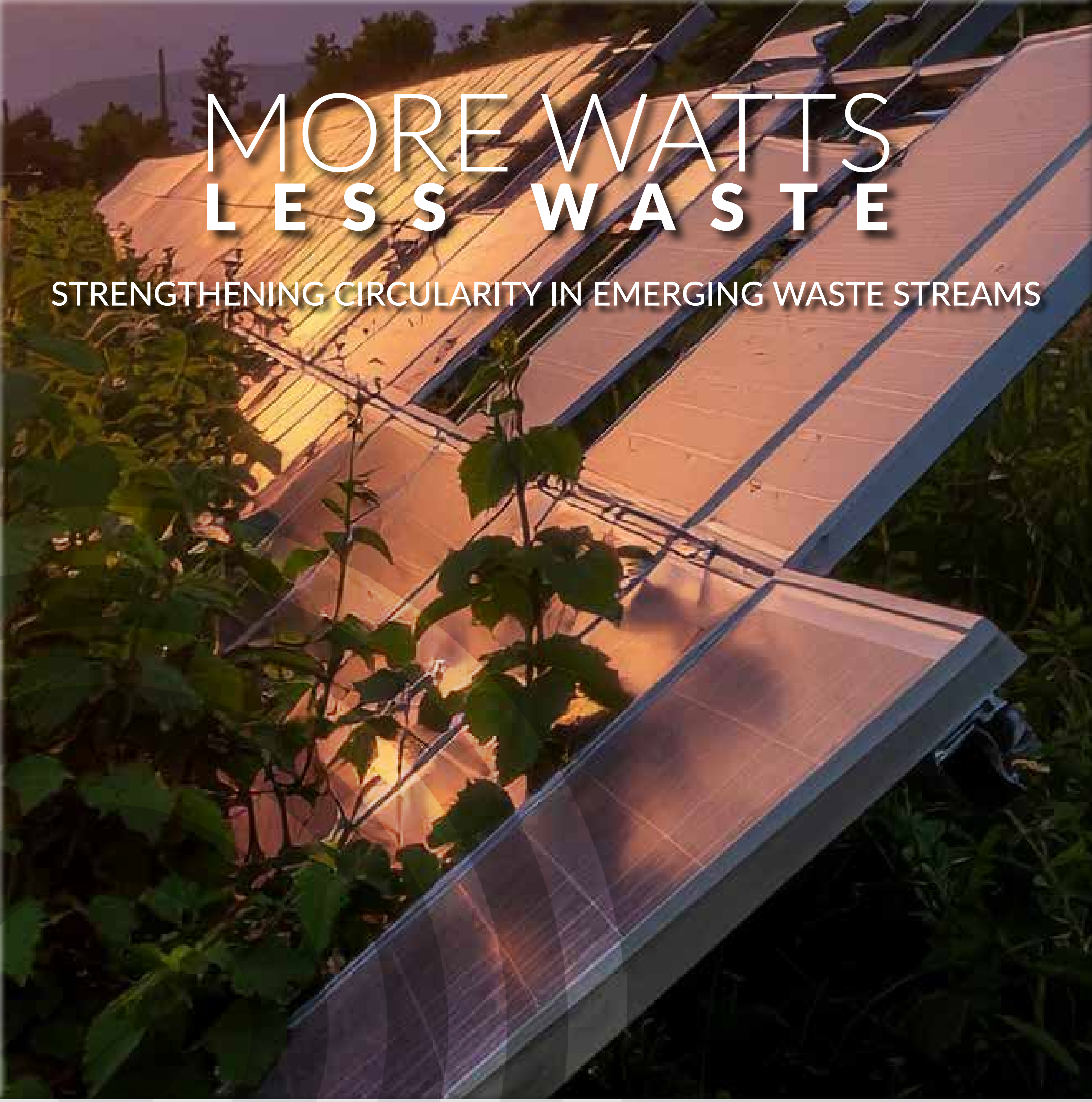
MORE WATTS
LESS WASTE

STRENGTHENING CIRCULARITY IN EMERGING WASTE STREAMS



APRIL 2026

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collaborating for climate and circularity

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Published by
Chintan Environmental Research and Action Group

About Chintan
Chintan is a non-profit Circular Society Do-Tank that improves the lives, livelihoods and leadership of the people who contribute the least to environmental pollution and climate change while combating the excessive and inequitable consumption that causes it.

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LIST OF ABBREVIATIONS

ACC	Advanced Chemistry Cell
BWMR	Battery Waste Management Rules
CBIC	Central Board of Indirect Taxes and Customs
CNG	Compressed Natural Gas
CPCB	Central Pollution Control Board
C-Si	Crystalline Silicon
Cd-Te	Cadmium Telluride
CEEW	Consumer Electrical and Electronic Waste
DGFT	Directorate General of Foreign Trade
DISCOM	Distribution Company (Electricity Distribution Company)
DoCA	Department of Consumer Affairs
DfD	Design for Disassembly
EPR	Extended Producer Responsibility
EVA	Ethylene Vinyl Acetate
EV	Electric Vehicle
FAME I	Faster Adoption and Manufacturing of Electric Vehicles (Phase I)
FAME II	Faster Adoption and Manufacturing of Electric Vehicles (Phase II)
GPCL	Gujarat Power Corporation Limited
GST	Goods and Services Tax
GUVNL	Gujarat Urja Vikas Nigam Limited
HS	Harmonized System
ICE	Internal Combustion Engine
LFP	Lithium Iron Phosphate
Li-Ion	Lithium-Ion
MNRE	Ministry of New and Renewable Energy
MoEFCC	Ministry of Environment, Forest and Climate Change
NDC	Nationally Determined Contribution
NEMPP	National Electric Mobility Mission Plan
NCMM	National Critical Mineral Mission
NITI Aayog	National Institution for Transforming India
OEMs	Original Equipment Manufacturers
PCB	Printed Circuit Board
PET	Polyethylene Terephthalate
PM-KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan
PMSGY	PM Surya Ghar: Muft Bijli Yojana (Pradhan Mantri Surya Ghar Yojana)
PRO	Producer Responsibility Organization

PV	Photovoltaic
PPE	Personal Protective Equipment
RTS	Rooftop Solar
SoH	State of Health
TNGECL	Tamil Nadu Green Energy Corporation Ltd.
TPD	Tonnes per Day
WEEE	Waste Electrical and Electronic Equipment

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EXECUTIVE SUMMARY

Study Context and Objectives

India's clean energy transition is accelerating rapidly, driven by the large-scale deployment of solar photovoltaic (PV) technologies and the electrification of transport through electric vehicles (EVs). Together, these technologies are central to advancing India's climate mitigation goals, improving air quality, and strengthening long-term energy security. However, the expansion of these technologies will generate large and complex waste streams over the coming decades, particularly from end-of-life solar PV modules and lithium-ion (Li-ion) batteries.

As of early 2026, India's cumulative installed solar power capacity had reached approximately 140 GW (Press Information Bureau, 2026) and is projected to grow steadily, potentially generating over 11,221 kilotonnes of cumulative solar PV waste by 2047 – more than 76 times the cumulative solar waste at the end of 2024 (Tyagi, Badal & Kale, 2025). Similarly, cumulative lithium-ion battery demand, from 2022 to 2030, is projected to reach approximately 600 GWh by 2030, with an estimated 128 GWh of spent batteries generated by that date, including nearly 59 GWh from electric vehicles (NITI Aayog, 2022). These emerging waste streams represent both environmental risks and strategic opportunities for domestic material recovery, critical mineral security, and industrial development.

Waste management in India is inherently complex, shaped by deeply interlinked formal and informal value chains. Informal actors play a critical role in collection, repair, refurbishment, and dismantling, while formal actors dominate capital-intensive and hazardous processing stages. Consumer behaviour, producer obligations, and regulatory enforcement interact in non-linear ways, meaning that circularity outcomes emerge from system-wide dynamics rather than any single policy lever.

This study focuses on advancing circularity in two emerging waste streams – EV lithium-ion batteries and solar PV modules. Beyond diagnosing current challenges, it outlines future-state circularity models and policy and regulatory measures that integrate consumer behaviour, informal-sector capabilities, producer responsibility frameworks, and industrial policy objectives.

Study Scope and Methodology

The study focuses on Delhi, Tamil Nadu, and Gujarat, selected for their policy leadership, high deployment of EVs and solar PV, and relevance to national regulatory frameworks. Within Tamil Nadu and Gujarat, districts were further identified based on EV adoption, installed solar capacity, and existing recycling infrastructure.

It combines secondary research with primary field-based inquiry, including value chain stakeholder interviews, consultations with informal-sector actors, focus group discussions, and structured surveys with households and organisations, such as offices, institutions, and commercial establishments, to capture end-user perspectives rather than industry or supply-side views. Survey findings are interpreted in aggregate and are not statistically representative of the broader population. Instead, they are used to identify system-relevant behavioural patterns and implications for policy design.

Key Insights

A. Consumer behaviour is driven primarily by convenience and economic value, limiting its effectiveness as a driver of circular outcomes, while trust becomes a critical constraint in the adoption of refurbished products.

B. A significant share of material entering informal systems remains repairable or reusable, indicating that value is often lost prematurely under current recovery pathways.

C. The informal sector is a dynamic and adaptive system – building capabilities through apprenticeship-based learning and likely to expand into new waste streams, including complex batteries – with material flows and operations concentrated in key hubs such as Delhi NCR.

D. Environmental and health risks are concentrated in hazardous downstream processing, and current recycling practices remain inefficient; the core policy challenge is to redesign systems to preserve value-adding roles while eliminating harmful practices.

E. Solar PV:

- PV modules are already entering informal channels, where value recovery is limited to aluminium frames and external wiring, with the remaining glass-polymer-cell mix often broken and discarded.

- Panel size, weight, and distributed installations create structural challenges for efficient collection.
- Long product lifetimes increase the risk of orphan waste.
- Current designs constrain repairability and high-quality material recovery, while data fragmentation limits lifecycle visibility and planning.

F. EV Lithium-Ion Batteries:
- Informal actors currently play a minimal role due to technical complexity, safety risks, physical constraints, and OEM-driven closed-loop systems.
- However, the informal sector's apprenticeship-based learning model suggests that capabilities may evolve over time, potentially in unsafe and inefficient ways without appropriate policy intervention.
- Circularity will depend on robust traceability and state-of-health (SoH)-based decision-making across the battery lifecycle.

Recommendations

These recommendations are designed to shift the system from fragmented, end-of-life waste management to integrated, lifecycle-based circularity.

A. **Mandate a simple, product-based coding system for electric and electronic products – recognising that consumer behaviour is driven primarily by convenience and economic value – that assigns products to a limited set of clearly defined, non-overlapping end-of-life pathways.**
Require all products to carry a clear, durable code on the product directing end-of-life handling. The code should be based on a standardised framework incorporating hazardousness, complexity, and criticality, with limited, non-overlapping pathways and clear multilingual instructions. Link the system to financial incentives such as deposit-refund or buy-back mechanisms.

B. **Require closed-loop systems for critical technologies.**
Mandate that products with energy and resource implications enter the market with defined pathways for repair, refurbishment, and recovery within the formal ecosystem. Extend this requirement to all emerging technologies at the point of market entry.

C. **Enable a repair-first, design-driven ecosystem.**
Shift policy focus upstream to repairability and refurbishment, enable access to parts, tools, and information, create certification pathways, and direct finance towards decentralised repair ecosystems to integrate informal sector capabilities.

D. **Integrate informal actors through incentive-linked, compliance-light pathways.**
Transition from project-based integration approaches to systemic reforms that embed

informal actors into markets and EPR systems; enable compliance-light pathways, link benefits to participation, support federation models, and define clear roles while restricting hazardous processing to authorised facilities.

E. Co-design systems with informal actors.
Develop policy and operating models through multi-stakeholder processes that include informal workers as co-designers to ensure trust, adoption, and operational viability.

F. Prioritise high-impact hubs
Focus early implementation in high-impact hubs such as Delhi NCR to maximise learning and impact before scaling.

G. Solar PV:

- Enable silicon recovery through R&D, pilots, and phased market development, while scaling domestic polysilicon, ingot, and wafer manufacturing to create future demand for recovered silicon.
- Strengthen PV EPR by setting progressive collection targets, introducing recycled material use targets, expanding eligible materials for EPR credits (e.g., copper, silicon, silver), and extending the scope to solar-enabled products (e.g., solar lights, lanterns, cookers, and other PV-integrated devices).
- Enable efficient first-mile PV waste collection through registered informal sector worker federations under a compliance-light framework; define clear roles limited to collection, testing, and non-hazardous dismantling, with mandatory routing to authorised downstream facilities; recognise federations on the EPR portal to enable credit generation; and support decentralised clusters to reduce logistics costs.
- Establish an upfront-funded PV waste management mechanism financed through producer contributions, integrate it with EPR certificate systems for verified activities, use it to address orphan waste risks, and calibrate contributions with a phased rollout to enable cost pass-through and planning.
- Link producer contributions to the advance pooled PV waste management fund to module repairability, using differentiated contributions to incentivise designs that are easier to repair, refurbish, and dismantle, thereby reducing end-of-life management burdens.
- Develop an integrated PV data repository linking manufacturing, installation, operation, and end-of-life data to enable end-to-end module traceability and strengthen regulatory oversight, EPR compliance, and long-term planning.

H. EV Lithium-Ion Batteries:

- **Strengthen recycled content provisions by introducing material-specific targets** for critical minerals (e.g., lithium, cobalt, nickel) and encouraging the use of materials recovered from end-of-life batteries, supported by robust traceability and verification systems.

- **Integrate emerging battery passport systems into EPR** to capture health data and prevent premature recycling.
- **Define standardised state-of-health (SoH) parameters and testing protocols** to guide repair, reuse, and recycling decisions.
- **Create certification frameworks** for refurbished and second-life batteries to build market trust.
- **Promote design for disassembly, repairability, and modularity in EV battery packs through EPR-linked incentives and compliance mechanisms**, enabling efficient material recovery and extending product life.

Conclusion

Circularity in emerging waste streams such as solar PV modules and EV batteries cannot be achieved through end-of-life waste management alone. It requires deliberate system design across the entire product lifecycle – from design and market entry to use, repair, and recovery – supported by aligned incentives, clear roles, and robust traceability, including the integration of informal sector capabilities into formal systems.

The assumption that waste challenges will resolve themselves as volumes grow is unlikely to hold. When systems are designed after waste reaches scale, recovery pathways become fragmented, environmental risks become entrenched, and material value is lost. For long-lived technologies, the window to act lies well before large volumes of waste emerge.

The choices made today will determine whether the material flows created by the energy transition become future environmental liabilities or strategic reservoirs of value in an increasingly resource-constrained world.

INTRODUCTION
Balancing Growth, Energy Security, and Climate Goals

India, currently the world's fourth-largest economy, is on track to become the third-largest by 2030, with its GDP projected to reach USD 7.3 trillion (S&P Global, 2023). Even in the face of global uncertainties, geopolitical tensions, and tariff-related risks, India has remained the fastest-growing major economy, driven largely by robust domestic demand. This growth trajectory is underpinned by a large and expanding population base. According to the United Nations Department of Economic and Social Affairs, India's population – now estimated at 1.45 billion – is expected to continue rising and peak at around 1.7 billion in the early 2060s (UN DESA, 2024).

India's rapid economic and demographic expansion is tightly coupled with a corresponding surge in energy demand. India's share in global primary energy consumption is projected to nearly double by 2035, reflecting rising industrial activity, expanding transport needs, and growing per-capita electricity consumption (Press Information Bureau, 2025a).

India's per-capita energy consumption has steadily risen - from 14,682 megajoules per person in 2014–15 to 18,410 megajoules per person in 2023–24 - reflecting a compound annual growth rate (CAGR) of 2.55 per cent (Press Information Bureau, 2025b).

In 2023-24, approximately 95 per cent of India's primary energy supply was met by fossil fuels, while only about 5 per cent came from non-fossil sources (Bureau of Energy Efficiency, 2024). Achieving India's long-term climate commitments – articulated in its updated Nationally Determined Contributions (NDCs), which include reducing the emissions intensity of GDP by 45 per cent by 2030 (from 2005 levels), attaining about 50 per cent cumulative installed capacity from non-fossil energy sources by 2030, and reaching net-zero emissions by 2070 – will require a rapid and sustained scale-up of renewable energy generation, energy storage, grid modernization, and other low-carbon technologies.

While India's growth targets are substantial, its contribution to the global climate crisis remains limited in historical and per-capita terms. Cumulatively, India accounts for only around 3.6 per cent of global CO_2 emissions since the industrial era, compared to approximately 24 per cent for the United States and 16 per cent for the European Union (Global Carbon Budget 2025, as cited in Our World in Data). On a per capita basis, India's emissions are less than half the global average and among the lowest for major economies (IEA, 2023a). Despite this, India has positioned itself as a proactive and responsible actor under the Paris Agreement, committing to ambitious nationally determined contributions that balance growth with climate action. Through rapid expansion of solar capacity, accelerated adoption of electric mobility, and growing leadership in green energy deployment, India is demonstrating a development-aligned pathway to climate mitigation.

Beyond its climate benefits, renewable energy is a strategic necessity for India's energy security. With high dependence on imported fossil fuels and exposure to global price and supply shocks, expanding domestic renewable energy capacity and storage infrastructure reduces vulnerability, stabilizes long-term energy costs, and strengthens national resilience.

Solar Energy's Critical Role in India's Energy Transition

India's solar potential is exceptionally high. Owing to its tropical location, most regions receive 4–7 kWh/m² per day of solar radiation, and clear, sunny days number around 250 – 300 annually, providing a strong natural basis for photovoltaic (PV) deployment (MNRE, Solar Overview). Large land availability in high irradiance areas makes capturing and use of this solar energy feasible.

India's vast natural potential is backed by strong and supportive policy architecture that makes large-scale deployment both viable and strategic. At the heart of this is the Production-Linked Incentive (PLI) Scheme for high-efficiency solar PV modules, which offers financial incentives over five years to manufacturers and aims to build gigawatt-scale domestic capacity. The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) Scheme supports farmers by solarizing their agricultural practices. The PM Surya Ghar Yojana offers subsidized rooftop solar installations to eligible Indian households.

It is therefore not surprising that India officially surpassed Japan in 2025 to become the world's third-largest solar power producer (Press Information Bureau, 2025c). As of early 2026, India's cumulative installed solar power capacity had crossed 140 GW (Press Information Bureau, 2026).

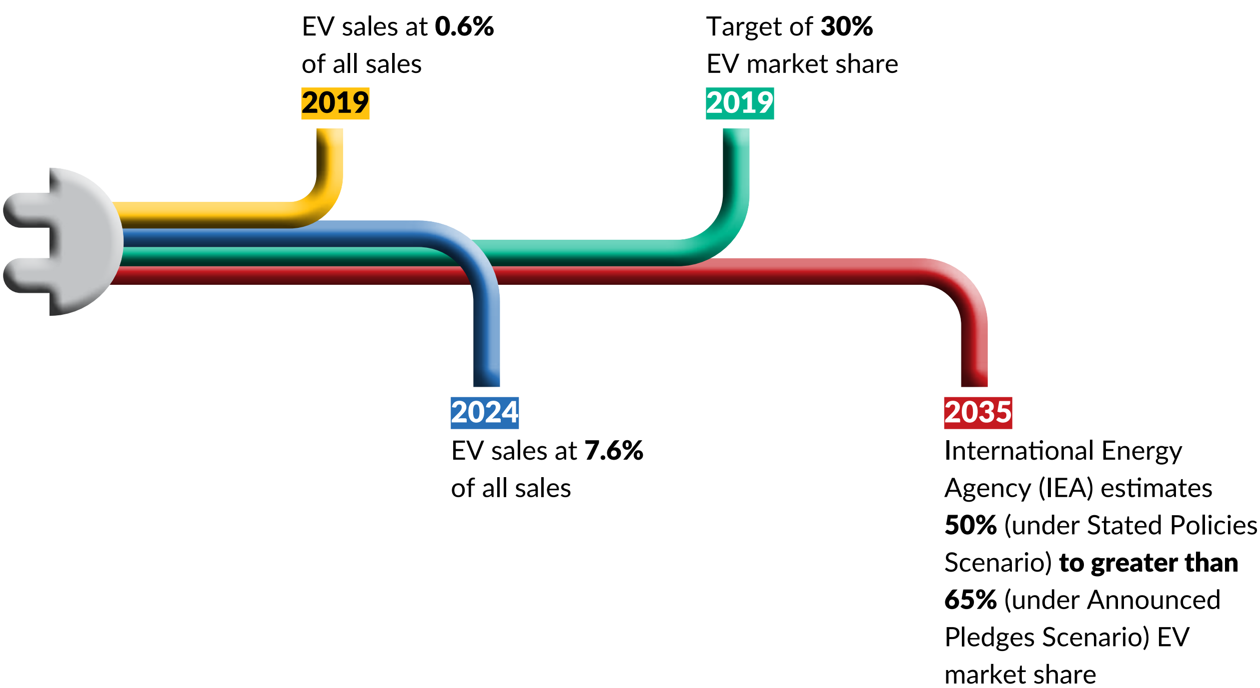
The Expanding Role of Lithium-Ion Batteries in India's Energy Transition

Lithium-ion (Li-ion) batteries have emerged as the core technology enabling modern energy storage, particularly as India scales renewable sources like solar whose generation is inherently intermittent. By storing excess power and releasing it when supply dips, lithium-ion systems enhance grid stability and allow renewables to play a larger, more reliable role in the energy mix.

Their importance extends beyond the grid: Lithium-ion batteries are central to India's transition to electric mobility, a sectoral shift that is critical given that transport accounts for about 50 per cent of the oil demand in India (International Energy Agency (IEA), 2021). Accelerating Electric Vehicle (EV) adoption, powered by efficient lithium-ion batteries, offers not only a pathway to significant emissions reduction but also improved energy security and reduced oil import dependence.

India's EV adoption has accelerated rapidly, with the share of EVs in new vehicle registrations rising from 0.6 per cent in 2019 to approximately 7.6 per cent in 2024 (VAHAN Dashboard, as cited in WRI India, 2025). India's EV market is expected to grow at a compounded annual growth rate of 49 per cent from 2022 to 2030 (Press Information Bureau, 2023).

FIGURE 1 | **EV Market Share in India**



Data Source: Press Information Bureau (2023), IEA (2024a).

India's EV ecosystem is anchored in the National Electric Mobility Mission Plan (NEMMP) 2020, which set the country's long-term vision for reducing oil dependence, cutting emissions, and building domestic manufacturing capacity. This vision has been operationalised through successive schemes – FAME I and FAME II – which provided targeted demand incentives for EVs and funded charging infrastructure and public-transport electrification. The PM E-Drive Scheme is expected to extend this policy trajectory by focusing on affordability, high-volume segments and expanded charging and swapping networks. Complementing these demand-side measures, the Production-Linked Incentives (PLI) schemes for Advanced Chemistry Cells and for automobiles and auto-components strengthen the supply side by incentivising domestic production of batteries and EV components, together forming a cohesive national policy framework for accelerating electric mobility.

Critical Mineral Dependence and Circularity Imperative

The rationale for transitioning to solar energy and electric mobility weakens if challenges around critical mineral dependence and circularity are not addressed proactively. Without a forward-looking approach, India risks shifting from one form of resource dependence to another - for instance, from dependence on imported oil to reliance on lithium and other strategically ring-fenced minerals that are not currently available domestically.

> Without a forward-looking approach towards circularity, India risks simply trading one form of resource dependence for another.

