CONFERENCE PROCEEDING

Battery circularity and raw material security in India

A SUMMARY OF EXPERT PERSPECTIVES ON ACTIONS REQUIRED TO ENABLE BATTERY CIRCULARITY FOR RAW MATERIAL SECURITY IN INDIA

January 24, 2024 | Hyderabad | Compiled by: Parveen Kumar, Mitradev Sahoo, Abhishek Meshram, and Lalit Mudholkar

BACKGROUND

The global demand for lithium-ion batteries (LIBs) is expected to increase because of the rising demand for electric vehicles (EVs) and renewable energy. Therefore, effective integration of circularity in the supply chain of LIBs is crucial to secure critical minerals, decrease primary mining demand, and reduce the environmental impact. WRI India hosted a panel discussion titled "Lithium-ion battery manufacturing in India: circularity and raw material security" to discuss various pathways to integrate circularity at various stages of the LIB supply chain. The panel discussed gaps in the regulatory system, implementation challenges, and the need for technological and design innovations to enable battery circularity in India. This session was part of the "Battery manufacturing and supply chain summit" organized by the India Energy Storage Alliance (IESA). Experts on the panel (see Appendix A) discussed the key challenges for battery circularity and India-specific solutions for integrating circularity at various stages of the LIB supply chain.

The topics of discussion included the following:

- Status of raw material criticality for battery manufacturing in India and the role of battery circularity
- Gaps in policy and regulation and barriers to the integration of circularity in the EV battery supply chain
- Challenges in the development of efficient reverse logistics for retired EV batteries in India
- Strategies for capacity building, public awareness, and stakeholder collaboration to enable battery circularity in India

CONTENTS

These conference proceedings reflect the presentations and discussions of participants and do not necessarily represent the views of WRI India or other participating institutions.

- Scope for the sustainable design of battery packs and digital solutions for circular economy
- Research and innovation requirements to support battery circularity and raw material security
- Opportunities and challenges toward the development of a sustainable market for battery and black mass recycling

OVERVIEW OF BATTERY CIRCULARITY AND RAW MATERIAL SECURITY

The global demand for LIB is projected to increase from 700 GWh in 2022 to 4,700 GWh (Fleischmann et al. 2023) by 2030. EVs are expected to account for approximately 90% of the total demand (JMK Research and Analytics 2022). To meet this rising LIB demand, the global manufacturing and mining capacity needs to be scaled up manyfold from the existing capacity. Integrating circularity by designing LIBs for reuse and recycling, and implementing processes for end-of-life (EoL) reuse and recycling can ensure efficient resource utilization and provide emission benefits throughout the LIB life cycle. For example, EoL battery recycling has the potential to reduce the global primary mining demand by 55% for copper (Cu), 25% for lithium (Li), and 35% for cobalt (Co) and nickel (Ni) (Dominish et al. 2021) by 2040. In addition, battery circularity can help achieve a 7–17% net reduction in battery life-cycle emissions.

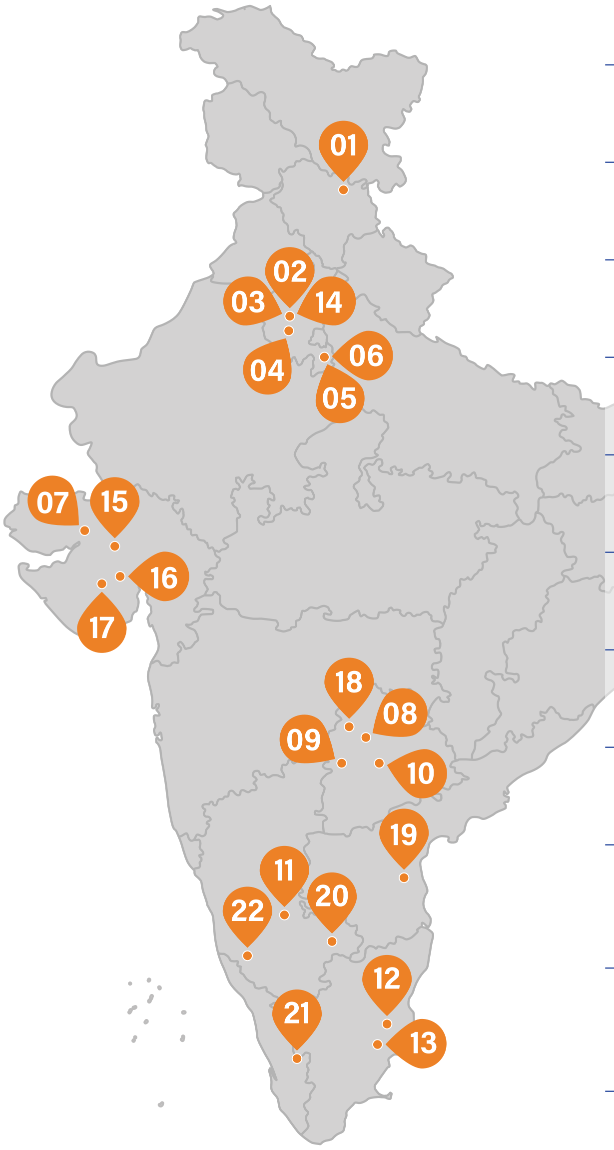
Globally, most feedstock for LIB recycling comes from production scrap, which is expected to shift to EoL LIBs by 2030. The production scrap rates vary, with the best manufacturers, typical manufacturers, and new battery manufacturers generating approximately 5%, 10%, and 30%, respectively (Gaines et al. 2021). The adoption of innovative solutions, such as automation and artificial intelligence, can help minimize production waste and facilitate second-life application (SLA) along with EoL recycling, thus reducing the primary mining demand for critical materials. Note that the remaining capacity (i.e. 70–80% of the initial capacity) of retired EV batteries can be utilized for SLAs. At the global level, the growing EV market is projected to offer approximately 200 GWh of second-life utilization capacity for retired LIBs, from EVs by 2030 (Zhu et al. 2021). However, a circularity-friendly battery design is crucial for making reuse and recycling cost effective and safe. For example, the various types of modules used in battery packs significantly affect disassembly costs. Currently, India is in the early stage of cell manufacturing, and there is an opportunity to adopt innovative solutions to integrate circularity at the manufacturing stage and develop an SLA market along with a robust recycling industry to secure battery-grade raw materials from urban mining.

