refurbisher/ recycler name, certification, service, support information}.	Compliance, Safety, & Environmental labels CE, FCC, RoHS, deviations due to refurbishing, modifications, recycling, product age to be highlighted, label as second life battery, carbon savings (if quantified), energy efficiency, battery health indicators, e-waste diversion icon}; and
Warranty Support information {new warranty duration, coverage under warranty}.	Unique Product Identifier {serial number, refurbished product ID, QR code to access product history, repair/ recycling information}.

Stakeholders along the battery value chain to be clearly identified with their roles & responsibilities highlighted to support cooperation between key network actors across the end-of-life value chain as given in the stakeholder mapping presented in below.

PRODUCERS

- Register on battery/e-waste portal & file annual returns
- Uptake of battery digital passport
- Meet targets for collection, recycling/repurposing and re-use of recycled material
- Ensure proper labelling and report non-compliance
- Buy EPR credits from recyclers to offset targets

RECYCLERS

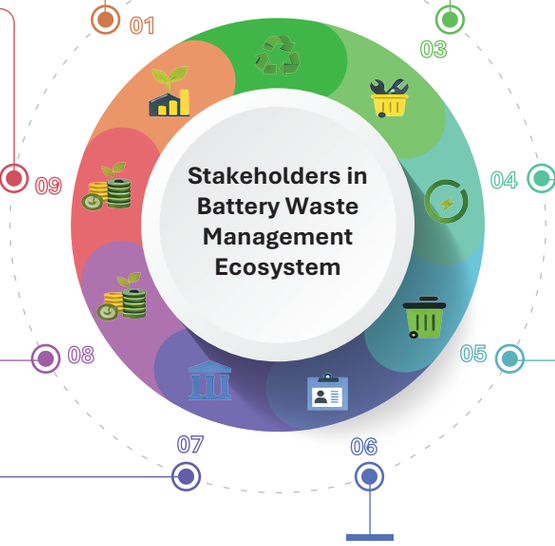
- Register on battery/e-waste portal
- Recycle batteries as per guidelines & file annual returns
- Generate EPR credits for recycled batteries and sell to producers

REFURBISHER

- Register on battery/e-waste portal
- Repurpose batteries for second life & file annual returns
- Assume responsibility for EoL management of second life batteries
- Development of SoP for echelon utilisation for second life re-use

FINANCIAL INSTITUTIONS

- Green financing/sustainability-linked loans for circular businesses
- Support ESG reporting with integration of battery waste data & EPR
- Sustainable finance platforms (UNEP FI, NetZero Banking Alliance)



CONSUMERS

- Disposal of batteries separately from other waste categories
- Return batteries to authorized collection centers
- Choose certified 2nd life batteries like ESS

THINK TANKS & RESEARCH INSTITUTES

- Alignment of EPR with waste generation, waste flows, infrastructure
- Technological Evaluation Framework to support use of 2nd life battery
- Development & uptake of battery digital passport

INFORMAL WASTE COLLECTORS/ KABADIWALA

- Maintain licenses and permits Collect and segregate waste batteries by type
- Record keeping of quantity, battery type
- Support EPR as collection partners

REGULATORY BODIES

- Registration of stakeholders on battery/e-waste portal
- Develop country-wise guidelines for safe handling & spent batteries
- Enforce guidelines and set EPR targets
- Monitor battery waste transboundary flows

PUBLIC WASTE MANAGEMENT AUTHORITIES

- Issue ID cards, licenses
- Documentation & Reporting on battery/e-waste portal
- Community engagement – Awareness & Education programmes

Figure 8: Stakeholder mapping of global battery value chains



In the global stakeholder consultation conducted by ISA, experts noted that purely voluntary or industry-led stewardship schemes are often undermined by free-rider challenges and lack of universal participation. Experts emphasized that effective battery recycling systems require mandatory regulatory frameworks, with industry bodies playing a complementary role in implementation. Specifically, industry associations were seen as critical enablers for workforce training, data generation, cost benchmarking, and operational support, but not as substitutes for regulation. This coordinated model of mandatory rules, combined with industry execution, was identified as essential to scalable, enforceable circular battery ecosystems.

Stakeholders also recognized that informal collection and dismantling networks will continue to play a role in many ISA member countries. However, experts stressed the need for clear functional delineation, whereby informal actors are limited to collection and aggregation, while safe dismantling, chemical processing, and material extraction remain restricted to licensed facilities.

2. Strengthening Traceability and Data Transparency in Battery End-of-Life Management

In waste management of electronics, including that of batteries, there is a gap between collection and recycling EPR targets attributed to producers and the actual capacity and infrastructure available to support the same. The absence of state's role in setting up regional collection centers, formalizing collection, and setting guidelines for safe storage and transportation prevents development of a robust recycling and recovery ecosystem needed to cater to the incoming waste volumes. There is a need to strengthen infrastructure with data-driven waste collection, transport, storage, and aligned EPR targets.

Traceability along the battery value chain is needed to build battery intelligence ecosystem, prevent counterfeit products, boost consumer confidence, forecast the incoming waste generation, and plan for supportive infrastructure development accordingly. The figure below indicates elements of a traceable battery and its end-of-life value chain.

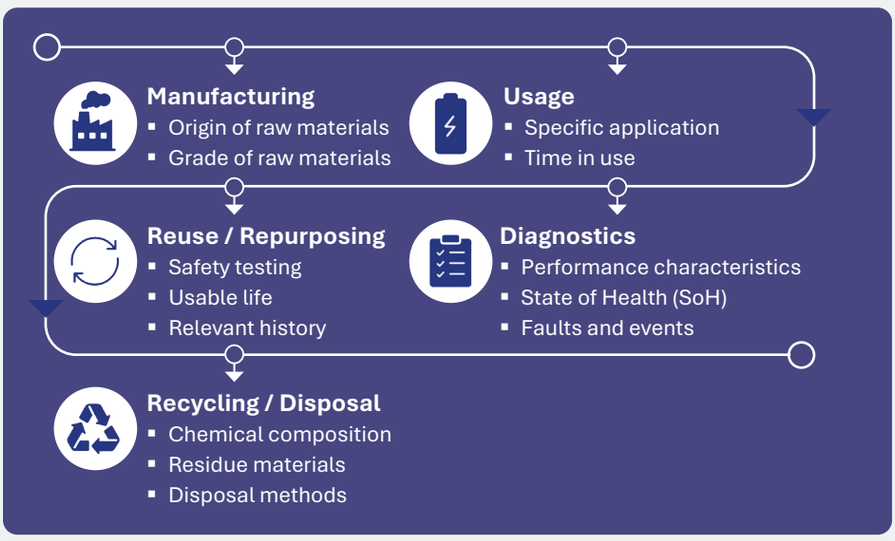


Figure 9: Enhancing traceability across the battery value chain

Traceable batteries with information on composition, material content, diagnostic information on performance characteristics, battery state of health (SOH) will support disassembly, refurbishing, and recycling can be established through supportive data frameworks for battery circularity – sharing data of primary use with second-life manufacturer and blockchain to track resources and processes along the supply chain.

For traceability – countries can adapt or directly adopt the **Global Battery Alliance's Battery Passport Initiative or Battery Aadhar Initiative** by the Government of India that allows for end-to-end lifecycle monitoring through decentralized blockchain enabled system. Batteries and battery packs are allotted a unique ID to every battery, create a digital twin and store battery data cross value chain - raw material sourcing, manufacturing, usage, recycling/re-use and disposal using blockchain.

EU Digital Product Passport (DPP) [57]	India's Battery Aadhar Initiative [58] [59]
▪ **Applicable to: Light Means of Transport (LMT)** batteries, industrial batteries with capacity >2KWh, and EVBs ▪ Information in battery passport based on open standards (yet to be determined) ▪ Data collection is in interoperable and transferable format ▪ Access to passport through QR code – linking to unique identifier by 'economic operator' defined as manufacturer/ importer/ distributor/ service provider placing battery on the market ▪ Data collection for public, notified bodies, market surveillance, and the EU Commission ▪ Spent battery responsibility - battery passport transferred to its producer or the waste management operator. ▪ Passports will cease to exist once battery is recycled ▪ Enforcement – to be mandated 2027 onward	▪ Initiative by Tata Elexi, Tata AutoComp systems, and IIT Kharagpur supported by MoRTH, NITI Aayog, and PSA office (GOI) ▪ Unique digital identity for each battery pack to include: – Battery Manufacturing Identifier (BMI): country code, manufacturer identifier – Battery Descriptor Section (BDS): capacity, chemistry, nominal voltage, cell origin, extinguisher class. – Battery Identifier Section(BI): date of manufacturing, factory code, sequential product number (unique serial number) – Battery Material Composition Section (BMCS): weight, warranty, cell type and form factor, disassembly method, recyclability, anode, cathode, electrolyte, casing, potting, and other material content. – Battery Carbon Footprint (BCF): $kgCO_2e/kWh$ for raw material acquisition, manufacturing, distribution, and end-of-life stage – Battery Dynamic Data (BDD): Battery category, status, State of Health, disassembly method, circularity method, QR recovery code. **MY008 A6FKKKLC 1DH80001** **Figure 10:** Battery Pack Aadhar Pilot – Battery chemistries covered-Lithium-ion, sodium-ion, solid-state, etc. – Public and private data access as described in the MoRTH guidelines: – Alphanumeric code – static and publicly available – QR code – static but limited availability to public through authorized access system – Server based data – dynamic information with private access only – Role-based dashboard for tracking regulatory compliance – Real-time analytics that are Built on blockchain integration, MOBIUS+

Moving forward, **for successful end-to-end lifecycle traceability through DPP or battery Aadhar Initiative, different DPP projects on-going globally need to be aligned and interoperable to not only enable collaboration between global network actors and stakeholders, but to prevent data silos, enable data and information exchange, and to track carbon footprints impacts across the value chain.**

Separate data framework around battery traceability is needed to support uptake of battery passport initiatives across the board. These frameworks may be country or region-wise to enable global initiatives tailored for local contexts. Local, context specific aspects including stakeholders involved, local practices (such as integration of informal sector), governance structure, and monitoring can be supported by global battery traceability networks, expertise, and innovation. Work on this can be seen in India, as done by WRI-India on the conference proceedings for *Development of data frameworks for battery circularity in India- A Summary of expert perspectives* -this report highlights the need to develop an India-specific battery data framework driven by consensus among key stakeholders for a shared and interoperable framewor. Such stakeholder-led frameworks can establish voluntary and mandatory data sharing, including governance and monitoring structures, and identify local business models for uptake.