There is no shortage of lessons from world's long reliance on a linear take-make-waste model, whether in plastic packaging, electronics, or other waste streams. The evolution of waste management rules, the implementation of extended producer responsibility frameworks, and the continued role of the informal sector have all generated insights that can inform the design of more effective and future-ready approaches for emerging waste streams such as used lithium-ion batteries and PV waste.

Rapid technological advancement is inevitable. Yet policy response often follows a predictable pattern marked by costly lag – global trajectories allow goods riding technological advancements to scale rapidly, but the questions about managing their waste and toxicity come much later. We begin to consider producer responsibility, traceability, data systems, and other safeguards only after critical time has been lost, resources wasted, and damage to the environment and health begun – a cycle we can no longer afford to repeat. Throughout this study, we repeatedly encountered the view that large-scale waste from early-stage solar panels or lithium-ion batteries is still years away, and that once volumes reach a critical mass, solutions and infrastructure will naturally emerge. This wait-and-watch mindset has not served us well in the past, and there is little reason to believe it will deliver better outcomes in the future. Preparing solutions before – or at least alongside – market expansion is therefore imperative. Doing so is central to the realisation of the Viksit Bharat mission. Early investment in circular economy systems can ensure resource security, create jobs, strengthen domestic value chains, and sustain the momentum of India's clean energy transition.

India's past waste challenges show that strong policy design, paired with effective implementation, must guide the shift to circular systems for future technologies.

Just as building safety codes and electrical wiring standards are established before construction or installation to prevent accidents, circularity and waste management for new technologies must be designed and implemented from day one. By creating modular, repeatable rules, standards, and frameworks, policymakers can evaluate and apply them alongside the rollout of any new product or innovation, ensuring that sustainability and accountability are embedded from the outset rather than retrofitted after critical mass is reached.

Some policy measures are already being implemented in these sectors, signalling an encouraging shift towards proactive governance. However, this study underscores that much more can – and should – be done, and sooner rather than later. By anticipating potential waste streams, strengthening regulatory frameworks, and scaling solutions in parallel with technological adoption, policymakers have an opportunity to avoid the reactive cycles of the past and ensure sustainable, responsible growth from day one.

STUDY OVERVIEW

This study focuses on photovoltaic (PV) module (commonly referred to as solar PV modules) waste and EV lithium-ion (li-Ion) battery waste due to their rapidly growing relevance in India's clean energy transition. As highlighted earlier, the deployment of solar PV modules is expanding at an unprecedented pace, while the adoption of electric vehicles is set to drive a sharp increase in li-Ion battery usage. Both these technologies, while critical for decarbonization, generate waste streams with unique management challenges and potential environmental risks if not addressed proactively. **By focusing on these two emerging waste streams, the study aims to anticipate challenges, identify opportunities for circularity, and inform policies and frameworks that can be applied early – before these materials reach critical volumes and become difficult to manage effectively.**

In-Scope Geographical Areas

Delhi, Tamil Nadu, and Gujarat were shortlisted for the study based on the following rationale:

- **Delhi** was selected for this study due to its policy and strategic significance. The city's EV Policy 2.0 is expected to drive substantial electric vehicle adoption and, in turn, li-Ion battery waste, which the policy anticipates. As the national capital and hub for government agencies and regulatory bodies, Delhi also offers high visibility for observing policy implementation and stakeholder engagement.

- **Tamil Nadu** was selected for its leadership in renewable energy and electric mobility. Tamil Nadu's installed solar capacity stands at 11,471.94 MW, placing it among the top solar-generating states in India (MNRE, 2025). On the EV front, the Tamil Nadu EV Policy 2023 aims to attract INR 50,000 crore in EV manufacturing investments, along with major demand-side incentives, including 100% road-tax exemption for EVs until end-2025 – underscoring the state's serious commitment to the EV transition and the associated li-ion battery ecosystem (Government of Tamil Nadu, 2023).

- **Gujarat** was selected for its strong leadership in solar deployment and its rapidly expanding electric-mobility ecosystem. Gujarat's installed solar capacity stands at 24,143.16 MW, making it the second-highest solar-generating state in India (MNRE, 2025). On the EV front, Gujarat has positioned itself as a major hub for EV and component manufacturing by designating electric vehicles and their components as a priority "sunrise sector" under the Gujarat Industrial Policy 2020, which offers capital subsidies and access to government land for eligible industries (Government of Gujarat, 2020). The state also promotes EV adoption through demand-side incentives under the Gujarat Electric Vehicle Policy 2021, including purchase subsidies and exemptions from registration fees – together signalling Gujarat's strong commitment to EV uptake and the growth of an associated li-ion battery ecosystem (Government of Gujarat, 2021).

All three regions also have a strong presence of informal actors across the waste value chain, making them well-suited for examining how PV and li-ion battery waste systems may evolve in practice. This provides a realistic basis for anticipating integration challenges, governance gaps, and inclusive circular-economy pathways before waste volumes reach critical scale.

A detailed description of the study methodology is presented in Appendix A.

THE CONSUMERS' POINT OF VIEW

This study draws on 506 primary survey responses – 419 from households and 87 from small to medium organizations that include academic institutions, non-profits, hotels, travel companies, and other private companies, to name some prominent categories. The surveys were conducted across three in-scope geographies – Delhi, Gujarat, and Tamil Nadu – to capture a broad, cross-sectional understanding of knowledge, attitudes, and perceptions related to EV lithium-ion batteries and solar PV module circularity. Respondents were selected using a simple, non-stratified random approach within the identified geographies, with field teams inviting participation across localities without prior screening. This method was adopted to minimise researcher bias and capture a cross-sectional range of awareness in the absence of reliable baseline data on EV and PV end-of-life practices. **While the overall sample size is substantial for exploratory research, it is not statistically representative in proportion to the population of the target cities or districts. Accordingly, the analysis does not attempt to derive gender-disaggregated, state-wise, or other demographic-correlated insights. Instead, survey findings are interpreted in an aggregated manner to identify common themes, awareness levels, and perception patterns emerging across the three geographies.** The survey instruments included questions intended to elicit information related to knowledge, attitudes, and practices in relation to waste handling and circularity.

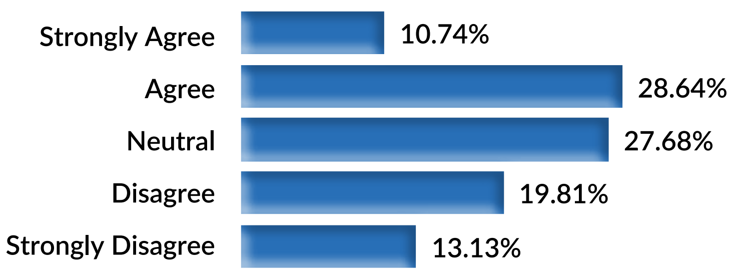
To supplement survey findings with qualitative insights, four Focus Group Discussions (FGDs) were conducted in Gujarat, and one stakeholder consultation was held in Delhi. In Gujarat, FGD participants were drawn primarily from survey respondents who expressed interest in follow-up engagement, supplemented by local outreach where necessary. In Delhi, a structured consultation was conducted with waste picker representatives to capture value-chain perspectives and ground-level handling practices. No FGD was conducted in Tamil Nadu due to logistical constraints; insights from that geography are based solely on survey responses.

Several survey questions used a five-point Likert scale: *Strongly Agree*, *Agree*, *Neutral*, *Disagree*, and *Strongly Disagree*. A relatively high proportion of respondents selected "Neutral" for certain questions. To better understand this pattern, participants in the Focus Group Discussions (FGDs) – Including individuals who had also completed the survey – were asked how they interpreted the "Neutral" option. Many indicated that they selected "Neutral" when they were unsure, did not have enough information, or had not yet directly engaged with EV battery or solar PV end-of-life issues. This suggests that higher neutral responses in the survey are more likely to reflect uncertainty or limited awareness rather than indifference. Accordingly, neutral responses are interpreted as signalling areas where information, clarity, or practical pathways for action may be lacking.
Insights from household surveys

A. Willingness exists, but behaviour is shaped by awareness, access, and convenience.
There is a distinct gap in awareness levels as indicated by the following responses (Note that for batteries, unless stated explicitly, the questions were posed in the context of all lithium-ion batteries):

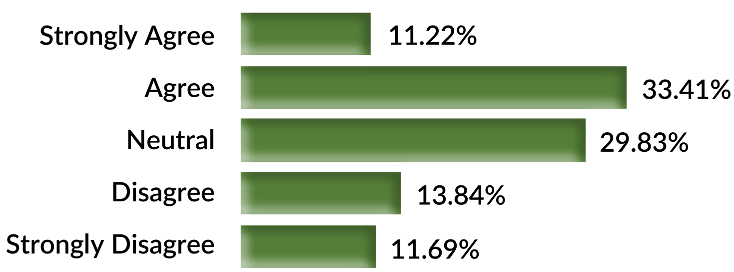
1. **Attitude:** When asked if **used batteries should be burnt and stripped by doorstep waste collectors or *kabadiwalas* to extract their contents and sell to recyclers**, only 32.94% either disagreed or strongly disagreed.

CHART 1 | **Attitude towards Battery Burning**



To the same question about solar PV modules, only 25.5% either disagreed or strongly disagreed.

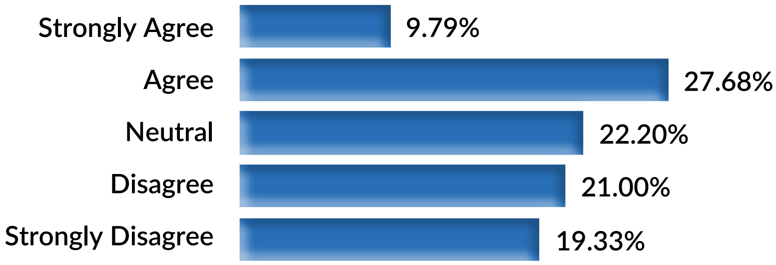
CHART 2 | **Attitude towards PV Burning**



The low level of disagreement with burning and stripping practices highlights weak awareness of hazardous recycling risks and underscores the need for stronger public awareness.

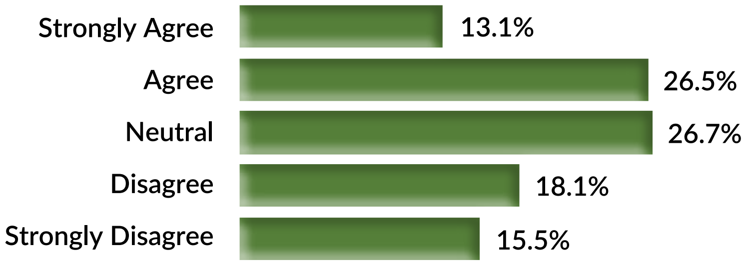
2. **Attitude:** When asked if **we are unnecessarily worrying over safe disposal of used batteries**, only 40.33% either disagreed or strongly disagreed. (CHART 3)

CHART 3 | **Attitude towards Safe Disposal of Batteries**



To the same question about solar PV modules, only 33.7% either disagreed or strongly disagreed.

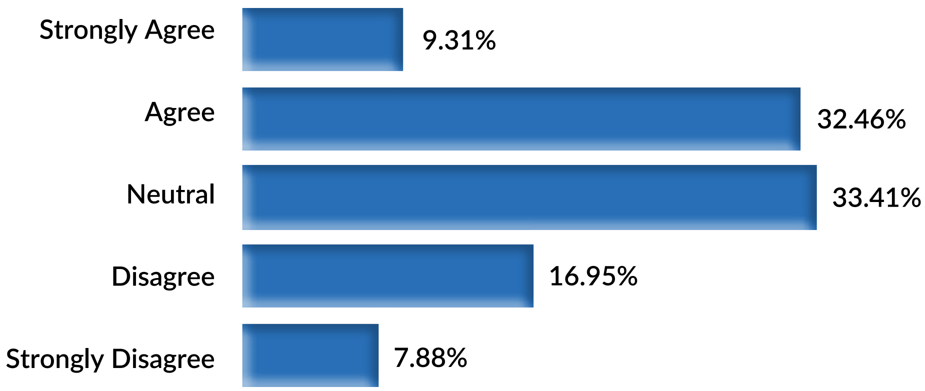
CHART 4 | **Attitude towards Safe Disposal of PV Modules**



Low levels of disagreement suggest that a large share of respondents do not view safe disposal of batteries and PV modules as a serious concern, highlighting a significant awareness gap and the need for targeted public education and risk communication.

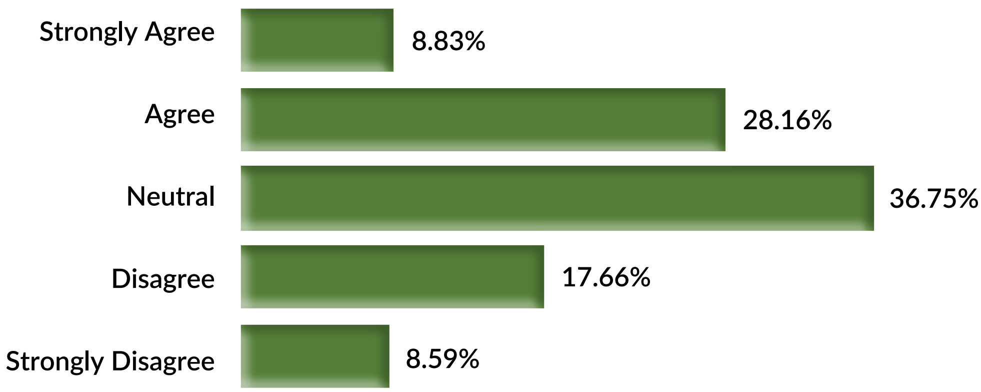
3. **Knowledge:** However, when asked if **they have sufficient knowledge about batteries to know how to dispose of them safely after use**, only 24.82% either disagreed or strongly disagreed.

CHART 5 | **Knowledge for Safe Disposal of Batteries**



To the same question about solar PV modules, only 26.25% either disagreed or strongly disagreed.

CHART 6 | **Knowledge for Safe Disposal of PV Modules**

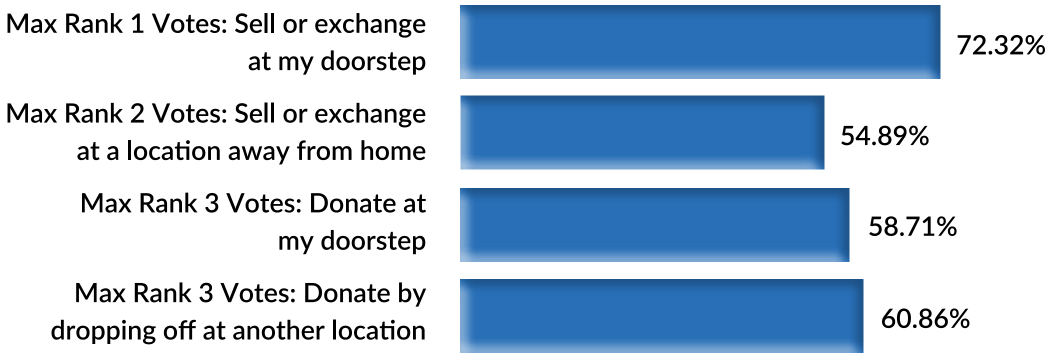


Most respondents believe they know how to safely dispose of batteries and PV modules, pointing to potential overconfidence and a critical need for clearer, accessible disposal guidance.

4. **Perception:** When asked to rank what **would be their preferred mode of disposal for used batteries (from among 4 presented options)**, the choices validated the assumption that economic benefit and convenience trump all else.

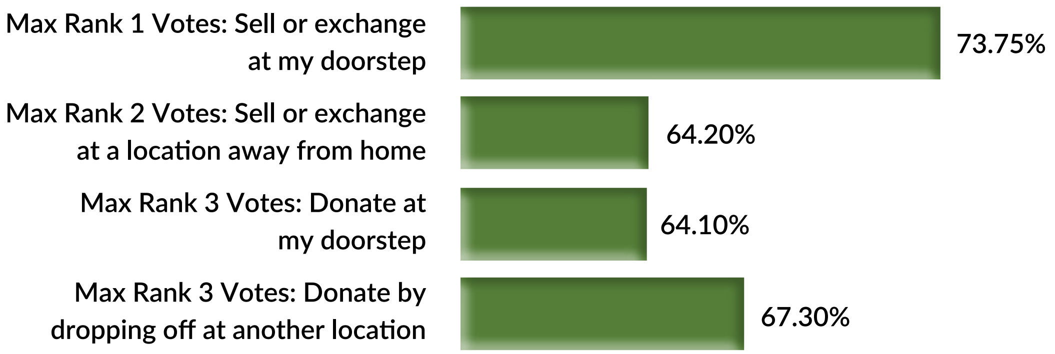
Charts 7 and 8 below show which options received maximum rank 1, rank 2, rank 3, and rank 4 votes.

CHART 7 | **Preferred Mode of Disposal for Batteries**



A similar pattern was observed for solar PV modules.

CHART 8 | **Preferred Mode of Disposal for PV Modules**



B. Households continue to lean on the doorstep Kabadiwala as a dependable value stream actor.

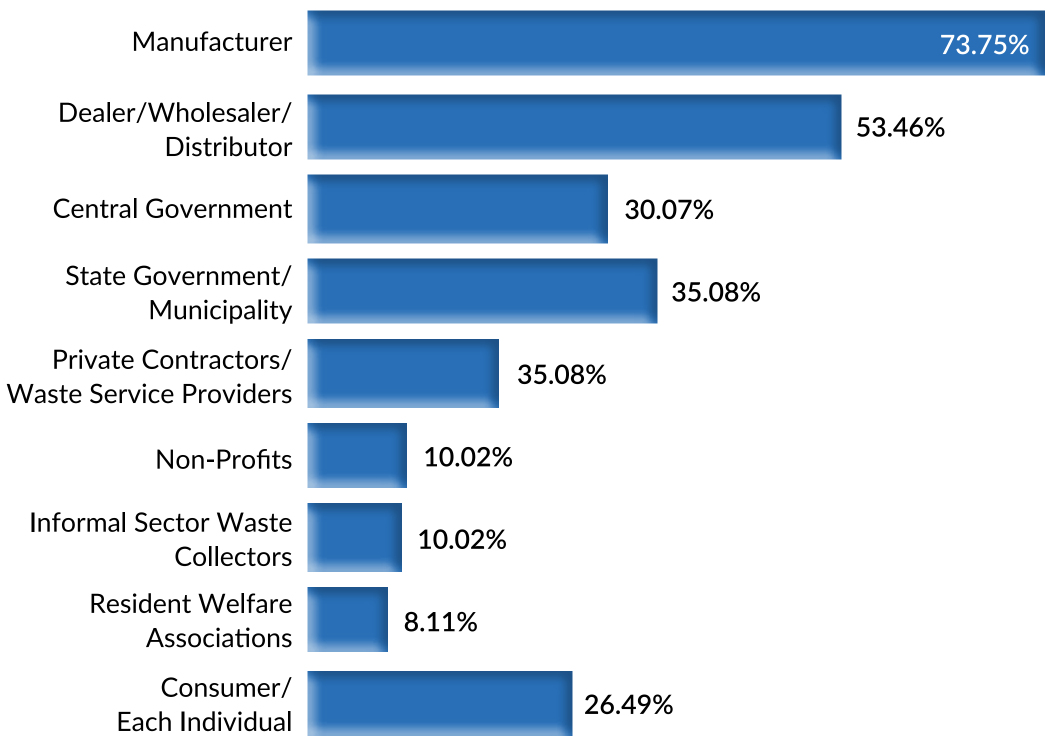
The reasons for this reliance are multiple, including prompt doorstep pickup and comparatively better rates, as discussed later in the report. When respondents were asked, **"When the battery in your electric vehicle (EV) needs to be replaced or disposed of, how would you do so?"** – with the option to select multiple responses – approximately 37% indicated that they would sell the battery to a *kabadiwala* or local scrap dealer.

This finding should be interpreted with caution. Most respondents did not own an EV at the time of the survey, and in practice, replacement of lithium-ion batteries is typically routed through OEM-linked dealerships or authorised service centres, particularly given EPR-linked take-back obligations. Consumers may therefore have limited practical opportunity to independently channel EV batteries to informal collectors. Nonetheless, the response highlights a deeply ingrained behavioural tendency within Indian households to turn to the ubiquitous *kabadiwala* as a default channel for end-of-life material disposal, even in the context of newer technologies, indicating that informal collectors should be thoughtfully considered as part of broader, regulated take-back and recycling frameworks. This preference may also reflect a rational response to constrained or imperfectly accessible formal systems. Where formal take-back channels are perceived as distant, procedurally complex, slower, or economically unattractive, households may default to the pathway that is most visible, convenient, and financially viable. The salience of the *kabadiwala*, therefore, should not be read solely as cultural inertia, but as a function of transaction costs and institutional accessibility.

C. Limited attribution of waste responsibility to consumers.

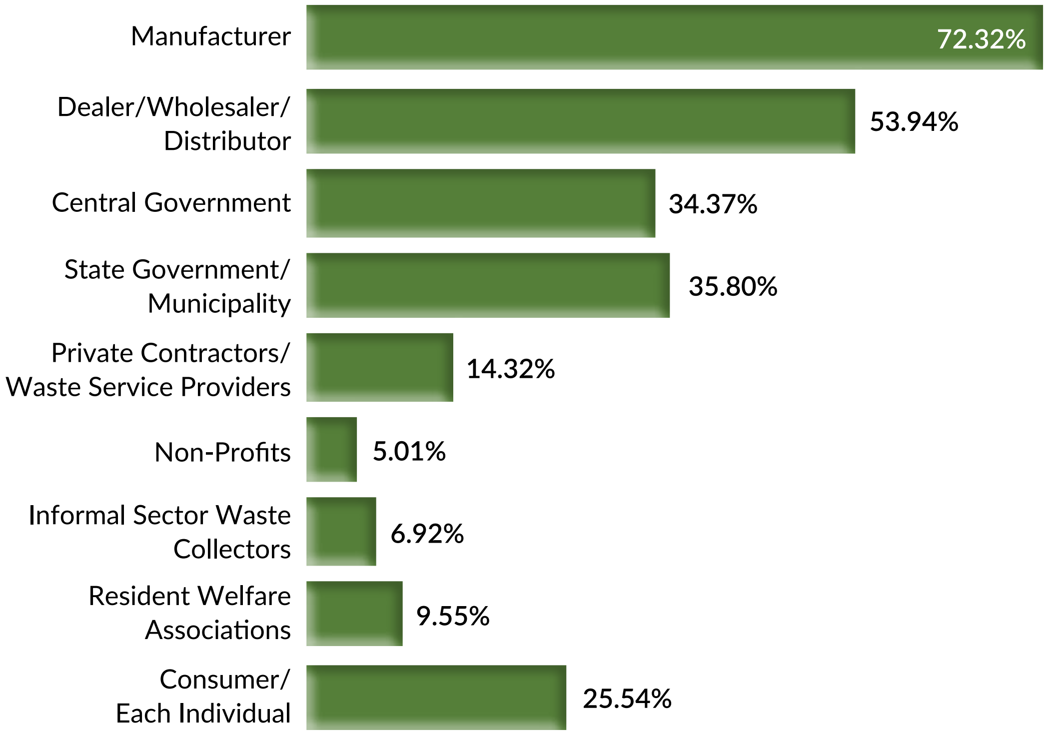
When asked to **identify responsibility for the proper management of battery waste** (with multiple responses permitted), only 26.49% of respondents selected the consumer or individual household, indicating limited attribution of primary responsibility to end-users.

