BHARAT GAIN

Bharat Growth And Inclusion Network

Assessing Gaps in India's Electric Vehicle Battery Recycling Ecosystem

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http://www.bharatgain.org | info@bharatgain.org

Authors

Yashvika Malhan
Devyani Wadera
Sasanka Kanuparthi

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Summary

India has set an ambitious target of achieving net zero emissions by 2070, aligning with global efforts to combat climate change. As part of this goal, the country aims to significantly increase the adoption of electric vehicles (EVs), with targets of 30% in private cars, 70% in commercial vehicles, and 80% in two and three-wheelers to be sold by 2030. The policy push with initiatives like FAME (Faster Adoption and Manufacturing of Electric Vehicles) and PLI (Production Linked Incentive) is expected to propel the country's EV market, projected to grow at an impressive CAGR of 49% from 2022 to 2030. These strategic initiatives provide India with a significant opportunity to establish itself as a central hub for EV battery recycling. They offer the advantage of reducing dependence on expensive lithium imports, which account for half the cost of EV batteries, thereby lowering production costs, and making EVs more affordable domestically and globally. In addition to this, by introducing a roadmap for decreasing India's reliance on China and Hong Kong, the current leaders in the global EV recycling sector, the country could enhance its autonomy and ensure supply chain stability in the face of geopolitical uncertainties in the future. Projections indicate that by 2030, the EV sector could create 10 million direct jobs and an additional 50 million indirect jobs, highlighting its potential to reshape the employment landscape. However, the electric mobility transition agenda faces a critical challenge: Managing end-of-life EV batteries, primarily comprising Lithium-ion batteries. NITI Aayog estimates foresee a substantial requirement of 600 GWh of lithium battery storage from 2021 to 2030, indicating an anticipated need to recycle 125 GWh of batteries.

This report examines the policy and implementation gaps that hinder the establishment of a robust EV battery recycling ecosystem in India. Our objective is to analyse existing policies at both state and central levels, compare them with global best practices, and develop recommendations to address the critical need for a strong recycling infrastructure capable of handling the anticipated surge in spent EV batteries.

Sectoral Overview

Electric vehicles (EVs) represent the latest advancements in the revolution that is gripping the transport sector. The primary technology driving the shift to EVs is the lithium-ion battery (LIB). Naturally, we are seeing significant advancements in battery technology, concurrent with the advent of EVs. EVs are thus expected to continue being the largest consumer of LIBs in the foreseeable future. The global demand for LIBs is projected to reach 2.8 TWh by 2030, driven by the increasing demand for EVs. Consequently, the demand for essential materials like lithium and other minerals is also expected to rise significantly. This substantial surge will likely lead to a supply shortfall, and recycling end-of-life LIBs can mitigate this material scarcity by decreasing reliance on, amongst other things, lithium mining. India has set an ambitious target of achieving net zero emissions by 2070 i.e. to significantly increase the adoption of EVs, with targets of 30% in private cars, 70% in commercial vehicles, and 80% in two and three-wheelers to be sold by 2030.[1] In addition, these goals are supported by production-linked incentives and other inducements, which could propel the EV market to grow at a CAGR of 49% from 2022 to 2030.[2] Projections indicate that by 2030, 10 million direct jobs and an additional 50 million indirect jobs could be created, potentially reshaping the employment landscape.[3] However, India's transition to electric mobility poses significant challenges, particularly in managing end-of-life EV batteries. EVs currently represent 35 per cent of India's LIB market share, which is anticipated to rise to approximately 90 per cent by 2030.[4] NITI Aayog estimates foresee a substantial requirement of 600 GWh of lithium battery storage from 2021 to 2030, indicating an anticipated need to recycle 125 GWh of batteries.[5] This growing demand faces challenges due to the limited geographical availability of critical materials, the projected shortages, and price volatility driven by geopolitical factors. Additionally, increased mining and improper disposal of retired EV batteries could lead to various environmental impacts.

Most EVs in India are currently powered by LIBs with the country entirely dependent on imports.[6] While the Indian government introduced production-linked incentive (PLI) schemes in 2021 to mitigate this dependence and promote domestic manufacturing of advanced chemistry cells (ACCs), challenges in sourcing materials for LIB manufacturing could accentuate the difficulties. To manage these dependencies the Government of India (GoI) seeks to enhance raw material sourcing through domestic mining and bilateral agreements with resource-rich countries. By this logic, recycling used batteries could bridge this gap and facilitate the creation of an indigenous circular economy for LIBs. The materials recovered from recycling could assist in substituting raw material imports. India could recycle domestic and imported spent LIBs by expanding recycling capacities and implementing supportive policies, allowing it to transition into a 'Source Hub' of recycled raw materials for global consumption. Despite its potential, India's battery recycling infrastructure is still in the developmental stages, with a largely fragmented sector dominated by numerous informal players. Key players in the reuse sector include Nunam and Ziptrax Cleantech. Notable domestic players in the recycling space such as LOHUM Cleantech, Attero, Exigo, and TATA Chemicals are emerging, while global companies like SungEel (Korea) and Recupyl (Canada) are beginning to venture into the Indian market.

Beyond these issues, challenges persist in implementation, policy congruence, and technological disruptions in the battery reuse and recycling spheres. Despite the government's efforts in introducing the Battery Waste Management Rules, 2022, the procedures largely focus on battery recovery and segregation, obligations for battery manufacturers, importers, and automakers vis-a-vis Extended Producer Responsibility (EPR). This entails the collection of batteries to ensure appropriate processing of battery waste by authorised recyclers. While the BWMR was introduced by central authorities such as the Central Pollution Control Board (CPCB), the responsibility of enforcing the BWMR lies with the state pollution control boards (SPCBs). Enforcement and monitoring by the SPCBs are observed to be inadequate and lacking the necessary scrutiny, presenting challenges vis-a-vis the enforcement of required standards.

