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NITI Aayog

Advancing Circular Economy of

Waste Electronic and Electrical Equipment (E-waste) and Lithium-Ion Batteries in India

DISCLAIMER

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Government of India
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Acknowledgements

We thank Shri BVR Subrahmanyam, CEO, NITI Aayog, for his guidance and valuable suggestions in the preparation of this report. We also thank the members of the Working Group on Circular Economy of Electronic waste (E-waste) and Lithium-Ion Batteries for their active participation and constructive inputs. We thank our knowledge partner, The Energy and Resources Institute (TERI), along with the concerned ministries and all stakeholders for their support in finalizing the report.

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Foreword

With the rapid transition to clean energy and digital technologies, electronic waste and the number of Lithium-ion Batteries reaching the end-of-life are rising. Appropriate recycling can turn electronic waste and Lithium-ion Batteries into a source of raw materials, including critical minerals and rare earth metals, as well as open new avenues for sustainable development and economic resilience by reducing import dependency on precious metals and critical minerals.

Currently, the informal sector accounts for the majority of electronic waste and end-of-life Lithium-ion Battery collection, processing, and recycling. However, the informal sector remains economically and strategically untenable due to inefficient processes and limited exposure to modern technologies.

Over the past few years, the Government of India has introduced various measures to build an organised system for the recycling of electronic waste and end-of-life Lithium-ion Batteries. These national policies and programmes aim to create better recycling facilities, support industry, and protect the environment, encouraging efficient use of resources and reducing the burden of waste on society.

The report *"Advancing Circular Economy of Waste Electronic and Electrical Equipment (E-waste) and Lithium-Ion Batteries in India"* reviews the current policy landscape and its implementation, outlines the challenges, and provides recommendations for mutually reinforcing economic growth and environmental protection in the collection, processing, and recycling of electronic waste and Lithium-ion Batteries.

I extend my appreciation to Team NITI Aayog, the working group members, and the knowledge partner, The Energy and Resources Institute (TERI), for their research, diligence, and insights in developing this report.

(Suman Bery)

Place- New Delhi
Dated- 20th January 2026

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MESSAGE

India's vision of Viksit Bharat and the goal of reaching USD 30 trillion in GDP by 2047 are closely linked to the country's transition to a low-carbon, resource-efficient development pathway. India's commitment to achieve Net Zero emissions by 2070, necessitates rapid electrification and the deployment of clean energy. In this context, electronic and electrical equipment, and Lithium-ion Batteries, are critical enablers for India's digital transformation, electric mobility, and energy transition goals.

Lithium-ion Battery demand is expected to increase from 29 GWh in 2025 to 248 GWh by 2035. This will be accompanied by an increase in electronic waste generation from 6.19 MMT in 2024 to 14 MMT by 2030. Therefore, India's transition to a circular economy for electronic waste and Lithium-ion Batteries is not merely an environmental imperative, it is central to realizing our Viksit Bharat 2047 vision of sustainable and inclusive growth.

Lithium-ion Batteries and electronic waste contain critical minerals and rare earth metals. The projected increase in Lithium-ion Battery demand and electronic waste generation thus presents a profound economic opportunity for material recovery from Lithium-ion Battery and electronic waste recycling. This will also strengthen domestic value chains, reduce import dependence, and support low-carbon development in achieving climate commitments under the Viksit Bharat framework.

This report ***"Advancing Circular Economy of Waste Electronic and Electrical Equipment (E-waste) and Lithium-Ion Batteries in India"*** outlines systematic challenges and proposes actionable solutions. The recommendations provide a strategy for policymakers, state governments, and stakeholders to build a robust ecosystem for electronic waste and Lithium-ion Battery recycling.

I appreciate the work done by the working group on E-waste and Lithium-ion Battery management, chaired by Maj Gen K Narayanan, PD (Security & Strategic Affairs and Law) and the support provided by Green Transition Energy & Climate Change division under Dr. Anshu Bhardwaj, Programme Director. I hope this report will ensure collective efforts by various stakeholders towards the circular economy of E-waste and Lithium-ion Battery recycling in India.

20/1

Dated: 20th January, 2026 **(B.V.R. Subrahmanyam)**

स्वच्छ भारत
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MESSAGE

The demand for Lithium-ion Batteries has surged globally; concomitantly, electronic waste generation has also increased. This has created an opportunity in India for material recovery to meet new material demand and reduce dependence on imports of critical and rare-earth minerals. Recognizing the urgent need, the NITI Aayog undertook this study to assess regulatory frameworks, infrastructure capacity, technology readiness, financial mechanisms, and institutional coordination across ministries and state governments.

The findings suggest that while formal electronic waste and End-of-Life Lithium-ion Batteries collection and processing have increased, the economically and strategically untenable informal sector still captures a predominant share due to implementation gaps and operational reality. Several successful models demonstrate that formalizing the informal waste sector is achievable through investment in technology, market access, and public-private partnerships that preserve livelihoods while building technical capacity.

This report highlights the need for prescriptive directives, collaborative support, and technical assistance for infrastructure planning, capital mobilization mechanisms, workforce development programs, and institutional frameworks for inter-agency coordination.

I congratulate Team NITI, our knowledge partner TERI and the working group members for their hard work, research and the successful completion of this report.

(Maj Gen K Narayanan)

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List of Abbreviations

Abbreviation	Description
BCD	Basic Customs Duty
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
CE	Consumer Electronics
CFC	Common Facility Centres
C-MET	Centre for Materials for Electronics Technology
CPCB	Central Pollution Control Board
CRM	Critical Raw Materials
DGFT	Directorate General of Foreign Trade
DPIIT	Department for Promotion of Industry and Internal Trade
EEE/E-waste	Electrical and Electronic Equipment Waste
EPR	Extended Producer Responsibility
ESS	Energy Storage System
GST	Goods and Services Tax
KT	Kiloton
LCO	Lithium Cobalt Oxide
LIB	Lithium-Ion Battery
LFP	Lithium Ferro Phosphate
LPW	Low-Priced Waste
MeitY	Ministry of Electronics and Information Technology
MHI	Ministry of Heavy Industries
MoE	Ministry of Education
MoEFCC	Ministry of Environment, Forest and Climate Change
MoF	Ministry of Finance
MoM	Ministry of Mines
MoMSME	Ministry of Micro, Small, and Medium Enterprises
MSDE	Ministry of Skill Development and Entrepreneurship
MMT	Million Metric Tonnes
NCA	Nickel Cobalt Aluminum Oxide
NCMM	National Critical Mineral Mission
NMC	Nickel Manganese Cobalt Oxide
OEM	Original Equipment Manufacturer
PCB	Printed Circuit Board
PLI	Production Linked Incentive
PPP	Public-Private Partnership
R&D	Research and Development
SOP	Standard Operating Procedure
SPCB	State Pollution Control Board
ULB	Urban Local Body

Executive Summary

The clean energy and digital transition are driving exponential growth in the usage of Lithium-ion batteries and the generation of electronic waste (E-waste) in India. Despite the gradual expansion of the formal recycling ecosystem, Lithium-ion Battery scrap and E-waste are largely handled by the unregulated informal sector, which often employs unscientific methods, resulting in economic losses, environmental contamination, and public health risks. Informal sector dominance also persists due to weak monitoring mechanisms and complex compliance requirements that deter informal recyclers from entering the formal ecosystem.

In recent years, the Government of India has introduced policies to promote circularity and ensure responsible management of E-waste and Lithium-ion Battery scrap. However, a robust circular ecosystem is yet to materialize due to multiple factors. For instance, Extended Producer Responsibility (EPR) coverage in E-waste recycling is limited to Gold, Copper, Iron, and Aluminum, restricting investment and innovation in the recovery of other valuable and critical minerals. Weak enforcement allows spurious and non-operational recyclers to distort EPR markets through fraudulent certification. Low skills, and limited accessibility of advanced recycling processes also restrict the scalability and efficiency of the sector. Collection inefficiencies, low consumer awareness, and inadequate financing further exacerbate systemic challenges, which risk resource leakages and environmental hazards, and undermine India's long-term energy security by deepening its dependence on critical mineral imports. Therefore, advancing the circular economy framework for E-waste and Lithium-ion Battery scrap is a national priority.

For E-waste management, recommended priority actions include expanding EPR coverage to other high-value metals. For Lithium-ion Battery scrap management, recommended priority actions include integrating the EPR-GSTN portal for seamless invoice verification, tightening EPR enforcement to track and ensure accountability across the value chain, and notifying chemistry-wise metal composition in Lithium-ion Batteries. BIS certification (IS 16046) to be updated to include mandatory chemical composition testing of the recycled Lithium-ion Batteries, and detailed guidelines to be issued for the collection, storage, transportation, refurbishment, and recycling of waste batteries. Purity standards be established, and additional incentives may be provided to manufacturers under the Production Linked Incentive scheme for Advanced Chemistry Cells to promote the uptake of recycled materials. Third-party agencies to be empanelled to conduct unit-wise periodic audits, thereby enhancing compliance and credibility. Parallel efforts to be build technical capacity through dedicated E-waste and Lithium-ion Battery recycling curricula in engineering colleges and technical universities, and improve access to finance for recycling infrastructure. Establishing Common Facility Centres equipped with recycling technologies would allow informal clusters to access safer a nd efficient processing methods. Simplified registration, fee waivers, and the formal recognition of informal workers can make the transition inclusive and just.

At the collection and consumer interface, public awareness campaigns, product-level recycling information, and expanded collection networks operated by Urban Local Bodies in public-private partnership would increase formal collection.

These measures outline a coherent pathway to embed circular economy principles across India's E-waste and Lithium-ion Battery value chains. By simultaneously tightening governance, deepening markets for secondary materials, and fostering domestic technological capabilities, India can convert E-waste and Lithium-ion Battery scraps into strategic resource reservoirs, reduce exposure to volatile global supply chains, and consolidate its leadership in sustainable and clean-tech value chains.

1. Introduction

India's transition towards a sustainable future is anchored in the Hon'ble Prime Minister's vision for Atmanirbhar Bharat (Self-Reliant India), which is centered on expanding clean technologies such as renewable energy, promoting electric vehicles (EVs), and digital infrastructure. Underlying this transformation, there is an unprecedented demand for critical minerals (Lithium, Cobalt, Nickel, and rare earth metals), essential components of Lithium-ion batteries powering EVs and renewable energy systems, and electrical and electronic equipment embedded across digital infrastructure.

However, this transition will also create challenges of accumulating end-of-life Lithium-ion Batteries and Electrical and Electronic Equipment. Despite the rapid accumulation of these waste streams, India's formal recycling infrastructure remains inadequate and fragmented. Most waste is either exported or abandoned in informal channels, representing both an economic loss and a resource security vulnerability, as India is entirely import-dependent for Lithium and Cobalt, and relies on imports for 75-80% of its Nickel and rare earth requirements (Eninrac, 2025; EXIM Bank, 2025). With a geopolitically volatile global supply chain, India's clean energy ambitions face critical supply-side vulnerabilities. Advancing a circular economy for E-waste and Lithium-ion Battery scraps is not an optional policy domain but a strategic imperative for India.

India has taken preliminary steps toward establishing a circular economy framework under the *E-Waste (Management) Rules, 2022*, and the *Batteries (Management and Handling) Rules, 2022,* for E-waste and end-of-life Lithium-ion Batteries, respectively. Despite these initiatives, implementation remains inconsistent, and the gap between waste generation and formal management reflects systemic deficiencies in India's circular economy framework.

This report examines the current state of India's E-waste and end-of-life Lithium-ion Batteries, recycling ecosystems, identifies systemic barriers to advancing the circular economy, and outlines targeted recommendations to transform these waste streams into strategic resources that advance India's transition while ensuring environmental stewardship and inclusive growth.

2. Background

2.1 Material Composition of E-waste and Lithium-ion Batteries

Electronic devices contain over 60 elements, including precious metals (Gold, Silver, Platinum, and Palladium), critical materials (Lithium and Cobalt), rare earth elements (Indium, Gallium, and Tantalum), and multiple hazardous substances and heavy metals (Lead, Mercury, Cadmium, and Chromium) (ITU & UNITAR, 2024). The concentration and combination of these materials vary across devices, requiring specialised processing. E-waste constitutes about 33% metals, 30% plastics, and 37% glass and other materials. Iron (52%) dominates the metal composition, followed by Copper (18%), Aluminium (12%), Zinc (3%), and Lead (3%). Other metals account for the remaining 12% (Fig. 1). Also, E-waste contains a higher concentration of precious metals compared to traditional ores, creating substantial economic opportunities for formal E-waste processing. For instance, mobile phones yield 300-400 g of Gold and 3,000-4,000 g of Silver per tonne of E-waste, while printed circuit boards from other devices contain 200-300 g of Gold and 1,000-2,000 g of Silver per tonne.

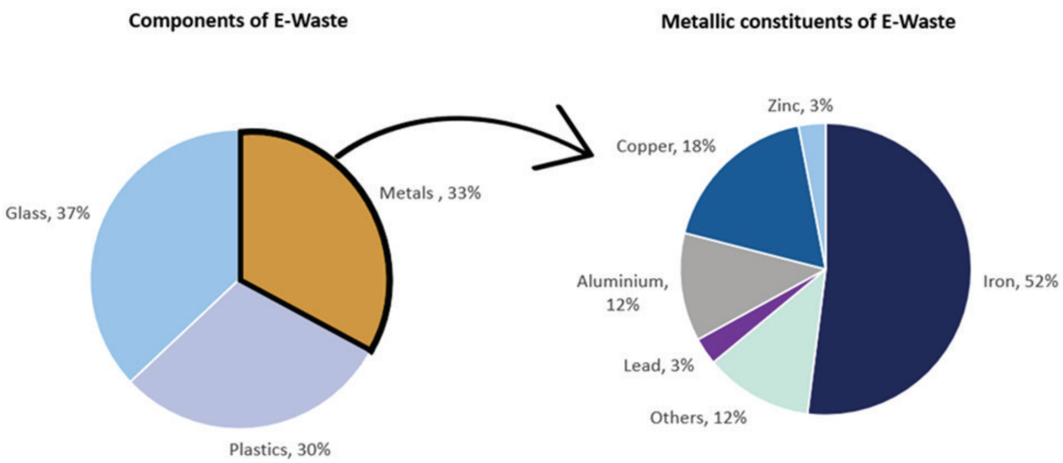

Fig. 1: E-waste material composition (ITU & UNITAR, 2024)

Lithium-ion Battery chemistries continue to evolve to meet diverse requirements across transport, energy storage systems, and consumer electronics. Cathodes made of Lithium Iron Phosphate (LFP), Lithium Nickel Manganese Cobalt Oxide (NMC), and Lithium Cobalt Oxide (LCO) are the most widely used in Lithium-ion Batteries. Depending on the specific cell chemistry, the cathode forms the majority share (40-65%) by weight in Lithium-ion Battery. The anode stores lithium ions during charging and is usually made of graphite or silicon. The separator facilitates the movement of lithium ions between the electrodes. Material composition in Lithium-ion Battery chemistries is shown in Fig. 2.