In August 2022, the Ministry of Environment, Forest and Climate Change introduced the Battery Waste Management Rules (BWMR), 2022, to integrate recycling into the LIB supply chain. This rule includes extended producer responsibility (EPR), which holds manufacturers and producers accountable for collecting used batteries. However, several challenges hinder the effective implementation of a circular economy for LIBs in India. These challenges include the presence of large-scale unorganized players in battery collection, lack of a domestic black mass recycling market, uncertainty in the economic viability of business models for reuse and recycling, lack of stakeholder collaboration, and low public awareness. Therefore, it is essential to develop the necessary policy and regulatory framework, standards, sustainable business models, and an India-specific strategy for battery circularity.

LIB manufacturing and circularity

In India, the cumulative demand for LIBs is projected to reach 785 GWh between 2022 and 2030. India has imported LIB cells worth US$2.8 billion in 2023 up from $328 million in 2017. To develop the domestic LIB manufacturing industry, the Government of India is incentivizing up to 50 GWh of cell manufacturing through the production-linked incentive (PLI) scheme for the advanced chemistry cell battery storage. With the emergence of new giga factories in India, the annual LIB cell manufacturing capacity is expected to scale to 500 GWh by 2035 (Business Standard 2023). Figure 1 shows the proposed cell-manufacturing companies and their respective capacities.