The BWMR does offer a compliance timeframe and well-defined targets, however, there are concerns over its visible gaps. For instance, insufficient labelling is seen as a challenge, with stakeholders suggesting the need for guidelines on the identification of chemicals in batteries. Further to this, existing design features of batteries are a concern, given the need to introduce standards for battery packaging and recycling-friendly designs. Operational costs are another obstacle, owing largely to the high transportation costs of spent batteries. Such issues act as disincentives, given their impact on recyclers and battery manufacturers, especially when regulatory mechanisms have struggled to achieve operational efficiency.

Policies oriented towards standardising designs could make way for uniform recycling processes, easing the separation process, and increasing efficiency for recyclers. Changes could be introduced to mandate transparent battery labelling, providing critical information such as chemical composition, for efficient refurbishing and recycling. However, it is important to note that consensus on adopting standards for battery designs is yet to be reached, owing to the contrarian views of private players within the battery recycling and EV industries. This poses additional challenges for policymakers vis-a-vis its enforcement, resulting in delays and process inefficiencies. Nevertheless, India must undertake several measures by devising a roadmap to ensure robustness in the EV battery recycling ecosystem. The strategy could focus on revising the BWMR, adopting suitable global best practices, negotiating standards by onboarding policy suggestions from the EV and battery recycling industry players, ensuring symmetry in policies across states, introducing appealing incentives, and optimising monitoring mechanisms and adherence to regulations.

Challenges in the Recycling Ecosystem

The recycling ecosystem linked with lithium-ion batteries confronts complex challenges, necessitating meticulous identification and robust solutions to foster a resilient framework. This ecosystem is pivotal for establishing a circular economy, vital for meeting India's escalating demand for electric vehicles (EVs), while simultaneously curbing the potential hazardous waste output. Among the preeminent challenges plaguing the sector are inadequate investment streams, technological limitations, and implementation hurdles. Addressing these formidable obstacles is imperative to lay the groundwork for sustainable battery recycling practices, propelling India's transition towards cleaner transportation and significantly mitigating environmental ramifications.

Economics of Recycling Lithium Batteries

- **Capital Cost:** Recycling lithium-ion batteries is a capital-intensive endeavour. Establishing a lithium-ion battery recycling plant with an annual capacity of 18,000 metric tonnes (MT) requires an investment ranging from INR 220 to 370 crores. Recycling of lithium-ion batteries costs between INR 100 and 150 per kilogram (on a per-unit basis). According to recyclers, the operating costs of a lithium-ion battery recycling unit are approximately 17 times higher than those of a lead-acid battery recycling unit. The annual operating expenses (OPEX) for a lithium-ion battery recycling plant are estimated to be around USD 5.25 million.[7] As there is a PLI scheme for EV manufacturing there is no PLI initiative catering to the recycling of batteries.

- **High Cost of Recycling:** According to some estimates, the total cost of recycling a lithium-ion battery in India is approximately INR 90-100 per kilogram.[8] However, the recycling process recovers only about 50% of the economic value of lithium and other metals, making it a costly endeavour. For these recycling plants to be profitable, they must operate on a large scale. At this rate, it will take plants 5 years to recover costs and generate profits. Lithium-ion battery recycling facilities require significant scale to be cost-effective. However, since the sector is still in its early stages, it could take 7-10 years for 'end-of-life' batteries to enter the recycling market in significant quantities. This long timeline emphasises the need for substantial investments and patience in the initial period before seeing financial returns.[9]

- **Transportation Costs of Battery Recycling:** Transportation costs significantly contribute to the overall recycling cost of lithium-ion batteries. Transporting these batteries accounts for about 35-50% of their purchase cost, approximately INR 200 per kilogram. For instance, transporting used EV batteries over long distances to recycling centres is typically done by truck. Because lithium batteries are classified as hazardous materials, they must be packaged and shipped under strict regulations. Adhering to these hazardous material regulations can increase transport costs to more than 50 times that of regular cargo. This high cost underscores the need for intervention in the transportation process to make battery recycling more economical.[10]

- **Financing Challenges:** Financing challenges related to EV battery recycling primarily stem from uncertainties surrounding the resale value of recycled batteries and the long-term profitability of recycling operations. Financial institutions are hesitant to invest citing the absence of standardised methodologies for determining the residual value of recycled batteries and the perceived risks associated with resale markets. Moreover, the high initial capital investment required to establish recycling facilities, and the slow return on investment due to the gradual accumulation of end-of-life batteries, further deter financiers. Additionally, the evolving regulatory landscape and uncertainty regarding future government incentives or mandates for battery recycling create additional investment risks.[11]

Adapting Recycling Technology to Keep Pace with the Changing Landscape of Battery Chemistry

The recycling technology for lithium batteries is in a nascent stage, presenting a significant challenge for recyclers and EV manufacturers. Unlike more established recycling processes, such as those for lead-acid batteries, lithium battery recycling techniques are still in the evolutionary phase and undergoing refinement. This nascent stage is characterised by the challenges in standardising methodologies and scaling infrastructure that could efficiently recover valuable materials from lithium batteries. Lithium batteries' diverse chemistries and configurations further complicate recycling, as tailored approaches become necessary for different battery types. As new chemistries are developed to enhance battery performance, safety, and sustainability, recycling methods must adapt accordingly to recover valuable materials and minimise environmental impact. Thus, while aligning technology with evolving battery technologies is essential for sustainability, the difficulties are multiplied due to the dynamic nature of battery innovation and the need for corresponding advancements in recycling techniques.