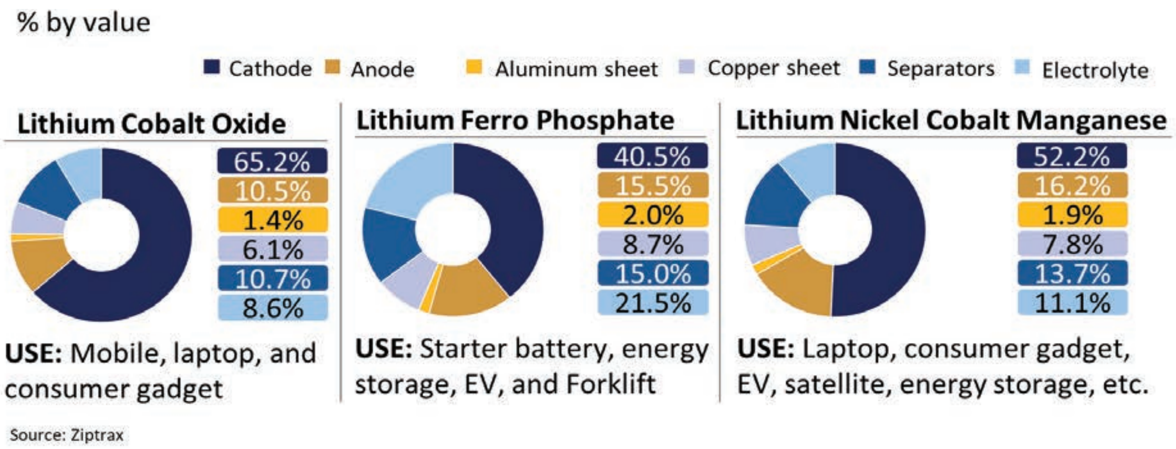

Fig. 2: Material composition in Lithium-ion Battery chemistries (Source: Industry Consultation)

2.2 Current and Projected E-waste and Lithium-ion Battery Generation in India

India is witnessing a sharp increase in E-waste generation. According to the Global E-waste Monitor, E-waste generation in India has increased from ~2.76 MMT in 2020 to ~6.19 MMT in 2024 and is projected to reach 14 MMT by 2030 (ITU & UNITAR, 2024). About 16.9% annual growth in E-waste generation (Fig. 3) reflects the rapid adoption of digital technologies and shorter product life cycles. Computer equipment accounts for the largest share of the E-waste stream (65%), followed by large appliances and medical equipment (15%), telecom equipment (12%), and consumer electronics (8%). Household E-Waste (including smartphones, computers, televisions, home appliances, and consumer electronics) contributes 60-70% of the total E-waste. Manufacturing units and bulk consumers (corporations, institutions, government agencies, and hospitals) account for approximately 30-40% of E-waste generation. In 2024, the annual E-waste recycling capacity in India was ~4.2 MMT. Large equipment accounts for the largest share of formally collected and recycled e-waste (37%), followed by small equipment (17%), screens and monitors (11%), and small IT and telecommunication equipment (7%). Although formal recycling capacity in India has increased since 2020, the informal sector remains dominant, accounting for ~62%. A category-wise breakdown of E-waste generation and share of formal and informal waste processing capacity is illustrated in Fig. 3.

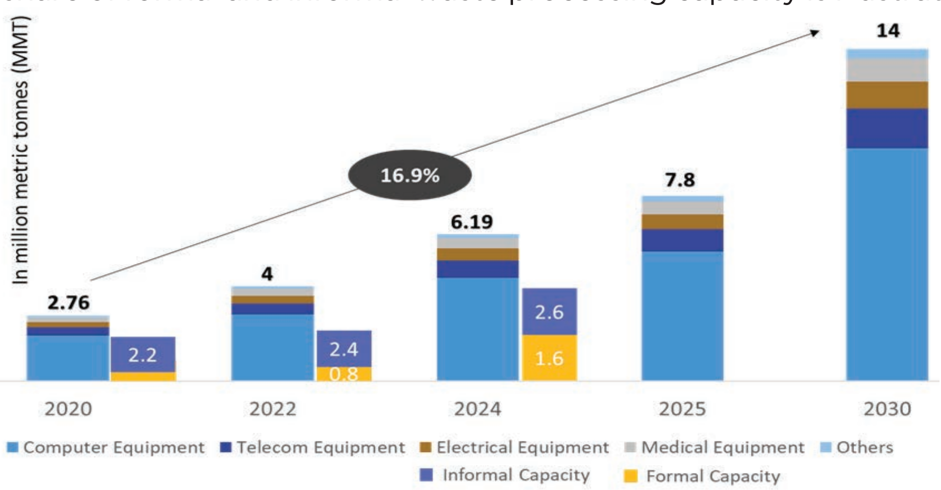

Fig. 3: Projected E-waste generation in India (ITU & UNITAR, 2024)

India's Lithium-ion Battery demand is also expected to grow rapidly in the coming years. As shown in Fig. 4, Lithium-ion Battery demand is projected to increase at a rate of 26% annually, from 16 GWh in 2023 to 248 GWh by 2035 (ITU & UNITAR, 2024). Lithium-ion Battery demand in Consumer Electronics is expected to decrease from 38% to 8%. On the other hand, Lithium-ion Battery demand in EVs is expected to increase from 56% to 63% and in energy storage systems from 6% to 29% by 2035, driven by the growth of electric mobility and increasing integration of renewable energy sources.

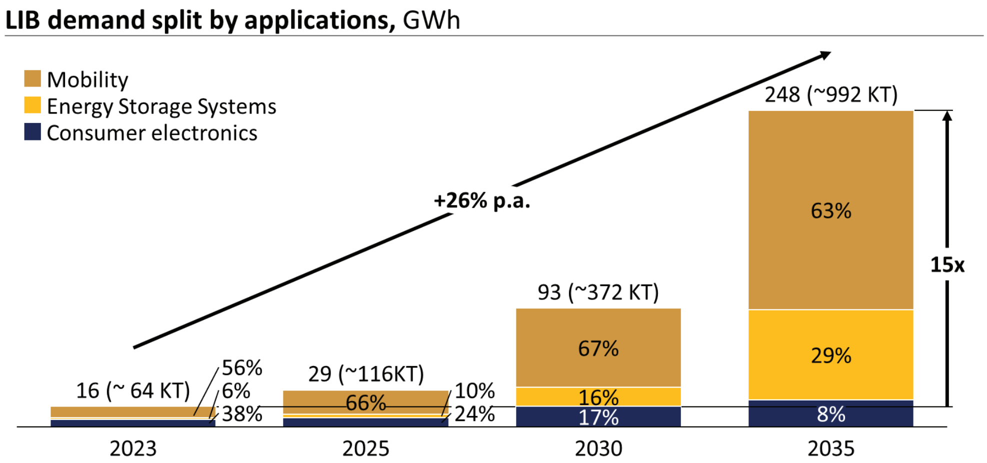

Fig. 4: Projected Lithium-ion Battery demand growth in India (ITU & UNITAR, 2024)

Consequently, end-of-life Lithium-ion Battery availability for recycling is projected to rise at a rate of 26% annually, from 19 kT in 2023 to 233 kT in 2035 (Fig. 5). This growth is primarily driven by end-of-life Lithium-ion Batteries from Electric Vehicles (EVs) and Energy Storage System, which are expected to increase from 2 kT to 123 kT by 2035. Each of consumer electronics and production scrap is expected to rise to 55 kT by 2035. Therefore, the projected rise in end-of-life Lithium-ion Battery highlights the urgent need to develop efficient recycling infrastructure and technologies to recover valuable materials and support India's clean energy objectives.

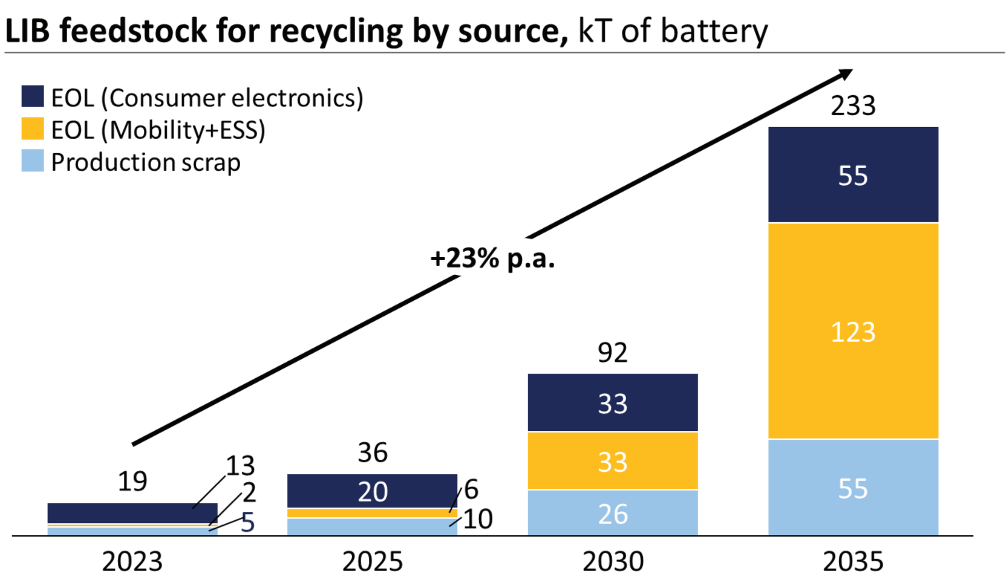

Fig. 5: Projected End-of-life Lithium-ion Battery availability in India

2.3 State of Formal E-waste and End-of-Life Lithium-ion Battery Recycling in India

As illustrated in Fig. 6, India is the third-largest E-waste generator (7% of global volumes). However, India's recycling rate is only 10%, significantly below the global average (~22%) and substantially lower than in the EU and the USA (55% and 56%, respectively) (ITU & UNITAR, 2024). Currently, majority of E-waste and end-of-life Lithium-ion Batteries are collected, processed and recycled through informal sector or remains in storage with consumers and bulk users, due to inadequate formal coverage. Only 2,808 collection centres serve India's population, creating access barriers that drive disposal toward informal channels. On the other hand, the informal networks achieve high collection coverage and provide livelihoods to over 500,000 workers. However, the informal workforce operates under conditions that pose significant environmental and health risks. Also, retailers' take-back compliance remains at only 12%, indicating non-compliance with mandatory take-back requirements and a lack of integration between retail operations and formal processing networks.

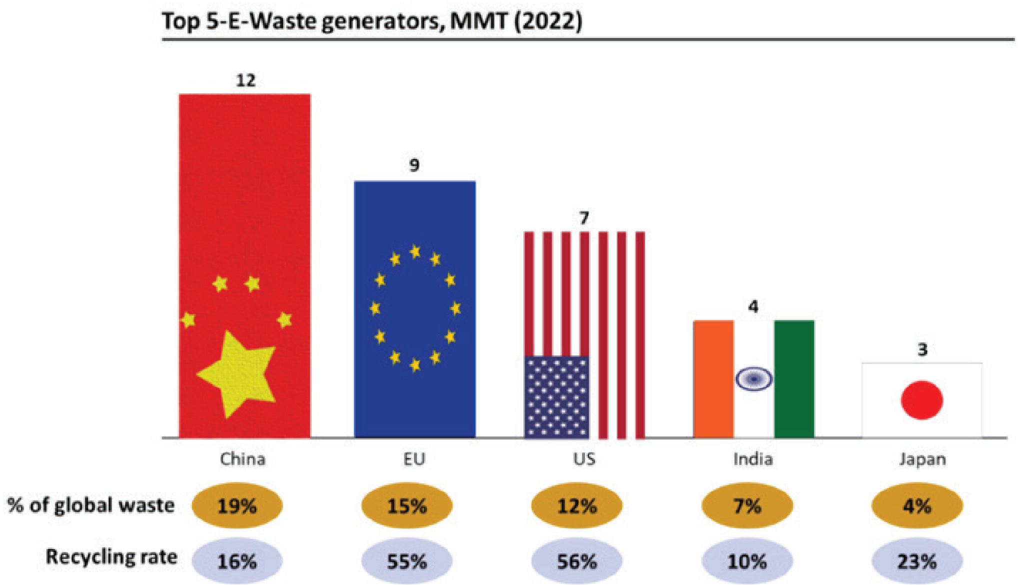

Fig. 6: India's position in global E-waste generation and recycling (ITU & UNITAR, 2024)

India's annual formal E-waste recycling capacity is ~1.75 MMT, distributed across more than 400 authorised recyclers and dismantlers. 48.2% of total capacity lies with 30 High-Capacity Recyclers (>10,000 MT), followed by 36.3% of capacity with 89 Medium-Capacity Recyclers (2,500-10,000 MT), 7.4% of capacity with each of 65 Small-Capacity Recyclers (1,000-2,500 MT), and 274 Micro-Recyclers (<1,000 MT) (ICEA, 2023). As demonstrated in Fig. 7, this distribution indicates that 6% of recyclers control over 60% of formal processing capacity, while 75% of recyclers contribute only 15% of total capacity.

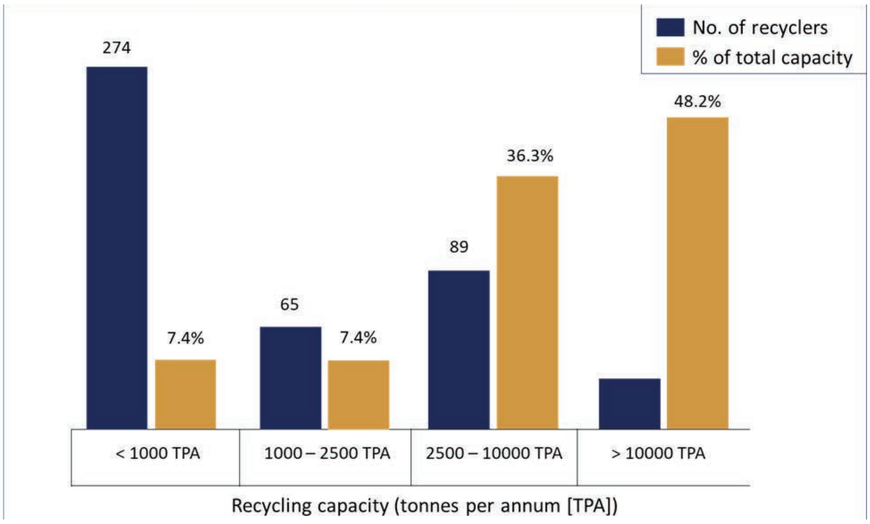

Fig. 7: Categorization of E-waste recyclers and recycling capacity (ICEA, 2023)

Furthermore, formal E-waste recycling capacity is projected to grow at 17%, achieving 40% formalisation by 2036 (Fig. 8) (REDSEER, 2025). This indicates that, despite significant investment in realizing formal sector growth, the well-entrenched informal sector ecosystem for E-waste recycling has a formidable hold on the market, making it difficult to divert material resources to the formal sector. However, aggressive support for the formal sector, combined with dedicated formal-informal integration, may achieve a 35% annual growth rate, potentially realizing 95% formalisation of the E-waste management sector by 2038.

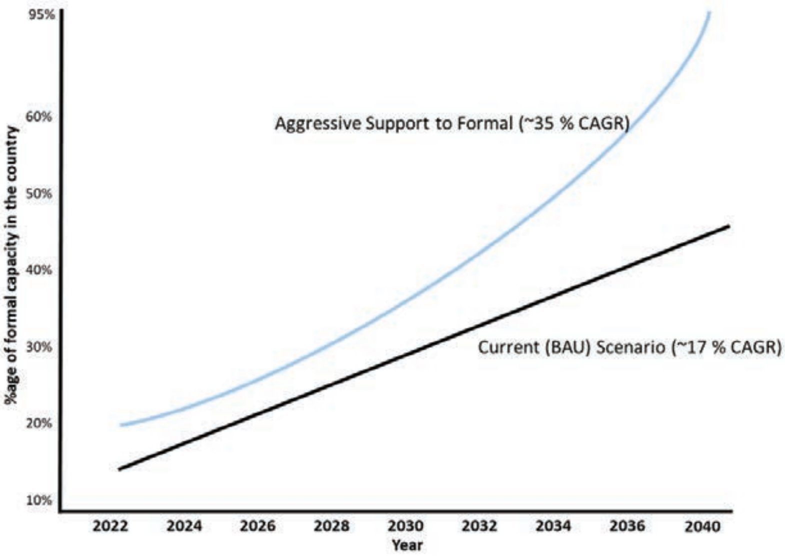

Fig. 8: Formal E-waste recycling projections (REDSEER, 2025)

On the other hand, estimates indicate that ~36 kT of Lithium-ion Batteries will reach the end-of-life in 2025, with 33.12 kT originating from Consumer Electronics, 1.08 kT from EVs, and 1.8 kT from Energy Storage System. Notably, about 12.6 kT of these Lithium-ion Batteries would remain uncollected, highlighting a considerable gap in collection efficiency. Also, informal collection would account for 18 kT, compared to just 5.04 kT through formal channels, underscoring the need to strengthen regulatory and infrastructural frameworks.