FIGURE 1 | Key LIB cell and pack manufacturers in India

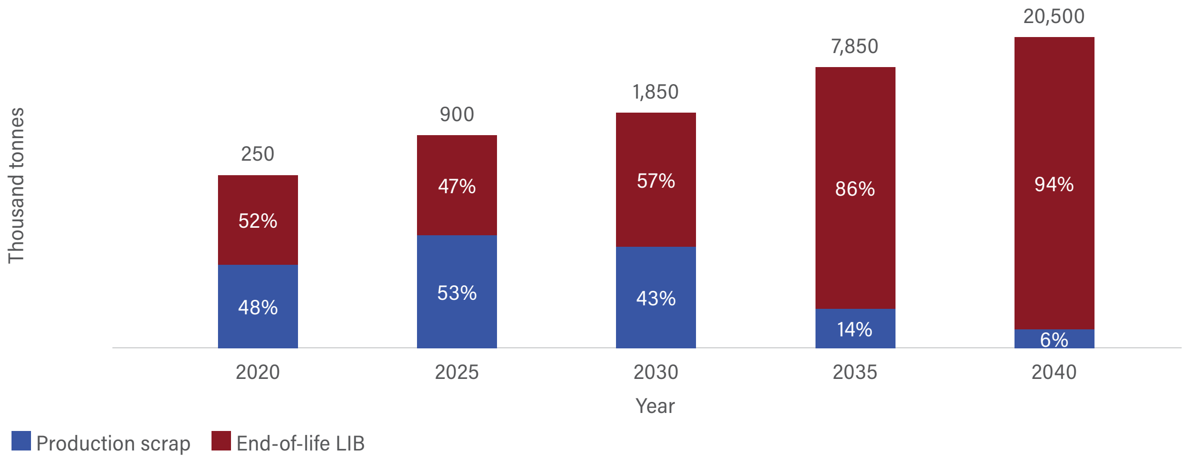


01.	OKAYA	Himachal Pradesh 288 MWh of packs/year (2022)
02.	EXICOM POWER SOLUTIONS	Gurugram, Haryana 1 GWh of packs/year (2022)
03.	CTECHE	Gurugram, Haryana NMC & LFP
04.	ipower Batteries	Kundli, Haryana ~155,000 packs/year
05.	INVERTED	Delhi 100 MWh of packs/year (2022)
06.	TRONTEK	Delhi 350 MWh of packs/year (2022)
07.	RELIANCE	Jamnagar, Gujarat 50 GWh LIB cells by 2027
08.	PURE	Hyderabad, Telangana, 250 MWh of packs/year (2022)
09.	cygni	Hyderabad, Telangana, 250 MWh of packs/year (2022)
10.	RACEnergy	Hyderabad, Telangana
11.	LOG9	Bengaluru, Karnataka 50 MWh of LIB cells (2023)
12.	GRINNTECH	Chennai, Tamil Nadu 400 MWh of packs/year (2022)
13.	ATHER	Hosur, Tamil Nadu 120,000 packs/year
14.	ATL Battery Technology (India)	Gurugram, Haryana Li-ion polymer
15.	TDSG	Ahmedabad, Gujarat LTO Cells Capacity: > 1 GWh (Plan)
16.	nexcharge	Prantij, Gujarat LTO & NMC cells Capacity: 1.5 GWh (Target)
17.	TATA CHEMICALS LIMITED	Dholera, Gujarat Capacity: 10 GWh (Plan)
18.	GODI	Hyderabad, Telangana LFP & NMC cells Capacity: 5 GWh (Plan)
19.	AMARA RAJA	Tirupati, Andhra Pradesh Low cost Li-ion battery
20.	C4V Charging Ahead!	Karnataka BM-LMP cells Capacity: 5 GWh (Plan)
21.	24m	Chennai, Tamil Nadu LIB/Semisolid lithium batteries Capacity: 10 GWh (Plan)
22.	EXIDE	Karnataka NMC, LFP, LTO cells Capacity: 12 GWh (Plan)

Source: Authors' analysis (till October 2023).

Currently, production scrap is the primary feedstock for the global LIB recycling industry. However, by 2030, EoL batteries are expected to become the main feedstock (Figure 2). Secondary analysis suggests that at the initial stage of manufacturing, production scrap can contribute approximately 30%, but this can be reduced up to 5% with the adoption of advanced technologies and industry best practices (Breiter et al. 2023).

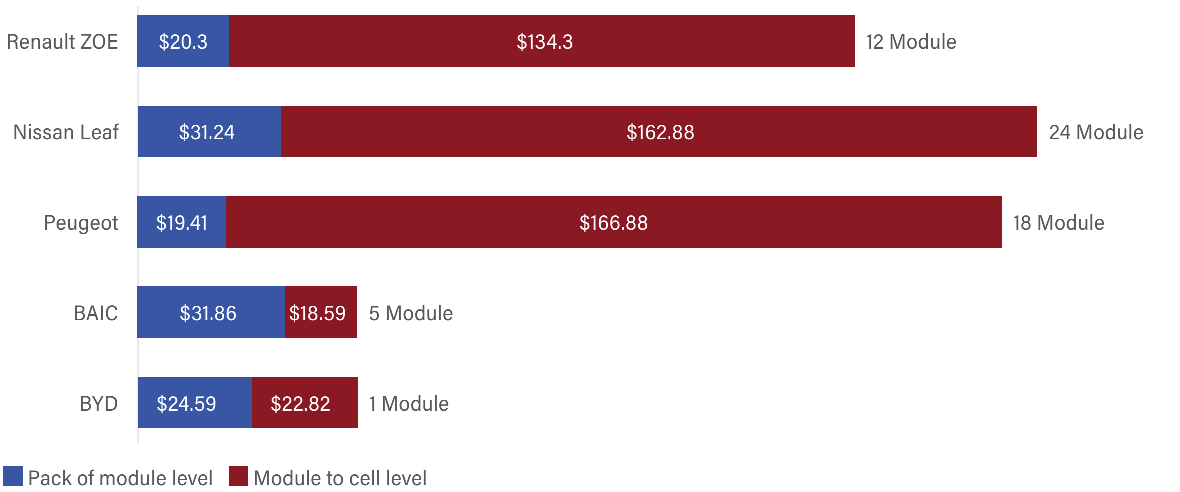
FIGURE 2 | Global scrap supply forecast by source for battery recycling



Source: Fleischmann et al. 2023.