Implementation Challenges

- **Labelling and their Lifecycle:** The current Battery Waste Management Rules do not address the need for labels indicating the battery chemistries, which can vary significantly. Labels are essential for recyclers to ensure efficient disassembly, separation, and recovery of materials. Different battery materials necessitate different treatment methods during recycling. Without information about the chemistries, recyclers must allocate additional resources to analyse the battery contents before processing. Often, lithium-ion batteries arrive at recycling plants with minimal or no information, complicating disassembly. Difficulty in dismantling batteries makes sorting them correctly challenging, rendering them unusable for reuse, recycling, refurbishment, or remanufacturing without a complex investigation and 'Characterization' process.[12]

- **Lack of Information on Carbon Footprint:** The rules overlook an opportunity to utilise labels to disclose the battery's carbon footprint. Lithium-ion batteries with materials sourced globally (e.g., lithium from South America and Australia, cobalt from Congo, nickel from Indonesia), carry a significant carbon footprint. Including this information on labels would enhance transparency regarding the battery's environmental impact throughout its lifecycle, including the percentage of recycled materials like cobalt, lithium, and nickel. This approach would promote more sustainable practices in battery manufacturing and disposal.

- **Reuse, Testing, and Classification:** The absence of regulatory standards for testing and classifying used lithium batteries presents several challenges. Firstly, consumers expect reliability and longevity of second-life batteries, including the specifics of their origin from certified sources. This lack of assurance can deter consumers from adopting these batteries for various applications, such as household energy storage or backups. Additionally, the absence of regulations complicates the development of efficient recycling and refurbishing processes. When clear guidelines are found lacking, difficulties arise in determining the residual value of these batteries, which is essential for creating viable business models such as buy-back programs by original equipment manufacturers (OEMs). Furthermore, the lack of regulatory standards hampers efforts to segregate batteries suitable for refurbishment from those requiring recycling, leading to inefficiencies in the overall battery lifecycle management process.

- **Recycling-friendly from the Product Design Stage:** Right from the design phase, the current BWMR rules lacked emphasis on eco-design principles that optimise products for end-of-life management. It is crucial to anticipate dismantling and component separation at this stage, ensuring that any part of the battery that complicates dismantling is replaced, while also minimising production waste. In addition to its economic viability, this approach is time-efficient, enhancing overall productivity.[13]

- **The Collection of Batteries is Largely Informal:** The landscape of battery recycling in India is predominantly informal, with the unorganised sector playing a significant role in the collection process of retired batteries. This sector comprises itinerant collectors, scrap dealers, and informal smelters, who gather the majority of used batteries. Subsequently, they sell the recycled materials to local battery manufacturers or assemblers, who then distribute the products to retailers. In contrast, the organised sector manages the movement of batteries from end consumers to recycling plants through clearly defined channels involving registered recyclers, battery manufacturers, or vendors.[14] A market snapshot of the Lithium-Ion battery market by BatX Energy showed that the sourcing of lithium-ion batteries (LIB) from all the sources is 75% from the unorganised sector.[15] India boasts a well-established infrastructure for Lead Acid Battery (LAB) recycling, processing a substantial 2.1 million tonnes annually. Leveraging this robust system, there is potential for developing a promising Li-ion recycling ecosystem. However, a significant challenge arises from the prevalence of the informal sector, which poses a dilemma for the LAB ecosystem, with approximately 90% of these batteries entering the informal market.[16] The prevalence of the informal sector in India's battery recycling industry complicates the management of retired batteries and raises concerns about environmental and health hazards caused by informal recycling practices.

Lack of Awareness Among Consumers

Inadequate awareness regarding battery recycling is prominent among both producers and consumers. Recyclers find it challenging to make inroads into the business-to-business (B2B) segment, in addition to the issues with access to the business-to-consumer (B2C) market, which seems distant in the current landscape. Logistically, the feasibility of recyclers tapping into the B2C segment raises several questions. Thus, the potential for market access relies primarily on the level of enforcement of Extended Producer Responsibility (EPR) norms by battery manufacturers. Additionally, the collection and transportation of waste lithium-ion batteries remain formidable tasks, with less than 5% of spent lithium-ion batteries being collected at present.

Lack of Transparency

Transparency issues plague the battery recycling industry, necessitating robust oversight throughout the value chain. Many recyclers outsource material processing to vendors, emphasising the importance of thorough audits and qualifications for these vendors and their processes, particularly concerning EV battery material processing. Recycling plants must adhere to Environmental, Social, and Governance (ESG) norms while balancing them with objectives linked to maximising throughput, recovering valuable materials, and minimising costs and battery waste. Despite claims of impressive productivity rates and material recovery percentages by some recyclers, ensuring transparency and accountability becomes crucial for sustainable and responsible battery disposal practices.

Complexities of Diverse Battery Technologies

Numerous EV manufacturers, such as Tesla, Toyota, Nissan, Hyundai, and Mini Cooper, each employ unique technologies tailored to their products. These technologies cover different types of batteries (like lithium-ion, nickel-metal hydride, lead acid, and ultracapacitors), varied battery shapes (cylindrical, prismatic, and pouch), and capacities. The sheer variety of BEV models worldwide—over 150 from different manufacturers—presents a significant hurdle in establishing standardised battery renewal processes. As the global BEV market witnesses formidable growth, the need for such standardisation becomes more pressing.[17] However, this goal is complicated by ongoing research and design updates from manufacturers aimed at improving battery efficiency. The constant evolution of battery designs and compositions, driven by manufacturers' efforts to enhance performance and longevity, further complicates efforts to implement a uniform recycling process. Currently, there are no mandates to design batteries with ease of recycling in mind. This means each type of battery requires a unique disassembly process, complicating efforts to scale battery recycling and repurposing. These differences hinder recycling efficiency while highlighting the importance of collaboration between manufacturers, policymakers, and recycling industry stakeholders to develop common standards and streamline the renewal of BEV batteries at scale.

