Towards Circular Electric Vehicle Ecosystem: Viksit Bharat's Global Vision

Perminder Jit Kaur*
Department of Economics and Public Policy,
Lal Bahadur Shastri Institute of Management, New Delhi, India
E-mail: perminder.dua@gmail.com

Introduction

Rising global temperatures, unpredictable weather patterns, and the growing incidence of urban heat islands are among the many consequences of vehicular emissions, such as carbon dioxide, which have galvanised the international community to pursue net-zero commitments. A cornerstone of this transition is the widespread adoption of electric vehicles (EVs). The Government of India (GoI) is firmly committed to a sustainable transportation system, aiming for EVs to constitute 30% of the transport sector by 2030. To this end, the GoI has introduced a suite of supportive policies, such as the Production Linked Incentive (PLI) Scheme, Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME India Scheme) Phase I and II, Phased Manufacturing Programme (PMP), etc. The Union Budget 2025-26 further allocates financial resources to boost the domestic EV manufacturing ecosystem.

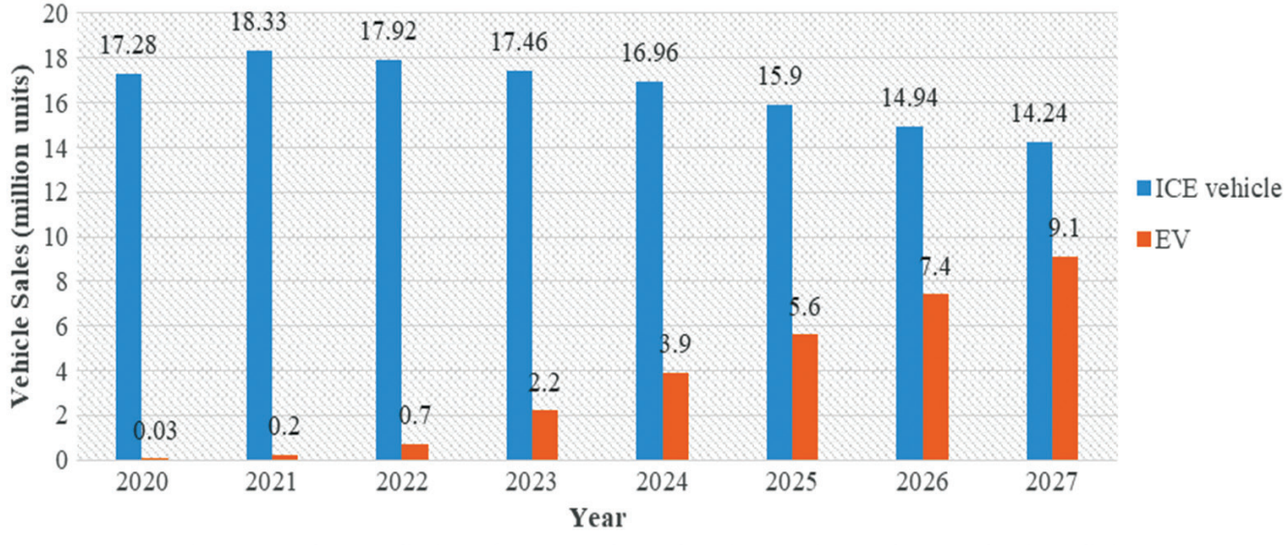


Figure 1. Sales Predictions for Internal Combustion Engine and EVs Sales in India[1]

* Orcid id: 0000-0002-1480-2798

India's EVs sector is anticipated to experience significant growth, with sales estimated to reach 9.1 million units by 2027 (Fig. 1). Consequently, the demand for EV components, such as batteries, is projected to rise sharply and reach $140 billion by 2025. Moreover, India will require 208.3 GWh of Battery Energy Storage System (BESS) by 2029-30.[2]

Circular Economy in the EV Sector

Globally, nations are working on developing charging infrastructure to facilitate EV adoption. However, equal attention must be paid to waste battery management, a key component of the EV value chain. After multiple usage cycles, the battery reaches a stage where it is no longer appropriate for vehicular applications. Depending on their charge state and capacity, they may be repurposed for stationary energy storage applications before eventually requiring disposal.[3] Many minerals used in EV batteries, like lithium, nickel, cobalt, and manganese, are designated critical minerals by India's Ministry of Mines.[4] These resources are not just economically valuable but also pose significant hazards to human health and the environment if disposed of in landfills.[5] The Battery Waste Management Rules (2025) mandate that producers of e-waste, including batteries, ensure their disposal in a scientifically designed manner.[6]