CHART 9 | **Responsibility for Management of Battery Waste**



To the same question about solar PV modules, only 25.54% of respondents selected the consumer or individual household.

CHART 10 | **Responsibility for Management of Used PV Modules**



D. Limited interest in refurbished batteries or PV modules.

Enabling true circularity requires the availability of multiple end-of-first-life pathways, with the appropriate route determined by the condition of the product or component. Depending on residual performance and safety, these pathways may include repair, refurbishment, or second-life applications prior to material recycling. However, household responses indicate limited current acceptance of such pathways. When asked **whether they would be willing to use devices with refurbished batteries or refurbished PV modules**, only 23.15% of respondents answered in the affirmative, while 59.43% indicated they would not, and 17.42% expressed uncertainty. This suggests that while refurbishment and second-life use are critical to circular system design, their uptake is likely to depend on trust, quality assurance, and appropriate safeguards rather than availability alone.

E. Low familiarity with waste management rules and policy instruments.

Survey responses indicate low familiarity with formal policy mechanisms governing waste management. More than 71% of respondents reported that they had not heard of Extended Producer Responsibility (EPR).

But interestingly, when asked, in a follow-up survey question, if they think individuals/households require more and clearer communication around laws for proper e-waste, battery, and PV waste management:

- 41.3% selected the option 'No – We have sufficient clarity.'
- 16.7% selected the option 'No – We do not think these laws are relevant to us.'
- 42% said 'Yes.'

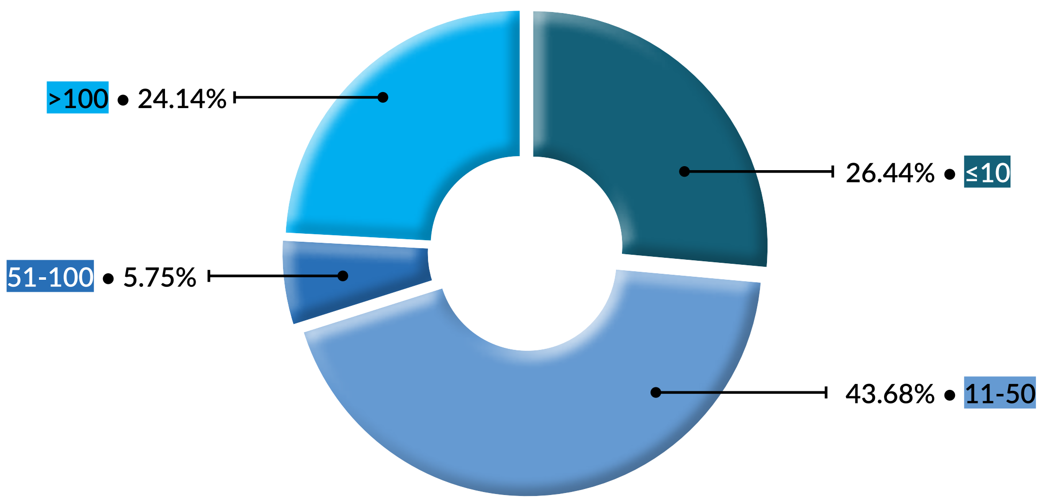
Earlier findings in the report show that a substantial share of respondents were unable to flag inappropriate disposal practices. Yet in the present question, many indicated that they have sufficient clarity or do not require additional communication on relevant waste management laws. This divergence between demonstrated understanding and self-assessed confidence suggests a degree of overestimation in perceived knowledge– consistent with a Dunning-Kruger type pattern, where perceived knowledge exceeds actual understanding.

Insights from organizational surveys

The surveys with organizations (87) yielded responses broadly consistent with those of households. Additional insights emerging from this cohort are discussed below. The organizational respondents comprised academic institutions, non-profit entities, and privately held for-profit establishments. These surveys did not include stakeholders from the solar PV or lithium-ion battery value chains. This is because the survey was designed to capture the perspectives of end-users and consumers of these products, rather than upstream value chain actors. Insights from PV and battery value chain stakeholders were collected separately through structured interviews and are incorporated in the relevant sections of the report.

The distribution of organizations by team size is presented below:

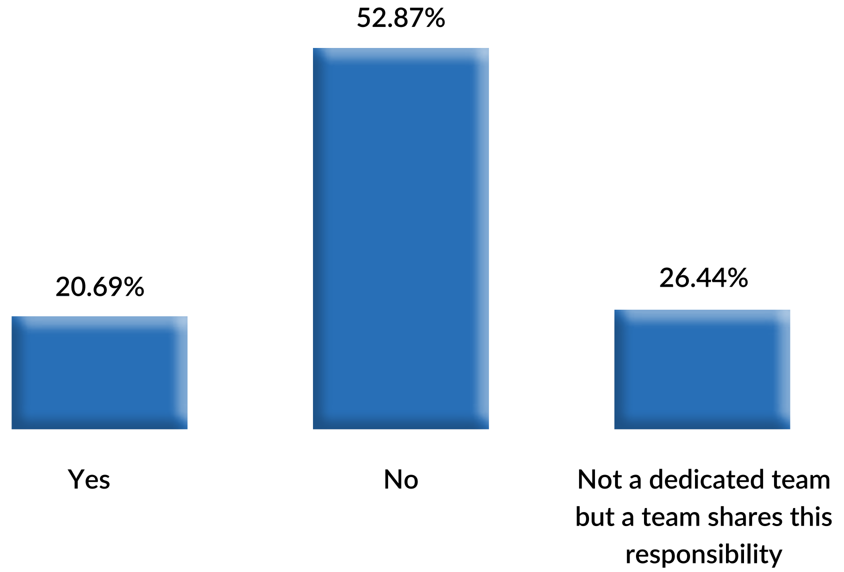
CHART 11 | **Distribution of Organizations by Team Size**



A. Majority do not have a dedicated environmental or sustainability team, or inventory tracking mechanisms.

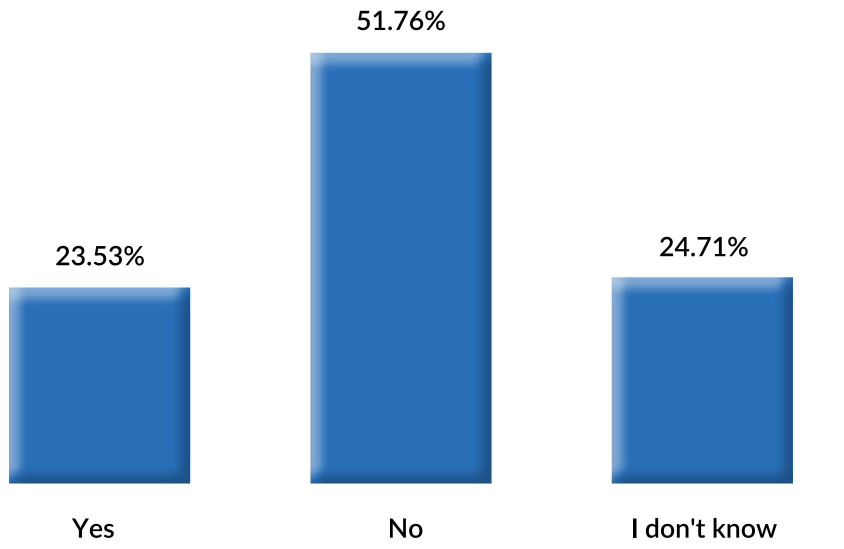
When asked **if their organization has a dedicated environmental or sustainability team**, 62.07% said No.

CHART 12 | **A Dedicated Sustainability Team**



When asked **if their organization maintains a record (inventory) of its electrical and electronic equipment, batteries, and li-ion batteries**, 51.76% said No.

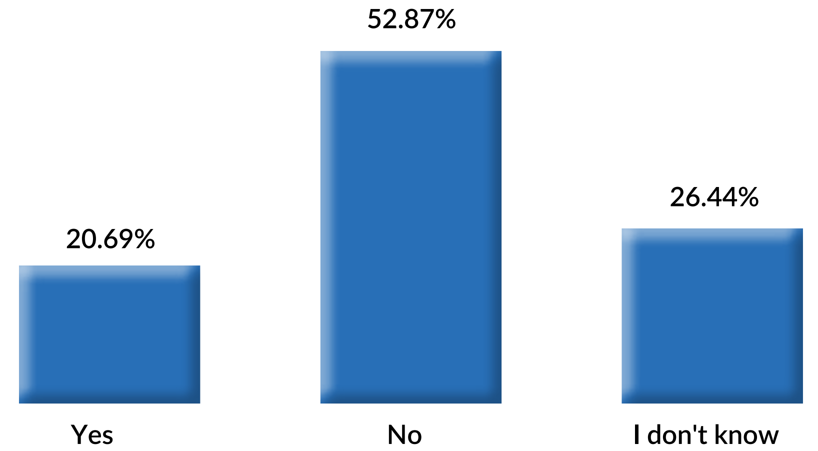
CHART 13 | **Inventory Tracking**



B. Majority do not have contracts with formal recycling companies, and many continue to use *Kabadiwalas*

When asked **if their organization has a formal contract with recycling companies**, 52.87% said No.

CHART 14 | **Formal Contracts**



When respondents were asked about their disposal practices for electronic devices – such as laptops, smartphones, inverter systems, and desktop computers – 43.68% reported handing them over to *kabadiwalas* while 18.39% indicated that they were unsure how to dispose of such items. As the question allowed multiple responses, respondents could select more than one disposal option.

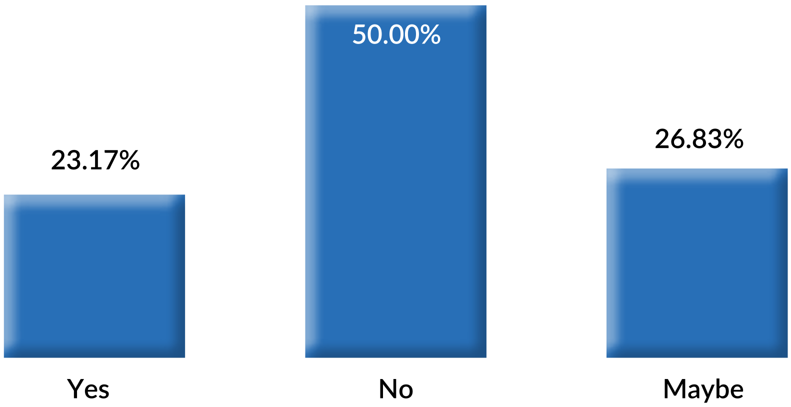
Discussions with a recycling start-up engaging small and medium waste generators reveal that many organisations are unaware that they have defined responsibilities under current waste management rules, including obligations related to authorised channelisation and record maintenance.

The absence of inventory systems and formal recycling contracts observed in the survey may therefore reflect a broader structural compliance gap. For EPR frameworks to function effectively, awareness must be coupled with institutional support that builds organisational capacity for tracking, documentation, and formal engagement with authorised recyclers.

C. Limited interest in refurbished devices

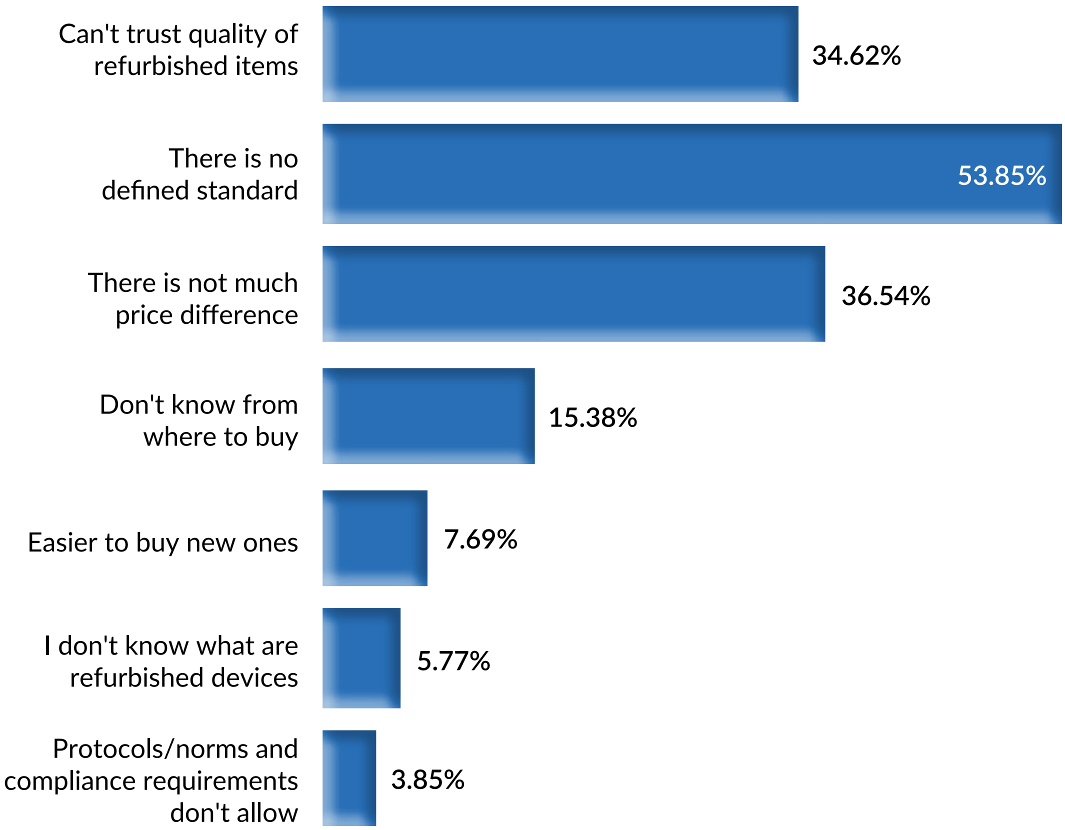
50% of the respondents stated that they **would not be willing to use devices with refurbished batteries or refurbished solar PV modules**.

CHART 15 | **Interest in Refurbished Devices**



53.85% of the respondents selected **lack of clearly defined standards** while 34.2% selected **low trust in quality of refurbished items as reasons for this disinterest**. As the question allowed multiple responses, respondents could select more than one disposal option.

CHART 16 | **Reasons for Disinterest in Refurbished Devices**



Focus group discussions

Four focus group discussions were conducted in Gandhinagar and Ahmedabad with randomly selected consumers, with each group comprising 10 – 12 participants. These discussions were designed to complement the survey by enabling deeper exploration of the motivations and reasoning underlying respondents' answers. While anchored in the survey themes, the conversations were intentionally broader in scope, encompassing lithium-ion batteries from other consumer electronics as well as additional e-waste streams. Key insights emerging from these discussions are summarised below:

A. *Kabadiwala* as the preferred pathway, but with uncertainty over final treatment.

Consistent with the survey findings, focus group participants expressed a strong preference for *kabadiwalas* as a convenient, doorstep option for e-waste disposal, often citing the assurance of immediate collection and better prices. However, when asked whether they believed *kabadiwalas* subsequently route e-waste through safe and environmentally sound end-of-life pathways, almost all participants responded in the negative.

When probed on their willingness to pay a modest premium to ensure that e-waste is directed towards safe repair, refurbishment, or recycling, responses were evenly divided. This finding should be interpreted with caution – stated willingness to pay may not fully translate into actual behaviour, and some participants who expressed willingness in principle may be disinclined to incur additional costs in practice.

B. Smartphones show how trust, not technology, determines acceptance of refurbished products.

Participants were generally reluctant to purchase refurbished products, citing uncertainty over quality and performance relative to new items. Mobile phones were a notable exception, with many participants willing to buy – and already using – refurbished or repaired devices.

Refurbished phones have gained acceptance in India because the ecosystem has reduced perceived performance and safety risks through pricing, warranties, and platform-led trust. Similar acceptance has not emerged for other refurbished products, such as batteries or photovoltaic modules, where performance is harder to verify, failure risks are higher, and credible intermediaries are lacking.

C. Safety concerns around li-ion battery failure are widespread

Focus group participants consistently expressed safety concerns related to lithium-ion battery failure, particularly risks of overheating, fire, and explosion. These concerns were heightened for repaired or refurbished batteries, where confidence in quality assurance and handling was low, and the perceived consequences of failure were severe.

D. Hoarding of small electronic devices remains common at the household level

Focus group discussions indicated that households commonly retain small electronic devices – such as mobile phones, chargers, and accessories – long after they cease to be used. Participants cited uncertainty over residual value, data security concerns, and the ambiguity about appropriate end-of-life options as key reasons for hoarding. In many cases, devices were kept as perceived "back-ups".

E. Consumers focus on device utility rather than underlying technology

Focus group participants reported limited awareness of the underlying technologies in electronic devices, including lithium-ion batteries. Their decisions around purchase, use, and disposal were driven primarily by observable functionality, price, and convenience, rather than by technical attributes such as battery chemistry, design, or safety features.

In addition, a community consultation was conducted with 25 women from a wastepicker community in Delhi. The group was selected due to the high levels of trust established with the participants, which enabled open and candid discussion. At least one member of each participant's household was engaged in waste-related work, though not necessarily in e-waste or battery waste. Key insights emerging from this consultation are summarised below:

A. Safety is interpreted through observable experience rather than technical knowledge

Participants recognised battery risk through visible and experiential cues – such as swelling, heating, or leakage – rather than through an understanding of battery chemistry or formal safety information. This suggests that consumer-facing safety interventions premised on technical literacy or abstract risk communication are unlikely to be effective; instead, safety needs to be embedded in clear, observable device-level signals and handling cues.

B. Repair and reuse depend on the presence of trusted market pathways

High willingness to repair mobile phones reflects the availability of familiar repair networks, predictable costs, and established resale value within informal markets. In contrast, the absence of comparable intermediaries, price signals, or assurance mechanisms for batteries or solar PV panels leads consumers to default to replacement rather than repair. This indicates that circular economy outcomes hinge less on attitudes and more on whether repair and reuse pathways are visible, trusted, and economically attractive.

C. Income needs often outweigh safety and environmental concerns

Participants were aware of the health and environmental risks associated with informal recycling, but many prioritised immediate incomes over these risks. For households that rely on waste-related work to make a basic living – often in hazardous conditions and with little or no social safety net – higher and instant monetary returns take precedence over longer-term safety or environmental considerations. This indicates that awareness alone is insufficient to change behaviour unless safer collection and recycling options also protect livelihoods and offer comparable economic returns.

D. Responsibility is externalised where control over disposal options is limited

Participants widely viewed safe disposal and recycling as the government's responsibility, reflecting their limited control over product design, disposal infrastructure, and access to formal recycling systems. While participants are closely connected to waste-related livelihoods, they have little influence over how products are collected, treated, or recycled at end-of-life. This suggests that policy approaches relying on individual consumer responsibility are unlikely to be effective unless producer- or state-led systems are made visible, accessible, and operational at the community level.

Consolidated Key Insights Based on Consumer Interactions

Survey responses in conjunction with focus group discussions and consultations indicate that a substantial number of consumers:

- Value convenience and accessibility when choosing disposal pathways for end-of-life products.
- Respond positively to economic incentives associated with waste disposal.
- Display limited knowledge of safe disposal methods for batteries and solar PV modules.
- Demonstrate low familiarity with formal policy mechanisms, including Extended Producer Responsibility (EPR).
- Show limited willingness to use products containing refurbished batteries or refurbished solar PV modules.
- Engage with devices primarily at the level of utility, with little concern for their underlying technologies or material composition.
- Organizations, particularly small and medium establishments, often lack clarity regarding their responsibilities and obligations under EPR and related waste management frameworks.

The limited interest in refurbished batteries and solar PV modules suggests that expanding circular pathways such as repair, refurbishment, and second-life use will require stronger trust and assurance mechanisms. Insights from focus group discussions indicate that concerns around safety, performance reliability, and the absence of clearly defined testing standards or warranties reduce consumer confidence in refurbished products. Strengthening refurbishment ecosystems may therefore require the development of clear quality standards, certification or testing protocols, and credible market intermediaries capable of signalling product reliability to consumers.

Any system of instruments, incentives, or disincentives intended to channel endoflife EV lithiumion batteries, used solar PV modules, or any other ewaste stream must start from the recognition that consumers rarely engage with, or even understand, the material composition and embedded value of discarded products. As technology evolves, the range of digital and electrotechnical applications – and therefore the diversity of products and chemistries placed on the market – will continue to proliferate, whether through new battery chemistries and form factors or novel applications of already existing technologies. Expecting endusers to internalise this complexity, fully comprehend the associated waste management challenges and opportunities, and reliably “do the right thing” on that basis is likely to remain a structurally weak policy lever, even if awarenessraising efforts are scaled up.

This does not negate the value of consumer awareness programmes; rather, it suggests a recalibration of their role within the policy mix. **We therefore recommend designing a limited, clearly defined set of waste management pathways for ewaste, solar PV, and battery waste, communicating these pathways simply and consistently to consumers, ensuring that the pathways are physically accessible, convenient, and financially attractive, and reinforcing them through robust regulatory obligations under instruments such as Extended Producer Responsibility (EPR) frameworks**. The subsequent section builds on this consumerbehaviour insight to examine the role of the informal sector in ewaste, battery, and PV value chains, and to propose a potential integrated collection and end-of-life management model that leverages informal capabilities while aligning them with formal regulatory objectives.

THE INFORMAL SECTOR

The International Labor Organization (ILO) defines the informal economy as "all economic activities by workers and economic units that are – in law or in practice – not covered or insufficiently covered by formal arrangements." (ILO, 2002). In practical terms, this includes individuals and enterprises whose work takes place outside formal regulatory frameworks and who therefore lack many of the legal protections, institutional supports, and social security benefits associated with formal employment.

The use of the term "informal" often evokes images of a grey or illicit market. However, this characterisation does not accurately capture the role played by many informal economic actors, particularly in the waste management sector. In cities across India, informal waste workers provide essential services by collecting, sorting, and channelling recyclable materials back into production cycles. In doing so, they contribute significantly to urban waste management, public health, and environmental protection, often at minimal or no cost to municipal systems.

The ILO estimates that about 2 billion workers, more than 61% of the world's employed population, make their living in the informal economy (ILO, 2018). This phenomenon, therefore, is not unique to India but a characteristic of economies worldwide. Informality persists for a range of structural reasons, including limited availability of formal employment, regulatory and institutional barriers to formalisation, low capital entry thresholds for informal enterprises, and the integration of informal workers into formal economic supply chains (ILO, 2018; Chen, 2012; Perry et al., 2007). Moreover, economic activity rarely exists in a simple binary between formal and informal. As Martha Chen notes, economic relations typically lie along a continuum between fully regulated and protected forms of work at one end and entirely unregulated forms at the other, with many intermediate arrangements in between (Chen, 2007). Contemporary economic structures illustrate this continuum clearly. Platform-based services, for example, often combine formally registered corporate entities with large networks of gig workers who operate with limited employment protections. Such hybrid arrangements demonstrate that relationships between formal and informal actors are deeply embedded within modern economic systems.

The informal sector plays a foundational role in electronic waste (e-waste) management in India, often acting as the primary gateway through which discarded electronics are collected, sorted, dismantled, and partially recycled. Informal actors include a diverse set of participants – household wastepickers, itinerant collectors, neighbourhood scrap dealers (locally referred to in India as *kabadiwalas*), small dismantling workshops and local refurbishers – who together form extensive networks that operate outside formal regulatory frameworks to recover materials and parts from discarded electronics. These actors typically function without formal contracts, modern technology, or environmental safeguards, yet they are critical to the initial stages of the e-waste value chain, accessing discarded devices directly from households and small businesses, and extracting reusable components and valuable metals through manual processes. In India, one of the world's largest producers of e-waste, the informal sector dominates e-waste handling. Historically, estimates suggest that over 90 to 95 per cent of e-waste in India has been managed through informal channels, with only a small fraction reaching formal recycling facilities. **As with much else in the world, this reality embodies a complex duality – of resilience and risk, material recovery and material loss – shaping both the challenges and the latent possibilities of India's e-waste ecosystem**.