Overview of Battery Waste Management Rules (BWMR) & Battery Types

Timeline of BMWR

- Draft BWMR, 2020 – February 2020[18]
- BWMR, 2022 – August 2022[19]
- BWM (Amendment) Rules, 2023 – October 2023[20]
- BWM (Amendment) Rules, 2024 – March 2024[21]
- BWM (Second Amendment) Rules, 2024 – June 2024[22]

Countries around the globe increasingly prioritised strategies to achieve net-zero emissions by adopting innovative, low-emission, and energy-efficient pathways that minimise reliance on fossil fuels. The rapid expansion of the electric vehicle (EV) market and growing dependence on battery technology raised significant concerns about the environmental impact of battery waste. In response, India introduced several key policies to tackle these challenges. This included the Battery Management and Handling Rules (BMHR) 2001, which specifically targeted lead-acid batteries (LABs), and the E-Waste (Management and Handling) Rules, first implemented in 2011 and subsequently amended in 2016 and 2018. The E-Waste Rules were designed to enhance the recovery and reuse of materials from electronic waste, effectively reducing the volume of hazardous waste generated.

The significant rise in the number of batteries being produced and used globally highlighted the inadequacies in earlier regulations in addressing battery waste management. The Ministry of Environment, Forest, and Climate Change (MoEFCC) introduced the Battery Waste Management Rules (BWMR) in August 2022 to comprehensively regulate the recycling and disposal of batteries. These rules have undergone three major amendments, in October 2023, March 2024, and June 2024, to further strengthen and clarify the regulations.

The 2022 rules introduced Extended Producer Responsibility (EPR), requiring manufacturers, producers, importers, and recyclers to take responsibility for managing the entire lifecycle of batteries, from collection to recycling. Producers must ensure that all waste batteries are collected and either recycled or refurbished, while strictly adhering to prohibitions on disposal in landfills or incineration. EPR obligations include measurable recycling targets based on battery types such as lead-acid, lithium-ion, and nickel-cadmium batteries. Producers can either manage the collection and recycling themselves or authorise other entities to do so. The rules mandate 100% recycling or refurbishment of the collected battery waste. There are also strict labelling requirements, including the "crossed-out wheeled bin" symbol to indicate batteries should not be disposed of with regular industrial waste, along with warnings for hazardous substances like mercury, cadmium, or lead.

The rules also introduced an online system managed by the Central Pollution Control Board (CPCB) to track EPR obligations, issue certificates, and facilitate the exchange of EPR certificates between producers and recyclers. The CPCB, along with the State Pollution Control Boards (SPCBs), is responsible for monitoring compliance and imposing penalties for violations. An environmental compensation mechanism, aligned with the Polluter Pays Principle, was also introduced, where entities failing to meet their obligations would be fined.

The October 2023 amendment expanded the definition of producers to include those involved in manufacturing, assembling, or refurbishing batteries, even if they did not sell them under their brand. Producers also became responsible for managing self-use batteries and pre-consumer waste. Another significant change was the elimination of the need for producers to renew their registrations, although they are still required to meet EPR obligations even after ceasing operations.

This amendment also revised the EPR certification process, removing material recovery targets and changing the use of GST data. New platforms for trading certificates were introduced, and the CPCB's role in pricing certificates and reporting was enhanced. Additionally, labelling requirements were updated, and deadlines for EPR targets related to electric vehicle (EV) batteries were extended.

The March 2024 amendment focused on simplifying the EPR processes. A key change pertains to tying EPR certificate pricing to Environmental Compensation, ranging from 30% to 100% of the compensation amount. The scope of violations was broadened by replacing "non-fulfilment of obligations" with "non-compliance," giving the CPCB greater authority over enforcement and guideline preparation.
The June 2024 amendment extended the timeline for achieving minimum recycled material content in automotive and industrial batteries. Initially set to begin in 2024-25, the targets were pushed to 2027-28 to give stakeholders more time to adapt to evolving technologies and infrastructure.

BWMR 2024				
Type of Battery	Minimum use of the recycled materials out of the total dry weight of a Battery (in percentage) in respect of a financial year			
	2027-28	2028-29	2029-30	2030-31 and onwards
1. Portable	5	10	15	20
2. Electric Vehicle	5	10	15	20
3. Automotive	35	35	40	40
4. Industrial	35	35	40	40

Under the recent guidelines issued, EPR credit costs are set according to battery type, with rates ranging from Rs 18 per kg for lead batteries to Rs 2,400 per kg for lithium batteries. Penalties for failing to comply with regulations begin at Rs 20,000 for a first offence and escalate to Rs 40,000 and Rs 80,000 for subsequent violations. Late payments incur up to 24% annual interest, with severe consequences for delays beyond three months, including possible unit closure and legal action.[23]

Different Types of Batteries[24]

The report also explores sodium-ion (Na-ion) cells, which present a promising alternative without cobalt or nickel. These batteries are expected to achieve a specific energy density close to LFP, around 160 Wh/kg. Although Na-ion cells have lower energy density and cycle life than LIBs, they offer a broader operational temperature range and enhanced safety. Na-ion batteries operate similarly to LIBs and are anticipated to be at least 20% cheaper due to the lack of lithium. However, higher costs may arise from separators and electrolytes. One of Na-ion's key advantages is its reduced sensitivity to rising material costs, as sodium is abundantly available in many regions. If material prices increase by 10%, Na-ion material costs could rise by only 0.8%, compared to 3.2% for LFP and 4.6% for NMC 532 batteries. As a result, Na-ion battery packs are expected to become more affordable over the next decade, easing supply chain pressures currently faced by LFP and NMC cells.