The industrial recycling supply chain starts with collecting and transporting end-of-life batteries to recycling units. Pretreatment involves discharging, dismantling, and crushing the batteries, as well as segregation of various components. Recovery of critical minerals involves either pyrometallurgical or hydrometallurgical processes. As of 2020, the global recycling capacity was more than 100,000 tons annually, with Europe having an annual recycling capacity of 52500 tons, China (33500 tons) and the US (11000 tons). India's current capacity is just 2,000 tons but is projected to reach 30000 tons by 2030.[7]

In countries like Japan and the United States, most recyclers employ pyrometallurgy, which is highly energy-intensive. Hydrometallurgical and mechanical processes are considered more environmentally sustainable but demand significant water resources and rigorous effluent management. Emerging laboratory-scale technologies, such as green adsorbents, ionic liquids and other chemical agents, offer promise for eco-friendly metal recovery.

India's Role in Global EV Progress and Circularity

India ascends as a pivotal player in clean mobility, underscored by substantial progress in research, innovation and skilled human resources. The Global Innovation Index (2023-24) shows India is at the top in the lower-middle-income countries and 39th in the overall innovation ranking. Remarkably, four Indian innovation clusters (Delhi, Mumbai, Chennai, Bengaluru) feature in the global top 100. India ranks 8th for factors such as finance for startups & scaleups and unicorn valuation % GDP.[8]

Key policy frameworks such as the National Electric Mobility Mission Plan (NEMMP) 2020 and the recently launched National Critical Mineral Mission (NCMM) 2025 aim to develop India's clean mobility sector holistically. The country is also positioning itself to provide trained and skilled human resources to the EV industry. The nation's premier academic institutions, such as the Indian Institute of Technology (IITs) and National Institute of Technology (NITs), are collaborating with leading automotive manufacturers (e.g. Mahindra and Mahindra, Tata Motors, Maruti Suzuki, and Bajaj Auto) to establish an innovative and industry-ready workforce.

Science Diplomacy to Strengthen the Circular EV Ecosystem

With increasing demand for EVs and, subsequently, batteries, it is necessary to examine the preparedness of the mining industry to meet the continuous demand for critical minerals. In 2022, the global lithium supply was 678 kilotons, projected to rise to about 4000 kilotons by 2035, calling for robust futuristic planning to meet the growing demands for minerals (Table 1).[9]

Table 1. Projected Global Demand for Raw Materials in EV Batteries by 2035[9]		
Raw Material	**Global Supply (2022, kilotons)**	**Global Demand (2035, kilotons)**
Lithium	678	4000
Cobalt	177	489
Nickel	3160	6200
Natural Graphite	1100	7210
Synthetic Graphite	2100	5200

Presently, two countries, Australia and Chile, supply 77% of global lithium, while Indonesia contributes more than half of the global nickel requirement. The existing intricately interwoven dynamic geopolitical tapestry of the critical mineral supply chain raises concerns about the long-term availability and access to these metals (Table 2).

Table 2. Geographical Availability of Selected Critical Minerals[10]		
Mineral	**Country**	**Share in Global Supply (%)**
Lithium	Australia	37
Nickle	Indonesia	59
Cobalt	Congo	76
Manganese	South Africa	37
Antimony	China	60
Vanadium	China	70
Tantalum	Congo	42
Magnesium	China	95
Barite	India	32

Batteries differ significantly in design and composition across manufacturers, complicating recycling standardisation. To tackle this, international cooperation in science, technology, and policy is imperative. Collaborative research and development in AI-powered systems can automatically detect battery types, assess their state of health, and determine whether they should be reused, repurposed, or recycled. AI, through the application of reverse logistics, can help optimise the entire recycling value chain through a transparent connection between major stakeholders, including EV users, waste battery collection and treatment units and supply of recycled metals to the required application. It can assist in predicting material recovery yields, automate disassembly processes, and guide robotic systems to extract metals safely. AI can also aid in creating data-driven strategies for logistics, inventory, and sustainability tracking, enabling companies to meet environmental regulations and improve circular economy outcomes in the EV battery ecosystem. Joint collaborative research and development projects will further help to leapfrog recycling technologies.