The duality of the informal sector

It is important to note that, **under India's waste management regulations, used PV modules are classified as e-waste and used EV lithium-ion batteries are classified as battery waste. However, for the sake of readability and to avoid repetition, this section, 'The Informal Sector,' refers to informal-sector workers managing either material collectively as working with 'e-waste.'**

The informal sector occupies a central yet frequently misunderstood position in India's electronics end-of-life landscape. Although policy frameworks treat discarded devices as "waste," much of what enters informal circuits is not waste in any meaningful economic or material sense. Local collectors, repairers, refurbishers, and dismantlers work within tight-knit neighbourhood networks where skills are passed on through practice and apprenticeship. These workers repair devices so they can be used again, recover parts that still function, and find new uses for materials that many people would throw away. As shown in studies of Bangalore's repair and dismantling clusters (Reddy, 2013), these actors operate through intricate social networks and tacit knowledge systems that convert discarded electronics into value, livelihood, and extended product life – functioning as a parallel circular economy long before the term entered policy vocabulary. Recognising this productive capacity is essential.

On the other hand, many recycling practices in the informal sector are inefficient and unsafe, especially for items containing critical materials or toxic components. These practices can have serious consequences for worker health, local environments, and India's long-term mineral and energy security. Given that more than 90% of the country's e-waste still flows through informal channels, these risks require urgent and careful attention.

- Secondary metal extraction from e-waste holds massive economic potential which is currently not being realized. As per one estimate, out of the total metal extraction potential of USD 6 billion (approx. INR 50,000 crore), only USD 1.1 billion (approx.

INR 9,100 crore) worth of metals are being extracted in India by inefficient informal recyclers that have limited technological expertise (Redseer Strategy Consultants, 2023). The recovery rates in India significantly lag global averages. For instance, for copper, recovery rates in India stand at 40-45 per cent, far below the global average of 75 per cent (Redseer Strategy Consultants, 2023). By optimizing metal extraction from e-waste, India can reduce import dependency and develop a reliable supply of high-value recycled metals. This becomes even more critical in case of critical ring-fenced commodities that are mined in limited countries with strong trade monopoly.

- The informal sector continues to be at significant risk while working with hazardous e-waste using unsafe methods. This puts the environment, and therefore anyone exposed to the compromised environment, at risk as well. E-Waste is considered hazardous waste as it contains toxic materials and can release toxic chemicals upon inappropriate treatment. Mercury, lead, dioxins, and brominated flame retardants are just some examples. Activities such as acid leaching, open burning, stripping of plastic coatings, and dumping on land and in water are especially dangerous as they release toxic pollutants, thereby contaminating the air, soil, and water.

Lessons from the Duality

India is now the world's third-largest generator of e-waste (UN Global E-Waste Monitor, 2024). National estimates indicate that India's e-waste volumes have risen sharply – by over 73% in just four years – from 1.01 million tonnes in 2019 – 20 to 1.751 million tonnes in 2023 – 24 (Government data as cited in Down to Earth, 2024). As India advances towards the vision of Viksit Bharat, powered by rapid digital expansion, consumer electronics uptake, and technology-led growth, the volume of discarded electronics will accelerate further. At the same time, India's clean-energy transition and critical-mineral security goals demand far more effective recovery of valuable materials from end-of-life products. Achieving these objectives requires recognising the dual reality of India's informal e-waste sector – and this duality has four immediate implications that should shape any future policy approach:

- **Not everything labelled as 'e-waste' is actually waste**. Much of it is repairable or serves as valuable feedstock for remanufacturing or repurposing. Treating all consumer discards as terminal waste misreads how the system functions, undermines existing livelihoods, and prematurely destroys materials and products that still have significant usable life.

- **A singular, sweeping narrative of 'keep e-waste out of the informal chain completely because e-waste is hazardous' is flawed**. Informal actors perform many non-hazardous but high-value tasks (collection, triage, repair, parts harvesting) that reduce overall material loss; policies that block these activities without providing viable alternatives will simply displace flows into clandestine or more dangerous practices.

- **The challenge is one of design, not of elimination**. The policy question therefore becomes how to create mechanisms, incentives and clear waste-flow pathways that preserve repair/reuse and formalise hazardous processing and critical material recovery, rather than attempting blanket exclusion.

- **Duality does not imply permanence of the status quo**. While informal actors play an important role in collection, aggregation, repair, and reuse – activities that are often high-value even if operationally lower-risk – hazardous and inefficient recycling carried out under unsafe and unregulated conditions cannot form part of a future-ready e-waste system. **A sustainable framework therefore requires informal activity to be steered towards these upstream functions (in a compliance-light model) that complement the formal sector, while environmentally sound recycling and critical material recovery are progressively consolidated within regulated facilities**.

  Such a transition, however, has livelihood implications, including potential short-term impacts on income streams and occupational roles within the informal sector. Recognising these transition dynamics is critical. Policies that seek to restructure the e-waste value chain must therefore ensure that alternative roles within collection, repair, refurbishment, or pre-processing systems remain economically viable for informal workers.

Informal Sector: Solar PV and EV Li-Ion Batteries

The informal sector activities are shrouded in secrecy due to the regulatory and legal risks associated with operating outside formal systems. On conditions of anonymity, we engaged in in-depth conversations with three informal aggregators and dismantlers in Delhi, two in Gujarat, and one in Tamil Nadu. Below are some key insights:

- **Majority of the e-waste is sent to National Capital Region (NCR):**
  Aggregators in Gujarat stated that they do not aggregate li-ion batteries, whether from EVs or other consumer electronics, nor do they collect PV modules. However, while the statement around PV modules might be accurate – primarily due to limited and irregular inflow, higher logistical challenges in transporting large panels, and low to non-existent downstream demand especially in the informal recycling sector – we are sceptical about the veracity of the statement around li-ion batteries from consumer electronics. The aggregators typically collect any item that comes their way and has downstream demand – li-ion batteries from consumer electronics are no exception. They also stated that they ship the e-waste to NCR for recycling, but they refused to divulge further details. This statement was validated in interviews with non-profits, start-ups, researchers, and formal recyclers. A combination of reasons, discussed later in this section, could be driving this value chain structure.

TAMIL NADU: CONVERSATIONS WITH AN INFORMAL SCRAP COLLECTOR

Jagan, name changed to preserve anonymity, works as a scrap dealer at the border of Coimbatore district in Tamil Nadu. He collects e-waste primarily via two channels:

1 Bulk pick-up – Bulk waste generators typically require submission of quotes by formally registered e-waste recyclers. Jagan partners with one such formal actor that meets the formal e-waste recycling registration requirements, at least on paper, and pays a negotiated fee to the formal actor. From that point onwards, the waste belongs to Jagan.
2 Household collection – Like many informal collectors in Tamil Nadu, Jagan regularly traverses nearby neighbourhoods in a small collection vehicle fitted with a loudspeaker, announcing the collection of discarded electrical and electronic items. Mixer-grinders, wet grinders, and televisions are among the most frequently collected and economically attractive items in this stream.

A local waste-focused organisation noted that successive Tamil Nadu government welfare schemes have distributed a wide range of electrical and electronic equipment to households. These interventions have undoubtedly generated significant social benefits – including improved access to information through televisions and time savings in domestic work through electrical mixers and grinders, particularly for women. However, an unintended consequence has been the growing volume of end-of-life appliances entering the informal e-waste value chain.

IMAGE 1 | **Aggregated television sets at the informal scrap dealer's site**

TAMIL NADU: CONVERSATIONS WITH AN INFORMAL SCRAP COLLECTOR

At his site, Jagan undertakes preliminary sorting and limited dismantling of collected e-waste, after which the material is sold to larger scrap aggregators. These aggregators typically transport the e-waste to Delhi-NCR, which functions as a major hub for downstream recycling activities.

However, no reliable quantitative data or traceability mechanisms are available to establish the proportion of this material that is ultimately processed through formal recycling facilities, informal operations, or mixed pathways in which informal actors channel material into formal systems. Information on downstream treatment is therefore based primarily on stakeholder perceptions rather than verified data. Interviewees indicated that a substantial share of the e-waste shipped from Tamil Nadu is believed to be processed through informal recycling operations in Delhi-NCR and other northern regions of India.

Jagan employs one individual. His account broadly corroborates statements made by other stakeholders: many workers engaged by scrap collectors and aggregators for sorting and dismantling e-waste are migrants from other states, including Bihar and West Bengal.

Jagan holds a GST registration. However, he acknowledged that most of his transactions are conducted in cash and remain unrecorded. His operational set-up is rudimentary, and even basic personal protective equipment was absent at the time of observation. Jagan stated that he does not undertake hazardous recycling activities such as acid leaching or open burning. Based on field observations at his site, this claim appeared consistent with the activities observed, which were limited to collection, sorting, and manual dismantling.

Other stakeholders interviewed independently reported similar patterns in Tamil Nadu, noting that informal actors are primarily engaged in collection, aggregation, and sorting, while highly hazardous recycling practices are not commonly observed within the state. Several stakeholders attributed this, in part, to comparatively stricter enforcement of pollution control norms.

While Jagan did not divulge his income, he mentioned that his income currently is sufficient to support his and his family's needs. Upon asking, in context of his work, what would be most beneficial, he mentioned the following:

- I would like easy access to capital. Prices fluctuate, so I would like to use the capital to get access to more space to store my inventory and wait for prices to increase.
- I don't know how I can get the paperwork that will allow me to pick bulk waste without depending on any other actor's paperwork.

Interestingly, Jagan had installed solar PV panels at his workshop – panels that had been discarded by a household but are now powering fans and lights at his shop.

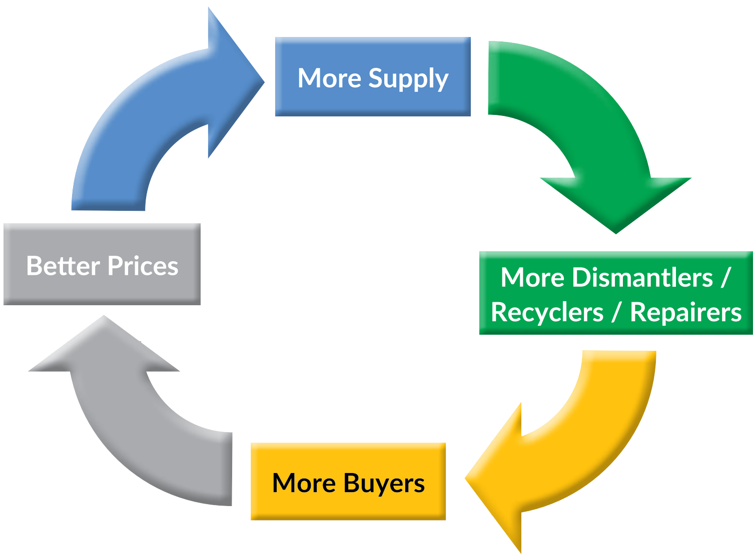
.IMAGE 2 | **Solar PV Panels at Installed at Jagan's Workshop**

Delhi/NCR has India's largest and most specialised informal e-waste clusters. As per a 2018 study (Toxics Link, 2018), in which 15 areas in Delhi/NCR were surveyed, Seelampur (New & Old) in Shahdara, Mustafabad in North-East Delhi, Behta Hazipur and Loni in Ghaziabad came across as the biggest hotspots for informal processing and handling units. The study estimated that the Delhi NCR region may have more than 5000 e-waste processing units that engage more than 50,000 people.

The concepts under economic geography, a field of study that examines how economic activities are distributed across space and why certain places become hubs for specific industries or trades, provide plausible explanations for this concentration of informal e-waste processing capacity in Delhi/NCR region.

- **Benefits of clustering:** The neighbourhoods, some of which were mentioned earlier in this report, in Delhi-NCR gradually developed specializations in a relatively closely located geography. Specialized dismantling shops, component extraction units, wiring and copper recovery, reuse and repair markets, and brokers and aggregators – all could be found in a dense clustered ecosystem. The dense clustering reduces search cost of buyers and sellers, minimizes transport and transaction costs, and mitigates risk by increasing the pool of potential buyers for each component. Therefore, this cluster offers higher prices for many used devices and parts, thereby pulling material into Delhi-NCR from across India.
- **Once a hub forms, it keeps growing:** Economic geography shows that early advantages tend to reinforce themselves. Once Delhi had an established ecosystem, it became rational for traders from other states to ship e-waste there, even over long distances, because the value recovery per kg in Delhi was higher.

FIGURE 2 | **Reinforcement Loop**



Source: Authors' Illustration

- **Labour skills and tacit knowledge concentration:** Informal recycling depends on skills learned through apprenticeship, not formal training. These skills are spatially sticky. Economic geography research shows that certain industries stay anchored in places where tacit knowledge is strongest. Delhi became irreplaceable because its workers accumulated decades of dismantling (and recycling) knowledge that cannot easily be replicated by other states.
- **National connectivity and specialized downstream markets:** Delhi's location and transport connectivity made it well-suited to be an ideal redistribution centre. The northern freight corridor passes through Delhi and Uttar Pradesh's vast scrap trading networks are right next door. Delhi's own specialized electronic markets, such as Nehru Place and Gaffar Market, provide downstream pathways.

Another factor which was not explored as part of the study but could have played a part in the differential in informal e-waste processing capacity between Delhi-NCR and other states is stricter enforcement, higher compliance pressure, and better-zoned industrial areas in the other states. It must be noted that the transactions are not confined to exchanges within the informal sector alone. The highly concentrated formal recycling infrastructure in and around Delhi-NCR area also serves as a downstream channel for the informal sector, especially the bigger aggregators.

- **Used solar PV modules are reaching the informal actors:**

A field visit to an e-waste aggregator in Delhi indicated that end-of-life or damaged PV modules are beginning to flow into informal waste networks. This shows that PV waste is already being generated. The aggregator – who requested anonymity – operates as a micro-entrepreneur with a valid GST registration and is therefore formally recognised as a business. However, his activities extend beyond simple aggregation into informal handling practices, highlighting the blurred boundary between formal and informal operations. PV modules typically reach him through bulk e-waste collection tenders issued by offices and commercial establishments. Once the modules arrive at his facility, however, the downstream flow is constrained by two critical factors:

- Lack of local formal recyclers equipped to handle PV module processing; and
- Limited technical knowledge on safely and effectively extracting valuable materials from PV modules.

In the absence of formal recycling capacity, end-of-life PV modules collected by this aggregator are treated using rudimentary dismantling and scrap-recovery techniques. The aluminium frames and external copper wiring or junction boxes are manually removed and sold as scrap, but the rest of the module – including glass, polymer encapsulant, silicon cells, and embedded metals – remains largely unrecovered. Often the panels are crushed or broken, and the resulting mix of glass, polymer and silicon fragments is disposed of as general waste or sent to landfill.

IMAGE 3 | **Discarded Solar PV Panels' Dismantling in Delhi**

- **EV lithium-ion batteries are not reaching the informal actors:**
  Informal-sector actors reported that end-of-life EV lithium-ion batteries are not currently entering their networks. They acknowledged having limited technical capacity to handle such complex battery systems and expressed concern about the safety risks associated with improper dismantling or storage. They also noted that EV lithium-ion batteries generally flow back to authorised service centres or dealers, rather than entering informal collection channels.

  One statement during our conversations revealed two key insights:

> "We currently do not dismantle or recycle EV lithium-ion batteries. But over time, we can learn to do that. Just how we figured out dismantling batteries from computers etc."

First, it underscored that the informal sector operates through an apprenticeship-based system, where skills are acquired experientially and passed down across generations. This mode of learning has long enabled informal actors to adapt, innovate, and sustain their livelihoods. As a result, it is highly plausible that the informal sector could eventually devise its own methods for extracting value from complex EV lithium-ion batteries, although such methods may be unsafe, inefficient, or environmentally unsound. Without proactive policy intervention, such capability expansion may occur through unsafe and inefficient practices, with significant environmental and health risks.

Second, it underscores a more immediate environmental, health, and resource-loss risk arising from lithium-ion batteries from consumer electronics, which routinely enter informal waste channels and are already being dismantled by informal actors.

- **Informal-Formal linkages:**
  The informal aggregators told us they routinely rely on paperwork supplied by partnering authorised recyclers to legitimise the downstream handling and disposal of collected e-waste. In practice, the aggregator collects waste under the formal recycler's documentation, then either carries out dismantling and partial recovery themselves or sells material onward to other informal actors; the authorised recycler's role is often limited to recording quantities on paper to satisfy EPR compliance. This informal – formal alliance has been documented in multiple studies and reviews of India's e-waste value chain, which find widespread linkages between registered recyclers and informal workers, weak monitoring of actual material flows, and instances where formal paperwork masks informal processing.

  Independent investigations corroborate these observations about the weak integrity of some formal e-waste channels. A recent media investigation by Newslaundry (2024) found that 75% of 41 government-approved e-waste recycling plants across four states were either non-existent or operating only on paper, despite collectively holding authorisations to recycle 8.49 lakh tonnes per year and generate an estimated INR 1,800 crore worth of EPR credits. While these findings are indicative rather than exhaustive, they reinforce the wider concern that formal compliance documentation can mask extensive informal handling, with reported 'ghost operations' allowing formal entities to claim recycling volumes that are, in reality, processed by informal workers.

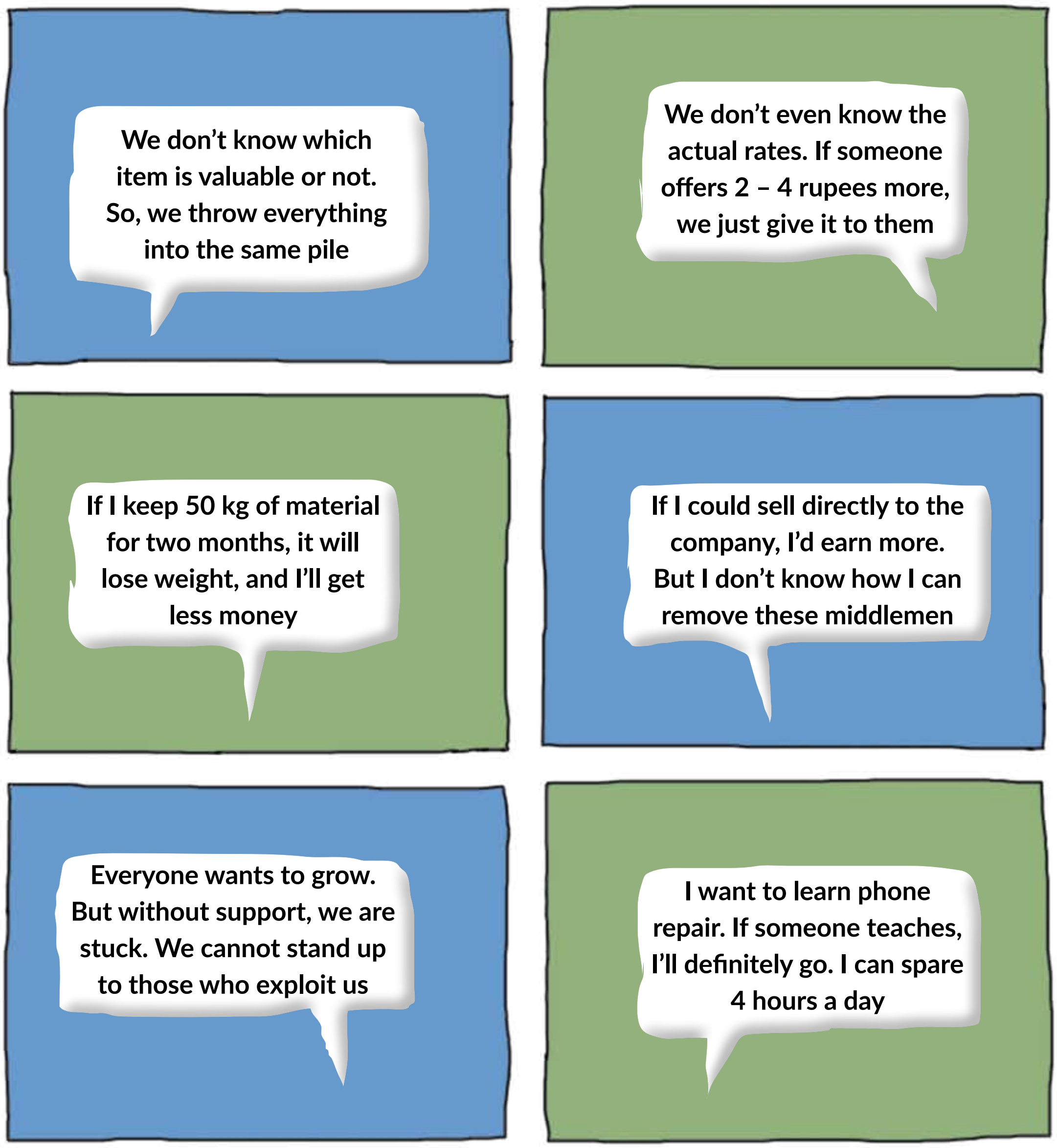
- **Obstacles to formalizations:**
  Although this report refers to the 'informal sector' as a single category, it in fact spans a wide spectrum. At one end are workers operating at subsistence levels, focused on day-to-day survival. At the other are larger, well-organised actors who have developed sophisticated operating models, extensive networks, and scale efficiencies, leveraging arbitrage opportunities to run highly profitable businesses. The informal ecosystem, therefore, is far from homogeneous and functions through diverse economic logics and capabilities.

We spoke with Sonu (name changed to preserve anonymity), an e-waste collector who works at the very margins of subsistence. He lives and operates out of an informal settlement in Delhi. The camp's narrow, slush-covered lanes, improvised housing, and fragile infrastructure stand in stark contrast to the upscale neighbourhoods that surround it – an everyday reminder of the city's deeply entrenched inequalities.

Sonu makes anywhere between INR 9,500 and INR 13,000 per month – not sufficient by any standard for a dignified existence in a city like Delhi. When urged to imagine a scenario where he could do any work he wished, he expressed his desire to become a repair worker and fix consumer electronics such as smartphones. But he very swiftly added that he has no clue how he could become one.

On the other end of the spectrum, we spoke with two informal aggregators whose views were divergent. They both held valid GST registration but engaged primarily in cash transactions. They both had well established downward supply chains for various material types, engaged in dismantling of e-waste, and employed individuals under them.