Battery technology and recycling are intrinsically linked, as advancements in battery design directly influence recycling processes and the recovery of valuable materials. The NITI Aayog report highlights various battery technologies and their mineral compositions, focusing on lithium-ion batteries (LIBs). One notable type is lithium iron phosphate (LFP) batteries, which researchers discovered in the 1990s.[25] LFP batteries offer strong performance with low resistance and advantages such as long cycle life, good thermal stability, high current ratings, improved safety, and tolerance to harsh conditions. A key factor that reduces the cost of LFP batteries is the absence of cobalt, making them cheaper than other cobalt-based LIBs. However, this also results in lower nominal voltage and energy density, making them ideal for large-scale applications like stationary storage and electric vehicles (EVs). LFP batteries are widely used in electric cars, buses, and trucks, particularly in sectors where cost, volume, and weight are less of a concern.

State Government Incentives for Recycling - Snapshot

Various state governments across India have introduced comprehensive EV policies to incentivise demand and supply sides of electric mobility within their respective territories. These policies encompass a range of measures designed to encourage the adoption of electric vehicles, including subsidies, fiscal incentives, infrastructure development, and awareness campaigns. The following table provides a summary of the recycling initiatives included in these state EV policies:

State	Incentives mentioned in the State EV Policy				
	Encourages Reuse	Promotes collaboration between battery and EV manufacturers to establish recycling businesses	Prohibition on dumping EV batteries in landfills	Fiscal Incentive	Additional Incentives
Delhi	✓	✓	✗	✗	✗
Tamil Nadu	✓	✗	✗	Recycling centres set up by EV/battery manufacturers and other stakeholders will receive incentives similar to those for battery manufacturing. Protocols will be established in consultation with stakeholders.	✗
Punjab	Promotes reuse and resale through buyback schemes and e-marketplace	✓	✓	✗	Encourages OEMs and private players to establish recycling facilities, supported by the Center of Excellence (CoE) to address EV industry challenges. The state facilitates the setup of recycling units with suitable incentives.
Uttar Pradesh	✗	✗	✓	✗	• Promote 'Battery disposal facilities' at Swapping/ Charging Stations • Promote setting up of 'Collection centres' for end-of-life batteries at dealerships by EV/Battery manufacturers

State	Incentives mentioned in the State EV Policy				
	Encourages Reuse	Promotes collaboration between battery and EV manufacturers to establish recycling businesses	Prohibition on dumping EV batteries in landfills	Fiscal Incentive	Additional Incentives
Telangana	✓	✓	✗	Subsidies for cell/ battery recycling on par with EV and ancillary manufacturing	A battery disposal infrastructure model shall be created to facilitate the deployment of used EV batteries
Maharashtra	✗	✗	✗	Incentive for recycling units akin to the manufacturing facilities for EVs	The state shall notify guidelines for the safe handling and disposal of electric vehicle batteries and their components.
Andhra Pradesh	✗	✗	✗	Battery recycling plants shall receive incentives to mine for compounds from used batteries.	✗
Madhya Pradesh	✓	✓	✓	✗	• Energy Operators (EOs) and Battery Swapping Operators (BSOs) will act as recycling agencies, offering remuneration for end-of-life EV batteries. • A nodal agency will oversee the sale and purchase of batteries for renewable energy storage reuse. • The Government is to invite battery recycling businesses to Madhya Pradesh and offer investment subsidies and protocols after stakeholder consultation.
Rajasthan	✓	✓	✓	End-of-life EV batteries will be recycled to extract valuable materials, with the government providing incentives for establishing recycling facilities through industrial policy incentives.	Through their networks, partnerships, and retail centres OEMs will channel battery collection for reuse.

State	Incentives mentioned in the State EV Policy				
	Encourages Reuse	Promotes collaboration between battery and EV manufacturers to establish recycling businesses	Prohibition on dumping EV batteries in landfills	Fiscal Incentive	Additional Incentives
Odisha	✓	✓	✗	✗	• EV batteries will be clearly labelled with their specific chemistry. Benchmark labels for recyclable materials will be established to enhance recycling techniques. • EV battery manufacturers will establish free waste battery collection schemes for end users. • A well-defined policy for encouraging Recyclers shall be notified. • Synergies with existing e-waste management agencies shall be explored.
Assam	✓	✓	✓	✗	• EV owners can deposit vehicle batteries at any charging point or swapping station landfills and in return get a remunerative price for the battery • A nodal agency shall be appointed to act as an aggregator to purchase EV batteries
Chandigarh	✓	✓	✓	✗	Through their networks, partnerships, and retail centres OEMs will channel battery collection for reuse. The guidelines for the same will be notified separately.
Goa	✓	✓	✗	✗	✗
Bihar	✓	✓	✗	✗	A well-defined Policy for encouraging the re-use of batteries shall be notified
Chattisgarh	✓	✓	✗	✗	✗

State	Incentives mentioned in the State EV Policy				
	Encourages Reuse	Promotes collaboration between battery and EV manufacturers to establish recycling businesses	Prohibition on dumping EV batteries in landfills	Fiscal Incentive	Additional Incentives
Meghalaya	✓	✓	×	×	• Charging Station operators as depositing agencies • The state will facilitate inviting battery recycling businesses to establish their presence in the State. • The Government is to notify Appropriate protocols and investment subsidies for setting up such units, in consultation with stakeholders. OEMs shall also be held responsible for recycling old batteries and their components.
Haryana	×	×	×	The first 5 units establishing manufacturing facilities in the state for battery disposal, recycling, or material recovery will be eligible for a capital subsidy of 15% of FCI or INR 1 crore, whichever is lower.	Large and Mega units shall compulsorily establish a battery disposal/recycling/material recovery facility at their proposed plant for claiming any incentive.
Andaman Nicobar Islands	✓	✓	×	×	• Strict compliance with Battery Waste Management Rules • Improper disposal of the EV Batteries shall attract a fine to the tune of Rs.1,00,000/- per instance
Karnataka	×	×	×	×	The government of Karnataka will facilitate the deployment of used EV batteries for solar applications, create a secondary market and provide battery disposal infrastructure in a PPP mode.