3. Supporting Alignment of Country-Specific EPR Targets with its Regulatory Framework, Market Dynamics, and Recycling Capacity

Current EPR targets do not always match local recycling and resource recovery capacity. Mismatch in targets and supporting infrastructure leads to stockpiling of waste or exporting waste to less strict or less enforceable countries. Under the current WEEE directive followed by EU member countries, there is a mismatch between collection and recycling targets and what is achieved in practice. The EPR target states a 65% collection rate and upto 85% recycling and recovery. However, in 2020 about 40.6% collection is achieved overall with only Bulgaria, Latvia, and Slovakia achieving 60% WEEE collection target in 2022. Further, only about 40% of the collected waste is recycled, and only 23% of recycling facilities are equipped to achieve advanced, high-quality treatment and raw material recovery [60].

In addition to lack of infrastructure, various other barriers exist in achieving EPR targets including economic factors, illegal trade, low public awareness, and fragmented implementation of EPR schemes along with gaps in enforcement. Discrepancies in calculating waste collected using different methodologies does not accurately correspond to actual amount of WEEE generated and collected in the country [61]. There is a need to revise collection target methodology to more accurately represent waste generation and directly link the product placed in the market with that of the actual waste collected. ***Spent battery collection target methodology should incorporate factors such as expected lifetime of product, technological upgrades and advancements, market trends and current consumption patterns, and the value of secondary raw materials recovered. The EPR targets should be aligned with product warranties, domestic recycling capacity, and any overlap of targets under other waste categories to be identified and eliminated.***

Stakeholders from the global consultation conducted by ISA, strongly recommended that minimum recovery and extraction efficiencies should be framed as mandatory performance benchmarks rather than indicative or voluntary targets, particularly in countries with established recycling, refining, or battery manufacturing capabilities. Experts noted that non-mandatory targets risk perpetuating low-technology operations focused only on mechanical processing or export of intermediates. At the same time, a phased approach was suggested, allowing countries at earlier stages of market development to progressively align with higher recovery benchmarks. Such differentiation, based on technical and institutional readiness, was viewed as critical to balancing ambition with implement-ability across ISA member countries.

4. Establishing Safe and Scalable Battery Waste Collection, Storage, and (trans-boundary) Transport Networks

Transparent, traceable, and scalable battery waste collection, storage, and transport can be achieved by following safe and uniform standards.

- Designated collection points for spent batteries such as retail stores, service centers, recycling facilities, or municipal collection points to be used to aggregate waste batteries in one place.
- Upon collection, standards for safe storage and transportation of end-of-life battery can include - dry, ventilated areas, low oxygen covered containers, ambient temperature as per battery chemistry, max height for pallet stacking, PPE for workers and minimum storage area. Standards for safe storage and transport requirements as given in UN 3480/ 3481 for Li-ion batteries in EV, solar energy storage, and portable power packs to be followed post clearing the UN 38.3 tests to declare spent batteries safe for transport.

Table 7: Standards for testing lithium-ion batteries for transport

UN 3480 — Lithium-ion Batteries (Transport Regulation)	UN 38.3 — Testing Requirements for Li-ion Batteries to declare safe for transport
▪ **Packaging – to be rigid, tested, and certified packaging designed to prevent short circuits, movement, and damage.** ▪ **Labeling – to include the UN 3480 number, Class 9 (miscellaneous hazardous materials) hazard label, and Lithium Battery Handling Label.** ▪ **State of Charge (SOC) (≤30% state of charge to reduce fire risk)** ▪ **Documentation (Dangerous goods Declaration mandatory)** ▪ **Prohibition on Passenger Aircraft**	▪ **Altitude simulation test** (testing low pressure conditions) ▪ **Thermal test** for varying temperatures ▪ **Vibration** from transport ▪ **Shock test** ▪ **External short circuit** resilience test ▪ **Impact (crushing) test** for battery cells ▪ **Overcharge** and f**orced discharge tests** to prevent explosion and incorrect installation.

Assess infrastructure - domestic recycling capacity and demand (based on production scrappage, BESS deployment, EV penetration and consumer electronics usage) to determine transport and location for recycling

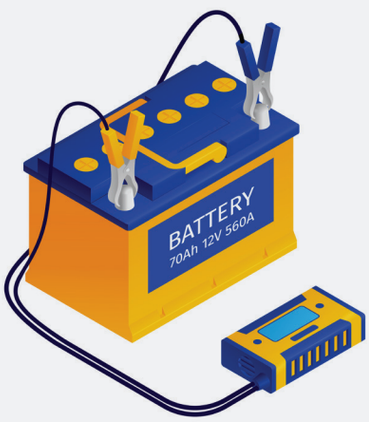
- In case of undercapacity, have protocol based on Basel Convention with nearest neighbouring recycling hub or material recovery facility and export waste for resource recovery.

- In case of sufficient capacity or upscaling plans, set up collection hubs in sync with battery waste generation sites & existing waste management/recycling units.

Based on stakeholder input from the global consultation conducted by ISA, it was widely agreed that not all ISA member countries need to develop a complete domestic battery recycling value chain. Experts strongly supported regional hub-and-spoke models, particularly in regions such as Africa, ASEAN, and small or low-volume/material-density markets, where feedstock aggregation is necessary to achieve economies of scale. Stakeholders recommended regional coordination of recycling infrastructure, testing facilities, data platforms, and incident-reporting systems, supported by harmonized standards and regulatory alignment. Such regional approaches were seen as critical to improving safety, reducing costs, and accelerating circularity without duplicative investment.

5. Implementing Global Standards and Protocols for Battery Dismantling and Second-life Certification

The absence of standards for battery traceability across stages, from manufacturing to waste processing, hinders efforts to formalize battery end-of-life value chain, promote reuse, and prevent premature recycling. Development and uptake of standards will support data-driven decision making about battery life extension and safe disposalassessment of the current collection system (such as drop box facilities) and recycling capacity, and incoming battery waste. Moreover, in the absence of benchmark metrics for tracking various parameters (water usage, GHG emissions, pollution control, acid leaching, heavy metal contamination, energy consumption, effluent treatment), emissions go unreported, reducing transparency for regulators and financiers concerned with ESG compliance.



From standards for battery chemistries, labeling requirements, primary and second-life usage, collection, refurbishing, recycling, and end-of-life management standards – standardized process across the value chain allows for efficiency through interoperability and compatibility, provide quality assurance and safety, scaling efforts thereby reducing cost through economies of scale, establishing robust reverse logistics, regulatory compliance with safe and transparent global trade, limited illegal trade, faster innovation, and robust monitoring and verification efforts. Standards across the battery value chain are detailed below. General standards with respect to battery value chain and labeling requirements used as of today are given below.

Ban on Landfilling and Incineration
Batteries must not be disposed of in landfills or incinerated due to the toxic substances they contain, such as lead, mercury, cadmium, and lithium, which can leach into soil or emit harmful gases.

Prohibition on Mixing Battery Types
Different types of batteries (e.g., lithium-ion, lead-acid) must not be mixed during collection and storage to avoid contamination or chemical reactions.

Restricted Use of Hazardous Substances
Certain toxic chemicals, such as mercury and cadmium, should be prohibited or strictly limited in battery production. For example, under the BWMR, India, batteries with up to 0.0006% (5 ppm) mercury are allowed only until 2025, batteries with up to 0.002% (2000 ppm) cadmium are permitted.

Improper Disposal by Consumers
Consumers are prohibited from disposing of batteries in household waste streams to prevent hazardous waste from entering the municipal waste system.

Improper Storage and Transport
Batteries must be stored and transported safely to prevent leakage, fires, or explosions during handling.

BATTERY LABELING REQUIREMENTS



CHEMICAL COMPOSITION AND HAZARD SYMBOLS



RECYCLING AND DISPOSAL SYMBOLS



CAPACITY AND PERFORMANCE INFORMATION



DIGITAL PASSPORT / UNIQUE IDENTIFICATION



TRACEABILITY



COMPLIANCE CERTIFICATION

No standardized testing, grading, or accreditation for recycled battery materials leads to manufacturers distrusting secondary materials due to inconsistency and contamination risks. Only a few countries have mandated purity/yield standards such as China, where the Chinese Ministry of Industry & Information Technology requires its licensed battery recyclers to generate minimum recovery efficiencies for key materials that is ≥ 98% for cobalt, nickel, and manganese, and ≥ 85% for lithium. Recyclers are required to produce industrial-grade specifications suitable for reuse in new batteries and this is a prerequisite for obtaining operating permits. Except for China, that requires its battery recyclers meet yield and purity standards, lack of clarity on quality or traceability standards for recycled material second-life battery producers and importers find it difficult to meet recycled content mandates of EPR.