IMAGE 4 | **Sonu's Aggregation Site (Doubles-Up as Home)**

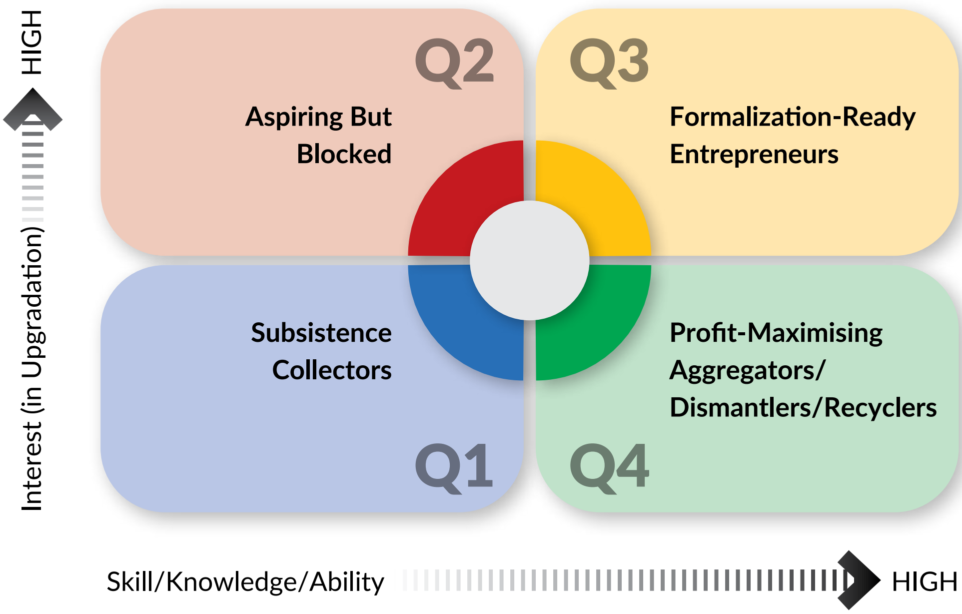


Informal Aggregator 1: Expressed aspiration to set-up a small formal e-waste recycling unit of 10 to 20 tonnes per day (TPD) capacity but lacked access to financing and compliance and regulatory knowledge.

Informal Aggregator 2: He expressed no interest in transitioning to a formal set-up. He emphasised that as long as dismantling and material extraction yield higher economic returns than selling whole aggregated items, he and others in similar roles will continue engaging in this activity. Existing studies note that GST rationalisation may help smaller recyclers comply with regulatory requirements and remain financially viable, while also generating broader benefits in the form of increased tax revenues and environmental gains. However, when asked whether GST rationalisation would influence his own business model in any way, he stated unequivocally that it would not affect his operations. His response suggests that as long as dismantled fractions command higher prices, he will persist with current practices. Meaningful change, therefore, would require a shift in downstream demand for these materials. (Note: The quote cited earlier – “We currently do not dismantle or recycle EV lithium-ion batteries. But over time, we can learn to do that. Just how we figured out dismantling batteries from computers etc.” – is attributed to Aggregator 2.)

Informal Sector: A Framework to Analyse Heterogeneity

FIGURE 3 | **A Framework to Analyse the Heterogeneous Informal Workers’ Pool**



Source: Authors’ Illustration

If we place Sonu in the above framework, he will feature somewhere in the top-left quadrant (Q2) – aspiring to earn better in safe and stable working conditions but blocked by skill, resources, and opportunities. Informal Aggregator 1 would be placed in the top-right quadrant (Q3) – ready to be formalized as entrepreneurs but lacking in enabling pathways. Informal Aggregator 2 would be placed in bottom-right quadrant (Q4) – profit maximisers interested in maintaining status quo. The term ‘profit-maximizing’ in this framework should not be interpreted as a normative judgement about the motivations of these actors. Rather, it reflects the economic incentives under which larger aggregators, dismantlers, and recyclers operate. Having already established relatively stable supply chains and processing arrangements, these actors may have limited incentives to alter

existing practices if doing so is perceived to reduce margins or introduce operational uncertainty. Their preference for maintaining the status quo therefore reflects rational responses to prevailing market conditions rather than any intrinsic resistance to safer or more formalised systems.

Chintan's more than two decades of experience working with Safai Sena – a Delhi-based wastepickers' collective, conversations with Safai Sena members, and insights from experts working with the informal sector reveal the following insights:

A. Collection & Aggregation (All quadrants)

- Door-to-door collection and street-level collection are likely to be dominated by subsistence collectors (Q1) and aspiring workers (Q2).
- Aggregation hubs that consolidate e-waste from multiple collectors are likely to be dominated by profit maximizing aggregators (Q4) and formalization-ready entrepreneurs (Q3).
- They provide high coverage, and low-cost and deep penetration into households and small businesses.

B. Sorting & Dismantling (Q2, Q3, Q4)

- Low-hazard, medium-complexity waste (desktop, printers, small appliances) is efficiently dismantled by organized informal actors (Q3, Q4).
- High-hazard waste (cathode ray tubes, batteries, PCBs) are often handled informally with high health and environmental risk and low efficiency. This is where formal intervention is most urgent (Q2, Q3, Q4).

C. Repair & Refurbishment (Q2, Q3)

- Aspiring workers (Q2) can be trained to test, repair, and refurbish devices with high repair potential, and less complexity and hazards.
- Formalization-Ready entrepreneurs (Q3) can be enabled to run small refurbishment units or partner with formal brands for take-back and resale.
- These roles could help extend product life, reduce waste, and create high-value jobs.

D. Material Supply to Formal Sector (Q3, Q4)

- Profitmaximizing (Q4) and entrepreneurial (Q3) aggregators can become reliable suppliers of sorted preprocessed fractions to formal recyclers. Thereby formal sector gains access to volume and local networks, and informal sector gains stable prices and reduced risk.

Formal Recycling: The Pain Points

Formal recyclers view the diversion of material from consumers to informal collectors and aggregators as one of the most significant threats to the development of effective formal recycling infrastructure. This perception is grounded in structural realities. With minimal compliance requirements and lower operational costs, informal collectors and aggregators are able to offer consumers higher prices for their e-waste. Their ability to provide rapid, doorstep collection services further strengthens their competitive advantage. In contrast, formal recyclers bear substantial fixed and operational costs, including labour, environmental safeguards, documentation, GST compliance, and investments in safe processing technologies. As a result, they find it difficult to match the informal sector's convenience and price offerings. Several smaller recyclers noted that these pressures can push formal entities toward wrongful practices. As discussed earlier, media investigations have uncovered instances of 'ghost operations' where formal recyclers report recycling volumes on paper while outsourcing actual processing to informal dismantlers, thereby bypassing safety and environmental norms.

E-WASTE: GHOST OPERATIONS AND MINIMUM GUARANTEED PRICING

In the context of the broader e-waste stream, floor prices refer to the minimum guaranteed prices set by the government for purchasing Extended Producer Responsibility (EPR) certificates which represent the formal recycling of e-waste. This mechanism is designed to ensure that recyclers receive fair compensation for their services that supports their viability. The producers are contesting these floor prices saying that these are much higher than the price currently paid. The recyclers, though, are split. Some believe that the low prices that the producers are referring to are feasible only because the recyclers that these producers have contracted with are very often running ghost operations. Chintan's conversations with recyclers and dismantlers point to the distinct possibility that even though the producers might have contracted with formal recyclers, some of these formal recyclers use informal actors to process the e-waste on their behalf. This allows the recyclers to sell e-waste EPR certificates at extremely low prices of Rs. 6 or 7 per kg, which is not feasible for a formal recycler with proper machinery, compliance overheads, and safety requirements. Another common scenario is where paperwork exists which allows selling of EPR certificates, but no infrastructure exists, nor recycling takes place. In the absence of mandated floor prices that reflect the actual cost of operations, the existing formal recyclers cannot sustain themselves, nor are new formal recyclers incentivized to enter the market. This situation will only lead to the proliferation of unsafe and inefficient unauthorized recyclers, undermining extended producer responsibility and impeding the recovery of critical minerals. However, setting floor prices alone will not resolve the issue; it must be complemented by robust monitoring and enforcement mechanisms to ensure compliance with e-waste management rules.

The desired path though lies somewhere in the middle – neither business as usual, nor complete stomping out of the informal sector can be the solution. Policy interventions that incentivize, enable, and enforce appropriate pathways for specific products and material types are key. Market forces alone cannot be relied upon to shape circular systems, particularly when climate goals, and resource and energy security considerations, are at stake.

Policy Considerations

Clear pathways' framework for used products

A prevalent theme that emerged in all of the focus group discussions with citizens from low- and middle-income groups was encapsulated in the statement, "We do not know what is inside a product." Some went further and said, "And we often don't care what is inside a product." Ignorance and apathy are not surprising, but it is nevertheless critical to remember these attributes when designing implementable policies. Technology and its applicable use cases continue to expand. The more sophisticated products that are critical for energy and resource sufficiency, such as photovoltaic modules or lithium-ion batteries, and that lend themselves neatly to better traceability, will eventually forge a path of circularity. The same cannot be said about the seemingly insignificant products that will continue to fill our landfills insidiously – for instance, that set of tiny solar-powered lights bought for the home garden that must be replaced every six months, or that toy which is a complex combination of electronics, plastic, metals, and battery.

Environmental knowledge and public awareness are just two of the determinants of recycling intentions. There are many additional factors such as willingness to pay, infrastructure, convenience, publicity, and data security (Michael, Hungund and K.V., 2024). Add to that the complexity of decision-making for a typical consumer. There is thus a need to mandate a limited number of clear pathways for used electronic products – a simple, visible code on the product that indicates which channel each used product should follow.

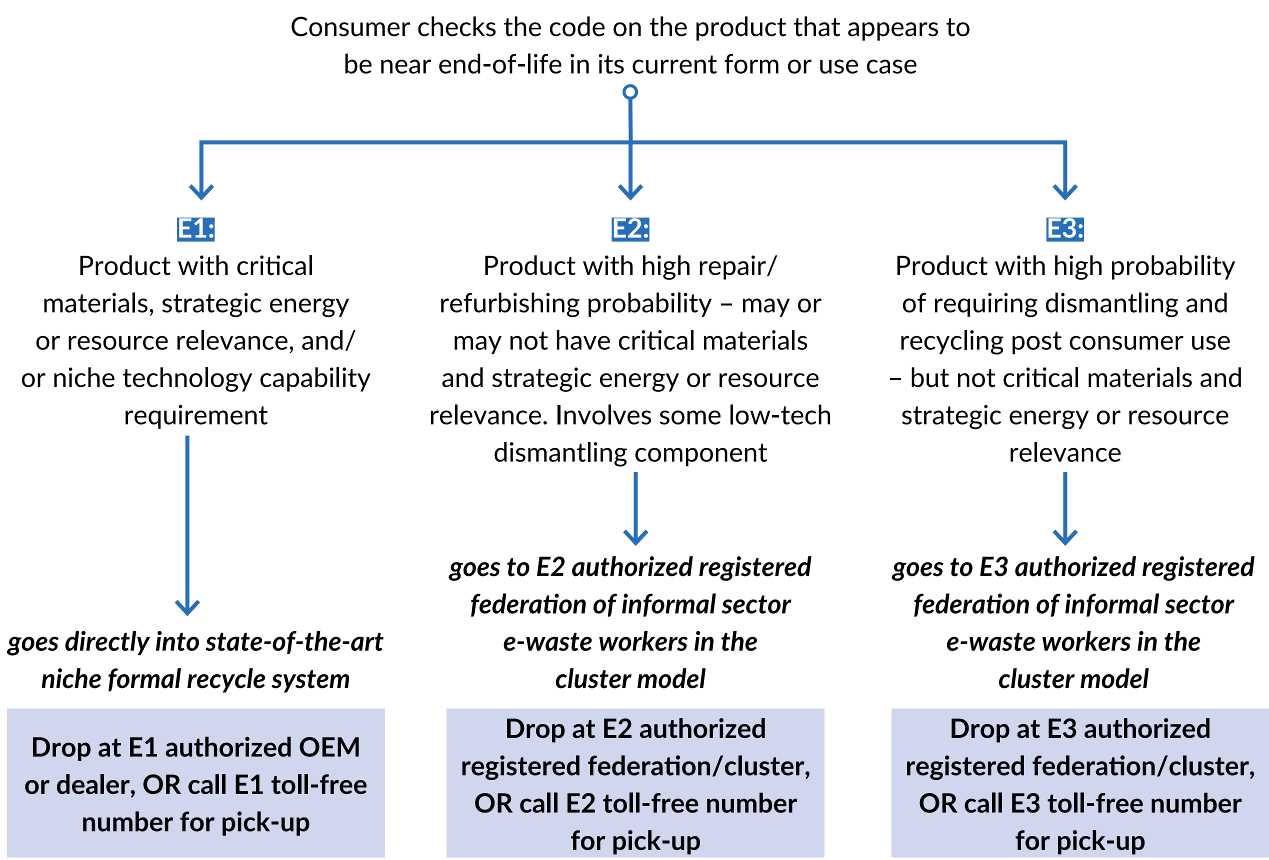
The recommended elements of such a framework would be:

- Products are complex combinations of various materials. The onus should be on the producer/brand owner to assign an easily readable, non-destructible code on the product itself – not on the packaging. The code should be based on an assessment methodology defined by the government in close consultation with all relevant stakeholder groups. Criticality, complexity, and hazardousness are three parameters that must feature in the assessment methodology, with highly hazardous products always routed to the most controlled pathway. Where relevant, accompanying instructions or parameters linked to the code should be available in multiple Indian languages, not only in English.
- A product should not be allowed to hit the shelves without the code.
- The code must take the majority of decision-making out of the consumers' hands.
- The corresponding waste pathways associated with the codes should be limited in number and non-overlapping.
- As a consumer, one should only have to make one of two decisions – whom to call or where to drop. That decision should be unambiguously facilitated by the assigned code on the electrical and electronic product.
- The coding system should be linked to a financial incentive mechanism, such as a visible deposit-refund or buy-back value embedded in the product price, to create an economic incentive for consumers to return end-of-life products through designated pathways.

Below is a potential conceptual flow in the proposed future state. Note that this is only to illustrate the idea. For such a mapping to be realistically possible, the informal e-waste workers will require skill upgradation, adherence to a lighter variant of compliance requirements, positive incentives, and an environment that builds trust. We discuss this in later sections of this document.

Inclusion does not mean allowing the informal actors to continue hazardous recycling; inclusion implies securing their place in collection, repair and refurbishment, sorting, and dismantling, while progressively eliminating crude recycling practices through better economics and regulations. Capitalintensive recycling operations - especially those involving high temperatures, chemicals, and complex emission control - should be reserved for regulated formal facilities, with informal actors integrated upstream in the E1-E2-E3 pathways and within the lightcompliance Q1-Q2-Q3-Q4 models. For illustration purposes, the diagram (Figure 4) shows generic E1-E2-E3 pathways. Product-specific allocations within these pathways for solar PV modules and lithium-ion batteries are discussed in the respective sections of this report.

FIGURE 4 | **A Conceptual Flow Under E-Waste Code Framework**



Source: Authors' Illustration

- **'Critical' products must be launched with closed loops and clear repair, refurbishment, and recovery pathways in the formal ecosystem**

  We explore this topic in detail in the section 'Extended Producer Responsibility'. But it must be noted here that while informal sector does have a significant role to play in the e-waste value chain (see above), products with energy and resource sufficiency implications must be mandated to be launched with defined closed loops and clear repair, refurbishment, and recovery pathways within the formal ecosystem.

  This category should explicitly include products with direct energy-security and climate implications. Accordingly, the requirement must not be limited to today's dominant technologies such as lithium-ion batteries or PV modules. Any emerging solar, storage, or other new energy technology should automatically be brought under this mandate at the point of market entry. Embedding repairability, refurbishment pathways, and end-of-life recovery into the design of future energy hardware ensures that circularity keeps pace with technological innovation, rather than reacting to it after systems are already widely deployed.

- **Enable design-driven, repair-first, refurbishment-centric ecosystem that includes informal workers as skilled human capital**

  The regulatory focus currently is on end-of-life and not design for disassembly or repairability. E-Waste Management Rules, 2022 introduced refurbishers as a new formal category. The refurbishers extend the life of products before they become e-waste and generate Refurbishment Certificates (RCs) that defer the EPR targets for producers based on the quantity refurbished and life extension period. But most refurbishing and repairing in India happens in the informal sector that is invisible to the EPR system and cannot help producers meet EPR deferral.

  EPR primarily targets collection and recycling tonnages. Incentives are not tied to how repairable or refurbish-able a design is. India's Right-to-Repair programme is in a nascent, early operational stages. The Department of Consumer Affairs (DoCA) launched a dedicated Right to Repair Portal in December 2022 to centralise repair information and list authorised/third-party repairers across four priority sectors (mobiles & electronics, consumer durables, automobiles/auto-equipment and farming equipment). The DoCA also convened a committee and in 2024–25 accepted a detailed Report on a Repairability Index (RI) for the mobile and electronics sector to help consumers compare products on ease-of-repair. The government has been running public outreach (for example a logo-design contest) as part of steps to operationalise the RI. While these are important institutional steps, the framework so far relies largely on disclosure, portal listing, and manufacturer participation rather than statutory mandates with clear, independent enforcement and audit mechanisms. And very importantly, it fails to include the informal sector.

  - Most devices reaching Q2/Q3 informal workers are still glued, riveted, or proprietaryscrewed, making safe repair and refurbishment unnecessarily hard and labourintensive. Informal refurbishers cannot easily access parts, schematics, or modular components, reducing the viability of highquality refurbishment.

- Q2 'aspiring but blocked' workers who want to become repairers remain excluded from official repair ecosystems and training pipelines. Q3 'formalizationready entrepreneurs' cannot easily leverage the Right to Repair ecosystem to become certified thirdparty repair/refurbishment hubs. In summary, they lack pathways to upgrade from collector/aggregator/dismantler to certified refurbishers or repairers.
- Finance flows to capitalintensive recycling, not to distributed repair/refurbishment and microdismantling enterprises that could employ Q2 and Q3 workers.

The European Union's regulatory framework offers valuable lessons for India in fostering a repair-first, refurbishment-centric circular economy and enabling the integration of informal repair workers into circular economy value chains. The Ecodesign for Sustainable Products Regulation (ESPR), which entered into force in 2024 and builds on and expands the Ecodesign Directive framework, shifts regulatory focus upstream to product design. It introduces requirements related to durability, repairability, disassembly, spare parts availability, repair information, and software support periods, with provisions to improve access to parts, tools, and diagnostics for independent repairers through delegated product-specific measures.

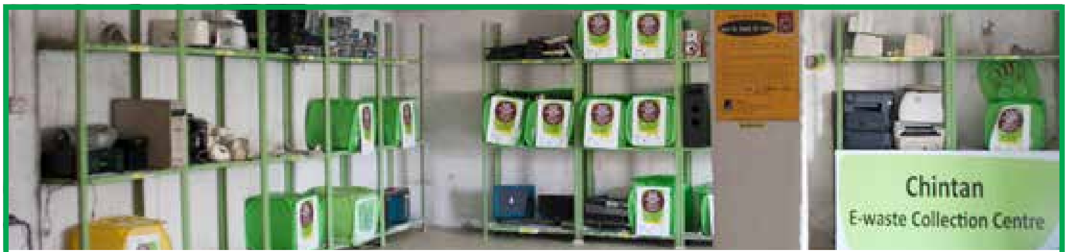
France pioneered a mandatory Repairability Index in 2021, which has evolved into the Durability Index. The Durability Index is a mandatory labelling system designed to inform consumers, through a numerical score on a scale of 0 to 10 and colour coding, how durable a product is. The index is based on three criteria: repairability, reliability, and upgradability.

The EU Waste Electrical and Electronic Equipment (WEEE) Directive establishes a comprehensive framework for the collection, treatment, recovery, and environmentally sound disposal of e-waste, based on the principle of extended producer responsibility (EPR). Beyond recycling, the Directive explicitly recognizes reuse and preparation for reuse as preferred waste management options, consistent with the waste hierarchy. It requires Member States to promote systems for the collection, testing, refurbishment, and resale of used electrical and electronic equipment, thereby supporting secondary markets and extending product lifetimes.

- **Develop a suite of pathways and enabling ecosystem that cater to the heterogeneity of the informal landscape**

A recent report on measures for upgradation of the informal workers in the value chain in electrical and electronic sectors in India (Sinha, Banthia & Shekhar, 2023) documents and analyses multiple intervention models – for example, NGO-facilitated cooperatives, municipal contracts with wastepicker groups, CSR-funded pilots, and social-enterprise collection and sorting centres.

While these are discussed, for good reason, as distinct approaches, **many share a remarkably similar underlying architecture: temporary funding, external coordination, and soft recognition of informal actors without systemic changes in market structure or regulation.**



CHINTAN'S APPROACH

Chintan was the first NGO to receive a collection licence from the Delhi Pollution Control Committee when the E-Waste (Management and Handling) Rules came into effect in 2012. On the supply side, Chintan works closely with informal wastepickers organised under the Safai Sena collective, while on the demand side it partners with authorised recyclers to ensure that collected e-waste is channelled safely and responsibly.

Chintan provides comprehensive training to wastepickers on safe collection, handling, and storage of e-waste, along with modules on occupational safety, communication skills, and financial management. Through Safai Sena, it facilitates ID cards, links wastepickers to e-waste generators, and supports access to social security, banking services, and digital payment systems. Chintan also runs educational centres for the children of wastepickers, strengthening long-term welfare outcomes.

Using its own vehicles, Chintan conducts decentralised pickups from participating wastepickers. Payments are made instantly through digital platforms. E-waste is then aggregated at Chintan's material recovery facility, from where authorised recyclers collect it, typically through a Producer Responsibility Organisation (PRO). This model has increased the monthly incomes of participating wastepickers by an average of 25%.

However, significant challenges persist:

- Scaling requires sustained investment: Wastepickers need better access to e-waste streams, improved temporary storage infrastructure, and opportunities to handle higher-value materials. Chintan requires predictable financing to maintain logistical operations, outreach, and programme management.
- Economic vulnerability persists: Most participating wastepickers remain at the bottom of the income ladder; even small differences in per-kilogram payments can prompt them to sell to alternative aggregators, potentially diverting material away from safe, compliant recycling channels.
- Low bargaining power: Unsteady and low volumes and limited options of partnering recyclers reduce the bargaining power. Hence better rates are tough to negotiate.
- Need to move beyond collection: Like most models facilitating formal and informal partnerships, Chintan's too focuses on facilitating e-waste collection and routing to formal recyclers. To unlock greater financial opportunities additional activities in the e-waste value-chain, such as repair and refurbishment, must be explored. But such exploration requires broader policy shifts.

Across the various operating models that are currently being implemented for upgradation, the multiple challenges can be distilled into a small set of foundational constraints:

- Dependence on external support: Most initiatives survive only as long as the non-profit, corporate social responsibility (CSR) or donor funding and facilitation continue. Once projects end, groups struggle to maintain operations.
- Weak integration into mainstream markets and EPR systems: Upgraded groups often lack stable, priceguaranteed offtake and are not structurally embedded in municipal contracts or producer responsibility frameworks.
- Limited access to space, finance, and lighttouch regulation: Cooperatives and enterprises operate from insecure sites, have little working capital, and face compliance demands that are either too heavy or too ambiguous.
- Opportunities limited to e-waste collection: As noted in the above case study from Chintan, most formal-informal partnerships are restricted to e-waste collection and aggregation. These activities have limited financial potential.

These challenges reinforce the need for systemic, incentive-centred reforms that embrace informal actors into markets, regulation, and EPR flows, rather than treating them as temporary project partners.

The quadrant framework developed in this study is not intended as an administrative classification of individual workers. Rather, it illustrates the diversity of skills, interests, and business models across the informal ewaste ecosystem. Policy should therefore offer a differentiated suite of enabling measures, ranging from basic safety to advanced training, lightcompliance licences and access to finance. Informal actors will selfselect into these opportunities according to their capabilities and aspirations, gradually revealing the functional 'quadrants' in practice without requiring the state to formally assign categories.