Some of the positive initiatives have already been underway. For instance, the India-EU Trade & Technology Council (TTC) made a joint call for the expression of interest of startups and SMEs in establishing recycling facilities and collaborating for a smoother transition towards carbon neutrality.[11] A collaborative project between NITI Aayog and the Government of the United Kingdom aims to prepare a roadmap for battery recycling.[12] Further, initiatives such as the Mineral Security Partnership (MSP),

a multilateral initiative involving 14 countries and the EU, underscore the need for diversification and strengthening the supply of global critical minerals.

Despite these initiatives, the global recycling policy landscape remains fragmented. The value chain of batteries is quite complex, involving multiple stakeholders, including battery producers, EV manufacturers, consumers, battery collectors, dismantlers, refurbishers, and recyclers. Figure 2 shows the stages and stakeholders involved in a circular EV waste battery value chain. Varied policies, geographical dispersion of stakeholders, and inconsistent standards hinder efficient cross-border collaboration. The lack of transparency, combined with geopolitical uncertainties, poses severe sustainability challenges.

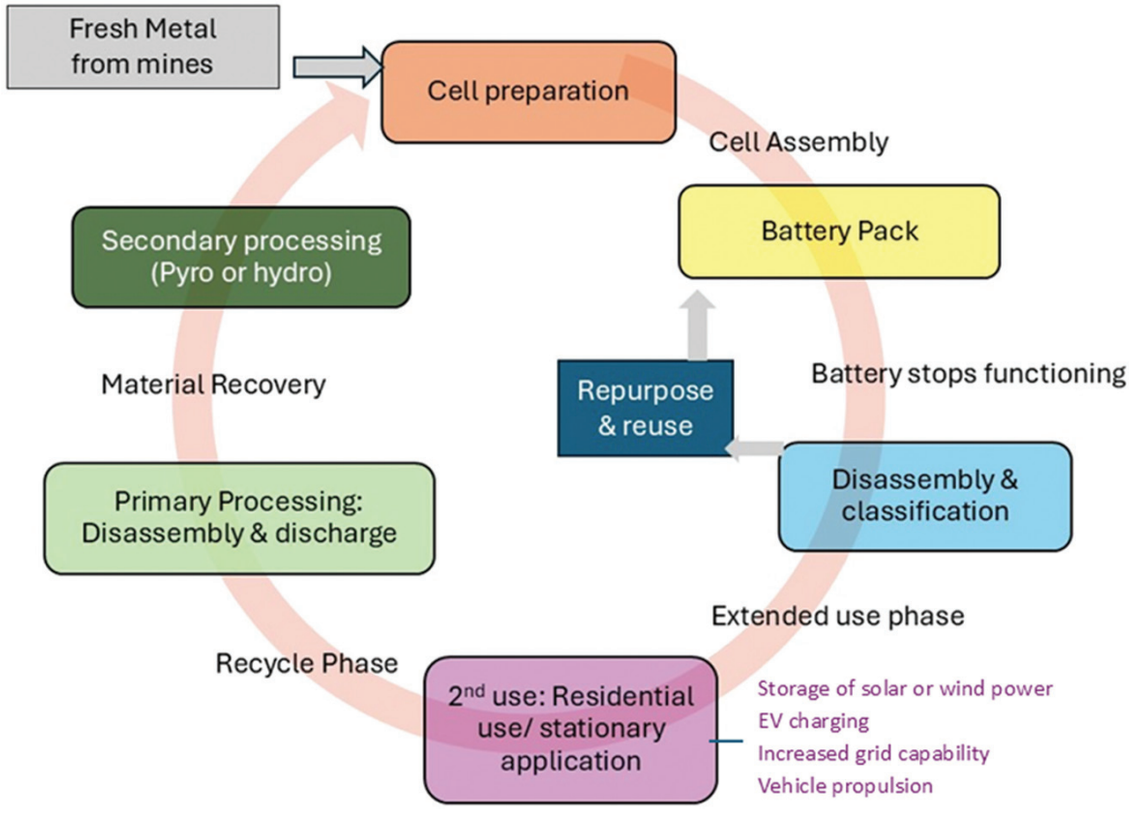


Figure 2. Circular Economy in the EV Batteries Value Chain

With the continuous global focus on expanding EVs, it is essential to establish clear and transparent global frameworks and greater international collaboration to develop a sustainable and profitable recycling system. Global funds can be established to support various clean recycling technologies that have the potential to add to the circularity of waste batteries; however, they are still at a low readiness level. For a global sustainable mobility ecosystem, it is essential to include technology transfer and global co-development for innovative battery chemistry and standardisation of recycling technologies.