Furthermore, battery pack design plays an important role in the overall disassembly cost and time. Disassembly costs are estimated to contribute 2–7%, 8–11%, and 12–21% to the overall recycling expenses in East Asia, US, and EU, respectively (Ran et al. 2024). Disassembling vehicle battery packs made by BYD with welded packaging takes up to 114 minutes, whereas disassembling the Nissan Leaf battery packs with screws takes only 16.4 minutes (Lander et al. 2023). Additionally, an increase in the number of modules in the battery pack corresponds to higher disassembly costs (Figure 3).

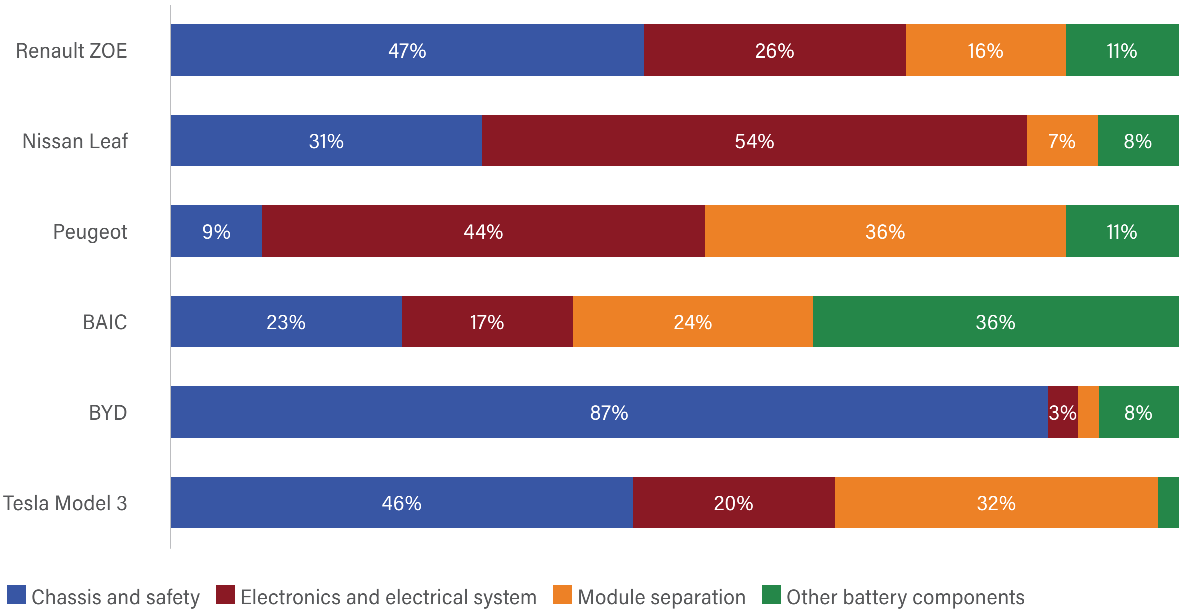
FIGURE 3 | Disassembly cost of different vehicle battery packs



Source: Lander et al. 2023.

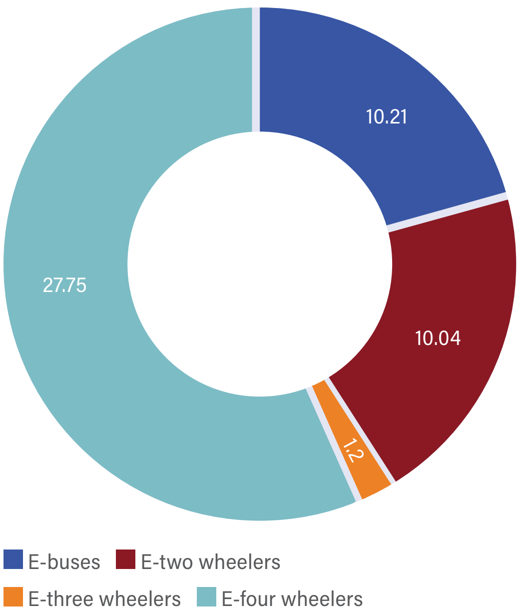
Figure 4 shows the contribution of each battery pack component toward the total disassembly cost of batteries from various EV models.

FIGURE 4 | Contribution of different battery components to the total disassembly cost of the battery packs



Source: Lander et al. 2023.

FIGURE 5 | Contribution of vehicle segments to cumulative reuse potential in India (GWh) (2022-2030)



Source: NITI Aayog and Green GGEFTCF 2022.