While no standards exist on recycled material content purity (with exception for China), Guidelines and certifiable standards for battery reuse, second-life applications may be used – such as standards UL 1974 – Standards for Evaluation for repurposing batteries and IEC 62933 Electrical Energy Storage (EES) system – Safety considerations for reused batteries or similar standards on safety and performance of second-life batteries may be adopted, SAE J3201 Battery Second Life (B2L) Application Guide for Use in Mobility and Stationary Applications, and IEC 62660 Secondary Lithium-ion cells for EV application can be referred to when repurposing batteries for second-life applications. Finally, Standards can be developed by regulating agency for safe and efficient dismantling and testing of batteries. Key elements of these standards and guidelines are described in Table 8 below:

Table 8: Standards for Evaluating Batteries for Second-life use

Key elements	UL 1974 – Standards for Evaluation for repurposing batteries	IEC 62933-5-1 – Safety for Reused Battery Systems
Initial Screening	▪ Determines age, chemistry, history for suitability for repurposing ▪ State of Health testing - capacity, internal resistance, and overall degradation	▪ Risk Assessment – hazards from reuse – that is from - thermal runway, short circuit, etc. if any
Designed for second-life	Yes – Safety focused certification	▪ Yes- deploy and integrate reused packs for energy storage setup or microgrid integration
Testing requirements	▪ Electrical – to operate within safe voltage and current ▪ Thermal – safe operations in varying temperatures and within thermal limits ▪ Mechanical – for physical damage, leaks, swelling, or corrosion	▪ Electrical, mechanical, and thermal inspection of spent battery modules and cells before use
Scope	▪ Module/ Battery Pack	▪ Battery Management System Level focus
System re-integration	▪ Battery Management System to be compatible with second life battery module/pack or be replaced	▪ System integration test for incorporating 2nd life batteries such as from EV into larger energy storage system

Key elements	UL 1974 – Standards for Evaluation for repurposing batteries	IEC 62933-5-1 – Safety for Reused Battery Systems
Labelling, traceability, and documentation	▪ Batteries to be labelled as "repurposed" and include source and testing data	▪ Document traceability of primary use, performance, and testing.
Lifecycle stage	▪ Battery removal and repurposing evaluation – post EV use assessment	▪ System level deployment & operation - Integration into new (stationary energy) systems
Certifiable	Yes	Yes

Table 9: Guidelines for Reuse of spent batteries for 2nd life application

Standard	Name	Focus Area	Scope	Designed for 2nd life	Lifecycle stage	Certifiable
SAE J3201	Battery Second Life (B2L) Application Guide	Reuse, feasibility, and classification	Module/ battery pack	Yes - Technical framework/ Guidelines for reuse	Battery removal and repurposing evaluation – post EV use assessment	No- guidelines for evaluation, sorting, and reuse
IEC 62660 series	Secondary Lithium-ion Cells for EV Applications	Cell stress and performance, safety tests	Cell-level (component level)	No – for new cells (indirect application for re-testing/ requalifying used cells).	Manufacturing - Cell-level testing for safety and performance	No

6. Developing standards, green certification, and quality assurance frameworks for sustainable battery recycling and resource recovery

Green labelling or similar certification can be provided to a recycling entity if its processes are compliant with benchmark energy consumption, water usage, emission and pollution control norms. Notified accredited national labs for testing, grading, and validating purity of recovered material for end-use industries, to include:

Black mass: Classification, Handling, and Guidelines for its Utilisation

Treat black mass as a critical mineral ore, not hazardous waste by default.

Mandate lab-based chemical profiling to determine hazard status. If tested as hazardous, - handling and transportation to be as per Basel Convention or domestic hazardous waste management rules of ISA member countries.

Use Basel Convention protocols for export and import, only for resource recovery

According to feedback from experts during the global stakeholder consultation, black mass should not be treated as a homogeneous material or regulated uniformly as waste. Stakeholders highlighted the need for a graded classification of black mass based on critical mineral concentration (such as lithium, nickel and cobalt content) as well as hazardous impurity thresholds (including

fluorides and residual electrolytes). Such differentiation would allow regulators to distinguish between high-value, recoverable material streams and those requiring stricter environmental controls. Furthermore, experts recommended a licensed, controlled trading framework for black mass, enabling transactions only between registered and technically capable entities, while allowing conditional cross-border movement to jurisdictions with adequate processing capacity. This approach was considered essential to prevent substandard, unsafe recycling practices and to support the efficient recovery of critical minerals, rather than imposing blanket export restrictions.

Recovered material quality assurance framework to enable creation of a reliable secondary raw material market and enhance the credibility of recycled inputs through network of accredited laboratories responsible for testing, certifying, and grading the recovered outputs as per their end usage industry like battery manufacturing, energy storage, paints, ceramics etc. These labs would assess the chemical purity, physical integrity, state of health and contaminant profile of materials such as lithium carbonate, nickel sulphate, manganese oxide, and cobalt salts.

Stakeholders during the global consultation consistently emphasized that recycling should translate into material circularity only when recovered outputs meet battery-grade quality standards suitable for reintegration into manufacturing value chains. Experts cautioned against equating processing volume with circular outcomes, noting that low-grade outputs may undermine both environmental objectives and long-term supply security. This principle was viewed as fundamental to ensuring that recycling efforts genuinely contribute to a circular battery ecosystem.

7. Designing for Disassembly: Enabling Battery Reuse, Repurposing, and Recycling through Eco-Design

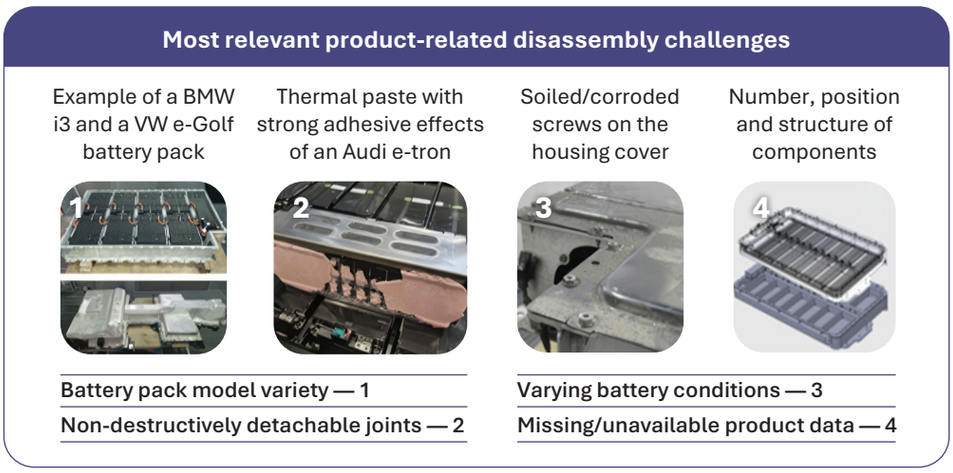


Figure 11: Disassembly challenges with current battery modules

Current battery designs hinder sustainable use of battery and do not support effective refurbishing or recycling due to battery disassembly challenges such as pack model variety, varying battery conditions, non-destructively detachable joints, and unavailable product data as shown in figure 11 above for BMW i3 and VW e-Golf battery packs. Tackling this major issue upstream is needed to support the creation of a sustainable end-of-life battery management ecosystem. While ensuring safety and optimal performance, incentives for producers promoting circularity through "eco-design" and "design-for-recycle" for easy to dismantle battery pack designs could include 'eco-mark' product certification for manufacturers adopting:



8. Regulating Black Mass as a Valuable and Recoverable Resource through Quality and Safety Standards

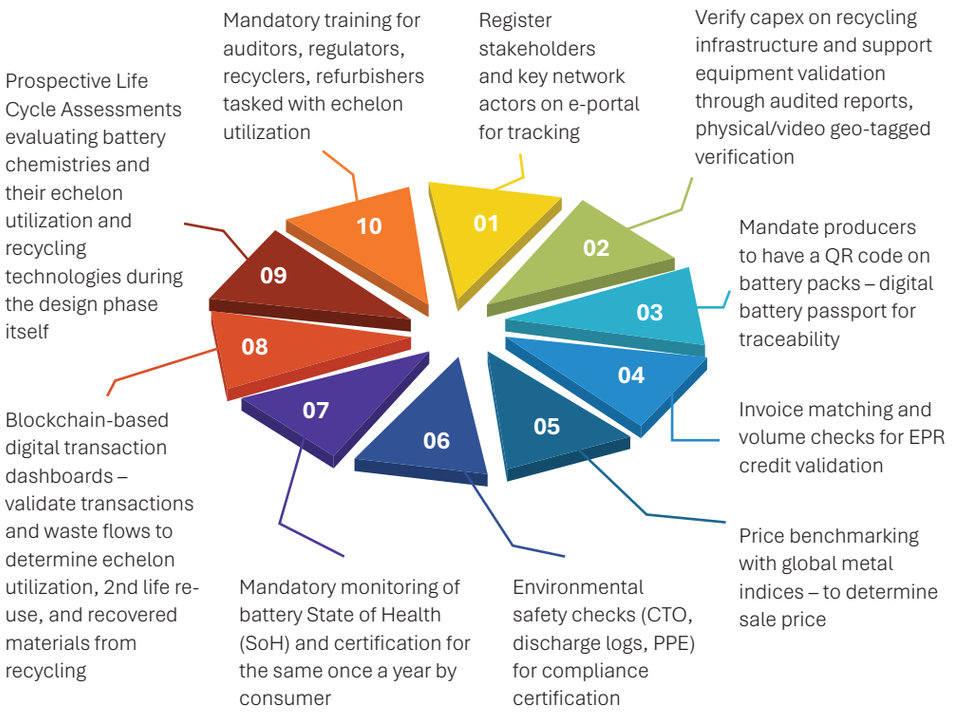
Globally, policies do not comprehensively cover critical aspects of battery waste management. Regulatory gaps and lack of policies supporting resource recovery from black mass- a critical mineral rich intermediate product of battery recycling – underscore the need for integrated, data-driven policy framework. Most countries list the resource rich black mass as hazardous waste. In India, while black mass is considered hazardous waste and should be classified under codes HS-8548 and HS-8549, it is still exported under the mixed metal salts category. Such regulatory inconsistencies lead to countries losing critical minerals from battery value chains and increasing their reliance on imports for the same.

Only China has emerged as a global leader by mandating purity and yield standards and usage classifications for black mass. China has also included impurity limits on black mass for iron and copper to be ≤0.5% while aluminum to be ≤ 1%. China's regulation GB/T-45203-24 details technical specifications, parameters, and additional usage classifications for black mass. In addition to this, the GB/T 6284 standards for testing and appearance requirements for black mass are also detailed to support critical mineral recovery. Countries looking towards critical mineral recovery from resource rich black mass should adopt similar standards.

9. Achieving Compliance through Standardized Monitoring, Verification, and Audit Mechanisms

Currently, informal waste trade evades regulatory oversight and taxation, leads to weak or no traceability of battery end-of-life value chain, prevents accountability from key actors along the value chain, and disrupts EPR enforcement. Digitized, data-driven monitoring is needed to strengthen the end-of-life battery value chain. ***To move towards a traceable end-of-life value chain, key stakeholders can register on a common battery/waste portal, where they upload data with respect to their refurbishing and recycling certifications, battery types and components, sale and re-sale price, materials recovered, and other recycling outcomes. With a QR code on a battery, producers can support uptake of digital battery passport that are tracked on a dashboard.*** EPR linked transactions on blockchain platforms will support secure and immutable tracking of battery waste flows, allowing for validation of transactions: each EPR certificate linked to a corresponding sales invoice will be traceable.