Formal recycling would produce 5.37 kT of black mass, which can be refined to produce 2.61 kT of industrial-grade salt for export and 1.74 kT reserved for non-battery domestic uses, underscoring the economic potential of recovered materials. Also, 0.5 kT of produced battery-grade salts can be reused in battery manufacturing.

The analysis underscores the urgent need to transition informal collections into formal systems to improve traceability, safety, and material recovery rates. Also, minimizing rejects and process waste (1.24 kT) through technological advancements can improve overall recovery efficiency. Material flow in the Indian Lithium-ion Battery sector is illustrated in Fig. 10.

India's Lithium-ion Battery recycling sector also faces challenges of higher announced processing capacities than the actual end-of-life Lithium-ion Battery supply projected for the coming years. Against over 80 kT of announced recycling capacity, only ~15 kT of end-of-life Lithium-ion Battery would need to be recycled in 2025. This gap is expected to persist till 2030, when announced processing capacity is expected to reach 115 kT, compared to an estimated actual supply of ~60 kT of end-of-life Lithium-ion Battery. Bridging the supply-capacity gap is crucial for achieving sustainability, ensuring critical mineral security, and fostering a robust circular economy. Therefore, strengthening end-of-life Lithium-ion Battery collection, logistics, and processing is crucial for India to increase recovery rates, meet demand, and establish long-term resilience in the Lithium-ion Battery value chain. Projected end-of-life Lithium-ion Battery availability and recycling capacity in India are presented in Fig. 9.

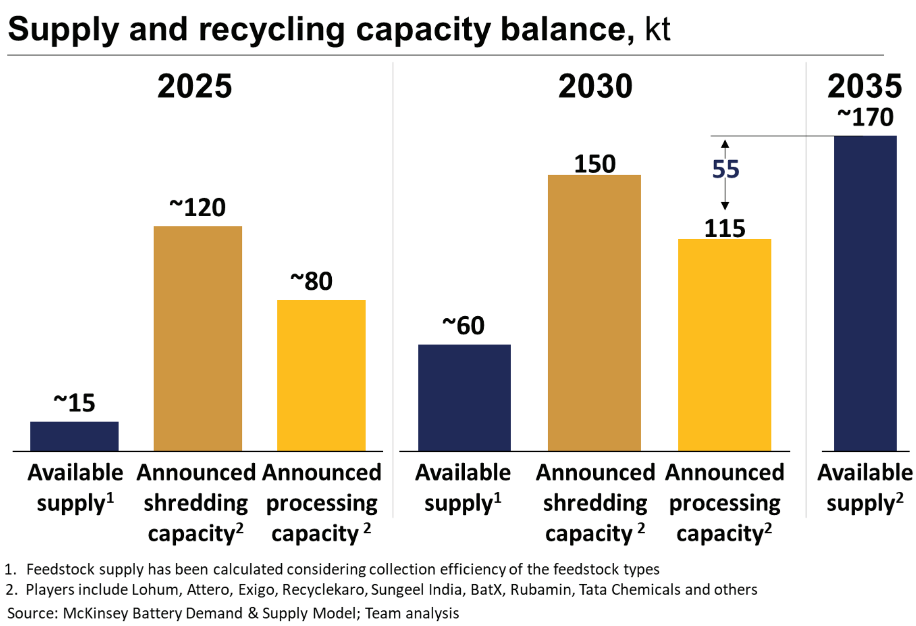

Fig. 9: Projected End-of-Life Lithium-ion Battery availability and recycling capacity in India

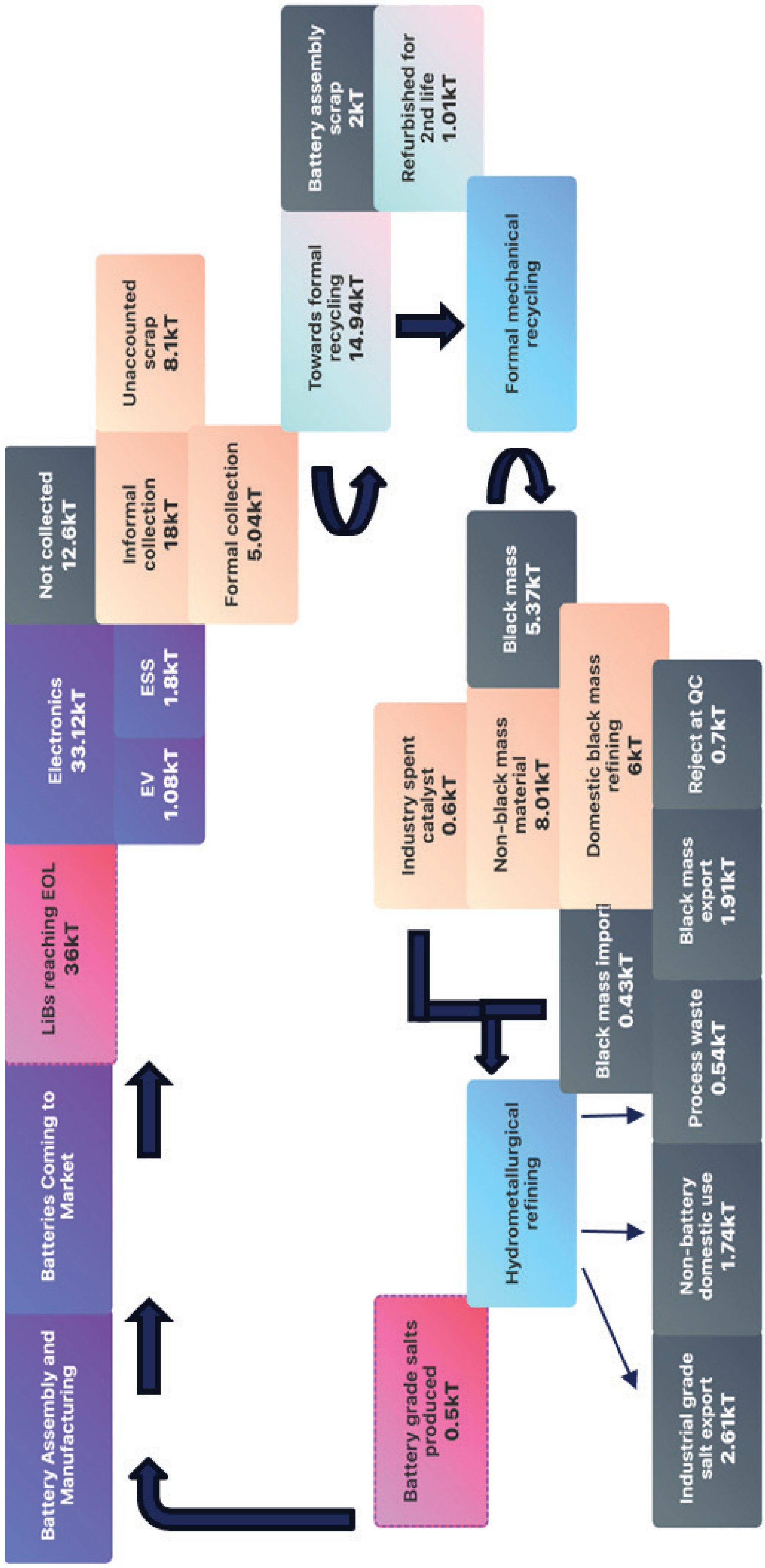

Fig. 10 Material flow in the Indian Lithium-ion Battery value chain

(Source: Industry Data)

3. Policy Landscape

The Ministry of Environment, Forests, and Climate Change (MoEFCC), along with other ministries, governs the recycling and management of End-of-life Lithium-ion Batteries and E-waste in India through its respective regulatory frameworks. The current policy landscape regarding E-waste and End-of-life-Lithium-ion Battery management has been discussed in this section.

3.1 E-waste Management Rules (EWMR)

The MoEFCC established an E-waste management framework through the *E-waste (Management) Rules, 2022*, which superseded the *E-waste (Management) Rules, 2016*. The framework was subsequently amended in 2023 and 2024 to address gaps and evolving technological challenges. Key highlights of *EWMR, 2022,* and its amendments are summarized in Table 1.

Table 1: Key highlights of EWMR, 2022, and its amendments

Title	Gazette Notification	Policy Description
E-waste (Management) Rules, 2022	G.S.R. 801(E) (02.11.2022)	Established an E-waste management framework with provisions of producer responsibility, collection and recycling targets, mandatory stakeholder registration and authorization, environmental safeguards for processing activities, and strengthened monitoring and compliance systems
		Apply to manufacturers, refurbishers, dismantlers, recyclers, and importers of electrical and electronic equipment and its components.
		Standardized reporting of material flow and processing outcomes, environmental clearances for facilities, and penalty enforcement by the CPCB and SPCBs.
E-waste (Management) Amendment Rules, 2023	G.S.R. 61(E) (30.01.2023)	Strengthened producer accountability by tightening reporting requirements.
		Expanded exemptions from hazardous substance restrictions for specified solar and medical equipment.
		Enhanced disclosure of hazardous substances in electrical and electronic equipment.
E-waste (Management) Second Amendment Rules, 2023	G.S.R.534(E) (24.07.2023)	Assigned responsibility for refrigerant destruction to manufacturers and recyclers.
		Introduced conversion factors for EPR certificates to standardize compliance estimates.
		Updated exemptions under Schedule II.

Title	Gazette Notification	Policy Description
E-waste (Management) Amendment Rules, 2024	G.S.R. 164(E) (08.03.2024)	Clarified definitions of dismantlers and extended reporting timelines in specified circumstances.
		Empowered the Central Government to establish EPR certificate trading platforms under CPCB to strengthen market-based compliance and traceability mechanisms.

3.2 Battery Waste Management Rules (BWMR)

The *Battery Waste Management Rules, 2022,* issued by the MoEFCC, laid down provisions for the sustainable management of all types of waste batteries, including Lithium-ion Battery. EPR-based rules mandated the collection, recycling, and refurbishment of waste batteries, prohibiting disposal through landfill and incineration. The Rules also specified collection targets for producers, recovery efficiency for recyclers, and minimum use of recycled materials in new batteries. These measures aimed to promote the circular economy in the battery sector, reduce dependence on imported raw materials, and strengthen domestic recycling capacity. Key highlights of *BWMR, 2022,* and its amendments are summarized in Table 2.

Table 2: Key highlights of BWMR, 2022, and its amendments

Title	Gazette Notification	Policy Description
Battery Waste Management Rules, 2022	S.O. 3984(E) (22.08.2022)	Established a framework for sustainable management of all waste batteries (portable, automotive, industrial, EV).
		Introduced EPR obligations for producers.
		Laid down provisions for registration, collection, recycling, reuse, and reporting.
Battery Waste Management (Amendment) Rules, 2023	G.S.R. 4669(E) (25.10.2023)	Strengthened the institutional and compliance framework.
		Updated definitions and clarified producer obligations.
		Enhanced CPCB's role in EPR oversight.
		Revised timelines for registration and reporting.
		Permitted EPR trading platforms with price bands.

Title	Gazette Notification	Policy Description
Battery Waste Management (Amendment) Rules, 2024	G.S.R. 190(E) (14.03.2024)	Refined the EPR framework with maximum/minimum price bands linked to environmental compensation.
		Amended Rule 13 on compliance and environmental compensation.
		Allowed carry forward (up to 60%) of excess EPR obligations across compliance cycles.
Battery Waste Management (Amendment) Rules, 2025	S.O. 958(E) (24.02.2025)	Advanced labelling and compliance framework with digital labels (QR/barcodes) showing EPR registration.
		Exempted packaging under Legal Metrology Rules from specific requirements.
		Mandated CPCB to publish a quarterly list of compliant producers on the online portal.

Use of Domestically Recycled Materials – Rule 4(14), BWMR 2022

MoEFCC, vide Office Memorandum dated 17.05.2024, clarified that the minimum use of domestically recycled materials refers to any type of material such as lithium, cobalt, aluminium, graphite, plastic, and paper recovered from recycling of waste products, including end-of-life Lithium-ion Batteries. In case of imported batteries or battery packs, the marking of the EPR registration number on the equipment or its packaging shall imply compliance with this provision.

3.3 Extended Producer Responsibility (EPR) for E-waste

The *EWMR, 2022,* established a comprehensive EPR framework requiring producers to assume financial and operational responsibility for the collection, processing, and sustainable disposal of their end-of-life products[1]. EPR obligations differ for importers and refurbishers. Importers must assume 100% EPR responsibility for nd-of-life imported equipment that is not re-exported. However, refurbishers must generate EPR certificates for the materials they process. The collection and recycling targets for manufacturers with obligations are summarized in Table 3.

Table 3: Summary of EPR obligations for Electrical and Electronic Equipment OEMs.

S. No.	Year	E-waste Recycling Target (by weight)
1	2025–2026	70% of the quantity of an Electrical and Electronic Equipment placed in the market in year Y-X, where 'X' is the average life of that product
2	2026–2027	
3	2027–2028	80% of the quantity of an Electrical and Electronic Equipment placed in the market in year Y-X
4	2028–2029 onwards	
Note: The e-waste recycling target may be reviewed and increased after the end of the 2028-2029 fiscal year.		

1 *Details of the environmental compensation and stakeholder application cost for the EPR is given in Annexure IV.*

EPR target for producers (started sales operations recently, i.e., the number of years of sales operations is less than the average life of their products mentioned in the CPCB guidelines		
S. No.	**Year (Y)**	**E-waste Recycling Target (by weight)**
1	2025-2026 onwards	20% of the sales figure of the financial year two years back
Note: Once the number of years of sales operation equals the average life of their product mentioned in the guidelines issued by CPCB, their EPR obligation shall be as per the targets mentioned above.		

3.4 Extended Producer Responsibility (EPR) for Lithium-ion Battery

Under the regulatory framework, producers are required to meet defined recovery targets for different battery categories, as outlined in Table 4. For portable and EV batteries, recovery targets progressively increase from 70% to 90%, while for automotive and industrial batteries, the minimum recovery ranges between 55-60%. These provisions ensure the systematic collection, recycling, and sustainable management of End-of-Life Lithium-ion Batteries, thereby preventing the leakage of hazardous constituents and securing producer accountability across all sectors.

Table 4: Recovery targets for recyclers

Battery Type	2024-25 (%)	2025-26 (%)	2026-27 and onwards (%)
Portable and EV batteries			
Portable	70	80	90
EV	70	80	90
Automotive and industrial batteries			
Automotive	55	60	60
Industrial	55	60	60

The minimum requirements for recycled content in new batteries are summarized in Table 5. Producers must incorporate 5-20% recycled material in portable and EV batteries, and 35-40% in automotive and industrial batteries. This provision enhances circularity by ensuring a stable demand for secondary raw materials, reducing reliance on virgin resources, and promoting long-term sustainability in battery value chains.