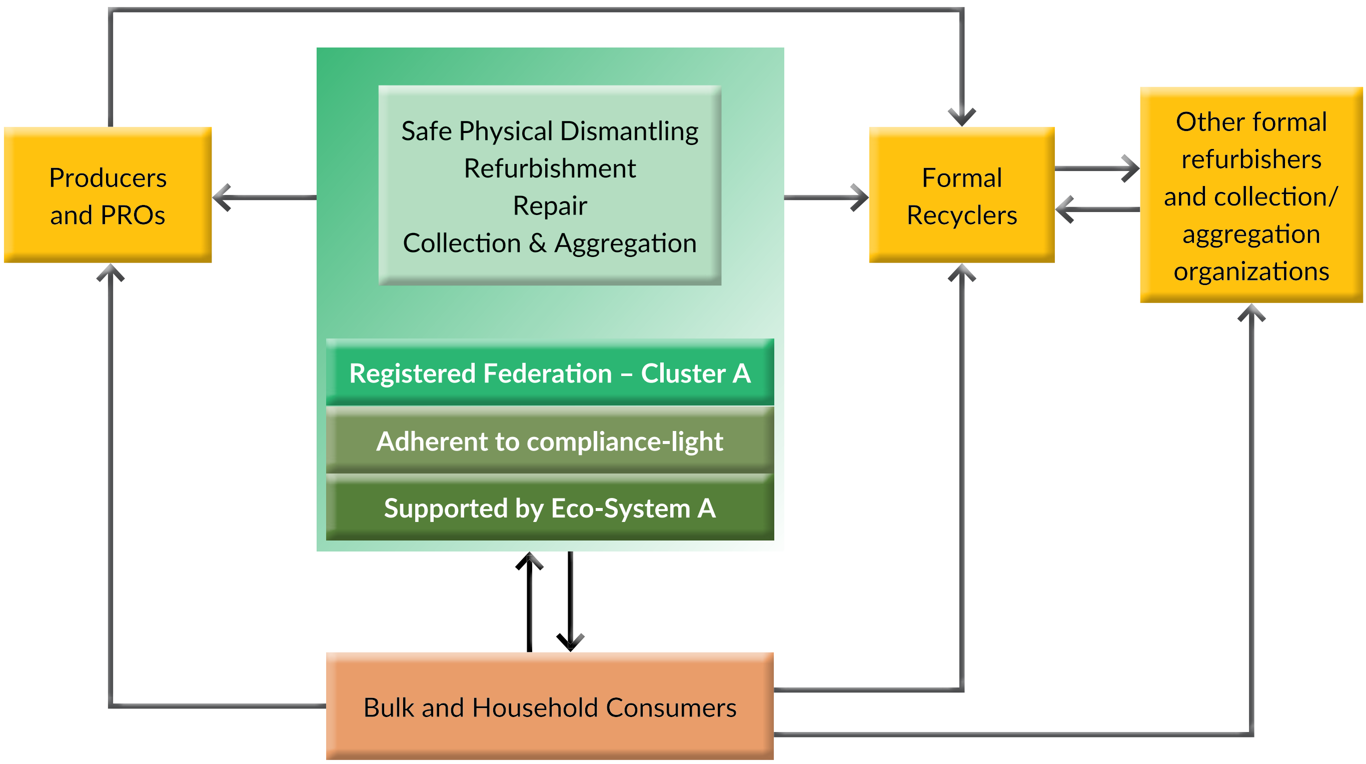
Below are key recommendations around policy levers:

A.	Offer registration-light/compliance-light pathways
•	A Tier-0 registration pathway with no fees, no immediate GST requirement.
•	Possibility of multi-year grace period to gradually move towards full compliance.
•	Link benefits to registration. Example: Eligibility for working-capital lines or micro-credits, minimum guaranteed prices that apply evenly across formal and compliance-light actors.
•	Community-level verification to form the basis of registration and issuance of relevant IDs and approvals.
B.	**Facilitate federation or cluster led formalization**
•	Instead of mandating individual compliance, support federation or clusterlevel entities in major ewaste hubs that take on health and safety management, basic traceability reporting, negotiation with PROs, and bulk procurement of tools and personal protection equipment (PPE) on behalf of members.

C.	**Set-up EPR mechanisms to benefit registered federations under compliance-light pathways**
•	Allow producers to claim EPR credits (via refurbishment certificates or repair certificates) from registered federations and clusters supported by digital traceability and third-party verification mechanisms to prevent credit integrity issues observed in the current formal-sector EPR system.
•	Set targets for PROs to buy a certain percentage of e-waste from registered federations and clusters at certain minimum guaranteed prices. The prices must be negotiated annually to reflect actual costs.
•	Allow registered federations and clusters to bid for EPR-funded collection programs, with preferential scoring to incentivize participation of informal sector federations or clusters and correct structural disadvantages in competitive procurement processes.
D.	**Map each registered federation or cluster to a support ecosystem of multiple stakeholders**
•	The support ecosystem would engage in activities such as regulatory, compliance, and bidding advisory, training delivery, and risk management and issue resolution.
•	A percentage of EPR budget can be earmarked for support system development - training, advisory support, and riskmanagement for clusters that supply ewaste or batteries to authorised recyclers or PROs.
•	The funding for such support system development activities should be for longer-term – not restricted to short-term projects. Funds can come from a combined pool of CSR funding, EPR budget, and other national and state schemes.
•	Each registered federation's/cluster's support group must comprise environmental lawyers/consultants, municipal liaison officers, PROs and authorized recyclers, non-profits, training and skilling partners, health institutions and safety experts, financial institutions, and community representatives.
E.	**Embed defined roles in specific waste management rules and EPR**
•	Manual collection, repair, refurbishment, and nonhazardous dismantling may be carried out by registered informal groups/federations or facilities operating under a lightcompliance regime. (Formal actors too would continue operating in this space – this role definition is not meant to exclude the formal players from these activities.)
•	Niche, hightemperature, chemical and other hazardous recovery processes may only be performed by authorised recyclers meeting full environmental standards.
F.	**Welfare schemes embedded in the registered federation/cluster structure**
•	NAMASTE scheme demonstrates that linking informal wastepickers to health insurance, PPE, training, and capital is politically and administratively feasible. A similar welfare package can be embedded into the economic structure of EPR-driven e-waste and battery systems. Participating in registered federation should be qualifying criteria for the workers, and the registered federation/cluster could be the channelizing bodies. The scheme could be co-funded through EPR budget.

Enforcement against nonparticipation must be phased and proportionate. The state should prioritise eliminating hazardous practices and bringing actors into registrationlight structures, rather than abruptly criminalising informal livelihoods. Current formal recycling capacity cannot replace informal collection and dismantling overnight; policy must therefore assume a long transition in which informal workers are progressively upgraded and integrated, not suddenly displaced.

FIGURE 5 | **Potential Material-Flow Scenario Under Recommended Future State**



Source: Authors' Illustration

- **The need for co-design with the informal sector**
  A high degree of mistrust characterises much of the informal waste ecosystem. Given the legally ambiguous nature of their work and long histories of exclusion, informal actors are often reluctant to open their operations to external scrutiny or to articulate challenges, risks, and aspirations – particularly to formal institutions, regulators, or intermediaries. This low-trust environment is not incidental; it is the outcome of repeated top-down interventions that have sought to reorganise informal systems without recognising informal workers as legitimate economic and governance actors.

However, any operating model that aims to gain traction and scale – such as the E1-E2-E3 and registration-light model discussed earlier in this report – cannot be effectively designed or implemented without the meaningful participation of informal sector actors in decision-making. Deciding what works for the informal sector in their absence reflects a paternalistic approach, wherein external actors assume superior knowledge of informal realities while denying informal workers agency over decisions that directly affect their livelihoods. Such approaches are likely to reinforce existing mistrust and result in institutional models that remain on paper but fail in adoption and practice. Accordingly, the design of the registration-light model and associated waste pathways must be undertaken through a multi-stakeholder, multi-disciplinary process that explicitly includes informal sector representatives as co-designers, rather than merely as implementers.

- **Prioritise high-impact e-waste hubs for pilot implementation**

  As discussed earlier in this report, Delhi/NCR functions as the primary hub for informal e-waste processing in India, with material – including Li-ion batteries from consumer electronics – flowing into the region from across multiple states. This spatial concentration of processing capacity, technical skills, and downstream markets implies that a relatively small number of geographies account for a disproportionately large share of value recovery in the current informal system.

  Applying the 80-20 principle (Pareto principle) – the idea that a large share of outcomes often arises from a relatively small share of inputs or actors – to operating model design suggests that early interventions should prioritise such high-impact hubs rather than attempting uniform rollout across regions. Piloting proposed models, such as the registration-light or hybrid formal-informal arrangements within established e-waste clusters in Delhi-NCR is likely to deliver disproportionately higher learning and impact relative to effort. This geography already possesses the right characteristics to test institutional design, governance mechanisms, and compliance pathways under real-world conditions.

PHOTOVOLTAIC (PV) MODULES/ SOLAR MODULES

As of early 2026, India's cumulative installed solar power capacity had crossed 140 GW (Press Information Bureau, 2026). The installed capacity is estimated to grow at a rate of 7 per cent compounded annual growth rate (CAGR) between 2025 and 2047 (Tyagi, Badal & Kale, 2025). Rapid growth in solar capacity today will translate into significant solar PV waste in the coming decades, underscoring the need for early end-of-life planning. The same study further finds that India could generate close to 11,221 kt of cumulative solar waste by 2047 – this is more than 76 times the cumulative solar waste at the end of 2024.

This projected rise in solar PV waste is not only an environmental challenge, but also a strategic opportunity to strengthen India's energy and material security. Effective recycling and recovery of materials from end-of-life PV modules can reduce dependence on external supply chains and lower exposure to energy and resource shocks – outcomes that are closely aligned with the Viksit Bharat vision. In this section, we delve into the various levers that are key to realizing this goal.

Policy Support Driving Solar Capacity

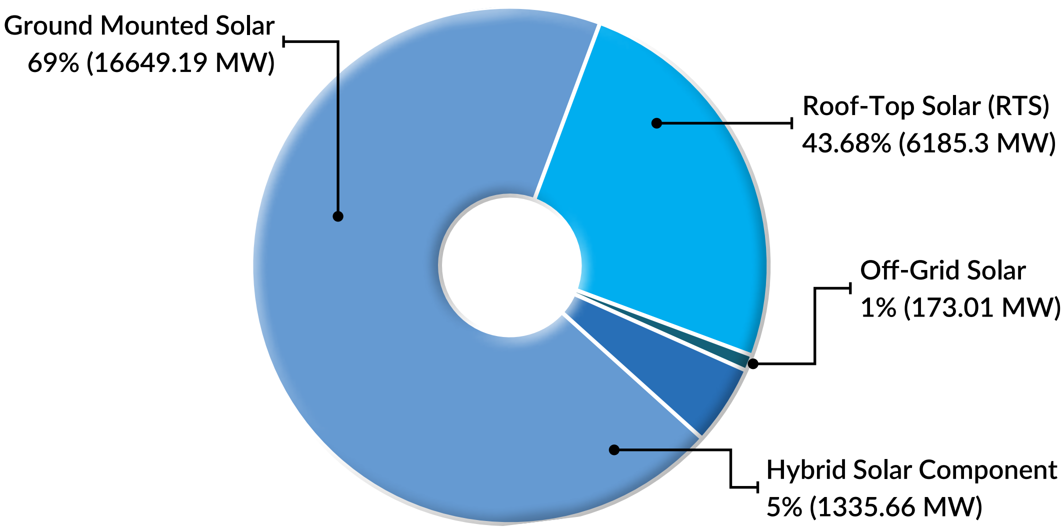
This rapid scale-up has been enabled by a layered policy architecture that combines demand creation, infrastructure development, and domestic manufacturing support. Over the past decade, India's solar expansion has been driven by flagship programmes that incentivise both distributed and utility-scale deployment. On the demand side, schemes such as PM-Surya Ghar: Muft Bijli Yojana aim to accelerate rooftop solar adoption by households through upfront capital subsidies, facilitative financing arrangements, and streamlined processes for grid connectivity, while PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan) targets decentralised solarisation in the agricultural sector by supporting standalone solar pumps, feeder-level solarisation, and grid-connected renewable capacity for farmers. Together, these schemes significantly broaden the ownership and geographic footprint of solar assets, embedding PV systems across rooftops, farmlands, and rural distribution networks.

At the utility scale, the Ministry of New and Renewable Energy (MNRE) Solar Park Scheme has played a central role in de-risking large projects by facilitating land aggregation, transmission infrastructure, and common facilities, thereby enabling rapid capacity addition through competitively bid projects. Complementing deployment-side incentives, the Government of India has also sought to localise and strengthen the solar manufacturing ecosystem through Production-Linked Incentive (PLI) schemes for high-efficiency solar PV modules, encouraging domestic manufacturing across the value chain. Additional policy instruments – including domestic content requirements in select public procurement, viability gap funding for storage-linked renewables, and long-term renewable purchase obligations – further reinforce investment certainty and scale.

Installed Solar Capacity: How the States Compare

GUJARAT: As of October 31st, 2025, with a cumulative installed solar capacity of approximately 24.14 GW, Gujarat has emerged as the state with second-largest installed solar capacity in the country, behind only Rajasthan. (Ministry of New and Renewable Energy (MNRE), 2024–25).

CHART 17 | **Gujarat's Cumulative Solar Power Capacity in Megawatts (As of October 2025)**



Source: Ministry of New & Renewable Energy, State-wise (Location based) installed capacity of Renewable Power as of 31.10.2025

The close to 6.2 GW of installed roof-to solar (RTS) capacity includes panels installed under Pradhan Mantri Surya Ghar Muft Bijli Yojna (PMSGY). According to data released by the state government's agency, Gujarat Urja Vikas Nigam Limited (GUVNL), as of May 11, 2025, 3.36 lakh solar rooftop panels had been installed in Gujarat under the PM Surya

Ghar Muft Bijli Yojana, the highest number in the country (Government of Gujarat, 2025). Stakeholder consultations reveal that ease of application process combined with extensive awareness campaigns that highlight the scheme's benefits to the citizens are driving this adoption.

In the above figure, off-grid solar includes standalone off-grid solar pumps installed to benefit farmers under Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM).

Hybrid solar component refers to the solar portion of hybrid renewable energy projects.

At around 69% (approximately 16.6 GW), ground-mounted solar constitutes the largest share of installed solar capacity in Gujarat. Ground-mounted solar refers to grid-connected photovoltaic systems installed on land, as classified in MNRE capacity reporting. This category includes projects located within MNRE-notified solar parks (generally ≥500 MW), including very large or 'ultra-mega' parks planned at capacities of 1,000 MW and above, as well as independent ground-mounted solar plants developed outside formal parks, including captive installations serving specific industrial or institutional entities. Gujarat Power Corporation Limited (GPCL) reports that it is currently developing and operating four large-scale solar parks in the state under the MNRE Solar Park Scheme and state initiatives (GPCL, 2023-24).

TABLE 1 | **Large-Scale Solar Parks in Gujarat**

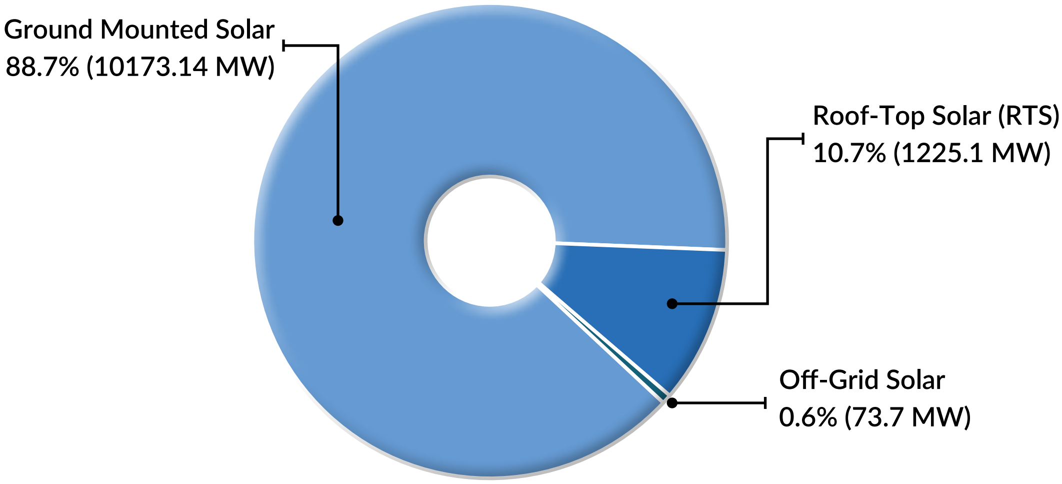
1.	Charanka (Gujarat Solar Park-1), Banaskantha	Operational Installed capacity of approx. 730 MW India's first large-scale solar park and a pioneering model for park-based solar deployment
2.	Radhanesda (Raghcanseda) Solar Park, Banaskantha	Operational Installed capacity of approx. 700 MW
3.	Dholera Solar Park, Dholera Special Investment Region (DSIR)	Sanctioned capacity: 1,000 MW Commissioned capacity of approx. 300 MW
4.	Khavda Renewable Energy Park	Under development Hybrid Park

Data Source: GPCL Annual Report (2023–24)

Gujarat's leadership in solar power is built on a combination of forward-looking policies, robust infrastructure, and strong institutional capacity, coupled with a strategic focus on both utility-scale and distributed solar deployment. This foundation has enabled the state to leverage its natural advantages of abundant land and high solar irradiance. Note that Gujarat was the first Indian state to adopt a dedicated solar power policy. The Gujarat Solar Power Policy 2009 (GSPP 2009) preceded the national programme, giving it a first-mover advantage in attracting developers and investment.

TAMIL NADU: As of October 31st, 2025, with a cumulative installed solar capacity of approximately 11.47 GW, Tamil Nadu has emerged as the state with fourth-largest installed solar capacity in the country, behind only Rajasthan, Gujarat, and Maharashtra. (Ministry of New and Renewable Energy (MNRE), 2024–25).

CHART 18 | **Tamil Nadu's Cumulative Solar Power Capacity in Megawatts (As of October 2025)**



Data Source: Ministry of New & Renewable Energy, State-wise (Location based) installed capacity of Renewable Power as of 31.10.2025

As the data suggests, rooftop solar (RTS) penetration in Tamil Nadu remains limited relative to states such as Gujarat. Off-Grid solar uptake, specifically through PM-KUSUM, also remains low. Stakeholder conversations pointed to the potential role of existing electricity subsidies that serve as disincentives for solar adoption under these schemes. A 2025 study states that Tamil Nadu's electricity subsidy has increased from INR 5,600 crore in 2014-15 to over INR 16,000 crore in 2025-26 (Auroville Consulting, 2023).

Tamil Nadu currently does not currently host any parks under MNRE's official solar parks scheme. However, Tamil Nadu has many large ground-mounted utility-scale solar projects, such as the Kamuthi Solar Power Plant in Ramanthpuram district with a capacity of 648 MW.

Tamil Nadu's new State Solar Energy Policy was issued in 2019. A dedicated state-owned company, Tamil Nadu Green Energy Corporation Ltd. (TNGECL), created in 2024, has taken over all renewable energy generation functions. These initiatives, along with robust grid infrastructure and market access, are expected to continue Tamil Nadu's expansion of installed solar capacity.

DELHI: As of late 2025, the National Capital Territory of Delhi has achieved a modest but steadily rising solar capacity. The solar capacity is dominated by grid-connected roof-top systems rather than utility-scale or off-grid installations – this is due to land constraints and densely populated urban setting. According to data reported by The New Indian Express, citing information provided by the Ministry of New and Renewable Energy (MNRE), Delhi has achieved over 228 MW of installed rooftop solar capacity, largely through grid-connected rooftop systems deployed across residential, commercial, and institutional buildings (The New Indian Express, 2025). Rooftop solar deployment in the National Capital Territory has been further accelerated by the PM Surya Ghar: Muft Bijli Yojana, which builds on earlier rooftop subsidy and net-metering frameworks to reduce upfront costs for households and streamline adoption.

Delhi's solar deployment is guided by the Delhi Solar Energy Policy 2023, which prioritises rooftop and distributed solar in recognition of the city's land constraints. The policy mandates rooftop installations on large government, public, and commercial buildings, and provides capital subsidies, generation-based incentives, and net-metering support to improve project viability. It also promotes models such as virtual net metering and community solar to enable participation by consumers without suitable rooftops. Together, these measures position rooftop solar as a core pillar of Delhi's clean energy transition, while also creating a highly decentralised solar asset base with important implications for future operations, monitoring, and end-of-life management.

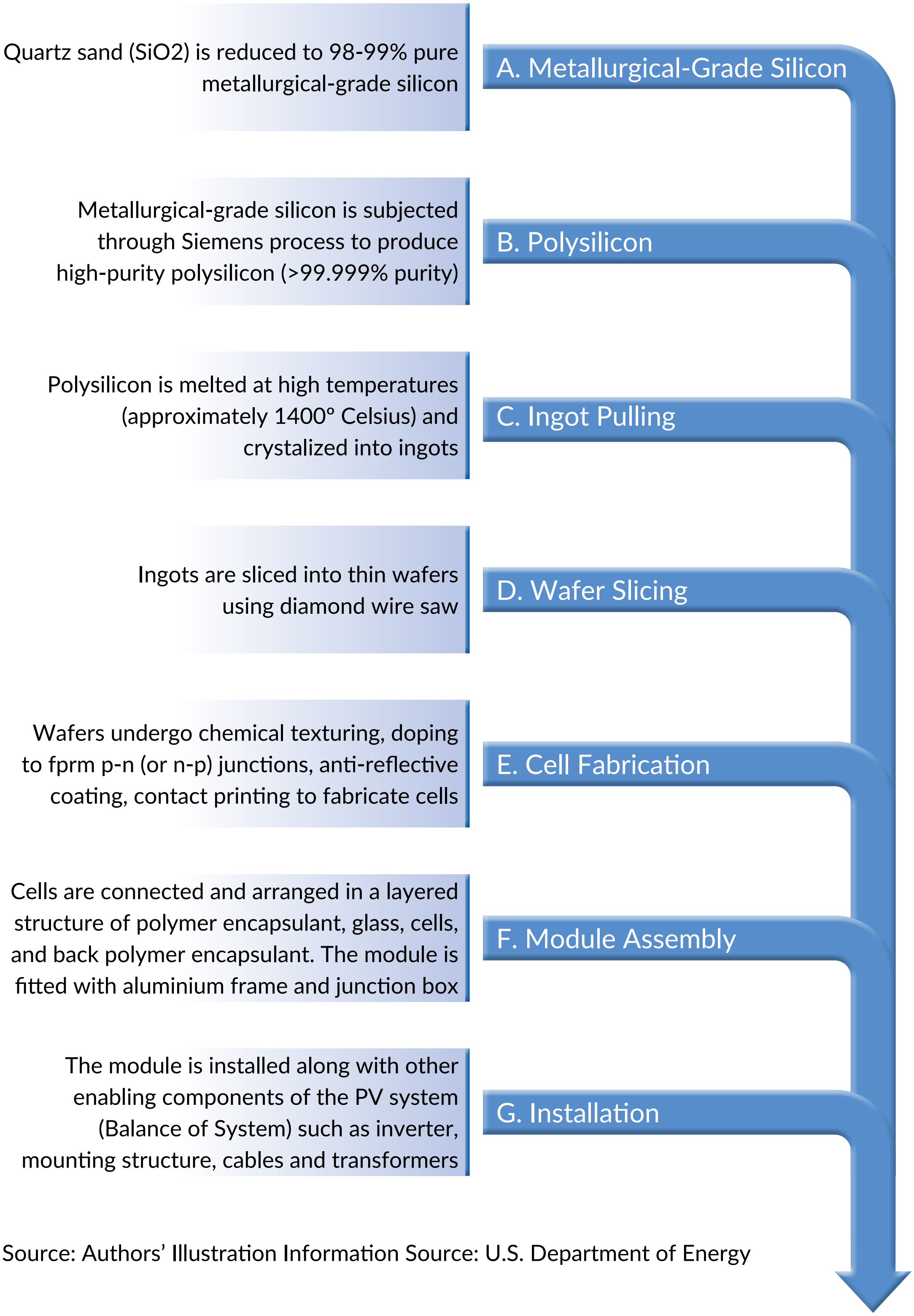
PV Manufacturing in India

To appreciate the critical role of material recovery and recycling in PV value chain, we must first briefly review the broad steps involved in PV manufacturing. There are two types of PV module technologies prevalent in India – crystalline silicon (c-Si) and cadmium-telluride (Cd-Te) thin-film. Consistent with the global trend, c-Si technology is used in more than 90% of India's installed capacity, while Cd-Te Thin-Film represents a minor niche segment.