Compliance Monitoring and Audit Mechanism



Global monitoring and evaluation of spent batteries will support mapping of waste flows and determine hotspots where waste batteries end up, predicting potential locations for regional recycling hubs. Transport of waste batteries to recycling centers or feedstock procurement is a major cost and supporting the same through collection centers can optimize costs.

Feedback from the global stakeholder consultation conducted by ISA underscored the need to strengthen EPR verification beyond digital traceability. Experts recommended a two-layer verification framework comprising licensing-stage audits to validate physical infrastructure, capital investment, and realistic processing capacities, followed by transaction-level verification to confirm actual material recovery and sale of outputs. This approach was considered essential to prevent false compliance, EPR certificate trading without material recovery, and erosion of trust in EPR systems.

10. Creating Market Incentives to Accelerate Battery Circularity

Battery recycling is mostly unprofitable, with voluntary fee models, whereby the industry including the producers and manufacturers contributes financially on a non-regulatory or non- mandatory manner, offers little security and may not be sustainable for large-scale compliance. A mandated floor price for EPR credits (As given in Section 4) can protect recyclers from market volatility. Further, current clean energy policies often overlook waste and circularity incentives like tax breaks and second-life subsidies are essential. For example, current 18% GST on waste batteries in India significantly adds to the cost of feedstock for recycling plants. Support of institutions, policy makers, and regulatory bodies is needed to create incentives to

further circular business models around batteries and battery waste management, starting with upstream measures of supporting eco-design or design-for-recycle for batteries. Green Procurement and Eco-Mark certifications are some ways in which uptake of easy-to-recycle, low toxicity new batteries, refurbished, and recycled batteries and battery products can be promoted at large-scale promoting trust and demand of such batteries.

- A reduced or differential tax structure should be considered for recycled inputs, refurbished battery products, and services such as collection, testing, and diagnosticswhile tax levies may be applied on polluting industries and sales of new batteries
- Advance recycling fee or Deposit Refund scheme can support reverse logistics of waste battery collection and transport to recycling units.
- Green Credit Programme (GCP): Reward battery collection, second-life use, cleaner recycling.
- Carbon Credit Trading: Monetise GHG reductions from recycling and reuse through verified standards (e.g., Verra, Gold Standard).
- EPR credit floor prices aligned with cost of recycling and ISA countries should explore and integrate below tools alongside EPR to promote investment in battery circularity.
- EPR fund will ensure equitable access- defined percentage of funds, especially from EPR penalties/green levies can be earmarked for skilling informal sector workers, R&D in eco-design and Consumer awareness programs to drive returns and sorting at source of waste generation.
- “Tipping fee” or “Environmental Compensation” paid by waste generators for non-compliance or shortfall in fulfillment of EPR targets will support in capturing domestic scrap trade.
- Green Procurement to develop market for re-use of recovered battery materials, second life batteries to be developed through quality standards and benchmarks.
- Other innovative models include:
  - Capital subsidies to support recycling units
  - Green bonds, priority sector lending and sustainability-linked loans tied to recovery or recycling performance indicators.
  - International Climate Funds such as the Green Climate Fund or Global Environment Facility, which can co-finance national recycling infrastructure under climate mitigation goals.

Stakeholders during the global consultation conducted by ISA and CES emphasized that battery recycling, particularly for emerging chemistries and low-value streams, remains capital and operating-cost-intensive and may not achieve commercial viability without targeted financial support. Experts recommended explicit recognition of viability gap funding mechanisms within the guidelines, especially for LFP-dominant recycling and early-stage markets. Suggested instruments included pooled producer contributions, dedicated recycling funds, concessional finance, and limited downstream levies linked to energy consumption.

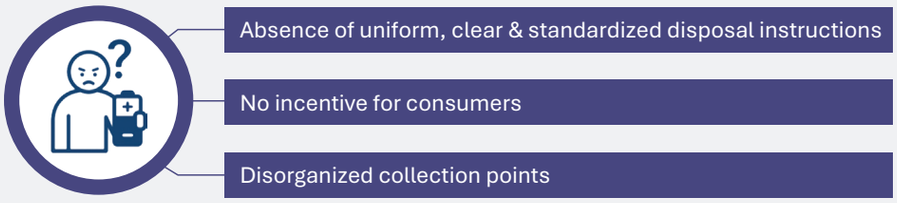
11. Strengthening Capacity and Skills for an Inclusive and Sustainable Battery Value Chain

Supporting development of organized and formal reverse logistics and end-of-life value chains for battery waste requires capacity building, skilling and re-skilling of workers across the battery lifecycle. Producer Responsibility Organizations (PROs) can be encouraged to partner with informal actors and build inclusive value chains that are both socially and environmentally sustainable. ***Semi-formal industrial clusters can provide skilling programs, provision of safety equipment, support for licensing and registration, and the creation of formal aggregator networks linked to authorized recyclers.*** Regular training of regulators and auditors is also required on specific aspects of emerging technologies and their recycling ecosystem.

12. Empowering Consumers through Awareness and Incentives for Battery Reuse and Recycling

Currently there is an absence of clear disposal instructions. Lack of awareness leads to consumer confusion, low battery return rates, and weak recycling participation. There is a need to boost consumer engagement in waste management, translating to higher end-of-life battery collection rate, such as through

- ***Battery labelling*** to include QR code for consumers to understand remaining battery life and its primary or secondary use applications.
- Producer funded ***awareness campaigns*** for consumers to understand their EV or energy storage batteries



- ***Deposit refund schemes -*** consumers to return used batteries – (automotive batteries) distributors must charge end consumers a deposit if they do not return a used battery when purchasing a new one. The deposit is reimbursed upon the return of the used battery.
- Transparency through ***digital platforms, such as Sweden's Recycling Registry,*** to increase consumer trust and participation by providing clear recycling data

13. Advancing Knowledge, R&D, and Data-Driven Decision Making for Emerging Battery Technologies

Emerging batteries are not part of current policies and guidelines on battery waste. Current regulations focus on Li-ion, Lead Acid, NiCd battery chemistries. Emerging technologies like sodium-ion, redox flow, and solid-state are not adequately covered. ***EPR systems and portals need updating to include new chemistries and recoverable materials.***

Emerging technologies can be incorporated and included as part of ***technical evaluation framework*** when selecting batteries for different applications to further

data-driven decisions on technology selection including its end-of-life management as suggested by ISA - in its technological evaluation framework given in the report on Framework for Energy Storage Prioritization to Boost Solar Deployment in LDCs and SIDs. To support this ***Data-driven benchmarking*** can be done by looking at battery lifecycle assessments to support development of uniform standards.

14. Fostering International Collaboration and Global Partnerships for Harmonized Battery Waste Management

To help secure critical and rare minerals, reduce dependence on mining of raw materials from primary sources, and reduce waste generated at the end-of-life, international cooperation is needed to build transparent and robust reverse logistics for collection of waste batteries. ISA member countries should ***harmonise waste codes with Basel Convention or EU standards*** to ensure smooth global scrap trade and regulatory compliance. This can include identification of unique HS codes for battery waste, black mass and production scrap. Countries should develop ***country-specific battery data (sharing) frameworks*** to support the battery passport initiative that requires producers and OEMs to share voluntary and mandatory information, with varying stakeholder access rights, and data ownership structures as centralised or decentralized, as summarised under the conference proceedings for Development of data frameworks for battery circularity in India- A Summary of Expert Perspectives (WRI, India 2024)23. In addition to this, ***regional Centres of Excellence and Joint R&D Platforms*** can come up nationally and/or regionally to support ISA member countries with development of traceable reverse logistics for waste battery collection. These centres can support stakeholders across the value chain in knowledge sharing, connecting with key network actors, support innovation and policy, especially to encompass new, emerging battery technologies, and provide waste mapping and forecasting to allow for evidence-based decisions, allowing for validation of transactions, for policy makers globally.

Annexure 1

Annexure 1: Comparative Analysis of Global Battery & e-Waste Regulation

Region	Country	Regulation	Aim / Scope	EPR applicability	Collection / recovery & recycled-content targets	Purity / yield standards	Black-mass handling
Europe	EU countries	EU Battery Regulation (2023) [62]	Harmonise battery value-chain, circularity, traceability (battery passports), reuse/ repurposing rules.	Yes	Collection targets: Portable: 63% (2027), 73% (2030) LMT: 51% (2028), 61% (2031) Recovered-material targets: 90% (Co, Cu, Pb, Ni) and 50% Li by 2027	From 2028 minimum percentage of recycled materials to be present in EV, SLI and industrial batteries with cobalt 16%, lead 85%, lithium 6% and nickel 6% (by 2031) Recycling target for LiB 61% [63]	Classified hazardous under the Waste Shipment Regulation and Basel Convention [64]
South Asia	India	Battery Waste Management Rules (2022) [65]	Strengthen EPR; producer accountability; digital labelling (QR/barcode in battery Aadhar); collection & reporting.	Yes	Collection targets: EV & Portable: 70% (2024–25), 80% (2025–26), 90% (2026–27). Automotive & Industrial: 55% (2024–25), 60% (2026 onwards) Recovered-material targets: Li 50% (2027), 80% (2031); Co/Cu/Pb/Ni 90% (2027), 95% (2031).	No mandatory purity/yield thresholds specified.	Classified hazardous; should be covered under HS codes 8548 or 8549 but is exported as mixed metal salts, cobalt powder, unwrought cobalt powder, causing regulatory inconsistencies.
East Asia	Japan	Basic Act for Establishing a Sound Material Cycle-Society (2000) [66] Act on the Promotion of Effective Utilization of Resources (2000) [67]	Promote 3Rs and circularity; industry-led EPR mechanisms; national targets being developed.	Voluntary (industry)	No national collection targets Recovered-material targets: Industry goals: 70–95% recovery of Li/Co/Ni by 2030.	No mandatory purity/yield thresholds specified.	No black-mass regulation yet; domestic recycling of black-mass planned [68]
East Asia	China	Circular Economy Law (2018 amendment) [69] + MIIT 2024 industrial requirements [70]	Mandates battery recovery targets, traceability (QR codes), stricter requirements for reuse/recycling and safety.	Yes	Collection Targets: As per Action Plan for Prevention and Control of Used Lead-Acid Battery Pollution in 2019, used lead-acid batteries collection rate- 40% (2020) and 70% (2025)[71] Recovered-material targets: Lithium ~90% (from 85% earlier); Ni/Co/Mn 98%; new targets: Cu/Al/rare earths 98% / ≥97% for some critical metals. Infrastruture: Over 1,200 registered battery collection points nationwide; More than 150 large-scale processing plants operational to aggregate feedstock; Current utilization rates remain suboptimal at 20-30% due to scrap shortages [72].	Specific impurity limits (Fe <0.5%, Cu ≤0.5%, Al ≤1%, moisture <2%) for black mass used in lithium-ion battery recycling	GB/T-45203-24 standards detailing technical specifications for recycled black mass for Li-Ion batteries; GB/T 6284 for Testing and Appearance Requirements for Black Mass [73]