Table 5: Mandate for minimum use of recycled content

Battery Type	2027-28 (%)	2028-29 (%)	2029-30 (%)	2030-31 and onwards (%)
Portable and EV batteries				
Portable	5	10	15	20
EV	5	10	15	20
Automotive and industrial batteries				
Automotive	35	35	40	40
Industrial	35	35	40	40

4. Global Best Practices

4.1 E-waste Management

The global framework and infrastructure development model for E-waste management are summarized in Tables 6 and 7, respectively.

Table 6: Global E-waste management frameworks.

Country	Legislation / Framework	Mechanism	Outcomes and Learnings
Switzerland	Ordinance on Return, Take-back and Disposal of Electrical and Electronic Equipment	Full producer financial and operational responsibility; Mandatory producer registration; Strict collection targets and reporting.	Highest global collection and recovery rates; Economically viable high-cost, high-efficiency systems supported by robust regulation and consumer participation.
Germany	Electrical and Electronic Equipment Act (ElektroG)	Differential EPR fees based on recyclability and hazardous content; Strong enforcement and tax incentives.	Eco-design and design-for-recycling; High compliance through strong enforcement and PPP.
European - Union (EU)	WEEE Directives (2002/96/EC and updates)	Harmonised EPR standards across member states with flexibility for national implementation.	Consistent high performance (Netherlands, Sweden); Strong consumer awareness; Convenient collection networks; Balance of common standards and national flexibility.
United States	EPA guidance under the Resource Conservation and Recovery Act; Regulation governed through 25+ State-level Acts	Consumers in California pay advance recycling fees at the time of purchase; Manufacturers in Oregon, New York, and Washington finance collection and processing based on the market/ return share.	Flexible implementation and strong private-sector participation; Uneven coverage and performance; Federal guidance and certification schemes give baseline environmental safeguards and encourage refurbishment and reuse.

Country	Legislation / Framework	Mechanism	Outcomes and Learnings
Japan	Home Appliance Recycling Law	Consumer-pay model with disposal fees collected at end-of-life; Strict producer obligations	~92% compliance and ~70% collection; Balance government oversight and private engagement; Importance of consumer awareness campaigns.
South Korea	Act on Resource Circulation of Electrical and Electronic Equipment and Vehicles	Hybrid system of producer fees and government funding; Non-compliance penalties up to 130% of recycling cost	~88% compliance and ~75% collection; Regional processing hubs reduce per-ton costs by 25–30%.
Taiwan	Waste Disposal Act (EPR system)	Comprehensive producer registration and strict enforcement	Strong performance driven by rigorous oversight and penalties.
Singapore	Resource Sustainability Act (2019)	Newly implemented EPR with IoT and blockchain tracking of waste flows	Technological innovation in waste tracking; Low consumer awareness is a challenge despite the use of advanced systems.
India	EPR under E-waste (Management) Rules, 2022	OEM's responsibility is to ensure E-waste recycling based on the quantity of Electrical and Electronic Equipment and its average lifespan. Obligations met through the purchase of EPR certificates from authorized recyclers.	National framework for producer responsibility with progressive recycling targets; EPR certificate gives market-based compliance and traceability; Strong enforcement and consumer awareness.

Table 7: Global E-waste management infrastructure development model.

Model	Country	Key Features	Key Learnings
Regional processing hubs	South Korea	Regional centers processing 100,000-200,000 tons annually for a 50-100 million population	The hub-and-spoke model reduces transport costs, enables scaling, and facilitates partnerships with the informal sector.
Collection infrastructure investment	EU, Japan	$50-100 per capita investment in collection points and transport systems	High collection rates correlate directly with upfront investment and convenient consumer access.
Authorised dismantling and recycling facilities	India	The combined capacity of registered recyclers and dismantlers exceeds total formal collection volumes. Formal collection facilities are concentrated in major urban areas.	Demonstrates early success in building formal capacity; highlights the need for geographical expansion and integration of the informal sector to increase actual throughput.

4.2 End-of-Life Lithium-ion Battery Management

Global regulatory frameworks for end-of-life Lithium-ion battery recycling vary from incentive-driven approaches to strong, legally binding mandates. While the EU and China have advanced compliance systems, India is emerging with a structured framework that prioritizes EPR, phased targets, and sector-specific focus to drive circularity and sustainability. The global scenario of end-of-life Lithium-ion battery recycling regulations is summarized in Table 8.

Table 8: Global scenario of end-of-life Lithium-ion battery recycling regulations.

Aspect	United States	EU	China	India
Blending Mandate / Incentive	Raw materials recycled in North America qualify for the IRA subsidy	2023: 50% 2030: 70%	No mandate	2027/2030: Portable and EV: 5%/20% Automotive and Industrial: 35%/40%
Battery End-of-Life Management	Most states: No commitments, guidelines under review Exceptions: New Jersey enacted EPR laws for battery OEMs	OEM is responsible for battery waste. 45-73% collection rate for portable batteries by 2030	OEM is responsible for battery waste Testing the obligation of end-of-life LIBs before recycling Storage and sorting requirements	Portable and EV: 70% Automotive: 70% Industrial: 60%

Aspect	United States	EU	China	India
Recovery Targets	Inflation Reduction Act guidelines: Extraction and processing of "critical materials"-40% in 2023 to 80% by 2027 Production and assembly of "battery components"-50% in 2023 to 100% in 2029	2031 Ni: 95% Li: 80% Co: 95% Cu: 95%	2020 Ni: 98% Li: 80% Co: 98% Mn: 98%	2024/25/26 Portable and EV: 70/80/90% Automotive and Industrial: 55/60/60%
Traceability	Not required	Required	Required	Not required
Enforcement	No binding regulations	"Battery passport"; fines of up to 10,000 EUR/ battery in Germany; other countries may follow	Accountability determined via EPR and Traceability Management (battery codification/ passport)	No enforcement mechanism is detailed as part of the regulation.

5. Addressing the Gaps in Policy Landscape

5.1 Weak Monitoring of Recyclers

Current Status/Legal Position:

Under Schedule V of the *EWMR, 2022,* SPCBs are responsible for conducting random inspections of recyclers and refurbishers, as well as for monitoring the utilisation of recycling capacity. Under Rule 12(1) of the *BWMR, 2022,* SPCBs shall verify the compliance of entities involved in the refurbishing and recycling of waste batteries through inspection and periodic audits. As per the directives of the CPCB and the National Green Tribunal (NGT), SPCBs are required to conduct random inspections of recyclers and refurbishers registered on the EPR portal.

Issue:

Despite a clear regulatory mandate, enforcement has remained weak across states. Poor enforcement has often enabled non-compliant recyclers to generate spurious EPR certificates at a lower cost, thereby undermining EPR certificate prices. Inconsistent inspections and limited audits have created gaps in compliance verification, resulting in a mismatch between registered entities on the EPR portal and actual operational recycling facilities.

Analysis:

As of 01 November 2025, there are 509 registered E-waste entities, including 381 recyclers, 128 refurbishers, and 43 Lithium-ion Battery recyclers. The existing audit mechanism relies largely on paper-based, checklist-driven verification, which fails to capture real-time recycling operations and actual processing. In the absence of regular, plant-level audits, unverified processing claims and non-operational entities continue to remain within the formal EPR system.

Therefore, to align with the systemic implementation framework, it is necessary to have a proper auditing system with specific criteria[2] aligned with international standards such as the Reuse and Recycling (R2) standards. It should have core requirements such as Environment, Health and Safety (EHS) management systems, periodic evaluation of the risk of exposure to hazardous substances, development of a legal compliance plan, import/export compliance, data security, monitoring compliance, and adherence to a mass balance approach[3]. These audit parameters would support the inspection and compliance verification of E-waste and Lithium-ion Battery recycling units, ensuring environmental compliance, transparency, and credibility within the formal recycling ecosystem. In addition to SPCB undertaking such audit

2 Machinery and Technical Setup Verification; Operational Expenditure (OPEX) Validation; Supplementary Equipment and Chemical Inventory; Labour Compliance and Workplace Welfare; Compliance with Waste Handling; EPR Registration and Compliance; Fire Safety and Groundwater Use; Contracts and Invoices with Downstream Vendors; Factory License and associated documents.

3 R2 Standard was established by Sustainable Electronics Recycling International (SERI) inspections, third-party agencies should be empowered to expedite these audits. Third-party agencies should have proper certification.

Key Recommendations:

MoEFCC to empanel third-party agencies to ensure unit-wise periodic audits.

5.2 Limited EPR Coverage Under Battery Waste Management Rules (BWMR)

Current Status/Legal Position:

The *EWMR (2022)* considers four metals (Copper, Aluminium, Iron, and Gold) under the EPR mandate.

Issue:

There are over 15 precious and critical minerals[4] with substantial recovery value. Despite the availability of material extraction technologies for these materials, the narrow scope for material recovery creates a structural mismatch, hindering wider material extraction and recycling initiatives and undermining the objectives of a circular economy.

Analysis:

E-waste material recovery assessment revealed that base metals and precious metals achieve ~52% and 55% recovery, respectively; however, critical raw materials recovery remains ~17% (Fig. 11). Estimates showed a cumulative loss of resources worth INR 42,500 Cr due to low recovery rates (REDSEER, 2025). This substantial economic and resource loss is tied to the critical recovery gap due to the regulatory scope under the current EPR framework.

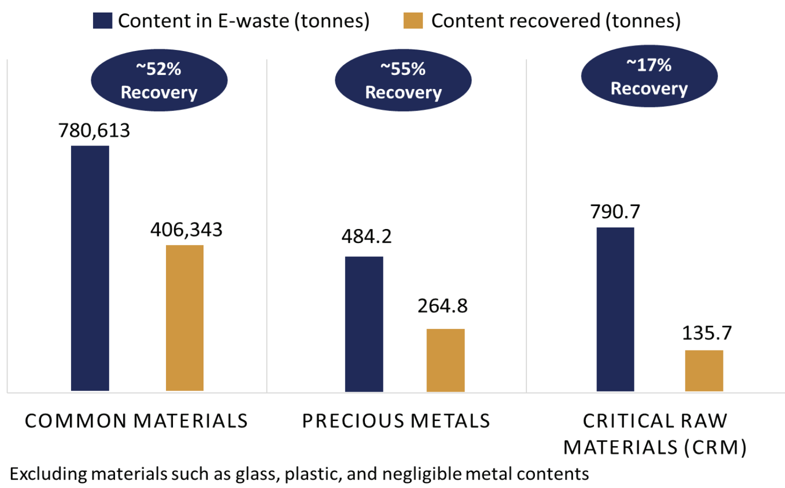

Fig. 11: Material Recovery from E-waste under the current EPR framework (Panchal et al., 2021)

Therefore, expanding material coverage under the current EPR mandate would address this gap, improve collection efficiency, and ensure that valuable resources are systematically channeled back into the economy, thereby enhancing resource security. A comparison of material recovery under current and expanded EPR mandates is shown in Fig. 12.

4 *Indicative list of materials: Silver, Platinum, Palladium, Lead, Tin, Zinc, Nickel, Cobalt, Antimony, Bismuth, Gallium, Tantalum, Rhodium, Iridium, Neodymium, Tellurium, Selenium, Indium, & Ruthenium (list drawn from Critical Mineral Recycling Incentive Scheme and international best practices). Criteria for expanding EPR may be technology, criticality, carbon saving, toxicity, financial viability, material concentration and others.*

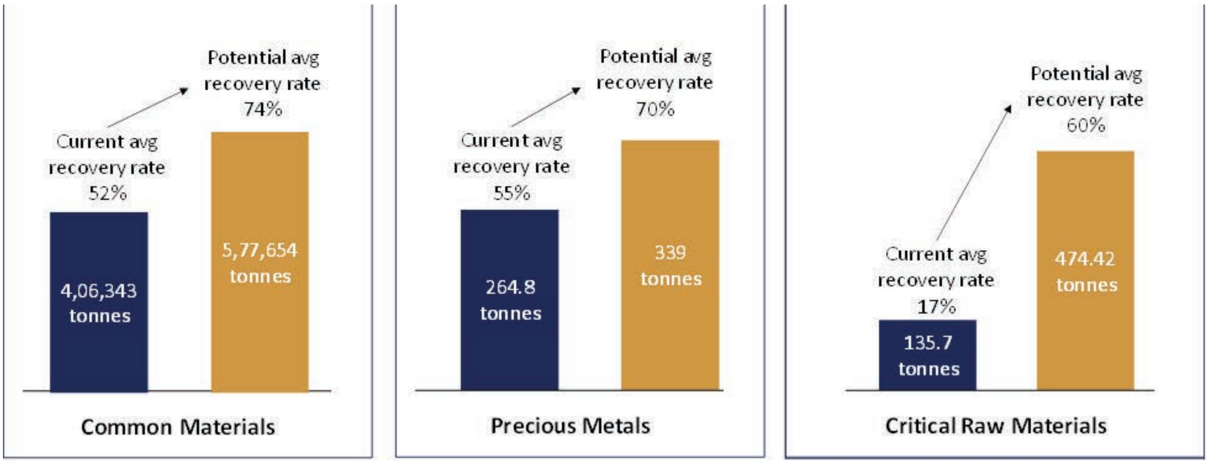

Fig. 12: Potential increase in material recovery under expanded EPR framework (Panchal et al., 2021)

Key Recommendations:

MoEFCC to develop a phased plan to expand the EPR mandate to other high-value metals.

5.3 Gaps in Battery Waste Management Rules

5.3.1 GSTN-EPR Portal Integration Gap

Current Status/Legal Position:

As per Rule 11(11) of the *BWMR, 2022,* the CPCB shall conduct data audits, including the use of information from the Goods and Services Tax Network (GSTN) portal, either directly or through a designated agency, of registered entities listed on the CPCB portal.

Issue:

Currently, the GSTN and EPR portals are not integrated, resulting in gaps in invoice verification, material traceability, and detection of fake EPR transactions. This prevents cross-verification of financial records with reported recycling activities.

Analysis:

Without invoice-level cross-verification, compliance assessments remain largely self-declared and document-based, thereby reducing the effectiveness of regulatory oversight. Integrating the GSTN portal with the EPR portal would enable verification of material flow against financial records, improving traceability across the recycling value chain. Such linkage is crucial for strengthening data authenticity, deterring fraudulent EPR claims, and supporting the credible implementation of EPR obligations under the BWMR framework.

Key Recommendation:

MoEFCC and CPCB to make improvements in the EPR portal by integrating GSTN-based invoice verification.

5.3.2 Inadequate EPR Pricing for Low-Value Lithium-ion Battery Chemistries

Current Status/Legal Position:

Rule 11(24) of the *BWMR, 2022,* empowers the CPCB to review battery recycling technologies for techno-economic viability with respect to battery material recovery.

Issue:

Currently, recycling low-value chemistries, such as Lithium Ferro Phosphate (LFP), is not economically viable due to the presence of materials like Iron and Aluminum in these chemistries. As a result, recovery of materials from such chemistries is not feasible, despite the availability of recycling technologies.

Analysis:

The economics of Lithium-ion battery recycling demonstrate a promising pathway for sustainable resource management and economic growth. Analysis (Fig. 13) of a 10 kT capacity plant reveals that the total cost of recycling, encompassing procurement, logistics, dismantling, processing, and capital expenditure, ranges from INR 294 to 350 per kilogram of battery.