Second-life market for retired LIBs

NITI Aayog and GGEFTCF (2022) report suggests a cumulative potential of 49.2 GWh for LIB reuse in India from 2022 to 2030. Figure 5 depicts the contributions of different vehicle segments to India's cumulative reuse potential. Emerging collaborations in the SLA market include Nunam and Audi's partnership to repurpose retired LIB packs from Audi e-tron vehicles for electric rickshaws. Additionally, Lohum is collaborating with Mercedes-Benz and MG Motor India to repurpose battery modules for stationary storage and non-automotive mobility applications. Other companies, such as BatX Energies and Attero, are also exploring the reuse of retired LIBs. However, there are significant uncertainties due to the decreasing cost of LIBs in the global market, the absence of remaining useful life assessment frameworks, unclear residual value of retired EV batteries, and the lack of standardization in battery packs.

Battery and black mass recycling market

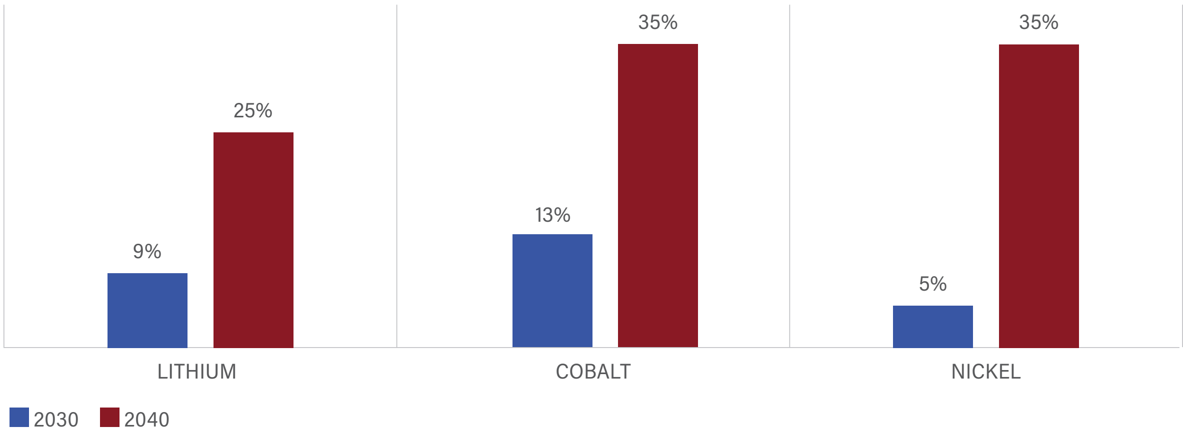
Retired LIBs can be shredded to extract black mass, which can then be refined into battery-grade precursor materials for active cathode and anode manufacturing. Currently, India recycles approximately 1% of EoL LIBs domestically (NITI Aayog and GGEFTCF 2022). By 2030, it is anticipated that 128 GWh of EoL LIB waste will be generated, with EVs contributing approximately 59 GWh (NITI Aayog and GGEFTCF 2022). While many recycling companies in India convert EoL LIBs into black mass, few can extract battery-grade raw materials from it. Due to the absence of a domestic market for recycled material, they are exported for further processing. India lost approximately 350, 71.7, and 215 tonnes of Co, Li, and Ni, respectively, by exporting black mass in one year starting from October 2022 (Jha 2023). Developing domestic refining capacity to convert black mass into battery-grade material will ensure the local availability of battery raw materials for emerging LIB cell manufacturing and reduce dependence on primary mining for these materials.

Battery circularity and raw material security

In June 2023, India joined the Mineral Security Partnership (MSP) as its 14th member. This partnership aims to strengthen the supply chains of critical minerals essential for economic growth and climate goals. The MSP seeks to promote the production, processing, and recycling of these minerals throughout the value chain by encouraging investments from both the government and the private sector. Despite having reserves of raw battery materials, such as Li, Ni, and Co, India is yet to begin mining, and exploration efforts may take 7–10 years. However, domestic recycling of EoL LIBs can ensure a local supply of battery raw materials, reducing reliance on primary mining and the associated environmental costs.

According to the World Economic Forum (2019), an estimated 54% of EoL batteries are expected to be recycled globally by 2030, contributing 7% of the overall demand for LIB production materials. Figure 6 depicts the impact of recycling on reducing the primary mining demand for certain battery materials. By 2030, recycled materials from old batteries are projected to enable the production of 60 GWh of LIB cells in India (Agarwal 2022).

FIGURE 6 | Possible primary mining reduction due to recycling



Source: Dominish et al. 2021; World Economic Forum 2019.

Research suggests that by 2025, reused and remanufactured batteries are projected to be 30–70% cheaper, constituting 26 GWh of global energy storage. The reuse and remanufacturing of EoL EV batteries contribute significant value to the overall EV ecosystem; nevertheless, recycling remains critical for the sustainable deployment of EV batteries.