Region	Country	Regulation	Aim / Scope	EPR applicability	Collection / recovery & recycled-content targets	Purity / yield standards	Black-mass handling
Europe	United Kingdom	Waste Battery & Accumulator Regs (2009) [74]	Take-back, collection, recycling obligations; bans on landfill/ incineration for batteries.	Yes	Collection & Recovered material targets: UK has aligned its battery recycling regulations closely with the European Union's battery directive and targets. Collection rate: Portable batteries collection rate for producers for any year after 2016): ~45%, (reported as part of producer obligations under The Waste Batteries and Accumulators Regulations 2009)	Not specified	Domestic black-mass refining capacity underdeveloped [75].
North America	United States	Resource Conservation and Recovery Act (RCRA): Universal Waste Regulations (40 CFR Part 273) [76]	Waste management framework; EPA developing harmonized battery management standards and EPR guidance.	Partial/ evolving [77]	No comprehensive national recycled-content or uniform recovery targets. However, the May 2023 RCRA memo outlines liability and management rules - a key step toward development of targets [78].	No statutory purity/ yield thresholds	Only designated RCRA facilities can process EOL batteries to black mass stage, which is an intermediate material sent for metals recovery (refining) or use in new products [79].
North America	Canada (Ontario)	Ontario Regulation 30/20 (Batteries)- Resource Recovery and Circular Economy Act, 2016 [80]	Producers to run collection systems; ensure collected batteries are managed/ recycled.	Yes- varies by province	Collection targets: From 2025, at least 45% collection of average weight of supply for batteries by producers, rising to 50% in 2026. >80% for Pb-acid, lower for LIB No targets for recovered materials	No mandatory disclosure of recovery efficiency	No explicit national regulation: the Critical Battery Materials Initiative supports R&D on black mass digestion and recovery technologies [81].
Asia-Pacific	Australia	Battery Stewardship Scheme under the Product Lifecycle Responsibility Act 2025 [82]; National Framework for Recycled Content Traceability (framework)[83]	Industry-led stewardship, traceability guidance; government-backed voluntary scheme.	Voluntary (industry)	Targets for collection and material recovery are anticipated to be shaped by 2026. Collection Rate: With >5,000 drop-off points; B-cycle reported ~73% recovery rate of materials recovered from used batteries (2023–24); 2,934533 batteries collected for recycling in 23-34 [82]	No mandatory purity/yield standards	no explicit black mass handling guidelines: working on developing a mandatory battery producer responsibility scheme, with initial legislation expected to be introduced in New South Wales in 2025 [84]
Southeast Asia	Singapore	Resource Sustainability Act (2019) [85]	EPR for e-waste; licensed handling for toxic industrial waste.	Yes	No fixed formal legal mandates: operators achieve ~90% recovery rates of critical battery materials. (reported) [86]	Not legally mandated	Black mass handling not explicitly regulated beyond Toxic Industrial Waste (TIW) provisions. Batteries classified as Toxic Industrial Waste (TIW) require licensed handling with strict transport and disposal controls [87].
South America	Colombia	Regulatory Decree for WEEE & batteries [88]	Producers must implement collection/ management systems; mandatory collection of used EV batteries initiated 2024.	Yes	Collection targets: EV battery collection: 0.5% (2024) rising to 65% by 2044	Not specified	No specific regulation

Region	Country	Regulation	Aim / Scope	EPR applicability	Collection / recovery & recycled-content targets	Purity / yield standards	Black-mass handling
South America	Peru	Supreme Decree No. 009-2019 (RAEE)[89]2019, the Supreme Decree No. 009-2019-MINAM with an updated Regulation for Management of Waste Electrical and Electronic Equipment (RAEE	Producers/sellers must collect, store, transport, valorise (reuse/ recycle) EEE.	Yes	EEE targets 2020–2024; no battery-specific targets.	Not specified	Limited black mass recycling infrastructure
South America	Brazil	National Solid Waste Policy (PNRS, 2010)[90]	Requires manufacturers/ importers to implement reverse-logistics take-back systems.	Yes	Take-back obligations, no well-defined targets	Not well enshrined	No specific regulation
Africa	Nigeria	Battery Control Regulations (2024) [91]	Full lifecycle coverage (production → disposal); formalised EPR & PRO (ARBR).	Yes	No national collection targets specified	No prescribed purity/yield thresholds	No specific regulation
Africa	South Africa	EPR Regulations (2020) under National Environmental Management Waste Act (NEMWA)[92]	Producers must register and run or join EPR schemes; lifecycle assessments & labelling required.	Yes	Portable batteries under EPR; automotive batteries have separate programs	Not specified	No specific regulation
South-east Europe/ West Asia	Turkey	Regulation of the European Parliament and of the Council concerning batteries and waste batteries, amending Directive 2008/98/ EC and Regulation (EU) 2019/1020, and repealing Directive 2006/66/ EC [54]	Includes stricter/ clearer collection targets; recovery of materials targets; extended producer responsibility obligations; Due diligence for raw material sourcing likely included [93].	Partial/ evolving	Collection targets: portable batteries (63% by 2027 & 73% by 2030) Recovered-material targets: lithium recovery from waste batteries- 50% by 2027 & 80% by 2031	mandatory minimum levels of recycled content for industrial, SLI batteries and EV batteries- 16% for cobalt, 85% for lead, 6% for lithium and 6% for nickel	Limited provisions for black mass

Annexure 2: Summary of 'Global Stakeholder Consultation'

As part of the research, a global stakeholder consultation was conducted on 13th January 2026 titled *"Unified Action for Circular Batteries: Global Stakeholder Consultation on Way Forward with Standard Methodology & Recycling Guidelines for ISA Member Countries"* to understand the status of the recycling eco-system in the ISA member countries. The report has benefited from insights provided by various experts (123 participants) present at this virtual consultation.

The consultation highlighted the need for convergence among stakeholders and key networks actors to strengthen the end-of-life value chain. This included supporting regional aggregation such as across Africa and other regions needed to achieve scale and reduce costs while overcoming challenges associated with the lack of infrastructure and skills. This can be strengthened and supported through international cooperation where differentiated national roles and cross-country specializations capture the full value of waste. Stakeholders deliberated that clear and harmonized definitions for battery waste and black mass is needed along with detailed descriptions of stakeholder responsibilities to strengthen reverse logistics. Since in countries where most waste ends-up there is a lack of capacity to support high-value material recovery, stakeholders must come together to formalize the informal sector and support safety provisions through environmental controls. Overall, the stakeholders agreed on the next steps to strengthen the global battery waste value chain should include recovery and material extraction benchmarks, digital traceability systems, and financing mechanisms.

The figure below details the key network actors present, across the battery value chain, guiding the discussion:

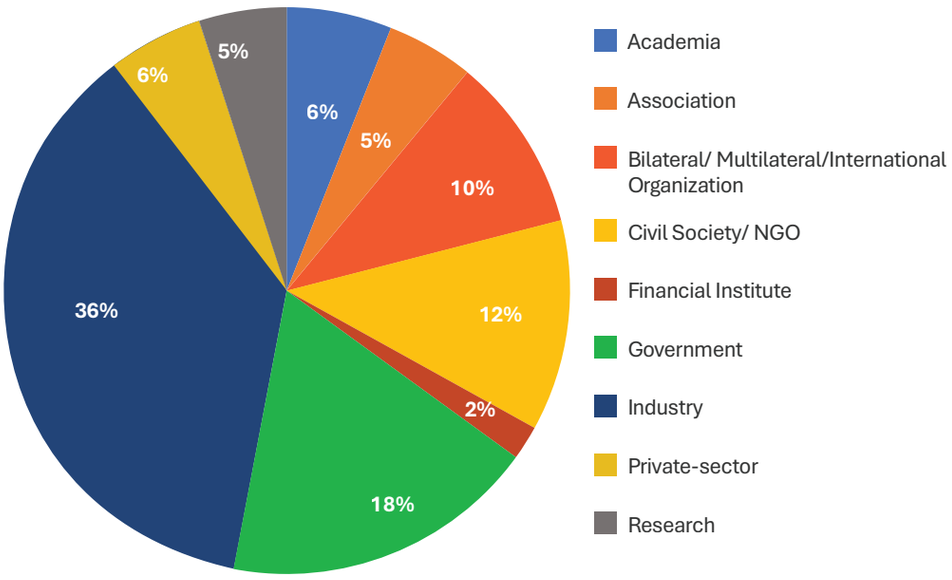


Figure 12: Stakeholder Distribution by affiliation category

Table 10: List of organizations present for the Global Stakeholder Consultation

- 3R Zerowaste, United Kingdom
- Abt Global, Nigeria
- Acumen, India
- Adani Group, India
- Advik Energy Private Limited, India
- Alignergy Advisory, India
- Alternative Energy Promotion Center, Nepal
- Amara Raja Advanced Cell Technologies Private Limited, India
- AMPIN Energy Transition, India
- Ansyst Consulting, India
- ArcelorMittal Green Energy, India
- Atal Incubation Centre, CV Raman College of Engineering, India
- Bangchak Corporation Public Company Limited, Thailand
- Battery360 Alliance, India
- Bureau of Indian Standards, India
- CarbonCare InnoLab, Hong Kong
- Center for Study of Science, Technology and Policy (CSTEP), India
- Central Electricity Board, Mauritius
- Chhattisgarh State Renewable Energy Development Agency (CREDA), India
- Circular Design Nairobi, Kenya
- Clairgies Tech, India
- Climate Energy Solutions, India
- Council on Energy, Environment and Water (CEEW), India
- Customized Energy Solutions India Private Limited, India
- Department of Energy, Ministry of Energy and Natural Resources, Bhutan
- Economic Development Board Mauritius, Mauritius
- Electricity Regulatory Authority of Bhutan, Bhutan
- EnerTrans Innovation Private Limited, India
- Entity2, India
- EPR Waste Association of South Africa, South Africa
- EWARE Group, Togo
- eWASA Pro Scheme, South Africa
- eWASA, South Africa
- First City Monument Bank Limited, Nigeria
- Fujitsu Consulting India, India
- GIZ India, India
- GNCORP Group, Australia
- HG Infra Engineering Limited, India
- Honeywell International Inc., India
- India Energy Storage Alliance (IESA), India
- Indian Institute of Technology Delhi, India
- Indian Space Research Organisation, India
- International Solar Alliance, India
- ITHRIVE Nature Private Limited, India
- John Crane Limited, United Kingdom
- Kathmandu University, Nepal
- Keystone Mercantile Limited, Nigeria
- Khon Kaen University, Thailand
- KPMG India, India
- KSJ Technocrats Private Limited, India
- M énergie, Niger
- Mahindra Susten Private Limited, India
- Maruti Suzuki India Limited, India

- Material Recycling Association India, India
- Mauritius Renewable Energy Agency, Mauritius
- Ministry of Communication, Niger
- Ministry of Petroleum, Energy and Mines, The Gambia
- Muhandiz Industries, India
- Nastech Limited, United Arab Emirates
- National Energy Technology Center (ENTEC), Thailand
- National Institute of Technology Hamirpur, India
- National Land Commission, Bhutan
- National Renewable Energy Platform Uganda, Uganda
- National Science and Technology Development Agency, Thailand
- National Water and Electricity Company, The Gambia
- NTPC Limited, India
- Observer Research Foundation, India
- Petroleum and Energy Authority, Ethiopia
- Pilot International, Uganda
- Powerhive, India
- PricewaterhouseCoopers (PwC), India
- Quratul Ayn Arena, Nigeria
- Regional Center for Renewable Energy and Energy Efficiency (RCREEE), Somalia
- Reliance Industries Limited, India
- ReNew Power, India
- Rystad Energy, India
- Ryukyu University, Japan
- Solarman, Sudan
- Solid Waste Management Division, Government of Mauritius
- Solution for Energy, Democratic Republic of the Congo
- Stratwon Business Consulting Private Limited, India
- Sunsure Energy Private Limited, India
- SustainMantra, India
- Suzlon Energy Limited, India
- Tanzania Renewable Energy Association, Tanzania
- Tata Capital Limited, India
- Tavasya Ventures, India
- Thailand Automotive Institute, Thailand
- Thailand Development Research Institute, Thailand
- The Energy and Resources Institute (TERI), India
- Titan Engineering and Engineering Limited, India
- Trade and Industrial Policy Strategies, South Africa
- UL Standards & Engagement, India
- United Nations Children's Fund (UNICEF), Bangladesh
- United Nations Children's Fund (UNICEF), India
- University of New South Wales, Australia
- University of Zambia, Zambia
- Vasudha Foundation, India
- Vikram Solar Limited, India
- Vish Wind Infrastructure LLP, India
- Vishvaraj Group, India
- Vishwadeep Trust, India
- World Resources Institute

Table 11: Attendee Summary

Country code	No of attendees	Country Name	ISA Member Country
AE	1	United Arab Emirates	**Y**
AU	1	Australia	**Y**
BD	1	Bangladesh	**Y**
BT	6	Bhutan	**Y**
CD	1	Democratic Republic of the Congo	**Y**
ET	1	Ethiopia	**Y**
GB	2	United Kingdom	**Y**
GM	3	The Gambia	**Y**
HK	1	Hong Kong (SAR, China)	**N**
IN	74	India	**Y**
JP	1	Japan	**Y**
KE	1	Kenya	**N**
MU	4	Mauritius	**Y**
NE	2	Niger	**Y**
NG	4	Nigeria	**Y**
NP	3	Nepal	**Y**
SD	1	Sudan	**Y**
SO	1	Somalia	**Y**
TG	1	Togo	**Y**
TH	6	Thailand	**N**
TZ	1	Tanzania	**Y**
UG	2	Uganda	**Y**
ZA	4	South Africa	**N**
ZM	1	Zambia	**Y**

References

[1] "Policy implications and recommendations – Batteries and Secure Energy Transitions – Analysis -," IEA. Accessed: Jan. 29, 2026. [Online]. Available: https://www.iea.org/reports/batteries-and-secure-energy-transitions/policy-implications-and-recommendations

[2] "Assessment of the Global Landscape for Sodium-Ion Batteries and their Potential in India", MNRE, Accessed: Jan. 29, 2026. [Online]. Available: https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2025/01/20250109186779654.pdf

[3] B. Team, "Global lithium ion battery demand rose 29% in 2025," Benchmark Mineral Intelligence. Accessed: Feb. 10, 2026. [Online]. Available: https://source.benchmarkminerals.com/article/global-lithium-ion-battery-demand-rose-29-in-2025

[4] "Global battery markets are growing strongly – and so are the supply risks – Analysis," IEA. Accessed: Mar. 12, 2026. [Online]. Available: https://www.iea.org/commentaries/global-battery-markets-are-growing-strongly-and-so-are-the-supply-risks

[5] J. T. Frith, M. J. Lacey, and U. Ulissi, "A non-academic perspective on the future of lithium-based batteries," ***Nat. Commun.***, vol. 14, no. 1, p. 420, Jan. 2023, doi: 10.1038/s41467-023-35933-2.

[6] G. Bree, J. Zhao, V. Majherova, D. Proprentner, G. J. Paez Fajardo, and L. F. J. Piper, "Practical Pathways to Higher Energy Density LMFP Battery Cathodes," ***Energy Fuels***, vol. 39, no. 7, pp. 3683–3689, Feb. 2025, doi: 10.1021/acs.energyfuels.4c06201.

[7] "Lithium-ion battery recycling - Market and Innovation trends for a Green Future | CAS and Deloitte." Accessed: Jan. 30, 2026. [Online]. Available: https://web.cas.org/marketing/pdf/INSGENENGBRO102412-CAS-Insights-Lithium-Ion-Full-Report-Digital.pdf

[8] Ria, A.; Dini, P. A Compact Overview on Li-Ion Batteries Characteristics and Battery Management Systems Integration for Automotive Applications. Energies 2024, 17, 5992. https://doi.org/10.3390/en17235992

[9] Fred Pearce, "Getting the Lead Out: Why Battery Recycling Is a Global Health Hazard," Yale E360. Accessed: Jan. 29, 2026. [Online]. Available: https://e360.yale.edu/features/getting-the-lead-out-why-battery-recycling-is-a-global-health-hazard

[10] Diéz, E.S., Poli, F., Soavi, F. (2024). Open Battery Systems. In: Passerini, S., Barelli, L., Baumann, M., Peters, J., Weil, M. (eds) Emerging Battery Technologies to Boost the Clean Energy Transition. The Materials Research Society Series. Springer, Cham. https://doi.org/10.1007/978-3-031-48359-2_11

[11] N. M. L. Huq, I. M. Mahbubul, G. Lotif, M. R. Ashrafi, and M. Himan, "Development and Performance Analysis of a Low-Cost Redox Flow Battery," ***Processes***, vol. 12, no. 7, Jul. 2024, doi: 10.3390/pr12071461.

[12] Inés Rosellón Inclán and Tim Wicke, "Analysis of global battery production: production locations and quantities of cells with LFP and NMC/NCA cathode material," Fraunhofer Institute for Systems and Innovation Research ISI. Accessed: Jan. 29, 2026. [Online]. Available: https://www.isi.fraunhofer.de/en/blog/themen/batterie-update/globale-batterieproduktion-analyse-standorte-mengen-zellen-lfp-nmc-nca-kathoden.html

[13] K.Hantanasirisakul, M.Sawangphruk, Sustainable Reuse and Recycling of Spent Li-Ion batteries from Electric Vehicles: Chemical, Environmental, and Economical Perspectives. Global Challenges2023, 7, 2200212. https://doi.org/10.1002/gch2.202200212

[14] S. Srinivasan, S. Shanthakumar, and B. Ashok, "Sustainable lithium-ion battery recycling: A review on technologies, regulatory approaches and future trends," ***Energy Rep.***, vol. 13, pp. 789–812, Jun. 2025, doi: 10.1016/j.egyr.2024.12.043.

[15] J. John, G. Kudva, and N. S. Jayalakshmi, "Secondary Life of Electric Vehicle Batteries: Degradation, State of Health Estimation Using Incremental Capacity Analysis, Applications and Challenges," ***IEEE Access***, vol. 12, pp. 63735–63753, 2024, doi: 10.1109/ACCESS.2024.3396164.

[16] M. N. Akram and W. Abdul-Kader, "Repurposing Second-Life EV Batteries to Advance Sustainable Development: A Comprehensive Review," ***Batteries***, vol. 10, no. 12, Dec. 2024, doi: 10.3390/batteries10120452.

[17] Y. Wang, F. Hu, Y. Wang, J. Guo, Z. Yang, and F. Jiang, "Revolutionizing the Afterlife of EV Batteries: A Comprehensive Guide to Echelon Utilization Technologies," ***ChemElectroChem***, vol. 11, no. 4, p. e202300666, 2024, doi: 10.1002/celc.202300666.