Germany's Gemeinsames Rücknahmesystem Batterien (GRS Batteries) program is one of the initiatives to generate consumer awareness about the leaching of metals to soil and water from batteries disposed of in landfills. Presently, the EV battery ecosystem suffers due to the "bystander effect", as consumers are unaware of the environmental and human health hazards posed by the unscientific disposal of waste batteries.

Conclusion

To realise its EV goals while safeguarding environmental and economic interests, India must advocate for and help establish a unified global framework. Adopting and contributing to a secure, AI-enhanced

"battery passport" system is crucial, with India leveraging its IT prowess. Moreover, proactive public engagement and incentivised return schemes are vital. India must actively participate in international R&D collaborations to advance recycling technologies, potentially focusing on low-carbon methods. Market-based incentives and harmonised logistics are needed to drive sustainable practices. By embracing a circular economy approach into its EV policy, India can not only meet its climate goals but also position itself as a global leader in sustainable mobility.

References

1. EY Parthenon, INDUSLAW, IVCA (2022) Electrifying Indian Mobility. https://induslaw.com/publications/pdf/alerts-2022/Electrifying-Indian-Mobility-Report-July-2022.pdf
2. Niti Aayog Report (2024) Developing Chemistry agnostic standards for energy storage technologies. https://www.niti.gov.in/sites/default/files/2024-07/Final%20report_for%20approvl_Chemistry_Agnostic_Standards.pdf
3. Kampker A, Heimes HH, Offermanns C, Frieges MH, Graaf M, Soldan Cattani N, Späth B (2023) Cost-Benefit Analysis of Downstream Applications for Retired Electric Vehicle Batteries. World Electric Vehicle Journal, 14 (4):110. https://doi.org/10.3390/wevj14040110
4. Ministry of Mines (2023) Critical Minerals for India. https://mines.gov.in/admin/download/649d4212cceb01688027666.pdf
5. Kaur PJ, Karuturi P, Malhotra R (2023) Building a Resilient Battery Value Chain. T20 India Policy Brief. https://t20ind.org/research/building-a-resilient-ev-battery-value-chain/
6. Battery Waste Management Rules (2025), The Government of India. https://cpcb.nic.in/rules-5/
7. NITI Aayog and Green Growth Equity Fund Technical Cooperation Facility, Advanced Chemistry Cell Battery Reuse and Recycling Market in India, May 2022. https://www.niti.gov.in/sites/default/files/2022-07/ACC-battery-reuse-and-recycling-market-in-India_Niti-Aayog_UK.pdf
8. GII (2024) https://www.wipo.int/web-publications/global-innovation-index-2024/en/
9. Maisel F, Neef C, Weidemann FM, Nissen N F (2023) A forecast on future raw material demand and recycling potential of lithium-ion batteries in electric vehicles. Resources, Conservation & Recycling, 192:106920. https://doi.org/10.1016/j.resconrec.2023.106920
10. U.S. Geological Survey (2025) available at https://tableau.usgs.gov/views/MCS2025_Workbook_01-28-2025_Public/MCSDashboard?%3Aembed=y&%3Aiid=1&%3AisGuestRedirectFromVizportal=y
11. PIB (2024) EU-India join forces to promote start-up collaboration on Recycling of E-Vehicles Batteries under Trade and Technology Council. https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=2017521
12. Vishvakarma S (2024) Lithium battery recycling: Opportunities, challenges, and sustainable practices. https://www.pv-magazine-india.com/2024/03/18/lithium-battery-recycling-opportunities-challenges-and-sustainable-practices/#:~:text=This%20policy%20enforces%20Extended%20Producer,battery%20reuse%20and%20recycling%20market.