GROUP DISCUSSION OUTCOMES

The panel discussion explored the following themes:

- Criticality of raw materials for LIB manufacturing in India
- Effect of circularity on the raw material requirement for batteries
- Role of material efficiency and design for circularity
- Importance of efficient reverse logistics for battery circularity
- Digital solutions for circularity: data management
- Role of research and innovation for efficient and cost-effective recycling technologies

Picture credit: Anindita Bhattacharjee, IESA event, January 24

Key lessons and entry point of actions

Unorganized sector and capacity building

Experts' inputs: In India, the informal sector handles lead-acid battery recycling and LIB collection. The LIB sector emphasizes safe battery collection, urging the need to incentivize capable entities for this task. Transitioning large-scale unorganized sectors into organized ones requires incentives and encouragement for LIB collection. Research and awareness are pivotal for sustainable battery management, necessitating capacity building to upgrade skills and ensure livelihoods while promoting sustainability. Internal combustion engine (ICE) industry workers are more vulnerable to the ICE to EV transition and ICE original equipment manufacturers (OEMs) can facilitate awareness programs to those workers. Educating people about LIB hazards and safety protocols is crucial. Digitization can yield valuable data and combined with increased incentives from the government the unorganized segments can become a part of the organized ecosystem.

Entry point of actions: To prevent inappropriate recycling by the informal sector, capacity building and skill development are imperative for workers and industries vulnerable to the EV transition. Raising awareness about the risks of unorganized recycling is vital for consumers and industry players alike.

Reverse logistics

Experts' inputs: Efficient reverse logistics management hinges on accurately identifying EoL LIBs and understanding their behavior to determine appropriate actions and handling procedures. This encompasses storage, diagnosis, validation, packaging, handling skills, transportation vehicles, and necessary certifications, all integral to the reverse logistics ecosystem. Government stakeholders are drafting a framework specifically for batteries, and industry experts can collaborate to expedite guideline implementation, thereby facilitating prompt adoption of solutions. Initiating a deposit refund scheme can ensure proper battery disposal, which can be implemented by states either independently or on a pan-India basis under the relevant ministry's guidance, scalable for various battery types. Implementing digital solutions for asset tracking and tracing is crucial to prevent system leakages; while cell labelling (quick-response code, bar code, serial node, etc.) is one solution, further research is required for effective ownership transfer management.

Entry point of actions: Prioritizing battery collection and separation based on their chemistry and potential for reuse or recycling is crucial. Industry collaboration in suggesting improvements to streamline reverse logistics processes and participating in regulation development is vital. Emphasizing battery and battery material traceability can ensure safe and organized reverse logistics processes.

Financing and funding for battery circularity

Experts' inputs: A comprehensive framework is required for incentivizing research and development (R&D), particularly in the recycling sector, with a focus on improving efficiency, energy management, and sustainability across all stages. R&D facilities should encompass multiple processes to effectively address various aspects of recycling. For the battery industry, R&D should extend beyond laboratory-level research to include establishing pilot plants, necessitating financial support. Government agencies provide incentives to support start-ups engaged in these R&D activities. Large conglomerates leading India's entry into the international recycling market can also establish R&D facilities. Similarly, conglomerates involved in battery production and utilization can invest in R&D for battery recycling. India already hosts extensive R&D efforts, which require incentives for transitioning from the technology readiness level (TRL) to the manufacturing readiness level (MRL). Given unique factors such as temperature, road conditions, and usage patterns, differentiating consumption patterns in India from those in other countries, R&D efforts focusing on understanding batteries under Indian operating conditions are crucial, be it in EVs, stationary applications, or powertrains. However, India's LIB recycling industry is nascent, with most funding sourced internally. Due to this nascent stage, there are significant challenges in establishing recycling facilities. Securing financing for establishing recycling plants is particularly challenging. While India is transitioning to adopting Lithium iron phosphate (LFP) batteries, recycling them poses significant commercial viability challenges. In regions such as Europe and America, disposal fees associated with batteries render recycling businesses commercially viable. Similar measures in India will foster a commercially viable recycling industry. In addition, the government can explore a PLI scheme for battery recycling and critical raw materials. As recycling lies at the bottom of the supply chain, supporting recycling initiatives through capital subsidies, disposal fees, or other means is crucial for advancing toward circularity.

Entry point of actions: Currently, R&D in the battery supply chain is crucial for India, given the country's nascent stage in EV adoption. R&D focusing on LIB recycling is essential for managing battery waste and creating secondary sources for the LIB manufacturing industry. In this context, incentivizing R&D, especially from the TRL to MRL stage, is crucial due to the significant funding required. Given the variability in battery chemistry and uncertainty in profitability, incentivizing through either a PLI scheme or disposal fee is essential.

Material efficiency and battery design for circularity

Experts' inputs: Current EV batteries lack circular design principles, typically prioritizing innovation and market entry over circularity. Circular design considerations often come into play once the battery manufacturing industry matures. Initially, the focus is on product innovation and market introduction. However, with increasing legal regulations and recycling legislation, producers neglecting circularity may incur higher disposal costs, creating a built-in disincentive to overlook circularity in battery design.