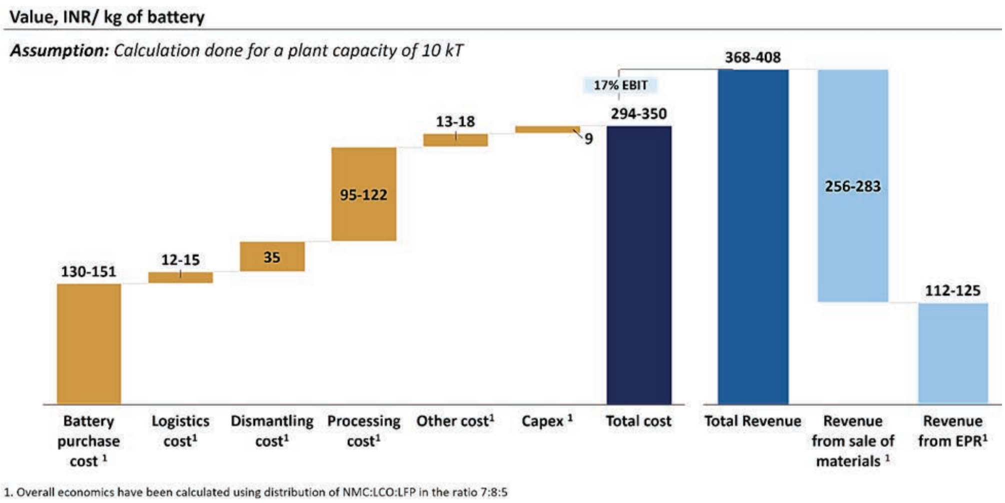

Fig. 13 Unit Economics of a 10kT Lithium-ion Battery recycling plant

(Source: Industry-provided data and consultations)

The viability of recycling is closely tied to the chemistry of the battery. Lithium Nickel Cobalt Manganese batteries provide the highest economic returns owing to their rich Cobalt and Nickel content, while Lithium Cobalt Oxide (LCO) chemistries yield moderate margins. In contrast, Lithium Ferro Phosphate (LFP) batteries generate negative margins, as the absence of low-value metals makes recovery commercially unattractive. A comparison of unit economics across key Lithium-ion Battery chemistries: Lithium Cobalt Oxide (LCO), Lithium Nickel Cobalt Manganese (NCM), and Lithium Ferro Phosphate (LFP) (Fig. 14) shows substantial variation in recycling margins driven by underlying metal value. Under the current BWMR framework, EPR targets are defined by battery type (portable, automotive, industrial, EV) and do not differentiate between Lithium-ion chemistries. As a result, low-value chemistries like Lithium Ferro Phosphate (LFP), despite their high processing cost and low intrinsic metal value, make Lithium Ferro Phosphate (LFP) recycling financially unviable for recyclers. This creates a structural misalignment between actual chemistry, economics, and the pricing assumptions built into the EPR mechanism.

Lithium Ferro Phosphate (LFP) chemistries are expected to account for nearly 60 % of India's battery demand by 2030. Therefore, without targeted interventions (such as differentiated EPR incentives or advances in material recovery), the dominance of Lithium Ferro Phosphate (LFP) could undermine overall industry profitability. On the other hand, separate EPR pricing mechanisms would compensate recyclers for low-value chemistries.

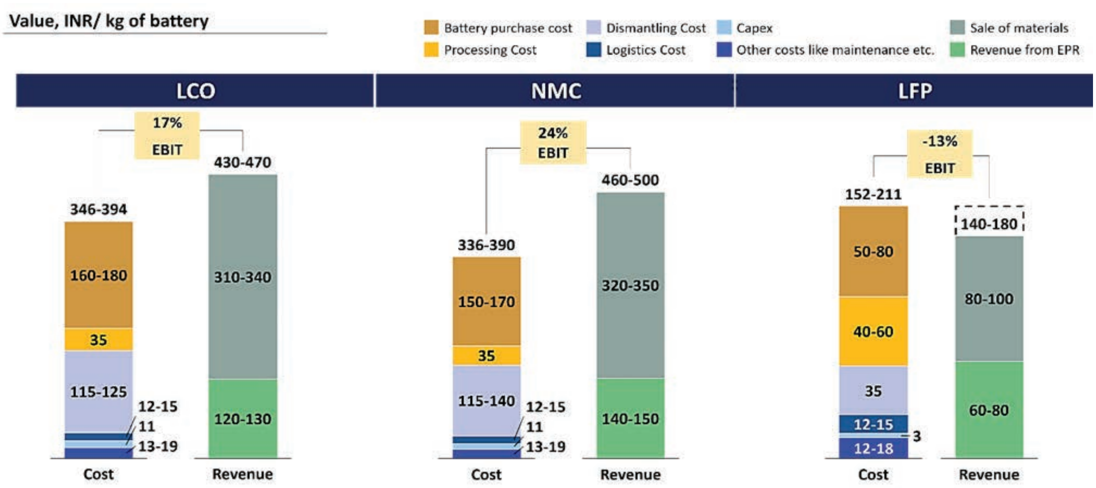

Fig. 14 Chemistry-wise unit economies of LCO, NMC, and LFP

(Source: Industry-provided data and consultations)

Various factors, including low-value material composition, emerging battery chemistries, conversion factors, and high processing and compliance costs, need to be considered when introducing a separate EPR regime for low-value chemistries. A differentiated EPR pricing mechanism for low-value chemistries, along with scale efficiencies, incentives under the National Critical Minerals Mission -Recycling Incentive Scheme, GST rationalisation, and monetisation of carbon credits, can provide critical supplementary revenue and cost support. Together, these interventions can bridge the viability gap and enhance overall economics. This approach would support recyclers and improve techno-economic viability. It also aligns EPR design with the rationale of BWMR to enable recovery of a broader range of battery materials.

Key Recommendation:

MoEFCC to develop a chemistry-specific EPR pricing framework for Lithium Ferro Phosphate (LFP) and other low-value chemistry Lithium-ion Batteries.

5.3.3 EPR Compliance Cycle for LFP EV (4W) Batteries

Current Status/Legal Position:

As per Schedule II, Table (xii) of *BWMR, 2022,* a 70% producer responsibility obligation is prescribed for four-wheeler (4W) EV batteries, with compliance commencing from 2029-30 for batteries placed in the market in 2021-22.

Issue:

The rules apply equally to all batteries, irrespective of their chemistry. Lithium Ferro Phosphate (LFP) batteries used in EVs (4W) are designed for extended operational life (~15-30 years), making early EPR compliance timelines (8 years) misaligned with the longer battery life.

Analysis:

EV batteries for 4W using Lithium Ferro Phosphate (LFP) chemistry are designed to last the lifetime of the vehicle. EPR target of 70% within eight years for Lithium Ferro Phosphate (LFP) chemistry batteries may adversely affect customer confidence and EV adoption. On the other hand, differentiated collection timelines for Lithium Ferro Phosphate (LFP) chemistry batteries used in EVs (4W) align with their longer operational life. Also, performance-based end-of-life criteria, linked to battery state of health, can inform appropriate EPR targets. For instance, Lithium Ferro Phosphate (LFP) chemistry batteries have a longer operational life and often continue in use beyond the intended service period of the EV due to their sufficient retention capacity for second-life applications. Therefore, aligning EPR compliance under BWMR with real end-of-life generation of Lithium Ferro Phosphate (LFP) batteries would support efficient resource planning, improve collection and recycling outcomes, and strengthen the circular economy. Comparative performance analysis for LFP and NMC is presented in Table 9.

Table 9: Comparative performance analysis for LFP and NMC (Source: Industry Consultations).

Parameter	LFP	NMC
Safety	High (More Stable Chemistry)	Low
Cycle life	High (2000+ cycles in first life and additional 2000 cycles in second life)	Low (1000 Cycles)
Residual capacity retention (fit for second life)	Very High	Very Low
Cost	Low	High
Energy density	Low	High
Recycling profitability	Low	High

Key Recommendation:

MoEFCC and CPCB to align EPR compliance with actual end-of-life generation.

5.3.4 Chemical Composition Verification Gap

Current Status/Legal Position:

Schedule I (2) of *BWMR, 2022,* requires producers to ensure that all batteries carry BIS-prescribed labelling. BIS certification for Lithium-ion Battery (IS 16046) emphasizes safety and performance tests, including electrical and thermal testing. There are no provisions for chemistry-wise metal composition declaration.

Issue:

In the absence of a notified chemistry-wise metal composition, producers declare variable metal content for a given chemistry, which makes it challenging to verify Lithium-ion Battery chemical composition and accurately assess material recovery and recycled content, weakening the EPR compliance verification.

Analysis:

BIS certification for Lithium-ion Batteries (IS 16046) emphasizes only safety and performance tests, including electrical and thermal testing, without requiring assessments of chemical or metal composition. Also, CPCB applies chemistry-wise metal composition ranges for Lithium-ion Batteries in the calculation of EPR certificates. The wide ranges in metal composition across Lithium-ion Battery chemistries result in producers declaring metal content on a self-assessment basis. In the absence of chemistry-wise fixed reference values, such self-declarations create variability in reported material content. In such a scenario, verifying the chemical composition of Lithium-ion Battery remains challenging in practice, which affects transparency in EPR compliance and the reporting of recovered/recycled materials. Therefore, chemical composition labelling is required to improve the accuracy of EPR determination, reduce misreporting, and enhance compliance across the Lithium-ion Battery value chain. Although the CPCB has proposed fixed metal content for Lithium-ion Batteries, chemistry-wise fixed composition benchmarks are also required. Such standardization would enhance transparency, facilitate uniform verification, and strengthen EPR accounting within the BWMR framework. The metal composition in a typical Lithium-ion Battery and different types of Lithium-ion Battery chemistries is presented in Tables 10 and 11, respectively.

Table 10: Metal composition (%) in a typical Lithium-ion Battery. (Source: CPCB)

Battery Type	Li	Mn	Zn	Ni	Co	Al	Fe	Cu
Lithium-ion	1 - 5	0 - 15	< 1	0 - 15	0 - 20	5 - 25	1 - 46	2 - 18
Lithium-ion (proposed in July 2025)	1.4	9.17	0	5	10	18.15	13.12	7.2

Table 11: Metal composition (%) based on Lithium-ion Battery chemistries. (Source: CPCB)

Lithium-ion Battery Type	Li	Mn	Ni	Co	Al	Fe	Cu
Nickel Cobalt Aluminium (NCA)	1 - 2	0	10 - 15	2 - 5	20 - 25	< 1	10 - 15

Lithium-ion Battery Type	Li	Mn	Ni	Co	Al	Fe	Cu
Lithium Manganese Oxide (LMO)	1 - 2	10 - 15	0	0	20 - 25	< 1	10 - 15
Nickel Manganese Cobalt (NMC)	1 - 2	4 - 8	12 - 16	8 - 12	20 - 25	5 - 10	12 - 18
Lithium Cobalt Oxide (LCO)	2 - 4	0	1 - 2	15 - 20	4 - 8	15 - 20	5 - 10
Lithium Iron Phosphate (LFP)	1 - 2	0	0	0	5 - 10	40 - 45	5 - 10

Key Recommendation:

(a) CPCB to notify chemistry-wise (e.g., NMC, LFP) fixed metal composition.

(b) BIS to update (IS 16046) to include mandatory chemical composition testing as part of the assessment for recycled Lithium-ion Battery.

5.3.5 Guidelines for Safe Handling of Lithium-ion Battery

Current Status/Legal Position:

Rule 11(17) of the *BWMR, 2022,* mandates the CPCB to issue guidelines for sustainable procedures for the collection, storage, transportation, refurbishment, and recycling of waste batteries, ensuring uniform and safe management practices.

Issue:

Currently, there are no guidelines for collection, storage, transportation, refurbishment, and recycling of waste batteries in place, and waste Lithium-ion batteries continue to be collected and handled through informal channels, resulting in unsafe handling practices, improper disposal, and limited traceability.

Analysis:

The absence of detailed guidelines for waste Lithium-ion Battery significantly elevates fire and safety risks across collection and transportation. Improper storage of damaged or end-of-life batteries, lack of segregation, and unsafe handling of intermediate materials, such as black mass, increase the likelihood of thermal runaway, fires, and explosions at collection centers, storage facilities, and recycling units. Therefore, clear guidelines covering safe storage conditions, packaging, labelling, and transportation protocols are critical. Standardised procedures would reduce accident risks, improve traceability, and ensure environmentally sound management of end-of-life Lithium-ion Batteries.

Key Recommendation:

MoEFCC and CPCB to issue detailed guidelines for the collection, storage, transportation, refurbishment, and recycling of waste batteries, including specific provisions for Lithium-ion batteries.

6. Nurturing the Lithium-ion Battery Recycling Industry

The demand for Lithium-ion Battery (especially for EV batteries) and the availability of end-of-life-Lithium-ion Batteries are expected to increase rapidly. However, Lithium-ion Battery recycling in India is still in its nascent stage, and capacity remains limited, with several structural constraints continuing to impede economies of scale. This section outlines the key challenges of the Lithium-ion Battery recycling industry and the recommendations for addressing them.

6.1 Standards for Recycled Content

Current Status/Legal Position:

India's battery value chain is transitioning from a disposal-focused approach to a closed-loop material system under the BWMR. As producers move towards meeting upcoming recycled-content obligations from 2026-27, the credibility, traceability, and quality assurance of recycled battery materials become central to EPR compliance. This transition requires systems that can reliably distinguish battery-grade recycled outputs from lower-grade material streams.

Issue:

Currently, there are no standards to verify the purity of recycled content recovered from Lithium-ion Battery, resulting in weak accountability in material recovery and hindering the use of recycled materials in Lithium-ion Battery manufacturing.

Analysis:

The absence of purity verification protocols creates uncertainty for producers required to use recycled content under BWMR. While initiatives such as the National Critical Minerals Mission (NCMM) set high-purity recovery targets (≥ 99.0%) for critical minerals, the lack of standardised testing and certification mechanisms hinders the consistent validation of recycled materials. Standardised protocols for verifying the purity of recycled materials can ensure a verified flow of materials and support compliance with global recycled content requirements in Lithium-ion Battery markets, thereby strengthening the outcomes of the circular economy.

Key Recommendation:

BIS to establish recycled material purity standards for Lithium-ion Battery.

6.2 Limited Recycled Content Uptake

Current Status/Legal Position:

Under the BWMR, producers are mandated to progressively use recycled content in new batteries, with obligations commencing from the 2026-27 financial year onwards. This requirement aims to promote circularity, reduce dependence on imported raw materials, and foster sustained demand for recycled battery-grade materials. Battery-grade material refers to metals recovered at high purity levels suitable for reuse in new batteries. For example, Lithium recovered as battery-grade Lithium carbonate or Lithium hydroxide at required purity levels can be directly used in cathode manufacturing. When such recycled materials replace imported virgin materials, value is added within India, strengthening the domestic battery supply chain. The effectiveness of this mandate is closely linked to the availability, quality, and commercial uptake of recycled materials within the domestic battery manufacturing ecosystem.

Issue:

The Lithium-ion Battery component manufacturing sector in India remains weak, and most battery-grade materials are imported. The demand for recycled battery-grade material remains low, constraining domestic value addition and limiting scale-up of India's battery recycling sector. This reduces commercial uptake of recycled outputs across the battery value chain.

Analysis:

Limited uptake of recycled battery-grade materials is linked to weak domestic cell manufacturing capacity, the absence of assured long-term offtake, and concerns about the consistency and quality of recycled inputs. As a result, recyclers face uncertainty in monetising recovered materials, which constrains the investment and scaling up of formal recycling infrastructure.

Therefore, the government schemes need to be leveraged, including upcoming battery manufacturing initiatives such as the Production Linked Incentive (PLI) for Advanced Chemistry Cells (ACC), which can help strengthen domestic demand for recycled battery-grade materials. Such an approach would support the utilisation of domestically recovered materials, reduce import dependence, and advance India's battery manufacturing ecosystem.

Key Recommendation:

MHI may consider leveraging upcoming battery manufacturing schemes (e.g., the PLI scheme for ACC) to support additional incentives for utilizing domestically recycled Cathode Active Material (CAM).