[18] K. Liu, Y. Wang, and X. Lai, "Data Science-Based Battery Reutilization Management," in ***Data Science-Based Full-Lifespan Management of Lithium-Ion Battery: Manufacturing, Operation and Reutilization***, K. Liu, Y. Wang, and X. Lai, Eds., Cham: Springer International Publishing, 2022, pp. 201–244. doi: 10.1007/978-3-031-01340-9_6.

[19] Matthew Bird, "Can US and European policy tackle China's EV dominance?," Benchmark Source.

Accessed: Jan. 29, 2026. [Online]. Available: https://source.benchmarkminerals.com/article/can-us-and-european-policy-tackle-chinas-ev-dominance

[20] "Battery Ecosystem: A Global Overview, Gap Analysis in Indian context, and Way Forward for Ecosystem Development.", GIZ, Accessed: Jun. 07, 2025. [Online]. Available: https://changing-transport.org/wp-content/uploads/GIZ_Battery-ecosystem-report.pdf

[21] "Advancing sustainablebattery recycling:towards a circularbattery system",Systemiq, Accessed: Jan. 30, 2026. [Online]. Available: https://www.systemiq.earth/wp-content/uploads/2023/11/Systemiq_Sustainable_Battery_Recycling_Full_Study_WEB-1.pdf

[22] "Recycling Lithium-ion batteries.", PEM, RWTH Aachen University, Presentation, Accessed: Jun. 02, 2025. [Online]. Available: https://www.pem.rwth-aachen.de/global/show_document.asp?id=aaaaaaaablhmcye

[23] L.-F. Zhou, D. Yang, T. Du, H. Gong, and W.-B. Luo, "The Current Process for the Recycling of Spent Lithium Ion Batteries," ***Front. Chem.***, vol. 8, p. 578044, Dec. 2020, doi: 10.3389/fchem.2020.578044.

[24] A. Mishra, "Explained: Why Lithium Prices Have Surged 400 Per Cent Despite The Planet Having Vast Quantities Of It," Swarajyamag. Accessed: Jun. 05, 2025. [Online]. Available: https://swarajyamag.com/commentary/explained-why-lithium-prices-have-surged-400-per-cent-despite-the-planet-having-vast-quantities-of-it

[25] L. Albertsen, J. L. Richter, P. Peck, C. Dalhammar, and A. Plepys, "Circular business models for electric vehicle lithium-ion batteries: An analysis of current practices of vehicle manufacturers and policies in the EU," ***Resour. Conserv. Recycl.***, vol. 172, p. 105658, Sep. 2021, doi: 10.1016/j.resconrec.2021.105658.

[26] "Regional Business Models of Battery Recycling: Economics, Strategies, and Technological Trends - E-motec." Accessed: Jun. 07, 2025. [Online]. Available: https://www.e-motec.net/regional-business-models-of-battery-recycling/

[27] S. Ezell, "How Innovative Is China in the Electric Vehicle and Battery Industries?," Jul. 2024. Accessed: Jan. 29, 2026. [Online]. Available: https://itif.org/publications/2024/07/29/how-innovative-is-china-in-the-electric-vehicle-and-battery-industries/

[28] M.Golden, "Confronting China's grip on graphite for batteries,", Standford Energy, Accessed: Jan. 29, 2026. [Online]. Available: https://energy.stanford.edu/news/confronting-chinas-grip-graphite-batteries

[29] C. P. Bown, "US-China Trade War Tariffs: An Up-to-Date Chart | PIIE." Accessed: Jan. 29, 2026. [Online]. Available: https://www.piie.com/research/piie-charts/2019/us-china-trade-war-tariffs-date-chart

[30] M. Bird, "Can US and European policy tackle China's EV dominance?," Benchmark Source. Accessed: Jan. 29, 2026. [Online]. Available: https://source.benchmarkminerals.com/article/can-us-and-european-policy-tackle-chinas-ev-dominance

[31] "Executive summary – The Role of Critical Minerals in Clean Energy Transitions – Analysis," IEA. Accessed: Jan. 29, 2026. [Online]. Available: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary

[32] J. Lepawsky, The changing geography of global trade in electronic discards, 2015, The Geographical Journal, 181: 147-159. https://doi.org/10.1111/geoj.12077, Accessed on May 13 2026

[33] "Global e-Waste Monitor 2024: Electronic Waste Rising Five Times Faster than Documented E-waste Recycling | UNITAR." Accessed: Jan. 29, 2026. [Online]. Available: https://unitar.org/about/news-stories/press/global-e-waste-monitor-2024-electronic-waste-rising-five-times-faster-documented-e-waste-recycling

[34] "New battery-related waste codes will boost circular management of batteries and their critical raw materials.", Directorate-General for Environment, Accessed: Mar. 12, 2026. [Online]. Available: https://environment.ec.europa.eu/news/battery-related-waste-codes-update-set-boost-circular-economy-2025-03-05_en

[35] M. Bartmann, "BASF starts commercial operation of Black Mass plant for Battery Recycling in Schwarzheide, Germany.", BASF, Accessed: Mar. 12, 2026. [Online]. Available: https://www.basf.com/global/en/media/news-releases/2025/06/p-25-112

[36] "Regulation (EU) 2023/ of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC".

[37] "Recycled black mass for lithium ion battery (English Version) - Code of China." Accessed: Jun. 02, 2025. [Online]. Available: https://www.codeofchina.com/standard/GBT45203-2024.html

[38] "The Ministry of Industry and Information Technology holds a press conference on the development of the automobile industry in 2021 (with transcript)." Accessed: Jun. 02, 2025. [Online]. Available: https://www.miit.gov.cn/jgsj/zbys/gzdt/art/2022/art_406f5c19283842ddac3af9b6becfece7.html

[39] "China releases proposed standards for battery recycling (Industry update)," Rho Motion. Accessed: Jun. 02, 2025. [Online]. Available: https://rhomotion.com/news/china-releases-proposed-standards-for-battery-recycling-industry-update/

[40] C. Hampel, "Battery reuse & recycling expand to scale in China - electrive.com." Accessed: Jun. 07, 2025. [Online]. Available: https://www.electrive.com/2022/01/29/battery-reuse-recycling-expands-to-scale-in-china/?utm_source

[41] Maekawa Y., “Japan’s SMM eyes Li-ion battery recycling plant by 2026 | Latest Market News.” Accessed: Jan. 30, 2026. [Online]. Available: https://www.argusmedia.com/en/news-and-insights/latest-market-news/2552470-japan-s-smm-eyes-li-ion-battery-recycling-plant-by-2026

[42] Farmer, A. and Watkins, E.,“Managing waste batteries from electric vehicles: The case ofthe European Union and Japan, Report, 2023, Institute for European Environmental Policy

[43] “Used Lithium-Ion Batteries.” , United States Environment Protection Agency, Website, Accessed: Jun. 02, 2025. [Online]. Available: https://www.epa.gov/recycle/used-lithium-ion-batteries

[44] CPCB, “WasteManagementRules-2022.” [Online]. Available: https://cpcb.nic.in/uploads/hwmd/Battery-WasteManagementRules-2022.pdf

[45] CPCB, “Technical Review Committee Meeting- 33: Evaluation of proposals for utilization of hazardous wastes under HOWM.” [Online]. Available: https://cpcb.nic.in/uploads/hwmd/Minutes_33_TEC.pdf

[46] MoEF&CC, “Technical Review Committee Meeting- Request to ban on export of Black Mass.” [Online]. Available: https://moef.gov.in/uploads/pdf-uploads/pdf_6776498a9a73b3.78318473.pdf

[47] “Amendments to four producer responsibility regulations for tires, batteries, electrical and electronic equipment, and hazardous and special products | Environmental Registry of Ontario.” Accessed: Jun. 02, 2025. [Online]. Available: https://ero.ontario.ca/notice/019-8866

[48] “Batteries,” RPRA. Accessed: Jun. 02, 2025. [Online]. Available: https://rpra.ca/programs/batteries/

[49] “Regulatory Decree of the Environment and Sustainable Development Sector addresses WEEE, batteries and accumulators – Policies,” IEA. Accessed: Mar. 12, 2026. [Online]. Available: https://www.iea.org/policies/21212-regulatory-decree-of-the-environment-and-sustainable-development-sector-addresses-weee-batteries-and-accumulators

[50] F. M. Dodero, “MARTÍN ALBERTO VIZCARRA CORNEJO,” 2019, Accessed on 13-05-26, Online : https://www.leyes.congreso.gob.pe/Documentos/2016_2021/Boletin_de_Normas_Legales/NL20190624.pdf

[51] “Law No. 12305. Brazilian National Policy on Solid Waste (batteries) – Policies,” IEA. Accessed: Mar. 12, 2026. [Online]. Available: https://www.iea.org/policies/15805-law-no-12305-brazilian-national-policy-on-solid-waste-batteries

[52] “Extended Producer Responsibility Regulations 2020 – Policies,” IEA. Accessed: Mar. 12, 2026. [Online]. Available: https://www.iea.org/policies/25167-extended-producer-responsibility-regulations-2020

[53] “National Environmental (Battery Control) Regulations, Statutory Instrument no. 11 of 2024. | UNEP Law and Environment Assistance Platform.” Accessed: Mar. 12, 2026. [Online]. Available: https://leap.unep.org/en/countries/ng/national-legislation/national-environmental-battery-control-regulations-statutory

[54] “REGULATION (EU) 2023/...OF THE EUROPEAN PARLIAMENT AND OF THE COUNCILof ...concerning batteries and waste batteries,amending Directive 2008/98/EC and Regulation (EU) 2019/1020and repealing Directive 2006/66/EC”, European Union, Accessed: Mar. 12, 2026. [Online]. Available: https://data.consilium.europa.eu/doc/document/PE-2-2023-INIT/en/pdf

[55] A. Andrenelli, P. Kowalski, C. Legendre, G. Garsous, E. Frysalaki, and N. Alan-Lee, “Trade and domestic effects of export restrictions: Insights from case studies of cobalt, lithium and nickel,” OECD Trade Policy Papers, Dec. 2025. doi: 10.1787/502e3bcf-en.