Improving battery design is essential to enhance reuse and recycling friendliness. Efforts should concentrate on optimizing material processing efficiency to produce battery-grade salts after recycling. While India boasts proven material processing technologies, adapting battery materials to local conditions is necessary for cost-effectiveness. Battery design adjustments are critical to accommodate Indian conditions, as externally procured materials may not align with giga factory requirements. Therefore, labelling battery chemistry in cells and packs is necessary for ease of reuse or recycling. In Asia, recycling or refurbishing models differ from those in Europe and the US, often involving mixed materials, posing economic challenges for consistent material acquisition and pack refurbishment. In addition, packs are typically not designed for reuse, making battery dismantling to the cell level and cell testing for pack assembly challenging. However, as the industry transitions toward prismatic and larger cells, the process is expected to become more streamlined. The second life of batteries holds promise for less-demanding applications, such as streetlights, torchlights, farm equipment, and various other uses in high-speed to low-speed vehicles in the two-wheeler segment. However, diagnosing battery health to assess reusability, particularly on a large scale, remains a challenge. Several start-ups are currently developing solutions to this challenge. Over the next 6 to 12 months, significant changes are anticipated in the management and utilization of second-life batteries in the country. Guidelines and standard operating procedures are being established, with innovative financing options becoming more prevalent in this sector. In addition, the difficulty in opening most packs poses challenges for recyclers in dismantling them for refurbishment or recycling purposes. Streamlining pack dismantling processes to find quicker and easier methods would add value, benefiting end customers. Establishing a feedback mechanism between recycling entities and producers would aid in understanding these challenges. Rather than relying solely on legislation or disincentives, information exchanges can lead to more effective solutions.

Entry point of actions: LIBs need to be designed considering the challenges and opportunities in India and tailored to Indian conditions. Producers failing to design for circularity may face financial and technical losses. However, batteries designed for circularity can be utilized for low-scale applications before recycling. For enabling LIB circularity fostering stakeholder collaboration is more promising over legislative mandates.

Opportunity for black mass recycling market

Experts' inputs: Recyclers embracing circularity recognize that the true value lies in closing the loop by promoting the reuse of recyclable materials. Encouraging recycled material reuse is crucial for sustainable economic approaches. Until India establishes sufficient refining capacity, banning black mass exports may not be advisable. India's current pricing model for black mass exports aligns with the global pricing base. Establishing a black mass recycling market exchange similar to Shanghai's black mass listing could aid in developing a pricing model. Instead of imposing an export ban on black mass, which disrupts the free market, India should focus on filling existing supply chain gaps to retain recycled materials domestically. This requires the development of a robust material processing and manufacturing industry to domestically source recycled materials. By demonstrating competitive recycling and refining costs, India could attract global black mass exports. If India could demonstrate to the world that the cost of recycling and refining in India is the lowest with the compliance of global standards, every country would undoubtedly export black mass to India. India boasts lower capital expenditure and labor and equipment costs, making battery recycling cost-effective compared to other regions. In addition, India's feedstock or energy prices are not prohibitively high. Therefore, India's ability to recycle batteries at a lower cost makes it a logical choice for global recycling operations.

Entry point of actions: Recycling companies play a crucial role in promoting the circular economy by encouraging the use of recycled or refurbished products. Instead of relying solely on the global price index, India can develop its own pricing model for exporting black mass. However, prioritizing domestic recycling, as India has the advantage of establishing and operating recycling industries within a better pricing range.

Recycled battery grade material for LIB manufacturing

Experts' inputs: As giga factories prepare to begin operations in India, there is a growing trend toward localizing supply chains. However, a significant challenge lies in establishing trust and ensuring the quality of chemicals provided by Indian recyclers or producers. Battery manufacturers typically start their production using imported raw materials that have undergone rigorous testing. As confidence in domestic processes grows, there will be a gradual shift toward using locally sourced materials. However, the challenge is in whether Indian manufacturers can gain the trust of customers regarding the quality and adherence to tolerance standards for battery-grade materials obtained through recycling. This involves not only testing product quality after production but also ensuring that every product consistently meets benchmark standards and adheres to standard deviation norms for individual parameters. Furthermore, recyclers often believe that they need not be knowledgeable about the products they handle, leading to a high degree of secrecy with producers. Producers must offer guidance and assistance to recyclers, including sharing information and promoting transparent communication, even if this involves signing non-disclosure agreements or other legal contracts. Therefore, incentivizing the use of secondary materials from recycling based on price fluctuations is essential. Encouraging industries, both buyers and consumers, to utilize these materials will facilitate the creation of a closed-loop model and promote sustainability.