6.3 Untapped Potential of Carbon Markets

Current Status/Legal Position:

Recycling of waste streams falls under the "waste handling and disposal" sector of the Carbon Credit Trading Scheme (CCTS) offset mechanism in the Indian Carbon Market (ICM).

Issue:

Currently, the absence of an approved carbon-credit methodology for Lithium-ion Battery recycling prevents recyclers from earning carbon credits and monetizing climate benefits generated through material recovery and resource efficiency under Carbon Credit Trading Scheme.

Analysis:

Lithium-ion Battery recycling delivers measurable greenhouse gas (GHG) emission reductions by avoiding primary material extraction, reducing energy use, and enhancing resource efficiency. However, in the absence of an approved carbon-credit methodology under the Carbon Credit Trading Scheme, these climate benefits remain unaccounted and cannot be translated into tradable Carbon Credit Certificates (CCC). This limits the ability of recyclers to materialize environmental benefits within their business models.

A dedicated carbon-credit methodology for Lithium-ion Battery recycling would enable the standardised quantification of emission reductions based on process efficiencies, recovery rates, and avoided upstream emissions, allowing recyclers to earn CCC based on GHG emission reductions. It would serve as an additional revenue stream, incentivise formal recycling, and support the growth of India's green industry. Therefore, integrating Lithium-ion Battery recycling into the Indian Carbon Market through a robust MRV (measurement, reporting, and verification) framework would improve the techno-economic viability of advanced recycling technologies, incentivise formal sector adoption, and support the scalable deployment of low-carbon recycling infrastructure in India. The benefits of the proposed intervention are illustrated in Fig. 15.

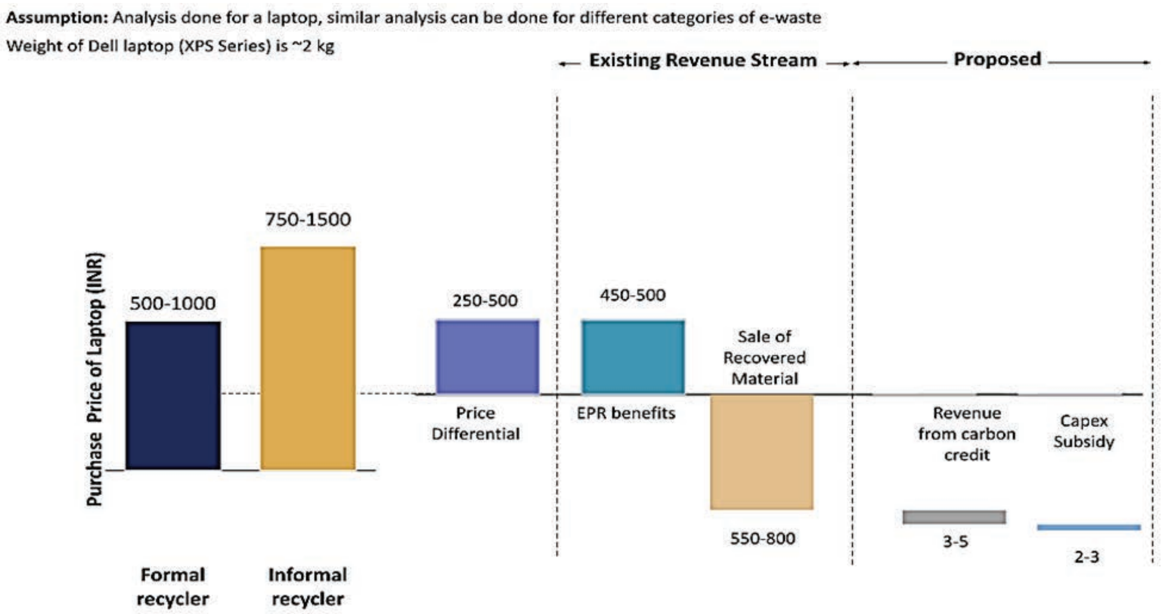

Fig. 15: Benefits of the proposed interventions

Key Recommendation:

BEE to develop a methodology for integrating Lithium-ion Battery recycling within the Indian Carbon Market through MoEFCC's Technical Committee.

7. Addressing Workforce Skill Gaps in E-waste and Lithium-ion Battery Recycling

7.1 Skilling for E-waste Recycling

Current Status/Legal Position:

E-waste recycling in the formal sector primarily relies on manual dismantling and mechanical separation.

Issue:

Manual sorting results in significant losses and leads to contamination in recovered materials, making them unmarketable for high-value applications.

Analysis:

This highlights a gap in the skilled human resources required to meet the operational demands of the E-waste recycling sector. To address this issue, the Centre for Materials for Electronics Technology (C-MET) offers E-waste management courses at the diploma and postgraduate levels through IITs (Ropar, Hyderabad, and Roorkee) and the National Institute of Electronics and Information Technology (NIELIT), Gangtok, along with the E-waste Kaushal Vikas online training portal. Despite these efforts, insufficient academic outreach limits the availability of a skilled workforce, constraining the operational efficiency and development of the E-waste recycling sector. Therefore, academic integration and outreach are necessary to address human resource gaps and support the scaling of formal E-waste recycling while maintaining technical and operational excellence.

Key Recommendation:

MeitY and MoE to establish recycling-focused material engineering and E-waste management electives across all engineering colleges and technical universities.

7.2 Absence of Certification Pathways for Informal Workers

Current Status/Legal Position:

Informal workers engaged in recycling acquire skills through on-the-job experience rather than formal training pathways.

Issue:

Despite being skilled, a lack of recognised certification limits the informal workforce's access to formal employment opportunities and keeps them confined to low-wage, low-productivity work. This gap restricts upward mobility and reduces overall workforce efficiency in the sector.

Analysis:

Streamlining onboarding requirements and easing compliance can encourage the informal workforce to transition into the formal system. This approach would also help increase the number of licensed recyclers, improve adherence to regulatory norms, and reinforce the overall performance of waste management and recycling systems.

Key Recommendation

MSDE; NSDC; CPCB; SPCBs to:

(a) Develop an industry-aligned certification and Recognition of Prior Learning (RPL) system with digital credentials to facilitate the transition of informal workers into formal employment and advanced skilling.

(b) Ensure recognition and registration of informal workers involved in dismantling and recycling.

8. Formalising the Informal Sector

Despite an established regulatory framework under the *EWMR, 2022,* the informal sector remains dominant in the recycling ecosystem and processes ~78% of India's total E-waste. While the informal sector demonstrates significant reach in collection, its operations often involve hazardous practices[5], defy compliance, and compromise safety, recovery value, and value retention, contrasting with the benefits offered by the formal sector and leading to environmental degradation. This creates massive inefficiencies, with the informal sector achieving only 10-20% material recovery rates compared to 95-97% in formal recycling facilities.

Informal E-waste processing facility (Pic: Hindustan Times)

Estimates indicate that the annual economic value of India's E-waste stream is ~INR 51,000 crores, of which ~60% is technically recoverable (Fig. 16). Current recovery systems capture only 18% of this potential. The formal sector claims only 5% and the rest flows to the informal sector (13%). The remaining 42% of the technically extractable value is lost due to poor processing and inefficiencies in the informal sector. As of today, 40% of the complex alloys and trace metals remain non-extractable due to current technological limitations. Massive soil and water contamination has also been reported at the informal recycling facilities in Bangalore, Chennai, and Delhi (Fig. 17).

5 *Environmental injustice: How informal E-waste recycling impacts human rights, Norton Rose Fulbright,* https://www.nortonrosefulbright.com/en/knowledge/publications/f54afc62/environmental-injustice-how-informal-e-waste-recycling-impacts-human-rights

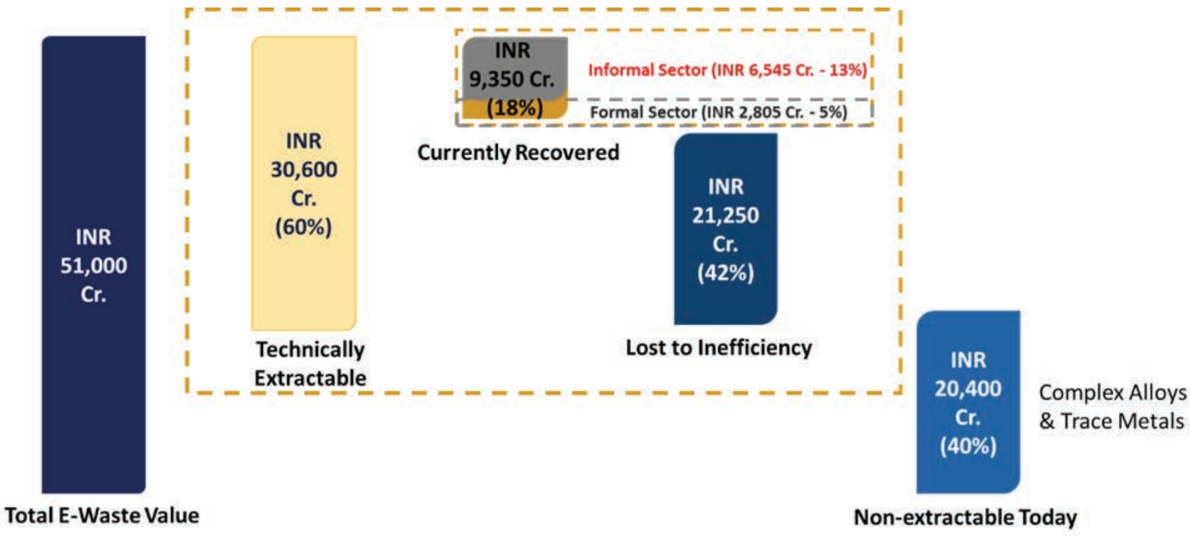

Fig.16: Economic Value Loss in the current E-waste ecosystem (REDSEER, 2025)

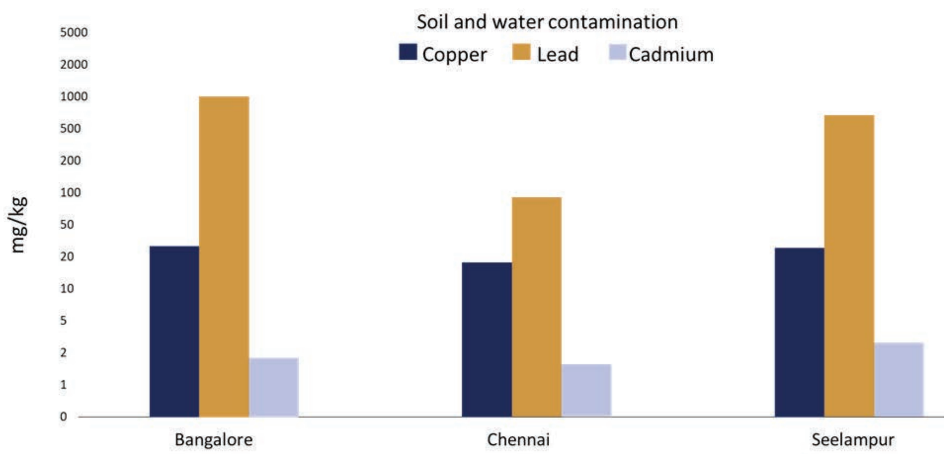

Fig. 17: Heavy Metal Contamination at Informal E-waste Processing Sites (Monday et al., 2025; Sambyal & Sohail, 2015; Shikarpur, 2016)

Given the disadvantages of the informal sector, which operates outside legal and environmental norms, efforts have been made to formalise the informal recycling system. However, it faces certain challenges, as discussed below.

8.1 Regulatory Barriers for Informal Sector Integration

Current Status/Legal Position:

The government has launched an integrated portal for mandatory registration under the *EWMR, 2022,* and the *BWMR, 2022*.

Issue:

The informal sector faces challenges in navigating the multi-stage registration process for entering the formal E-waste recycling ecosystem. Complex regulatory compliance and document requirements also pose significant barriers to the informal sector's participation in and operation within the formal system. In addition, the absence of provisions to recognise and legitimise informal workers discourages their transition into the formal recycling framework.

Analysis:

These regulatory hurdles perpetuate informality, limiting the reach and inclusivity of the country's E-waste management ecosystem. Simplifying registration procedures and lowering entry barriers can facilitate the formalization of informal recycling units, broadening the base of authorised recyclers, and enhancing regulatory compliance across the sector.

Key Recommendation:

MSME, State Governments, CPCB, and SPCBs to:

(a) Utilise the single window registration system for recyclers and the state government to facilitate their registration process.

(b) Provide a one-time waiver of liability and registration fees to informal units.

8.2 Underutilization of Government Schemes for Sector Formalization

Current Status/Legal Position:

The government has launched the Recycling Incentive Scheme (RIS) under the National Critical Mineral Mission (NCMM) and Micro and Small Enterprises - Cluster Development Programme (MSE-CDP).

Issue:

The predominant informal operations limit the availability of quality feedstock for authorised recyclers, suppressing margins and undermining the commercial viability of the formal sector. Also, eligibility conditions for incentives, "the minimum investment (in KTPA) threshold (₹25 crores)" under section 6 of National Critical Mineral Mission- Recycling Incentive Scheme, are too high for smaller and informal units.

Analysis:

Inadequate access to compliant feedstock constrains capacity expansion and dampens investment in formal recycling infrastructure. Adopting cluster-based interventions under government schemes, such as the MSE-CDP and the NCMM - Recycling Incentive Scheme, can help balance this structural imbalance by enabling shared access to safe infrastructure, skill development, and institutional finance for informal units. Linking financial and policy incentive mechanisms to verify sourcing would strengthen feedstock availability for formal recyclers, improve operational viability, and accelerate sector-wide formalization across the E-waste and Lithium-ion Battery recycling ecosystem.

Key Recommendation:

MoM, MeitY, MoEFCC, SPCBs to:

(a) Establish cluster-based Common Facility Centres (CFCs) for E-waste and Lithium-ion Battery that provide training and safe facilities for informal workers under MSE-CDP.

(b) Another category may be added in 6.1.1 as Group C (1 KTPA capacity) with a minimum investment threshold (₹1 crore), along with the addition of a revised methodology for Capex and Opex Incentive Allocation (Section 7) to benefit small informal units from the scheme for E-waste and Lithium-ion Battery waste recycling. Handholding of informal units for credit access is required under schemes with a cluster approach.

(c) Establish a separate vertical in MoM/National Critical Mineral Mission (NCMM) only on recycling.

9. Strengthening E-waste Collection and Consumer Awareness

Current Status/Legal Position:

No established template or framework for E-waste collection. Urban Local Bodies (ULBs) are conducting door-to-door collection only in a few major cities. Also, consumer awareness of safe E-waste disposal practices remains low in India.

Issue:

A fragmented and underdeveloped formal E-waste collection network and insufficient consumer awareness regarding responsible end-of-life E-waste and Lithium-ion Battery management perpetuate informal and unregulated material handling practices, leading to poor recovery rates and undermining the effectiveness of the EPR framework.

Analysis:

The consumer awareness gap is also evident from the fact that only 22% of E-waste enters authorised recycling facilities. Nearly 60% of consumers retain unused devices, resulting in an estimated 1.3 MMT of E-waste withheld from circulation. Key deterrents include the perception that devices might be useful later (31%), concerns over data privacy and data theft during disposal (28%), and the low perceived resale value of discarded electronics (24%). It is also evident from Fig. 18 that the retention rate is higher among older individuals, suggesting a greater awareness of formal waste disposal mechanisms among the younger populations.