**Note: The data is derived from the officially notified electric vehicle (EV) policies of the Indian states mentioned above. For relevant state-specific policies, please refer to the Annexure.*

General Observations

- Almost all states mention promoting reuse and collaboration between battery and EV manufacturers to establish recycling businesses while emphasising the prohibition on the disposal of EV batteries.
- States like Haryana, Maharashtra, Tamil Nadu, and Telangana suggested that specific fiscal incentives for battery recycling shall be considered.
- Odisha is the only state that mentions labelling requirements for EV batteries.
- States like Uttar Pradesh, Maharashtra, Madhya Pradesh, and Meghalaya, discuss efficient disposal mechanisms through charging stations.
- States whose EV policies do not mention recycling include Kerala, Uttarakhand, Gujarat, Jharkhand, and West Bengal.

Global Best Practices

Examining global best practices is necessary to develop effective policy tools for battery recycling. Various countries have implemented strategies in this sector, demonstrating diverse approaches to collection, disposal, traceability, and regulatory measures. The following sections highlight practices from Japan, the European Union, China, the United Kingdom, and California, providing insights for shaping robust battery recycling policies.

Country	Area of intervention	Practice
Japan	Collection and Disposal	Established in 2004, the Japan Battery Recycling Centre (JBRC) functions as a producer-responsibility organisation dedicated to facilitating the recycling of waste batteries. Consumers and businesses using battery-powered devices can return their spent batteries to registered collection sites at retailers cooperating with the JBRC. Collection sites are equipped with four types of labels for sorting different battery types. Upon request from retailers and forwarding agents, who handle collection and transportation, the JBRC arranges the collection of sorted waste batteries. The JBRC covers the costs associated with collection and recycling, typically borne by recyclers. Once received by recyclers, crushed battery residue undergoes further sorting and is either sold as recycled materials or sent to final disposal facilities. This process in Japan has effectively implemented an Extended Producer Responsibility (EPR) mechanism, legally obligating battery manufacturers to ensure safe recycling and disposal of their products. The JBRC, acting as a collective organisation, consolidates multiple manufacturers, to collectively assume responsibility for their products. Membership fees paid by manufacturers to the JBRC support an efficient battery waste management system in Japan, ensuring that recycling and delivery costs do not impede the recycling process.[26]
United Kingdom	Research and development	The United Kingdom is working to establish itself as a leading authority in battery material recovery and recycling through its Critical Mineral Strategy. Various funding initiatives have been implemented under the United Kingdom Department for Business, Energy & Industrial Strategy, since 2022 to foster a circular economy.[30]

Country	Area of intervention	Practice
European Union	Battery information	In March 2022, the EU introduced the battery passport, a digital record system, that lists information about every industrial or electric vehicle battery on the EU market with a capacity of over 2 kWh. This requires data inputs from cell producers, module producers, battery producers, automotive OEMs, and companies involved in battery servicing, refurbishing, and repurposing. The battery passport will maintain a record of each battery's components to enhance transparency throughout the supply chain. The regulation mandates a carbon footprint declaration for batteries sold in Europe starting in 2024, facilitated by the battery passport. It aims to increase transparency and traceability across the entire lifecycle of all batteries above 2 kWh through labelling and digital identity. All storage systems must include a visible QR code that provides information about the battery, including composition, capacity, durability, and environmental performance. The regulation's goal is to ensure that all batteries in the EU are sustainable, circular, and safe, setting global standards for environmental and social responsibility.[27]
China	Traceability and data management	China initiated pilot projects for battery collection, reuse, and recycling, in 2018 across 17 cities and regions, followed by a new round of projects in 20 cities in 2021. These initiatives, conducted in collaboration with automakers and recycling companies, aim to promote green battery supply chains and establish efficient tracking mechanisms for batteries throughout their life cycle. Local governments have also provided support, with examples such as Shenzhen offering incentives for local battery recycling based on the capacity of new vehicles sold, and Jiangsu province supporting nearly 1,000 electric vehicle battery recycling centres responsible for collection and initial processing. [28]
		New energy vehicles (EVs), including imported ones, must have product certification to enable traceability management. Traceability management must be applied to battery products designated for secondary use. Each enterprise is required to upload traceability information to the traceability management platform. Automobile manufacturers must upload information about recycling service outlets to this platform. Sellers are responsible for promptly reporting sales information to the vehicle manufacturer and informing the vehicle owner of the procedures for updating record information when changes occur. Recyclers, automotive manufacturers, and dealerships also incorporate recycling data. Industry and information technology departments, at the same level as the relevant regional departments, monitor and inspect the implementation of traceability responsibilities by the relevant enterprises.[29]

California

a. The Californian state established a Lithium-ion Car Battery Recycling Advisory Group in 2019 under the California Environmental Protection Agency (CalEPA) to bring policy reforms for end-of-life reuse and recycling of batteries. The advisory group informs policy reforms and legislative changes to recover and recycle lithium-ion vehicle batteries sold with motor vehicles in California.[31]

b. Members of the group include the Department of Toxic Substances Control (DTSC), the Department for Resources Recycling and Recovery (CalRecycle) and additional members from the environmental community, auto dismantlers, public and private representatives involved in the manufacturing, collection, processing and recycling of electric vehicle batteries, and other interested parties.