[56] “Lithium-Ion Battery Recycling Frequently Asked Questions.”, United States Environmental Protection Agency, Website, Accessed: Jun. 07, 2025. [Online]. Available: https://www.epa.gov/hw/lithium-ion-battery-recycling-frequently-asked-questions

[57] V. Rizos and P. Urban, “Implementing the EU digital battery passport Opportunities and challenges for battery circularity”, Website, Accessed on 13-05-2026, Available: https://www.ceps.eu/ceps-publications/implementing-the-eu-digital-battery-passport/

[58] J. Singh, “A robust ecosystem will help India propel itself to be the world’s third-largest economy from the recently achieved Rank 4, while low-carbon technologies will be key to achieving India’s Net Zero 2070 target: .” Accessed: Jan. 29, 2026. [Online]. Available: https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=2132105

[59] “Guidelines for Implementation of Battery Pack Aadhaar System”, PSA India, Accessed on 13-05-2026, Online: https://psa.gov.in/CMS/web/sites/default/files/publication/Battery%20Pack%20Aadhaar%20Guideline.pdf

[60] “New evaluation looks at how to improve WEEE Directive - Environment”, Directorate General for Environment, Accessed: Jan. 29, 2026. [Online]. Available: https://environment.ec.europa.eu/news/new-evaluation-looks-how-improve-weee-directive-2025-07-02_en

[61] “Missing the Targets: Revise the WEEE Directive to match market realities - APPLIA.” Accessed: Jan. 29, 2026. [Online]. Available: https://applia-europe.eu/news-applia/missing-the-targets-revise-the-weee-directive-to-match-market-realities

[62] “Regulation (EU) 2023/ of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC”.

[63] “EU Battery Regulation 2023/1542: obligations and updates,” Flash Battery. Accessed: Mar. 12, 2026. [Online]. Available: https://www.flashbattery.tech/blog/eu-battery-regulation-obligations-updates/

[64] K. Linnenkoper, “Black mass now ‘officially’ hazardous in the EU • Recycling International,” Recycling International. Accessed: Mar. 12, 2026. [Online]. Available: https://recyclinginternational.com/commodities/battery-recycling/black-mass-now-officially-hazardous-in-the-eu/60304/

[65] “Battery_Waste_Management_(Amendment)_Rules,_2025.pdf.” Accessed: Aug. 01, 2025. [Online]. Available: https://eprbattery.cpcb.gov.in/upload/adminDoc/Battery_Waste_Management_(Amendment)_Rules,_2025.pdf

[66] “Basic Act on Establishing a Sound Material-Cycle Society - English - Japanese Law Translation.” Accessed: Mar. 12, 2026. [Online]. Available: https://www.japaneselawtranslation.go.jp/en/laws/view/3799/en

[67] “The Basic Act for Establishing a Sound Material-Cycle Society”. Accessed on 13-05-2026, Online: https://www.env.go.jp/content/900452892.pdf

[68] Eco-Business, “Japan to join global race to recycle lithium batteries and curb e-waste hazards,” Eco-Business. Accessed: Mar. 12, 2026. [Online]. Available: https://www.eco-business.com/news/japan-to-join-global-race-to-recycle-lithium-batteries-and-curb-e-waste-hazards/

[69] “Circular Economy Promotion Law”, Shanghai Cooperation Organization Environmental Information Sharing Platform, 2008, Accessed: Mar. 12, 2026. [Online]. Available: https://www.greenpolicyplatform.org/sites/default/files/downloads/policy-database/CHINA)%20Circular%20Economy%20Promotion%20Law%20(2008).pdf

[70] Li, W. and W. Lin (2016), ‘Circular Economy Policies in China’, in Anbumozhi, V. and J.Kim (eds.), Towards a Circular Economy: Corporate Management and Policy Pathways.ERIA Research Project Report 2014-44, Jakarta: ERIA, pp.95-111.

[71] B. International, “China issues new collection and recycling plan for lead batteries – Batteries International.” Accessed: Mar. 12, 2026. [Online]. Available: https://www.batteriesinternational.com/2019/02/14/china-issues-new-collection-and-recycling-plan-for-lead-batteries/

[72] J. Zadeh, “China’s Lithium-Ion Battery Recycling Leadership & Outlook.” Accessed: Mar. 12, 2026. [Online]. Available: https://discoveryalert.com.au/chinas-lithium-ion-battery-recycling-2025-outlook/

[73] “A Brief Overview of the New Requirements for the ‘Recycled Black Mass Standard for Lithium-Ion Batteries’ - Shanghai Metals Market (SMM).” Accessed: Mar. 12, 2026. [Online]. Available: https://news.metal.com/newscontent/103146698

[74] “The Waste Batteries and Accumulators Regulations 2009 No. 890.” Accessed: Mar. 12, 2026. [Online]. Available: https://www.legislation.gov.uk/uksi/2009/890/2014-06-13/data.xht?view=snippet&wrap=true

[75] “Battery-related waste codes update set to boost circular economy - Environment.”, Directorate-General for Environment, Article, Accessed: Mar. 12, 2026. [Online]. Available: https://environment.ec.europa.eu/news/battery-related-waste-codes-update-set-boost-circular-economy-2025-03-05_en

[76] “Universal Waste.”, United States Environmental Protection Agency, Website, Accessed: Mar. 12, 2026. [Online]. Available: https://www.epa.gov/hw/universal-waste

[77] “Extended Battery Producer Responsibility (EPR) Framework.”, United States Environmental Protection Agency, Website, Accessed: Mar. 12, 2026. [Online]. Available: https://www.epa.gov/electronics-batteries-management/extended-battery-producer-responsibility-epr-framework

[78] “Resource Conservation and Recovery Act (RCRA) Laws and Regulations.”, United States Environmental Protection Agency, Website, Accessed: Mar. 12, 2026. [Online]. Available: https://www.epa.gov/rcra

[79] K. W. Bergin Todd Fracassi, Chris, “U.S. EPA Issues FAQ Memo on Lithium-Ion Battery Management Under RCRA,” Environmental Law and Policy Monitor. Accessed: Mar. 12, 2026. [Online]. Available: https://www.environmentallawandpolicy.com/2023/06/u-s-epa-issues-faq-memo-on-lithium-ion-battery-management-under-rcra/

[80] “Ontario Regulation 556/24 BATTERIES.”, Ontario Gazette, 2025, Accessed: Mar. 12, 2026. [Online]. Available: https://www.ontario.ca/laws/regulation/r24556

[81] “Critical Battery Materials Initiative (CBMI) | Waterloo Industrial Ecology Group | University of Waterloo.” Accessed: Mar. 12, 2026. [Online]. Available: https://uwaterloo.ca/industrial-ecology/projects/critical-battery-materials-initiative-cbmi

[82] “Positive Charge 2023-24 Report.”, Battery Stewardship Council, Report, Accessed: Mar. 12, 2026. [Online]. Available: https://bcycle.com.au/wp-content/uploads/2024/12/250-003-B-cycle-Positive-Charge-Report-2024-v8-20241202.pdf

[83] “A national framework for recycled content traceability- Guidelines”, Department of Climate Change, Energy, Environment and Water, Australian Government, 2025, Accessed on 13-05-2026, Online: https://www.dcceew.gov.au/sites/default/files/documents/national-framework-recycled-content-traceability.pdf

[84] “16 January 2025, ASSOCIATION FOR THE BATTERY RECYCLING INDUSTRY.”,Association for the Battery Recycling Industry, 2025, Newsletter, Accessed: Mar. 12, 2026. [Online]. Available: https://www.batteryrecycling.org.au/bulletinsblog/blog-post-title-one-zbr29-84cjr-b8r8x-6395x-mlaat-rr4pw-sdc4x-8x5b3-mekc9-lakyb-gckng-naaef-l69r6-e3f5n-6rp6r-fzyb3-fphpg-jby3f-tf7ey-tkyth-d88ek-7h84h-c7bzc-e7yjy-jpnms

[85] “Extended Producer Responsibility (EPR) System for E-waste Management System.”, National Environment Agency, Singapore, Website, Accessed: Mar. 12, 2026. [Online]. Available: https://www.nea.gov.sg/our-services/waste-management/3r-programmes-and-resources/e-waste-management/extended-producer-responsibility-(epr)-system-for-e-waste-management-system

[86] “Lithium Ion & EV Battery Recycling Services | SK Tes Company.” , Website, Accessed: Mar. 12, 2026. [Online]. Available: https://www.sktes.com/services/commercial-battery-recycling

[87] “Environment Protection and Management Act 1999”, Singapore Statutes Online, 2024, Accessed: Mar. 12, 2026. [Online]. Available: https://faolex.fao.org/docs/pdf/sin86441.pdf

[88] “Waste from Electrical and Electronic Equipment (WEEE) - Environment.”, Website, Accessed: Mar. 12, 2026. [Online]. Available: https://environment.ec.europa.eu/topics/waste-and-recycling/waste-electrical-and-electronic-equipment-weee_en

[89] “Peru - Updated Regulation on Management of Waste Electrical. ° 009-2019-MINAM-”, Government of Peru, Website, Accessed: May 12 2026. [Online]. Available: https://www.gob.pe/institucion/minam/normas-legales/354138-009-2019-minam

[90] “Law No. 12305. Brazilian National Policy on Solid Waste (batteries) – Policies,” IEA. Accessed: Mar. 12, 2026. [Online]. Available: https://www.iea.org/policies/15805-law-no-12305-brazilian-national-policy-on-solid-waste-batteries

[91] “National Environmental (Battery Control) Regulations, Statutory Instrument no. 11 of 2024. “ UNEP Law and Environment Assistance Platform, Accessed: Mar. 12, 2026. [Online]. Available: https://leap.unep.org/en/countries/ng/national-legislation/national-environmental-battery-control-regulations-statutory

[92] “Extended Producer Responsibility Regulations 2020 – Policies,” IEA. Accessed: Mar. 12, 2026. [Online]. Available: https://www.iea.org/policies/25167-extended-producer-responsibility-regulations-2020

[93] “Council adopts new regulation on batteries and waste batteries,” Council of European Union. Accessed: Mar. 12, 2026. [Online]. Available: https://www.consilium.europa.eu/en/press/press-releases/2023/07/10/council-adopts-new-regulation-on-batteries-and-waste-batteries/



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