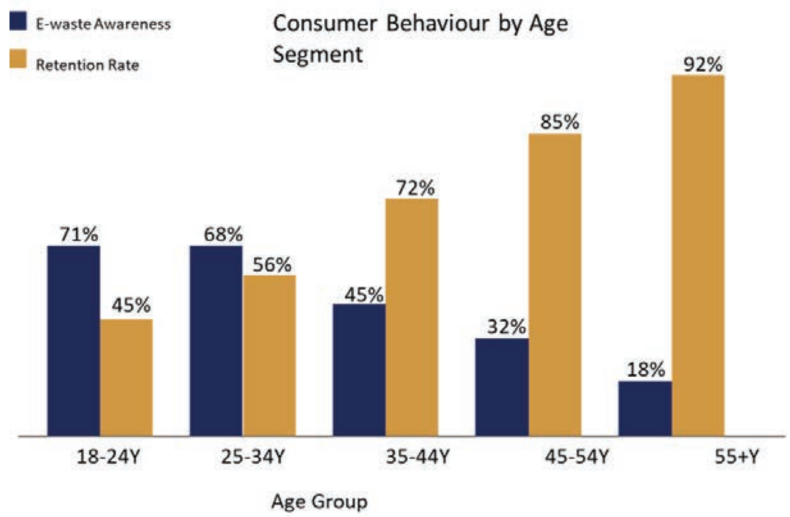

Fig. 18: Age group-based consumer behaviour on E-waste disposal (Namo eWaste, 2026; Toxics Link, 2016)

The poor accessibility of formal E-waste disposal mechanisms (only one formal collection point per 4.9 lakh people) further hinders convenient E-waste disposal for consumers.

However, as shown in Table 12, global experience suggests that the larger the number of collection centres, the higher the collection rate.

Table 12: Comparison of global and Indian E-waste collection load (REDSEER, 2025).

Country	Collection	No. of Collection Centres (for every 1 lakh population)
Germany	85%	45
Japan	78%	38
India	11%	0.1

Furthermore, the rural population has lower consumer awareness of formal waste management (<5%) than the urban population (~32%), which is directly linked to the number of formal collection points in the area. The area-wise optimised number of collection centres is presented in Fig. 19.

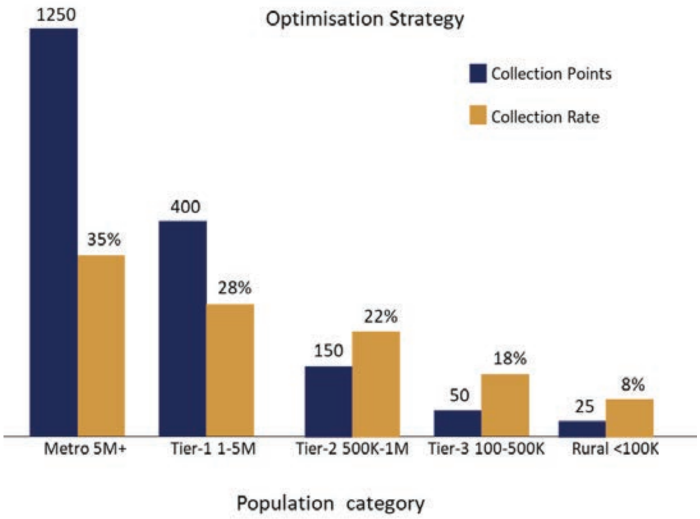

Fig. 19: Required number of collection points for optimised collection by population category (REDSEER, 2025)

Therefore, government support for collection infrastructure is required to increase formal collection. Also, wider exposure to formal E-waste management systems is necessary to sensitise citizens to the responsible disposal of E-waste.

Key Recommendation:

MoEFCC, MeitY, MHI, State Governments, and ULBs to:

(a) Support formal E-waste collection efforts (such as Selsmart, ReLoop, Bino, KaroSambhav) by establishing collection centres run on a PPP model.

(b) Provide details of collection centres and consumer-facing platforms on central and state government websites (such as *Greene*).

(c) Provide targeted advertisements in newspapers and digital media containing information and contact details (Phone number, QR Code, Hyperlinks) for formal E-waste collection platforms.

(d) Mandate the compulsory inclusion of E-waste disposal details on product packaging and manufacturers' websites.

10. Conclusion – Summary of Recommendations

As India moves forward to integrate the circular economy framework within the waste management landscape, sustainable E-waste and Lithium-ion Batteries management present a complex policy challenge and a priority resource imperative. This report has examined the current policy framework, institutional mechanisms, technological aspects, the requirement for a skilled workforce, incentivization routes, and behavioural dimensions shaping the E-waste and Lithium-ion Battery ecosystem. This report identifies persistent gaps that limit the formal collection, processing, and recovery of high-value materials from E-waste and Lithium-ion Battery scraps. The recommendations are designed to guide coordinated action by the designated implementing agencies to ensure the sustainable management of E-waste and Lithium-ion Battery scraps. A summary of the recommendations on E-waste and end-of-life Lithium-ion Battery management has been provided in Table 13.

Table 13: Summary of the recommendations on E-waste and end-of-life Lithium-ion Battery management

Recommendations	Implementation Agency
Addressing Gaps in Waste Management Rules	
Monitoring of recyclers through audits	
Empanel third-party agencies to ensure unit-wise periodic audits.	MoEFCC
E-waste Management Rules (EWMR)	
Expand E-waste EPR coverage to other high-value metals.	
Develop a phased plan to expand the EPR mandate for other high-value metals.	MoEFCC
Battery Waste Management Rules (BWMR)	
GSTN–EPR portal integration	
Enhance the EPR portal by integrating GSTN-based invoice verification.	MoEFCC; CPCB
Enhanced EPR pricing for Low-Value Lithium-ion Battery chemistries	
Develop a chemistry-specific EPR pricing framework for LFP and other low-value chemistry Lithium-ion Batterys.	MoEFCC
EPR compliance cycle for LFP EV (4W) batteries	
Introduce EPR compliance provision for LFP batteries used in EV (4W), with the compliance cycle aligned with the battery life offered by OEMs (e.g., 15 years by Tata/Mahindra).	MoEFCC

Recommendations	Implementation Agency
Chemistry-wise metal composition and labelling requirements for Lithium-ion Battery	
Notify chemistry-wise (e.g., NMC, LFP, etc.) metal composition.	MoEFCC; CPCB
Update BIS certification (IS 16046) to include mandatory chemical composition testing as part of the assessment for recycled Lithium-ion Battery.	BIS
Guidelines for Safe Handling of Lithium-ion Battery	
Issue detailed guidelines for the collection, storage, transportation, refurbishment, and recycling of waste batteries, including specific provisions for Lithium-ion Battery.	MoEFCC; CPCB
Nurturing the Lithium-ion Battery Recycling Industry	
Standardising protocols for recycled-content verification	
Establish purity standards for recycled materials in Lithium-ion Batteries.	BIS
Promoting recycled-content uptake	
Upcoming battery manufacturing schemes (e.g., the Production Linked Incentive scheme for Advanced Chemistry Cells) may consider supporting additional incentives for utilizing domestically recycled Cathode Active Material (CAM).	MHI
Leveraging carbon markets for Lithium-ion Battery recycling	
Develop a methodology for integrating Lithium-ion Battery recycling within the ICM through MoEFCC's Technical Committee.	BEE
Enhancing Skilling in E-waste Management	
Skill Development for E-waste Recycling	
Establish recycling-focused material engineering and e-waste management electives across all engineering colleges and technical universities.	MeitY; MoE
Skilled informal workers certification for better employability in the formal sector	
Develop an industry-aligned certification and Recognition of Prior Learning (RPL) system with digital credentials to facilitate the transition of informal workers into formal employment and advanced skilling. Ensure recognition and registration of informal workers involved in dismantling and recycling.	MSDE; NSDC; CPCB; SPCBs

Recommendations	Implementation Agency
Formalising the Informal Sector	
Regulatory Reforms for Informal Sector Integration	
Utilise a single-window registration system for recyclers and the state government to facilitate their registration process. Provide a one-time waiver of liability and registration fees to informal units.	MSME; State Governments; CPCB; SPCBs
Leveraging Government schemes for sector formalisation	
Leverage the following schemes: Establish cluster-based Common Facility Centres (CFCs) for E-waste and Lithium-ion Battery that provide training and safe facilities for informal workers under MSE-CDP. Another category may be added in 6.1.1 as Group C (1 KTPA capacity) with a minimum investment threshold (₹1 crore), along with the addition of a revised methodology for Capex and Opex Incentive Allocation (Section 7) to benefit small informal units from the scheme for E-waste and Lithium-ion Battery waste recycling. Handholding of informal units for credit access is required under schemes with a cluster approach.	MoM; MeitY; MoEFCC; SPCBs
Establish a separate vertical in MoMines/National Critical Mineral Mission (NCMM) only on recycling.	MoM
Strengthening E-waste Collection and Consumer Awareness	
Support collection and increasing awareness about E-waste disposal	
Support formal E-waste collection efforts (such as Selsmart, ReLoop, Bino, KaroSambhav) by establishing collection centres run on a PPP model. Provide details of collection centres and consumer-facing platforms on central and state government websites (such as *Greene*). Provide targeted advertisements in newspapers and digital media containing information and contact details (Phone number, QR Code, Hyperlinks) for formal E-waste collection platforms. Mandate the compulsory inclusion of E-waste disposal details on product packaging and manufacturers' websites.	MoEFCC, MeitY, MHI, State Governments, and ULBs

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Annexure I

Importance of E-waste Management and Circular Economy

E-waste management is crucial in advancing the circular economy, ensuring that materials retain their highest value for as long as possible through reuse, refurbishment, and recycling, rather than being disposed of linearly. This transition holds importance across several dimensions of sustainable development and economic competitiveness.

(i) **Circular Economy Integration**: The E-waste circular economy goes beyond material recovery to encompass design innovation, producer responsibility, and consumer behaviour change. Integrating E-waste management creates synergies with renewable energy and advanced manufacturing. Recovery of critical materials also reduces dependence on imports, aligning environmental and economic goals.

(ii) **Economic Opportunity:** The current E-waste management system causes significant economic losses by foregoing value recovery. Electronic devices hold far higher concentrations of valuable metals than conventional ores, showing the formal sector's potential to generate safer, better-paying jobs and enhance efficiency and environmental performance. However, innovation and technology upgradation are limited by insufficient domestic investment.

(iii) **Strategic Material Security:** E-waste management is crucial for India's material security, particularly for resources essential to clean energy and advanced manufacturing. Materials such as rare earths and specialty alloys in electronic devices remain underutilised or lost due to limited domestic processing, reinforcing import dependence and strategic vulnerability.

(iv) **Environmental Concerns:** Improper E-waste processing releases persistent toxic substances (lead, mercury, cadmium, brominated flame retardants) that cause long-term environmental harm. Soil contamination renders land unusable; toxic leachates critically contaminate groundwater; and fumes (from burning plastics and chemical processing) cause severe community health impacts, including respiratory and neurological damage, as well as increased cancer risks.

(v) **Occupational Health Hazards and Social Justice in the Informal Sector:** Workers in informal E-waste processing face severe occupational risks due to hazardous exposure (inhalation of fumes/particulates, skin/chemical contact, ingestion) and unsafe conditions/lack of protection. Adverse health effects include respiratory disorders, neurological damage, skin disorders, and reproductive issues. Child labour is a critical concern, exposing children to toxins during development. Gender dimensions include women's sorting/dismantling work in homes, contaminating entire families.

Annexure II

Methods for Recovering E-waste and Limitations

(i) **Hydrometallurgy (Water-Based Processing) -** This approach utilizes specialized chemical solutions to selectively dissolve and separate metals from E-waste components. (Fig. 19) The process works optimally for the extraction of Gold, Silver, copper, cobalt, and lithium, producing very pure metals with lower energy requirements than thermal methods. Hydrometallurgical processes achieve only 35% efficiency, compared to the 80% standard, primarily due to limited chemical processing capabilities and the absence of selective extraction systems. Current facilities lack the sophisticated chemical control systems necessary for high-efficiency metal extraction. This prevents the achievement of material purity levels demanded by secondary metal markets.

(ii) **Pyrometallurgy (Heat-Based Processing)** - High-temperature smelting operations melt E-waste to separate metals through density and chemical property differences. This method excels for mixed waste streams and high-volume processing of Gold, copper, platinum, and palladium. Current pyrometallurgical capabilities operate at only 45% efficiency, compared to the global benchmark of 85%, resulting in a substantial loss of value in high-temperature processing operations. These deficiencies prevent the processing of specialized electronic components containing high-value alloys, forcing recyclers to either export materials for processing abroad or accept significantly reduced recovery rates.

(iii) **Bioleaching -** Emerging biological processes use microorganisms to produce natural acids that dissolve metals from E-waste, offering energy efficiency and environmental benefits. However, these methods remain slow and require specific waste compositions. Indian research institutions are exploring bioleaching as a potential solution for low-grade PCBs and mining tailings, with the aim of commercial scaling. The current biometallurgical capabilities operate at only 5% efficiency in research stages, far below the 75% global efficiency achievable in biological metal extraction. Despite zero commercial deployment, bioleaching presents a critical opportunity for sustainable metal recovery, particularly for complex electronic components where biological processes offer higher selectivity and lower environmental impact than conventional chemical methods.

(iv) **Mechanical Separation** – A physical process that involves shredding E-waste and sorting the fragments by size, density, or other physical properties to recover metals, plastics, and other materials. *Its effectiveness is limited by inconsistent waste segregation, inadequate access to high-precision sorting equipment, and an inability to recover high-purity trace elements.*

(v) **Electrorefining** – An electrochemical technique used to purify metals such as copper and Silver recovered from E-waste by dissolving impure metal and redepositing it in a refined form. *This process faces challenges due to high energy requirements, chemical management issues, and limited availability of pure input streams.*

(vi) **Vacuum Metallurgy** – A method of recovering rare or volatile metals from E-waste by processing them under vacuum conditions, which allows for controlled melting, evaporation, and condensation of valuable elements. *High capital costs and limited domestic expertise have constrained its adoption.*

(vii) **Cryogenic Crushing** – A technique that uses extremely low temperatures to make materials brittle, enabling efficient separation of plastics and metals from E-waste through controlled crushing. *Its use is minimal owing to high operational costs and limited infrastructure for cryogenic processing.*