Limitations

1. A serious limitation concerns the significant data deficit regarding EV battery collection and their subsequent recycling or refurbishing by various companies. The BWMR mandates that the Central Pollution Control Board (CPCB) make this information available online for broader public access. Additionally, the State Pollution Control Board is expected to publish an annual list of entities that fail to fulfil their Extended Producer Responsibility obligations. This data deficiency is a hindrance, as it denies a comprehensive understanding of the EV battery ecosystem and its development over time.

2. In the 2024 Union Budget, the Central Government announced reductions in basic customs duties on 25+ critical minerals. However, despite the EV industry's efforts, EVs and their components, battery waste, etc., will see the continuation of existing GST rates.[32] Moreover, Battery recyclers and other players in the EV ecosystem suggest that varied rates for e-waste and battery waste work to the detriment of EV adoption. For instance,
   a. The tax slab imposed for e-waste is 5%, while primary cells, primary batteries and electric accumulators' waste is 18%.
   b. Recyclers and other EV industry players argue that a tax rebate would be an impactful incentive, leading to import substitution and the formalisation of the battery recycling ecosystem.[33]
   c. The high cost of compliance is viewed as a significant hurdle, as the 18% GST rate could create an informal market, slowing down the integration of recycling into the broader circular economy.

3. While stakeholders consider the custom duty reduction on critical minerals a key measure in spurring economic growth and manufacturing, India's supply chain vulnerabilities could pose long-term challenges to the domestic EV industry and battery recyclers. While it reduces the immediate cost burden for manufacturers, excessive imports from competitors like China could destabilise the domestic battery recycling ecosystem, which is struggling to remain cost-competitive and establish market demand. EV adoption is impacted further due to the high cost of batteries and scarce domestic reserves of Lithium, Nickel, Cobalt, etc., forcing OEMs to import.

4. A significant challenge also pertains to the low Extended Producer Responsibility (EPR) floor price set for battery waste recycling, with recyclers arguing that it could lead to the proliferation of illegitimate recyclers and fraudulent compliance practices. While the Ministry of Environment, Forest, and Climate Change (MoEFCC) and CPCB are currently reviewing the EPR floor price under the BWMR, fears persist over a lack of accountability.[34] These challenges are exacerbated, as a robust battery recycling policy framework and stronger guidelines on recycled battery usage are yet to be formulated.Although environmental compensation measures already exist to penalize non-compliance with BWMR rules, their enforcement must be more stringent to ensure producers adhere to recycling obligations.

5. EV industry stakeholders and battery recyclers have been advocating strongly for a PLI scheme for secondary materials, and the government responded in early July 2024 by suggesting that a PLI scheme for critical mineral recycling is under consultation.[35] As of October 2024, the government has yet to announce whether a PLI for secondary materials is still under consideration. Moreover, the centre notified the launch of a new PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM E-DRIVE) scheme in late September (to be applicable from October 2024), which it said replaced the long-awaited phase three of the Faster Adoption and Manufacturing of Hybrid & Electric Vehicles (FAME III) initiative. The scheme emphasises providing affordable and environment-friendly public transportation options and developing charging infrastructure, with any mention of the battery recycling ecosystem missing from the scheme guidelines.

Proposed Policy Measures for Fostering a Sustainable Recycling Ecosystem

India's ambition to establish itself as a premier EV hub highlights the necessity for a strategic roadmap in the battery recycling sector to overcome current challenges. To achieve this objective, the following policy interventions are proposed to enhance India's position as a sustainable recycling hub:

1. **Strengthen Labelling Requirements:** Amend the Battery Waste Management Rules 2022 to mandate clear and transparent labelling of batteries. These labels should provide essential information on battery composition, state of health, and performance metrics to facilitate effective refurbishing and recycling processes. Develop comprehensive guidelines for accurately capturing this information and ensuring it is readily accessible to recyclers. Here, we can take inspiration from the California Code of Regulations, April 2022, mentioned in Table 2.

The concept of Battery passports can also be implemented which can significantly enhance transparency and efficiency in battery recycling by providing a digital twin of the physical battery. This digital record conveys comprehensive information about the battery's composition, usage history, manufacturing details, and sustainability performance. This transparency enables recyclers to accurately identify and sort batteries, ensuring they can safely and efficiently extract valuable materials such as lithium, cobalt, and nickel. Moreover, by meticulously tracking the lifecycle of batteries, these passports optimise reuse and refurbishment efforts, thereby reducing waste and the demand for raw materials. Analysis of battery information and tracking will also enhance safety by providing detailed data on battery performance and any identified safety issues.[36]

2. **Standardisation of Batteries:** It is crucial to encourage the standardisation of lithium-ion batteries to enhance recycling efficiency. Manufacturers use diverse methods presently for battery chemistry, shapes, and sizes, complicating sustainability and repurposing efforts. The NITI Aayog's draft Battery Swapping Policy addresses the technical aspects of standardisation to facilitate interoperability across the battery-swapping ecosystem. Standardising batteries would streamline this process, allowing EVs reliable battery swapping, regardless of the manufacturer. This approach would reduce manufacturing costs and promote the use of batteries in a reusable market. Establishing recycling centres with standardised battery chemistries and uniform battery forms tailored to specific applications simplifies dismantling. Chances of hindrances to upstream innovations due to this standardisation are remote, ensuring continuous technological advancement. China's draft rules, 2017, also state that battery makers must adopt standardised and easily dismantled product designs.