In India, cadmium telluride (Cd-Te) ThinFilm PV modules are currently manufactured exclusively by First Solar, which operates a vertically integrated facility in Tamil Nadu that includes both module manufacturing and an inhouse endoflife recycling programme. Cadmium, a key input to CdTe modules, is a regulated toxic metal; under the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, cadmium and cadmiumbearing wastes are classified as hazardous and subject to controls on handling, storage, transport, and disposal. Tellurium, the other primary input, is a rare and strategically important mineral with limited global availability. Operating within a closedloop system enhances material traceability, supports compliance with hazardouswaste and ewaste regulations, and facilitates the recovery of cadmium and tellurium for use in new PV modules. Beyond regulatory alignment, this model strengthens circularity by returning recovered materials into the same product category, thereby reducing dependence on virgin critical minerals.

Given the market share of c-Si PV modules, this report focuses on this specific technology.

FIGURE 6 | **Macro View of c-Si PV Module Manufacturing Process**



Source: Authors' Illustration Information Source: U.S. Department of Energy

Polysilicon production accounts for approximately 40% of the total energy required to manufacture a photovoltaic (PV) module. This stage involves converting quartz silica into metallurgical-grade silicon through high-temperature smelting, followed by further purification to produce solar-grade polysilicon – most commonly using the Siemens process. Both stages are highly energy-intensive due to the extreme temperatures and sustained energy inputs required.

Manufacturing in India has typically predominantly focused on step F of the process – Module Assembly. This can be attributed to several reasons:

- The high energy demand of upstream steps makes locations with cheap, reliable electricity far more attractive for manufacturing.
- The scale of investment required for PV manufacturing is substantial, with polysilicon, ingots and wafers, cell production, and finally module assembly needing successively lower capital outlays. In emerging markets with limited access to finance, starting with module assembly is therefore the most practical entry point into the solar manufacturing value chain (Becquerel Institute & RTS Corporation, 2023).
- Lenders have historically been more comfortable funding module assembly than upstream polysilicon–wafer–cell projects, which are capitalintensive and viewed as higher risk.
- The large scale and deep vertical integration of China's solar industry give Chinese-made cells a clear cost advantage, making modules built with these cells cheaper than modules manufactured entirely in India.

The scenario is changing. Government and Industry see import dependence in the PV value chain as a strategic vulnerability and are trying to address it. Through the PLI Scheme for High-Efficiency Solar PV Modules (Tranche-I and Tranche-II), the Government of India has awarded about 48.3 GW of domestic module manufacturing capacity, much of it in fully or partially integrated lines spanning ingots, wafers and cells, rather than standalone module assembly (Press Information Bureau, 2023). As of mid-2025, at least 9.7 GW of solar cell capacity and 2.2 GW of ingot–wafer capacity have been commissioned under the scheme (Lok Sabha, 2025).

Circular PV Ecosystem in India

Regain Energies Solutions Pvt. Ltd. operates a crystallinesilicon module recycling plant in Surat, with capacity to process roughly 250 MW (about 500,000 modules) per year. Using a combination of mechanical separation, thermal pyrolysis and chemical recovery, the facility extracts highgrade aluminium, copper, float glass, silver and 2N–4N purity silicon, which are then sold into domestic secondary markets (Tyagi, Badal & Kale, 2025).

Regain's model illustrates what effective PV recycling can look like for India's predominantly cSi installed capacity. At the same time, the fact that only a handful of formal PV recyclers are currently operational is both a symptom and a consequence of the complex policy, economic and technological barriers that still constrain this sector. This section unpacks these drivers and associated themes with the aim of identifying practical recommendations to scale circularity across the PV value chain.

A. Waste is already at significant levels

Solar panels typically last 25 to 30 years. This lifespan reflects the period until efficiency drops to around 80 – 85% of the original output.

Yet field studies show PV waste accumulating sooner due to transport damage, natural disasters, defects, and accelerated degradation in harsh conditions – reaching 146 kilotonnes by end-2024 (Tyagi, Badal & Kale, 2025).

A lax 'wait for market demand to build infrastructure' view, often heard in consultations, overlooks recycling's capital/labour intensity, lengthy ecosystem buildout, and circularity's role in energy security.

The Ministry of Mines launched the INR 1,500 crore Incentive Scheme for Critical Mineral Recycling in September 2025 as a cornerstone of the National Critical Mineral Mission (NCMM), providing turnover-linked incentives over six years to build 270 kilotonnes (kt) of annual recycling capacity from e-waste, lithium-ion batteries, and catalytic converters, aiming to secure 40 kilotonnes of critical minerals like lithium, cobalt, and nickel for India's clean energy transition (Press Information Bureau, 2025d).

Critically, the scheme excludes solar-grade silicon recovery, despite its critical role in developing India's solar energy capacity.

Recommendations:

- Support research & development, pilot projects, and demonstration-scale initiatives for high-purity silicon recovery from end-of-life PV modules, recognising that current technologies face technical and economic constraints. A phased approach may be adopted, beginning with technology development and demonstration, including collaborations and technology transfer with global technology providers and research institutions, and gradually moving toward market incentives for solar-grade silicon recovery under schemes such as NCMM once technologies mature.
- In parallel, continue scaling domestic polysilicon, ingot, and wafer manufacturing capacity through PLI and related initiatives which can create future offtake demand

for recovered silicon and enable circularity in the PV value chain once recovery technologies mature.

B. Current Extended Producer Responsibility (EPR) Limitations

India's latest E-Waste (Management) Rules, 2022, notified by the Ministry of Environment, Forest and Climate Change and effective from 1 April 2023, regulate the management of electrical and electronic waste (e-waste) across the country. These rules explicitly include solar photovoltaic (PV) modules, panels, and cells – referred to with the code CEEW14 (CPCB, 2022).

Under Rule 12, every manufacturer and producer of solar photo-voltaic modules or panels or cells shall (CPCB, 2022) –

Ensure registration on the Central Pollution Control Board's EPR portal

Store solar photo-voltaic modules or panels or cells waste generated up to the year 2034- 2035 as per the guidelines laid down by the Central Pollution Control Board

File annual returns in the laid down form on the portal on or before the end of the year to which the return relates up to year 2034-2035

Ensure that the processing of the waste other than solar photo-voltaic modules or panels or cells shall be done as per the applicable rules or guidelines for the time being in force

Ensure that the inventory of solar photo-voltaic modules or panels or cells shall be put in place distinctly on portal

Comply with standard operating procedure and guidelines laid down by the Central Pollution Control Board in this regard

Additionally, the rules also state, "Recycler of solar photo-voltaic modules or panels or cells shall be mandated for recovery of material as laid down by the Central Pollution Control Board in this regard." The Central Pollution Control Board also issued draft guidelines in 2025 that clarify safe transport, storage, and handling practices for PV waste.

However, Extended Producer Responsibility (EPR) recycling targets – which require specific percentages of waste to be collected and recycled – do not currently apply to solar PV modules under the rules' EPR framework. In other words, PV producers do not yet have binding targets for recycling a certain percentage of the end-of-life PV modules introduced by them in the market. In practice, some recyclers already accept PV modules and apply the recovered aluminium and iron against targets for other electronic categories in the EPR system, because the framework and portal allow EPR certificates to be generated for these metals wherever they come from. This is a reasonable market response to this waste stream, but it means PV waste is effectively subsidising compliance for other products rather than building a dedicated PV recovery ecosystem.

At the same time, CPCB's draft framework for EPR certificate generation treats only aluminium and iron/steel as 'key metals' for PV (CEEW14), with no PVspecific norms yet notified for copper, silicon, silver, or other highvalue materials found in PV modules. Without notified composition tables and recovery norms for those metals under CEEW14, the portal cannot credit them in a standardised way. The implication is that although the recyclers recover a richer mix of materials from PV modules than the EPR system recognizes, they cannot monetize the entire mix via EPR certificates. Thus, they rely solely on volatile secondary market prices for those wastes. This weakens the business case for investment in recycling infrastructure.

Beyond utility-scale and rooftop PV modules, a growing volume of waste will also arise from distributed and embedded solar applications, including solar lanterns, torches, chargers, consumer electronics, lighting systems, and other off-grid products. These products integrate small solar cells with batteries and electronics but are not explicitly classified under the PV-specific CEEW14 category. The absence of clear classification and EPR obligations for such distributed solar products risks regulatory gaps, leakage into municipal waste streams, and processing without environmental safeguards.

Recommendations:

- Set PV-specific EPR obligations for producers that require specific quantities to be collected and recycled each year. The EPR obligations can be incrementally increased over the years.
- EPR obligations could also be expanded to include targets for use of recycled/ recovered materials from recyclers to drive market uptake of recycled materials. Unlike plastic waste management rules in India, which focus on circularity via market uptake of recycled products and therefore have explicit targets for use of recycled plastic, e-waste rules in India focus on collection and environmentally sound recycling – not so much on market uptake of recycled material. This could be attributed partially to the fact that recycled glass, metals etc. already have strong commodity markets. But

PV-specific materials like high-purity silicon lack similar demand pull, making recycled-content targets essential not only to close the loop for solar manufacturing but also to decrease reliance on polysilicon imports. Thereby supporting India's self-reliance goals amid PLI-driven manufacturing capacity growth.

- Expand CEEW14 to include copper, silicon, and silver as eligible materials that factor in EPR certificate generation for PV end-of-life management.
- Expand the scope of solar PV EPR to explicitly cover solar-enabled products (e.g., solar lanterns, torches, chargers, lighting systems, and other solar-enabled consumer devices) in addition to PV modules, panels, and cells, to prevent regulatory gaps and unmanaged end-of-life flows.

PV producers do not yet have binding targets for recycling a certain percentage of the end-of-life PV modules introduced by them in the market. In practice, some recyclers already accept PV modules and apply the recovered aluminium and iron against targets for other electronic categories in the EPR system

C. PV waste is leaking

A field visit to an e-waste aggregator in Delhi indicated that end-of-life or damaged PV modules are beginning to flow into informal waste networks. As revealed during interview with informal aggregators in Delhi, PV modules typically reach him through bulk e-waste collection tenders issued by offices and commercial establishments. Once the modules arrive at his facility, however, the downstream flow is constrained by two critical factors:

- Lack of local formal recyclers equipped to manage PV module processing; and
- Limited technical knowledge on safely and effectively extracting valuable materials from PV modules.

In the absence of formal recycling capacity, and the presence of opportunity to earn some extra income, end-of-life PV modules collected by this aggregator are treated using rudimentary dismantling and scrap-recovery techniques. The aluminium frames and external copper wiring or junction boxes are manually removed and sold as scrap, but the rest of the module – including glass, polymer encapsulant, silicon cells, and embedded metals – remains largely unrecovered. Often the panels are crushed or broken, and the resulting mix of glass, polymer and silicon fragments is disposed of as general waste or sent to landfill. This is highly detrimental to the environment and human health:

- PV module glass commonly contains small amounts of antimony – used as a fining agent to reduce micro-bubbles and prevent glass discolouration – though antimony-free glass is also available. While antimony is safely bound within the glass during normal panel operation, it is a regulated toxic heavy metal. Improper disposal or uncontrolled crushing of end-of-life panels can increase the risk of antimony leaching into soil and groundwater, underscoring the need for scientific handling and recycling.
- Encapsulants that surround the solar cells are typically made of ethylene-vinyl acetate (EVA), a polymer. When burned, EVA releases smoke, acids and particulates that can irritate eyes and affect the respiratory system. The backsheet – the protective outer rear layer – is also polymer-based, and its combustion impacts vary by material: PET backsheets generate organic fumes and soot, while fluoropolymer backsheets can release more hazardous emissions such as hydrogen fluoride.
- Sharp edges from crushed or shattered glass can cause cuts and lacerations, especially when managed without using appropriate personal protective equipment (PPE). Fine particles from crushed glass can enter the respiratory tract and can impact respiratory health.

Beyond environmental and health concerns, the physical characteristics of PV modules create additional operational challenges for formal recycling systems. PV panels are large and heavy. For example, one monocrystalline solar PV module had the following dimensions: 525 – 550 W power output, weight approximately 28.2 Kgs, and size 89.53 x 44.65 x 1.38 inches (Rooftop Solar India, 2025). The logistical costs and challenges of collecting and transporting such heavy and large panels from remotely located solar plants or densely populated and dispersed rooftop installations can severely impact profitability and therefore viability of formal PV recyclers. These logistical constraints reinforce the importance of efficient first-mile collection and aggregation systems.

Recommendations:

The key challenge, therefore, is to design a system that enables efficient first-mile collection of bulky PV modules while ensuring that downstream processing occurs within scientifically managed recycling facilities.

As discussed earlier in the section The Informal Sector, the informal sector's extensive reach, local knowledge, and willingness to work in waste management positions it well to support first-mile collection and aggregation – provided the role is structured within an appropriate institutional framework.

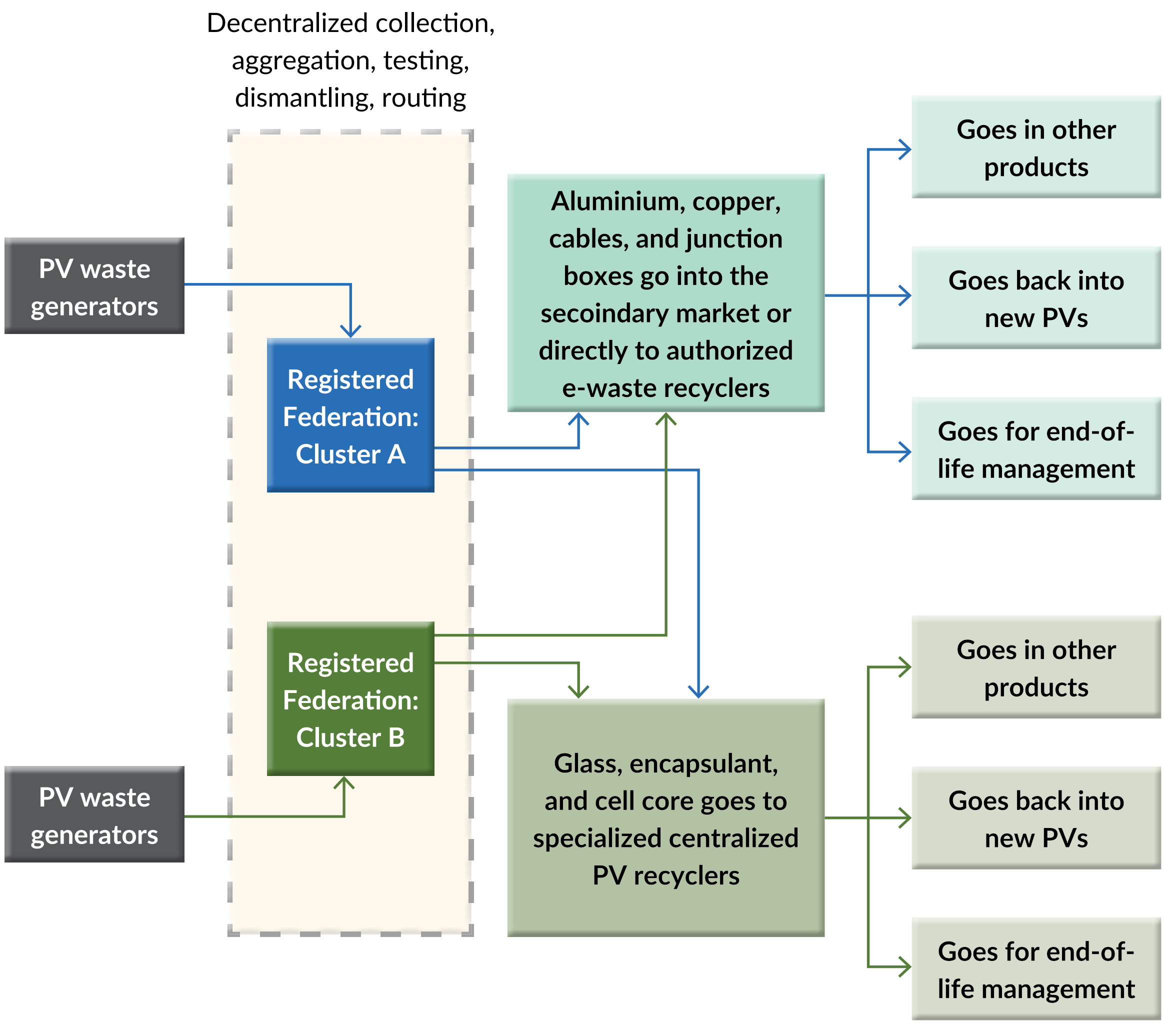
Reproducing a portion of the figure from the section, The Informal Sector:

FIGURE 7 | **Future-State E-Waste Informal Sector Structure**

Under a light-compliance model, registered federations emerging from existing e-waste clusters could play a critical role in addressing first-mile collection and logistical challenges associated with large and heavy PV modules. As illustrated in the simplified E1-E2-E3 waste pathways in Figure 4, PV waste could potentially be classified under an E2 pathway (for illustration only; actual pathways would depend on formal classification and codification of PV waste streams). Each registered federation should be permitted to handle only those waste categories for which it is registered on the CPCB e-waste EPR portal, and to undertake only those activities explicitly authorised for those waste types under the light-compliance framework.

For solar PV waste, these activities could include collecting and aggregating of panels, conducting basic testing to either route panels to second-life uses or refurbishing units, or engage in dry dismantling. Individual fractions from dismantling (aluminium and copper) would flow to appropriate metal and ewaste recyclers, while the glass–encapsulant–cell core would be shipped to specialised PV facilities. Because these federations/clusters also handle other ewaste streams, they can achieve economies of scale in logistics and negotiate fair prices with downstream actors. On the EPR portal, they should be recognised as authorised collection and dismantling centres, eligible to generate EPR credits for metals recovered and, over time, for verified repair and refurbishment activities, without taking on the complex niche processes reserved for fully licensed and specialized recyclers.

FIGURE 8 | **Potential Future-State Used Solar PV Flow**



Source: Authors' Illustration

Thus, formal and informal sectors, in the proposed future state, would serve complementary functions in the reverse value-chain. Note that bulk PV waste generators, such as the solar parks, may not be geographically close to such clusters or registered federations/clusters. But setting-up of decentralized clusters near (or at) such solar parks may provide value. This decision should be based on deeper financial modelling that factors the geographical spread of e-waste and upcoming formal PV recycling infrastructure.

As noted earlier in the report, common challenges that trouble various informal-formal partnership models are reliance on a facilitating organization and over or complete dependence on just collection of e-waste. Any attempt to set-up the light-compliance registered federation structure will most likely fail if it is not backed by additional, high-value revenue streams and enabling policies and ecosystem. Therefore, the recommendations around this potential informal sector operating model must not be looked in isolation from other recommendations in this section.

D Long product lifetimes create risk of orphan PV waste

Solar PV panels are engineered to survive decades of exposure to harsh conditions. This design feature could translate into a policy and responsibility problem. Because panels may outlive original producers, producers that should take responsibility for their waste under extended producer responsibility, may no longer exist when modules reach end of life, producing so-called orphan waste problem.

In the European Union, solar PV panels are covered under the broader framework of extended producer responsibility for electrical and electronic equipment through the Waste Electrical and Electronic Equipment (WEEE) Directive. While this framework was not designed specifically to address orphan waste, it requires producers to contribute financially in advance to the collection, treatment, and recycling of PV modules, typically through pooled, collective compliance schemes. As a result, funds are accumulated while producers are active in the market and can later be used to manage end-of-life panels, even if individual manufacturers have exited by the time the waste arises. This advance pooling of responsibility has the additional effect of reducing the risk that long-lived PV modules become orphan waste and that end-of-life costs are shifted to public authorities.

Recommendations:

An approach suitable for India could therefore combine advance pooling of funds, as seen in the EU, with the existing EPR certificate system. Below we discuss one such potential model:

- Producers would make a one-time payment at the point of manufacture or import, calculated per watt or per kilogram of panels placed on the market. This payment would be collected into a dedicated solar PV waste fund, used to cover the future costs of collection, transport, dismantling and recycling of PV modules, including those whose original producers can no longer be identified.
- When panels are collected, refurbished, or recycled, authorised federations/clusters and recyclers would record verified activity through a central portal and generate EPR certificates.
- Producers would use these certificates to demonstrate annual compliance, with their certificate obligations adjusted to reflect their earlier contribution to the fund. In this combined system, the fund ensures that financial responsibility is secured decades in advance, while EPR certificates continue to recognise and document real collection, refurbishment, and recycling activity as it occurs.
- EPR certificates serve primarily as proof of verified activity and regulatory compliance, and because recycling costs are already covered by the fund, these certificates are expected to be priced lower than those in other e-waste categories.

- Producers may recover part of the upfront contribution through module prices. For utility-scale projects, these costs may ultimately be reflected in the electricity tariffs agreed under power purchase contracts. To address potential concerns from producers, the contribution level should be calibrated carefully and implemented with sufficient transition time, allowing firms to incorporate the cost into their pricing and planning.

E. Lack of design standards that enable repair

The robust structure of solar PV modules is a double-edged sword. The design that allows long-life and protection against the elements also makes dismantling and separation of closely sandwiched layers difficult. As discussed earlier in the report, EPR primarily targets collection and recycling tonnages. Incentives are not tied to how repairable or refurbish-able a design is. In addition to statutory mandates with clear, independent enforcement and audit mechanisms, it is important to design the right incentives.

Recommendations:

- The contribution to the central advance pooled fund for producers could be tied to the repairability, as indicated by the repairability index, of the PV modules. Modules with higher repairability scores would pay a lower upfront fund contribution, reflecting that they are easier to maintain, repair, or refurbish, and therefore generate less waste or lower recycling costs. Modules with lower repairability scores would pay a higher upfront contribution, anticipating greater end-of-life management costs.

F. Limited data availability and traceability across the value chain

Currently in India, PV module production data is reported to the Central Pollution Control Board (CPCB) for environmental compliance and tracking of manufacturing activity. PV module commissioning and installation data is maintained separately through DISCOM (Distribution Company) level, state net-metering portals, or program-specific registries. This separation means that information on what is manufactured, what is installed, and where it is deployed remains fragmented across databases and institutions. Encouragingly, recent initiatives such as the India Smart Grid Forum (ISGF)-led National Solar Rooftop PV Registry pilot represent a significant step toward centralising installation-level data for distributed solar assets. The pilot demonstrates the value of a national, interoperable database that aggregates rooftop PV capacity and maps installations to feeders, distribution transformers, and substations - substantially improving visibility for DISCOMs and system planners (Balasubramanyam, Khosla, Suri & Pillai, 2025).