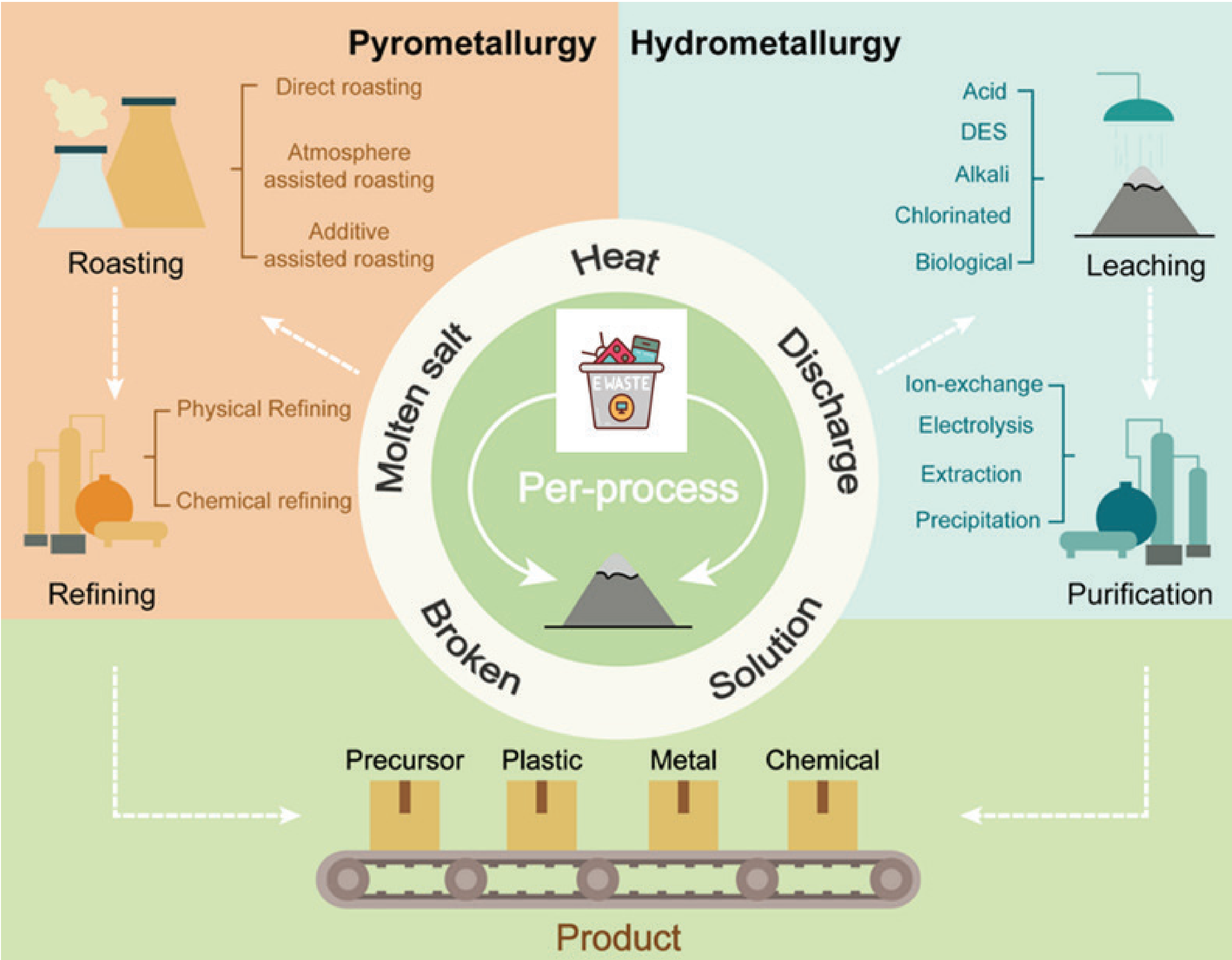

Fig. 20: Pyrometallurgy and Hydrometallurgy Processes for E-waste Recycling (Yang et al., 2022)

Annexure III

Lithium-ion Battery Recycling Technologies

Several key recycling technologies are currently available for lithium-ion batteries, as outlined below. These technologies play essential roles in recovering valuable materials and supporting circularity in the battery value chain. However, despite the availability of multiple technologies, their actual uptake remains limited due to broader economic, operational, and viability-relat ed considerations that continue to restrict large-scale adoption by recyclers.

Hydrometallurgy

In this method, the black mass is dissolved in chemical solutions, followed by leaching, solvent extraction, and crystallization to recover high-purity lithium, cobalt, nickel, and manganese. It offers high recovery efficiency with lower energy consumption compared to Pyrometallurgy. The approach, however, is more complex, requiring precise process control and adjustments for variations in battery chemistry, which can challenge standardisation at scale.

Advantage: High recovery efficiency; lower energy consumption than pyrometallurgy.

Disadvantage: Complex chemical process; requires precise control; variable by battery chemistry.

Pyrometallurgy

This high-temperature smelting process recovers metals such as cobalt, nickel, and copper, while organic materials, including electrolytes, separators, and binders, are destroyed to produce slag. It is highly tolerant of variations in feedstock and can process different Lithium-ion Battery chemistries without equipment modifications. However, lithium and aluminium are typically lost in the slag phase, and the process requires advanced gas-cleaning systems to manage emissions, leading to a higher environmental burden.

Advantage: Robust process tolerates variations; processes different chemistries without modification.

Disadvantage: High energy use, material losses, and significant environmental control requirements.

Direct-Recycling

This emerging technology recovers and regenerates cathode active materials such as NMC and LFP without breaking them down into individual metals. By preserving the structural integrity of these materials, direct recycling supports a closed-loop manufacturing model, reducing reliance on primary raw materials and eliminating specific refining steps. The main challenges include the need for uniform battery chemistry to ensure consistent quality and the additional purification needed to meet industry specifications.

Advantage: Preserves cathode integrity; supports closedloop manufacturing and reuse.

Disadvantage: High post-treatment costs; needs uniform chemistry; additional purification required.

Black Mass Recycling: Main Processes

Based on the above recycling technologies, two dominant processes are currently in use, enabling the recovery of valuable metals from black mass for reuse in the production of new batteries.

Pyrometallurgy and Hydrometallurgy

Pyrometallurgy and Hydrometallurgy are two primary methods used for recycling lithium-ion batteries. The process begins with collecting and sorting used batteries from various sources, including electric vehicles, energy storage systems, and consumer electronics. After collection, batteries are carefully tested, discharged, and dismantled to prepare them for processing. During Pyrometallurgy, batteries are smelted at high temperatures to recover valuable metals, such as cobalt, nickel, and copper, as alloys, while other elements form slag. Hydrometallurgy then utilizes solutions to extract and refine metals, resulting in compounds like nickel sulfate and cobalt sulfate. Together, these approaches help recover essential materials and support a circular economy for battery waste.

By combining safe collection, organised dismantling, and advanced processing techniques, Pyrometallurgy and Hydrometallurgy make it possible to recover key resources from spent batteries, supporting environmental sustainability and resource security.

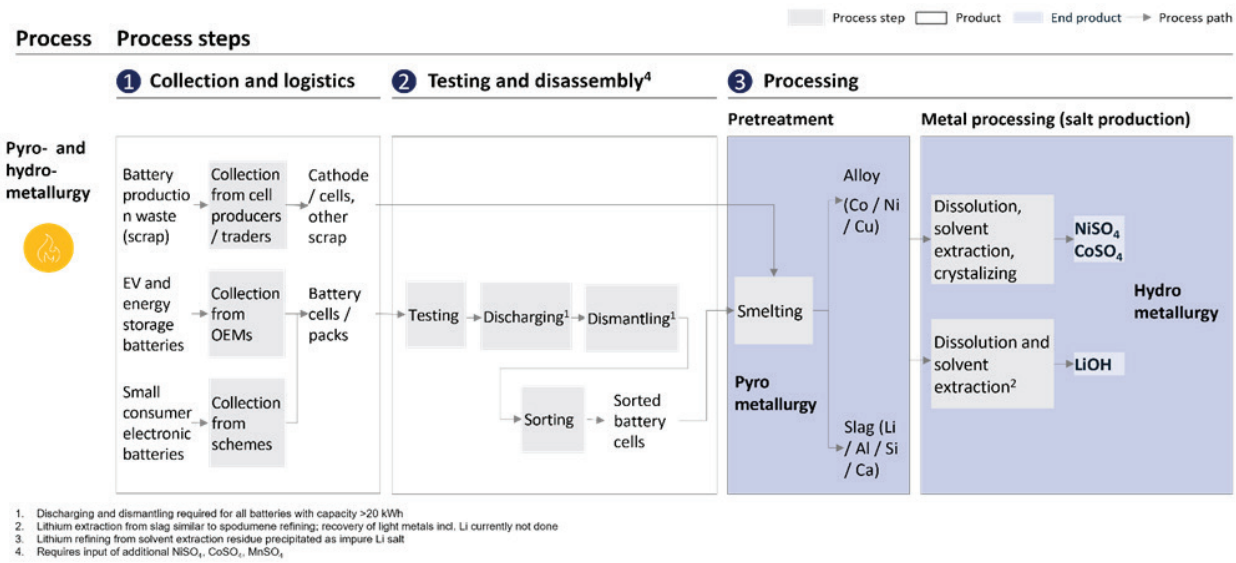

Fig. 21: Pyrometallurgy and Hydrometallurgy: Metal Extraction Pathways

Mechanical and Hydrometallurgy

Mechanical and hydrometallurgical recycling is a stepwise process that begins with the safe collection and sorting of used batteries from sources such as electric vehicles, energy storage systems, and consumer electronics. After sorting, the batteries are tested, safely discharged, and dismantled. Mechanical treatment involves crushing and separating components to produce "black mass," containing valuable metals like cobalt, nickel, and lithium, along with metal foils and plastics. The black mass then undergoes Hydrometallurgy, where leaching, purification, and crystallization recover essential metals in the form of salts. This systematic approach enables efficient recovery of critical materials and supports a sustainable, circular battery value chain.

This method aligns with best practices, emphasizing efficient material recovery with a lower environmental footprint and reinforcing sustainable battery lifecycle management.

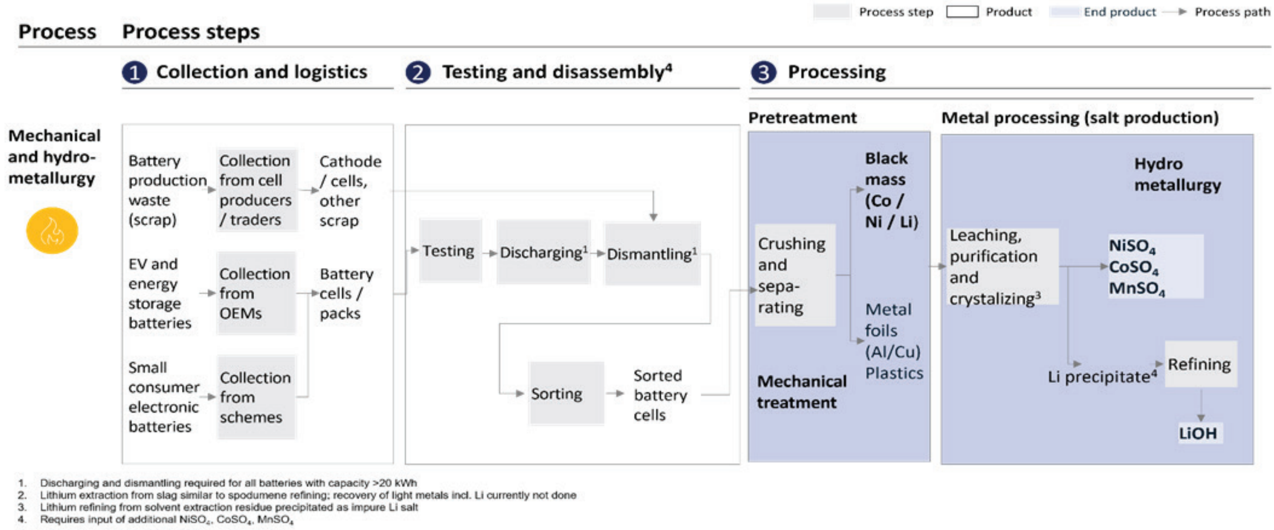

Fig. 22: Mechanical and Hydrometallurgical Processing Pathways

SOP for Utilisation of Black Mass from Lithium-ion Battery

The CPCB issued a Standard Operating Procedure (SOP) in January 2025 for the utilisation of black mass generated from dismantling and recycling of end-of-life-Lithium-ion Batteries. The SOP, notified under Rule 9 of the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, lays down the mandatory facilities, authorization process, and compliance requirements for recyclers. It also covers recovery of carbon/graphite and key metal compounds such as cobalt, manganese, nickel, lithium, copper, iron, aluminium, and sodium through hydrometallurgy. This provides a clear regulatory pathway to promote scientific recycling, ensure resource efficiency, and advance circularity in the Lithium-ion Battery value chain while safeguarding environmental and occupational health standards.

Annexure IV

(a) Regulatory Framework and Compliance Structure

CPCB Registration and Fee Structure

Registration Requirements:

- Recycler registration: ₹15,000 for five years
- Additional charges for renewals and transactions
- Mandatory manifest maintenance and mass balance reporting
- Audit requirements for EPR certificate issuance and retirement

EPR Certificate Pricing Mechanism: CPCB establishes EPR certificate price bands based on environmental compensation (EC) calculations[6], which measure the per-unit cost of collection, transportation, and processing for each material (in Rs/kg for copper, aluminium, and iron; Rs/gram for Gold). The price floor and ceiling are set at 30% and 100% of the EC, respectively. A key operational constraint is that certificate revenue is realized post-verification rather than upfront at collection, creating working capital challenges for formal operators.

Provisions in Union Budget 2025-26

To boost domestic Lithium-ion Battery manufacturing and promote a circular battery economy, the Government of India, through Notification No. 11/2025-Customs (01.022025), extended Basic Customs Duty exemption to a wide range of capital goods used in battery production, including powder dryers, blending systems, slurry transfer systems, vacuum pumps, and electrode slitting machines. Complementing this, the Union Budget 2025-26 granted full BCD exemption on Lithium-ion Battery scrap and several critical mineral wastes, including cobalt powder, lead, zinc, and twelve other minerals, to improve secondary raw material availability, lower production costs, and strengthen clean-technology industries.

(b) Global Best Practices and Technology Models

Advanced Recovery Technologies Currently Deployed

Pyrometallurgical Systems

- **Rönnskär Smelters (Boliden, Sweden)**: Processes over 100,000 tonnes annually using Kaldo furnaces and refining technology, co-treating E-waste with industrial scrap to achieve economies of scale.
- **Umicore (Belgium)**: Hybrid pyro-hydrometallurgy facility processing diverse E-waste streams with high-capacity centralized operations.

Hydrometallurgical Innovations

- **Royal Mint (UK, Wales)**: Ambient leaching technology extracting precious metals (Gold, copper, Silver) from 4,000 tonnes annually of printed circuit boards with low-emission processing.
- **BARC Resin-Based Process**: Continuous, scalable hydrometallurgical method using polymeric resin to extract high-purity copper oxide nanoparticles from PCBs.

6 *Specifics of EC mechanism as per CPCB - https://eprewaste.cpcb.gov.in/assets/PDF/EC-Guidelines-under-E-Waste-Management-Rules-2022-25.08.25.pdf.pdf*

Battery-Specific Technologies

- **VW/Duesenfeld (Germany)**: Pilot hybrid pyro-hydrometallurgy achieving ~90% EV battery recovery through LithoRec process.
- **European Battery Recycling Plants**: Facilities like Accurec (Germany) and Nickelhütte Aue, which operate with capacities of 7,000-120,000 tonnes annually, share capacity for EV and consumer batteries.

Examples of Indian Infrastructure Models

- **C-MET Demonstration Plant (Hyderabad)**: A publicly operated center featuring shredding, smelting with a rotary tilting furnace, electrorefining, and leaching. Achieves copper recovery of ~90% with Silver and Gold at 99.9% purity—accessible to informal collectors on a fee basis, providing a formalization pathway.
- **Hindalco-Metso Facility (Gujarat, upcoming):** Large-scale integrated copper recovery plant from E-waste using Kaldo furnaces and Hydrometallurgy, targeting 50,000 tonnes annually of low-carbon copper production. Located near existing copper infrastructure, enabling shared metal extraction networks.

Centre for Materials for Electronics Technology (C-MET)'s Technology Portfolio

The C-MET has developed nine critical technologies at Technology Readiness Levels (TRL) 5-8, including Lithium-ion Battery recycling system (>95% recovery efficiency), PCB processing unit (1 tone/ day pilot scale), and hydrometallurgical systems for precious metals extraction. C-MET's hydrometallurgical processing include specialized resin-based systems for extracting high-purity copper oxide nanoparticles from printed circuit boards. These technologies recover gold and silver with 99.9% purity, matching international standards for direct use in electronics manufacturing. However, commercialization remains limited at 15% success rate, constrained by high capital requirements, lack of innovation financing mechanisms, and inadequate private sector engagement in bridging the commercialization gap.

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NITI Aayog