3. **Streamlining Battery Collection:** The battery collection system in India is highly informal, primarily due to the absence of formal structures to streamline battery collection. An independent government agency

should oversee the collection and recycling of batteries to address this, a measure also suggested by NITI Aayog. Additionally, a private collective of producers can be formed, who can take on the responsibility of collecting batteries and recycling them. A successful example of this is in Japan, which established the Japan Battery Recycling Centre (JBRC) in 2004, a producer-responsibility organisation that ensures the continuous recycling of waste batteries. Consumers drop off used batteries at retailer collection sites registered with JBRC, which sorts them by battery type. JBRC arranges for collected batteries to be transported to recyclers, covering the costs. Recyclers then further segregate the waste for recycling or disposal. This system, funded by membership fees from battery manufacturers, creates an efficient extended producer responsibility (EPR) mechanism, ensuring manufacturers are accountable for their products' end-of-life management. Under their EV policy, states like Uttar Pradesh, Meghalaya, and Assam have designated charging and swapping stations as battery disposal centres. Other states can replicate such models with support from the union government. Increasing awareness about this initiative will help build trust among consumers. Additionally, introducing buyback schemes can further facilitate this process, ultimately promoting the adoption of electric vehicles (EVs).

4. **Support Research and Development of Recycling Technologies and Process:** Investments in research could create viable recycling methods for better yields and purity of refined battery raw materials, enhancing battery longevity and safety, and exploring alternative battery solutions with a low-CO2 supply chain abundant in India. By allocating research grants and establishing innovation hubs, India can drive significant progress in this field, leading to the development of efficient and cost-effective recycling technologies. The EU and India recently launched an Expression of Interest for start-ups in Battery Recycling Technologies for EVs under the India-EU Trade & Technology Council (TTC).[37] This initiative aims to enhance cooperation between European and Indian SMEs and start-ups, identify and support innovative start-ups, and explore investment opportunities. A matchmaking event in June 2024 featured twelve start-ups (six from each region) pitching their solutions, with six finalists selected for further collaboration and international visits. While this initiative represents one form of support, governments could take proactive steps by assisting new recycling technologies. Specifically, governments should prioritise providing robust research and development support, including funding and resources, to accelerate the development of innovative recycling methods and technologies.

5. **Cultivating a Skilled Workforce:** India can enhance its workforce by investing in vocational training and skill development programs focused on recycling technologies.[38] The Ministry of Skill Development and Entrepreneurship can lead these efforts to develop a proficient workforce. Many state EV policies already offer incentives to upskill professionals in Lithium-ion battery manufacturing, recycling, and energy transition materials.

6. **Enhancing Recovery Rates through Recycling-Friendly Design Practices:** Promoting recycling-friendly design practices through close collaboration with battery manufacturers could significantly improve recovery rates within Battery Waste Management Rules. By institutionalising these practices, we can achieve higher recovery rates for mature technologies while continuously improving recovery processes for emerging technologies. In China, for example, regulations encourage the adoption of standardised

and easily dismantled product designs to facilitate automation in the recycling process.

7. **Industry-Government Collaboration:** Fostering collaboration between the EV industry, recyclers, and the government provides fiscal support and credible backing to expand the recycling sector's growth. The recent partnership between The Technology Development Board (TDB) and startup Remine India, aimed at establishing a recycling plant in Uttarakhand, is a prime example of this synergy.[39] Encouraging such collaborations at a national scale, with state governments facilitating similar partnerships within their jurisdictions, will amplify their impact.

8. **Enhancing Battery Recycling Through Comprehensive Incentive Schemes:** The Government of India has established Production-Linked Incentive (PLI) schemes for advanced cell manufacturing, however, similar incentives are yet to be announced for battery recycling. While incentives are currently provided on a case-by-case basis, there is a need for a more direct, industry-wide approach. Under the Battery Waste Management Rules (BWMR), EV battery producers must use a specific percentage of recycled material: 5% by 2027-28 and 10% by 2028-29, with further increases planned, fostering a market for recycled materials.[40] The PLI scheme's localisation mandate also promotes the use of recycled materials. We recommend incentives under the PLI ACC scheme be distributed using a combined approach, explicitly requiring manufacturers to utilise recycled materials. For instance, Haryana offers incentives based on specific criteria, such as having a recycling facility. This approach can be expanded and refined to enhance support for integrating recycled materials in battery production.

   Alternatively, a PLI scheme focused on secondary materials could enhance the battery recycling sector by establishing a strong supply chain for recycled materials and creating a mechanism for OEMs to adopt secondary materials and recycled batteries. This approach would foster a market for recycled products, ensuring sustainable practices in battery production while benefiting both manufacturers and recyclers.

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ANNEXURE

State- wise EV Policies

State	EV Policy
Delhi	Delhi EV Policy 2020
Tamil Nadu	Tamil Nadu Electric Vehicles Policy 2023
Punjab	Punjab Electric Vehicle Policy 2022
Uttar Pradesh	Uttar Pradesh Electric Vehicle Manufacturing and Mobility Policy 2022
Telangana	Telangana Electric Vehicle and Energy Storage Policy 2020-2030
Maharashtra	Maharashtra Electric Vehicle Policy 2021
Andhra Pradesh	Andhra Pradesh Electric Mobility Policy 2018-23
Madhya Pradesh	Madhya Pradesh Electric Vehicle (EV) Policy 2019
Rajasthan	Rajasthan Electric Vehicle Policy 2022
Odisha	Odisha Electric Vehicle Policy, 2021
Assam	Electric Vehicle Policy Of Assam, 2021
Chandigarh	Chandigarh Electric Vehicle Policy – 2022
Meghalaya	Meghalaya Electric Vehicle Policy – 2021
Goa	Goa Electric Mobility Promotion Policy-2021
Bihar	Bihar Electric Vehicle Policy, 2023
Chattisgarh	Chhattisgarh State Electric Vehicle Policy 2022
Haryana	Haryana Electric Vehicle Policy 2022
Andaman Nicobar Islands	Andaman And Nicobar Islands Electric Vehicle Policy 2022
Karnataka	Karnataka Electric Vehicle and Energy Storage Policy 2017

BHARAT GAIN

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http://www.bharatgain.org | info@bharatgain.org