Entry point of actions: The battery-recycling industry is still in its early stages, leading to some uncertainty about the quality of recycled materials. To address this issue, introducing standardized outputs from the recycling process would build trust among manufacturers. The government can encourage the use of recycled materials by leading procurement efforts or incentivizing buyers to do so.

Regulations and implementation strategy for battery circularity

Experts' inputs: Establishing an import-based recycling industry requires the extension of licenses for importing battery waste, as frequent renewal of import permits hinders the industry's growth. Although waste management laws exist, the focus should be on their consistent implementation. State Pollution Control Boards should receive clear directives to ensure the uniform application of these laws across the country rather than only in specific states. Regulations must be strictly enforced at the subnational level. Currently, the state provides subsidies for the manufacture of EVs and batteries. Similar incentives should be extended to cover land, water, sewage treatment plants, power/electricity, and goods and services tax for recycling efforts. These incentives will encourage the establishment of recycling plants using hub-and-spoke models. Implementing a local collection model based on this approach will improve battery collection efficiency. Additionally, the state could integrate recycling into its e-mobility programs within the state transport system, which would generate revenue and reduce costs. Innovative thinking is crucial for transitioning from merely generating revenue to creating impactful and unique solutions.

Entry point of actions: To ensure a reliable supply of raw battery materials, the government should extend its support to import-based battery-recycling industries. Strengthening the system requires prioritizing the implementation of existing regulations at the subnational level. In addition, the state should encourage innovative ideas to attract recycling companies and promote recycling within state boundaries, thereby minimizing the need to transport retired batteries.

NEXT STEPS

- Battery manufacturing companies set up in India present an opportunity to standardize aspects of battery design. This standardization will enable circularity across the battery life cycle.
- Relevant stakeholders can be brought together on a common platform to identify gaps in the system, without significant regulatory intervention to develop a circular supply chain.
- Market-ready research projects can be piloted through various government agencies, facilitating technology demonstrations to promote and activate research outcomes.
- The Central Pollution Control Board can develop a standardized implementation mechanism for activities such as EPR and reverse logistics. This framework can be adopted by all state governments to make the recycling ecosystem uniform throughout the country.
- As the central government facilitates reverse logistics regulations, state governments can facilitate the infrastructure required for safe collection and storage.
- The government should incentivize the battery-recycling industry using schemes such as PLI. India's competitive cost of power indicates that it has the potential to become a hub for the production of secondary source of raw material for battery manufacturing.
- At the city level, consumer awareness programs and capacity-building workshops can be conducted with the assistance of regional governments. These programs would eliminate unsafe practices adopted by consumers and local businesses.

APPENDIX A

List of experts

A. L. N. Rao, CEO, Exigo Recycling Pvt. Ltd.

Bhuwan Purohit, Director, Corporate Strategy and Planning, Rubamin Pvt. Ltd.

Gourav Dolwani, CEO and Executive Director, LICO Materials Pvt. Ltd.

Debi Prasad Dash, Executive Director, India Energy Storage Alliance

Trupti Deshpande, Senior Program Manager, Shakti Sustainable Energy Foundation

Parveen Kumar, Senior Program Manager, WRI India

List of abbreviations

EoL: End of Life

EPR: Extended producer responsibility

EV: Electric vehicle

ICE: Internal combustion engine

LIB: Lithium ion battery

MRL: Manufacturing readiness level

MSP: Mineral Security Partnership

PLI: Production-linked incentive

R&D: Research and development

SLA: Second-life application

TRL: Technology readiness level

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ACKNOWLEDGEMENTS

We gratefully acknowledge the contribution of the India Energy Storage Alliance (IESA), the co-organizer of this event under the "Battery Manufacturing and Supply Chain Summit." We acknowledge the Nationally Determined Contributions–Transport Initiative for Asia (NDC–TIA) Forum for funding this project. We thank Pawan Mulukutla, Executive Program Director; Aparna Vijaykumar, Senior Program Manager; and Chaitanya Kanuri, Program Associate Director, WRI India for their assistance and support. We also extend our gratitude to all the experts who participated in the panel discussion for their valuable inputs toward enabling battery circularity and raw material security in India and for making the event successful. We appreciate the efforts of our colleagues, Anindita Bhattacharjee and Ankita Rajeshwari, Cactus Communications for editorial support and Zebra Kross for design support.

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WRI India, an independent charity legally registered as the India Resources Trust, provides objective information and practical proposals to foster environmentally sound and socially equitable development. Our study focuses on building sustainable and livable cities and working toward a low-carbon economy. Through research, analysis, and recommendations, WRI India puts ideas into action to build transformative solutions to protect the Earth, promote livelihoods, and enhance human well-being. We are inspired by and associated with the World Resources Institute (WRI), a global research organization. Available online: www.wri-India.org.

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