However, the current scope of such registries remains largely confined to system- and network-level attributes and does not yet extend to module-level traceability or lifecycle integration. Production data, RFID-based module identifiers, quality and certification information, operational performance, ownership changes, and eventual decommissioning or recycling pathways are not linked within a single framework. As a result, regulators and planners are unable to track a PV module end-to-end – from factory to field to end-of-life – limiting the effectiveness quality enforcement, EPR compliance, and long-term waste and recycling planning.

Recommendations:
Building on the strong foundation created by national installation registries, the next logical step is the creation of an integrated, end-to-end PV data repository that connects manufacturing, installation, operation, and end-of-life datasets, enabling informed decision-making, regulatory oversight, and a more circular solar economy.

Other Considerations

This report does not delve into the specifics of PV recycling technologies; however, it is important to acknowledge a fundamental technical constraint that shapes long-term circularity outcomes. While the removal of external components such as aluminium frames, junction boxes, and cables is relatively straightforward and can be achieved through conventional mechanical processes, the core challenge lies in separating the tightly bonded, sandwiched layers of the PV module itself. Glass, encapsulants, silicon cells, and backsheet materials are laminated together using durable polymers designed for decades of outdoor performance, making their separation both technically complex and cost-intensive. Scalable and commercially viable recycling solutions must therefore focus on enabling efficient, low-cost delamination of these layers into clean, individual material streams. This requirement becomes particularly critical if the sector aims to move beyond bulk material recovery toward high-quality silicon and glass extraction that can be reintegrated into new solar module manufacturing – an essential condition for achieving true circularity in the solar PV value chain.

ELECTRIC VEHICLE (EV) LITHIUM-ION BATTERIES

The transport sector accounts for 12% of India's energy-related carbon dioxide emissions. Under existing policy trajectories, emissions from the transport sector are projected to more than double by 2050, raising transport's share of India's energy-related CO_2 emissions to roughly 20–25% by mid-century in the absence of strong mitigation measures (IEA, 2023b).

Lithium-ion (Li-ion) batteries play a critical role in addressing climate change and urban air pollution. By enabling hybrid and electric vehicles, they offer a pathway to reducing tailpipe air pollutants and greenhouse gas emissions from India's rapidly expanding vehicle fleet. A recent meta-analysis of six life-cycle assessments for Indian passenger cars finds battery electric vehicles (BEVs) emit up to 38% less CO_2-equivalent per kilometre than internal combustion engine vehicles under today's grid mix. The emission cuts will only increase as the grid decarbonizes (Down To Earth, 2025).

India's electric vehicle market has grown rapidly over recent years. In FY 2022–23 it reached approximately 1.25 million, increasing to about 1.76 million in FY 2023–24 and surpassing 2.03 million in FY 2024–25, reflecting strong year-on-year growth (EVreporter, 2025a; compiled from vehicle registration data reported on the MoRTH Vahan dashboard).

DELHI

Delhi has become one of India's leading electric vehicles (EV) markets, with an EV penetration rate of about 11.5 per cent of total vehicles sold, the highest among Indian states as of late 2024-25, driven by strong adoption across multiple segments including two- and three-wheelers (FICCI-Yes Bank report, 2024). As of late 2024, Delhi had over 3 lakh registered electric vehicles and approximately 3,100 charging stations with 4,793 charging points; the city plans to scale this to around 18,000 charging points by 2025-26 (Commission for Air Quality Management (CAQM), 2024).

This adoption has been underpinned by the Delhi EV Policy launched in 2020, which offered purchase subsidies, exemptions from road tax and registration fees, and mandates for charging infrastructure. Building on this, the proposed Delhi EV Policy 2.0 aims for even higher targets – including an ambitious target for 95 per cent of all new vehicles sold in the city to be electric by 2027. The proposed draft policy aims to achieve these penetration levels through measures such as bans on certain internal combustion engines (ICE) and compressed natural gas (CNG) vehicles, enhanced subsidies, and mandatory building charging.

TAMIL NADU

Tamil Nadu has emerged as one of India's leading electric vehicles (EV) markets, ranking fourth nationally in EV sales in FY 2024-25 with about 137,700 electric vehicles sold, accounting for roughly 7 per cent of total EV sales in India based on Vahan-sourced state retail data (Autocar Professional, 2025). As of August 2025, the state had approximately 447,000 registered electric vehicles, reflecting strong cumulative adoption across vehicle segments (Guidance Tamil Nadu & ITDP, 2025). But the same report cited the number of charging stations at 1,413. This translates into a vehicle-to-charging station ratio of approximately 316 – a ratio that needs improvement, especially considering that the neighbouring state of Karnataka has 81 vehicles per charging station.

Tamil Nadu's EV adoption has been underpinned by a proactive policy framework aimed at positioning the state as both a major EV manufacturing hub and a growing consumer market. The state first notified the Tamil Nadu Electric Vehicle Policy in 2019, followed by the updated Tamil Nadu Electric Vehicle Policy 2023, which emphasises demand incentives, manufacturing support, and charging infrastructure (Government of Tamil Nadu, 2023). On the demand side, the policy provides 100% exemption from road tax for EVs (extended to December 2025) and registration-fee concessions, alongside reduced electricity tariffs for charging stations. On the supply side, it offers capital subsidies, payroll incentives, and land concessions to EV/battery manufacturers. Charging infrastructure expansion is guided by 2025 Public Charging Infrastructure Guidelines (Guidance Tamil Nadu & ITDP, 2025), standardising deployment in urban clusters and highways to bridge the EV-charging gap.

GUJARAT

Gujarat ranks among India's top 10 EV markets by volume with approximately 318,000 registered EVs (FY2014 to FY2024 data) (CEEW Electric Mobility Dashboard, 2025). This is despite a 25% dip in passenger EV sales in 2024 which is largely attributed to the discontinuation of the subsidy, a maximum of Rs. 1.5 lakhs, available to EV buyers (The Economic Times, 2025).

Gujarat's EV adoption has been supported by the Gujarat State Electric Vehicle Policy 2021, operative July 2021 - June 2025, which offered demand incentives via Direct Benefit Transfer (DBT) for the first 200,000 EVs, alongside 100% exemptions from road tax and registration charges for 5 years from purchase date, electricity duty waivers for charging stations, and 25% capital subsidy (up to Rs. 10 lakhs per station) for the first 250 public chargers (Government of Gujarat, 2021). These measures targeted positioning Gujarat as an EV manufacturing hub, with additional convergence to national FAME-II schemes and support for factories in GIDC zones (industrial estates developed by Gujarat Industrial Development Corporation). Although direct purchase subsidies were depleted by mid-2024, the state responded in April 2025 by slashing motor vehicle tax to 1% (from 6%) for all new EVs until March 31, 2026, while road tax exemptions and charging incentives remain active.

Policy Support Enabling Battery Circularity

National Critical Mineral Mission & Critical Mineral Recycling Incentive Scheme

In September 2025, the Union Cabinet approved a INR 1,500 crore incentive scheme under the National Critical Mineral Mission (NCMM) aimed at developing domestic recycling capacity for critical minerals from secondary sources such as e-waste and spent lithium-ion batteries. This scheme is intended to strengthen supply chain resilience in critical minerals – including lithium, cobalt, and nickel – by making recycling economically viable through capex and opex subsidies for eligible recyclers of battery and electronic waste (Press Information Bureau, 2025d). The scheme's detailed guidelines were issued by the Ministry of Mines in October 2025.

Alongside financial incentives, the National Critical Mineral Mission also emphasises the creation of a domestic knowledge ecosystem for critical minerals. The mission proposes the establishment of Centres of Excellence in collaboration with leading national institutions to support research, technology development, and capacity building across critical mineral value chains, including processing and recycling (Press Information Bureau, 2025e).

Meeting this scale of battery demand through a predominantly linear, importdependent model is neither environmentally nor economically sustainable.

Battery Recycling

While states, and India building on the cumulative efforts of the states, accelerate EV adoption, the battery value chain demands urgent circularity to avert crisis.

According to NITI Aayog's Advanced Chemistry Cell Battery Reuse and Recycling Market in India report, cumulative demand for lithium-ion batteries across all applications in India from 2022 to 2030 is projected to reach around 600 GWh, and approximately 381.4 GWh (about 64 %) of this demand is attributable to EVs (NITI Aayog, 2022). As these batteries reach end of life, the report estimates that around 128 GWh of spent lithium-ion batteries will be generated by 2030, with roughly 59 GWh coming specifically from EVs, highlighting the scale of future waste volumes that will need to be managed through reuse and recycling systems (NITI Aayog, 2022).

At present, the vast majority of lithium-ion cells used in electric vehicles are imported, primarily from China, South Korea, and Japan, while domestic activity is largely limited to battery pack assembly and integration rather than cell manufacturing. Although several large-scale cell manufacturing facilities have been announced under the Production Linked Incentive (PLI) scheme for Advanced Chemistry Cell (ACC) batteries, operational cell manufacturing remains limited to pilot or early-stage facilities, and meaningful domestic supply is expected only in the latter half of the decade.

India's dependence extends upstream as well. Critical battery materials, including lithium chemicals, cobalt and nickel sulphates, cathode precursors, electrolytes, and separators, are almost entirely imported, reflecting the absence of domestic refining and precursor manufacturing capacity (WRI India, 2023). This exposes the EV battery ecosystem to global price volatility, supply disruptions, and geopolitical risks. As a result, while EV deployment is accelerating, India currently captures only a small share of the total value chain, concentrated in module assembly, vehicle integration, and downstream services.

Therefore, the emerging battery recycling sector represents a nascent but strategically important node in the supply chain. As noted earlier, by 2030, significant quantity of EV li-ion battery waste is expected to be generated. It is estimated that effectively recycling end-of-life electric vehicle batteries could reduce global demand for newly mined battery metals by 2040, cutting demand for copper by around 55 per cent, lithium by about 25 per cent, and both cobalt and nickel by approximately 35 per cent relative to business-as-usual scenarios, thereby significantly lowering the need for new mining activity (Dominish, E., Florin, N. and Wakefield-Rann, R., 2021). Scaling recycling and material recovery from this waste is therefore a complementary pathway to strengthen supply security and reduce import dependence over time.

It is important to understand, very briefly, the structure and composition of EV li-ion batteries before delving into the recycling landscape.

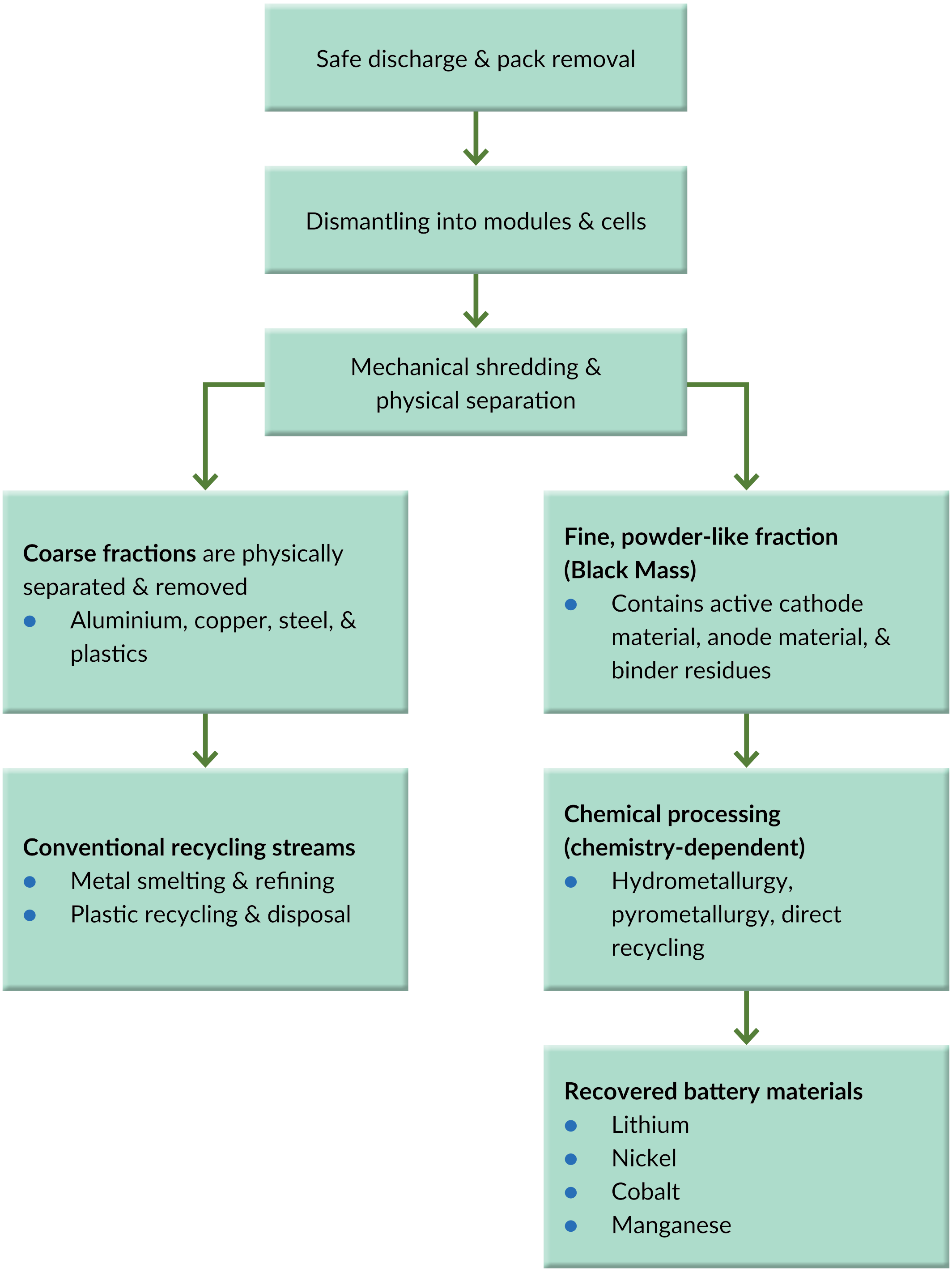
Electric vehicles in India predominantly use two lithium-ion battery chemistries: lithium iron phosphate (LFP) and nickel manganese cobalt (NMC). These chemistries differ significantly in material composition, energy density, cost, and recycling value. The table in Appendix B contrasts the differences, including the use cases.

While LFP and NMC are the dominant chemistries discussed here, lithium-ion batteries encompass a range of other chemistries, and new formulations continue to emerge over time.

Beyond differences in battery chemistry, lithium-ion EV batteries share a common set of components, each with distinct material compositions and implications for recycling. The table in Appendix C lists these key components.

The recycling of EV li-ion batteries involves a series of mechanical and chemical steps. The figure below broadly describes these steps.

FIGURE 9 | **Steps Involved in EV Li-Ion Battery Recycling**



Source: Authors' representation based on publicly available data.

Although India has begun recycling end-of-life EV lithium-ion batteries, the current recycling ecosystem remains largely concentrated at the black-mass stage. Only a limited number of recyclers currently claim the capability to recover battery-grade materials – such as lithium, nickel, and cobalt – that can be reintegrated into new EV batteries through original equipment manufacturers (OEMs). The majority of recyclers focus on mechanical processing to produce black mass, which is then sold or exported for further refining outside the country, limiting domestic value addition and constraining progress toward true battery circularity.

Under India's Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, black mass from spent li-ion batteries is classified as hazardous waste and listed under HS code 8549. HS code refers to Harmonized System of nomenclature used to classify traded products. Black Mass export is thus restricted and requires:

- Prior approval from Ministry of Environment, Forest and Climate Change (MoEFCC).
- Export license from Directorate General of Foreign Trade (DGFT) to legally ship the material overseas.
- Declaration to Indian Customs under correct HS codes classification.

But instances of mislabeled black mass shipments to bypass hazardous-waste controls are rampant and have caught the attention of the authorities. This has prompted tighter scrutiny and enforcement by the Central Board of Indirect Taxes and Customs (CBIC) (EVreporter, 2025b). According to black mass export data interpreted from CPCB's portal and summarised by an industry analyst (Jha, 2023), India lost approximately 350 tonnes of cobalt, 71.7 tonnes of lithium, and 215 tonnes of nickel through black mass exports over a 12-month period between October 2022 and September 2023, although some media reports describe these losses in broader year-on-year terms (as cited in EVreporter, 2023).

Achieving true battery circularity will require moving beyond black mass production towards domestic recovery of battery-grade materials, supported by aligned recycling technology, downstream manufacturing demand, and regulatory enforcement.

Role of the Informal Sector

As with most other waste streams, India's experience with battery recycling has historically been shaped by the informal sector, particularly in the case of lead-acid batteries. Lead-acid batteries in India have achieved recycling rates of over 90 per cent, with an estimated 60 to 70 per cent of collection and recycling historically occurring via the informal channels. Informal aggregators, dismantlers, and smelters played a central role in collection, breaking, and secondary lead recovery, supplying recycled lead back into domestic battery manufacturing. This system evolved due to the relatively simple chemistry of lead-acid batteries, the high intrinsic value of lead, and stable downstream demand, albeit at significant environmental and health costs.

However, the role of the informal sector in the EV lithium-ion battery value chain remains limited. This can be attributed to several factors that were both mentioned during our interactions with the informal sector actors in Delhi and have been mentioned by other key stakeholders in the value chain.

- Limited technical knowledge: As discussed earlier in the report, skills in the informal sector are typically transmitted through apprenticeship-based, intergenerational learning within close-knit communities. The development of technical expertise therefore depends on gradual, experiential learning by an initial cohort of workers, often through trial-and-error processes. Lithium-ion batteries are a relatively recent entrant to the Indian market, and the sector has not yet had sufficient time or exposure to develop the specialised technical knowledge.
- Risk perception tied to complex chemistries: The workers are aware of the fire and explosion risks associated with unknown chemistries in these complex batteries and are averse to this risk.
- Heavier, bulkier, and integrated into vehicle platforms: While relatively light for two-wheelers (10 to 25 kg approximately) and three-wheelers (30-50 kg approximately), lithium-ion batteries for cars can range anywhere from 250 to 400 kg, and for buses upwards of 1,000 kg. Moreover, these batteries are designed as long-lived structural components of the vehicle rather than simple modular units that can be easily removed, dismantled, and processed by informal recyclers.
- EV battery ecosystem remains relatively closed-loop: Various factors play a key role in keeping this ecosystem fairly closed-loop via formalized structures. Extensive dealership networks facilitate collection, vehicle mobility enables easy transport to authorized end-points, and lifetime warranties, such as Tata Nexon EV's 15-year warranty, ensure batteries return via OEM-controlled channels, bypassing informal markets.

Although the informal sector may currently lack the technical skills to manage these complex batteries, history suggests that it could eventually develop such capabilities. While larger and more sophisticated batteries are likely to remain within formal, closed-loop systems, lighter and less complex batteries from two- and three-wheelers are more susceptible to entering the informal recycling stream.

While current factors discussed above, in combination with EPR mandates under India's Battery Waste Management Rules 2022, largely channel EV lithium-ion batteries through formal ecosystems, the critical minerals essential for resource and energy security, combined with the hazardous nature of battery processing, demand proactive safeguards against future informal sector leakage. EV batteries must be explicitly positioned within the E1-E2-E3 framework (See Figure 5; section 'The Informal Sector) to prioritize formal pathways from the outset. E1 pathway – formal licensed recycling – is non-negotiable due to safety and recovery imperatives. This is in contrast to solar PV modules where E2 pathway could be enabled via registered federations in clusters that can support first-mile connectivity and initial dismantling.

Regulatory Framework for Circularity

India's Battery Waste Management Rules, 2022 (as amended through 2025) establish a comprehensive regulatory framework for managing batteries across their full lifecycle, anchored in the principle of Extended Producer Responsibility (EPR). The rules apply uniformly to all battery type, including EV batteries. The primarily responsibility is placed on producers, defined to include manufacturers and importers, to ensure the collection, recycling, and refurbishment of waste batteries corresponding to the weight of batteries they place on the market.

How EPR Works for EV Li-Ion Batteries?

- Under the Battery Waste Management Rules, annual EPR targets are initially ramped up and then stabilised at a fixed percentage (typically around 70%), which is applied each year to batteries placed on the market in specified earlier years. In parallel, the Rules require full (100%) recycling or refurbishment by the end of the applicable lifecycle compliance window. Both the annual target percentage and the lifecycle compliance window vary by battery type (for example, between two-, three- and four-wheeler EV batteries). The table in Appendix D illustrates the EPR targets applicable to four-wheeler EV batteries.
- For battery categories subject to a fourteen-year compliance cycle, the Rules require 100% collection and refurbishment or recycling of batteries placed on the market within that period by the end of the cycle. A limited carry-forward provision allows producers to defer up to 60% of the average annual quantity placed on the market during the cycle into the next compliance period.
- Producers must register on the Central Pollution Control Board's Battery Extended Producer Responsibility (EPR) Portal, declare quantities of batteries placed on the market, track assigned annual EPR targets, procure and upload valid recycling or refurbishment certificates from registered recyclers/refurbishers, and submit annual returns to demonstrate compliance with the Battery Waste Management Rules.

- Under the EPR system, certificates are generated by authorised recyclers or refurbishers only after waste batteries are processed and the recovered key metals are sold. For lithium-ion batteries, these include metals such as lithium, cobalt, nickel, manganese, aluminium, iron, and copper. Certificates are issued one-to-one by the weight of pure metal sold, as verified through sales invoices uploaded on the CPCB portal. This ensures that EPR credits reflect actual material recovery, rather than the weight of batteries collected or dismantled.
- Producers meet their EPR obligations by purchasing these metal-specific certificates to match their calculated targets. These targets are determined using notified rules that convert the quantity of batteries placed on the market into the required amount of metal recovery. As part of this calculation, conversion factors are applied – these are government-prescribed numbers that adjust for the expected practical recovery of each metal from the batteries. For example, if lithium content in a battery type is 5% and the conversion factor is 0.75, a producer with 500 kg of that battery type would be required to procure 18.75 kg of lithium certificates (500 × 5% × 0.75). Producers purchase the required certificates through the portal as part of their annual EPR compliance.

The below box illustrates EPR compliance using an example.

EPR IN ACTION: 4WHEELER EV NMC LIION BATTERY

A. Producer sales

A battery producer sold 500 kg of NMC (NickelManganeseCobalt) lithiumion batteries for fourwheeler EVs in FY 202425.

Under Schedule II of the Rules, the 202930 compliance year (Cycle I, Year IV) requires producers to achieve minimum 70% collection and recycling of batteries placed on the market in 202425 i.e., 350 kg of battery equivalent.

B. Battery metal composition

The producer declares the battery chemistry (typical for NMC):

Lithium (Li) →	1.5% by weight
Nickel (Ni) →	14% by weight
Manganese (Mn) →	6% by weight
Cobalt (Co) →	10% by weight
Aluminium →	22% by weight

(Note: This example chemistry is illustrative. Official compositions vary within ranges and are reported by producers on the portal.)

C. Calculate EPR targets using conversion factors

Producers must calculate the kg of certificates required for each key metal using the formula:

Metal % × Battery target (kg) × Conversion factor

Conversion factors are notified in the CPCB guidance to reflect practical recovery expectations.

Example calculations (202930):

- Lithium:
  1.5% × 350 kg × 0.75 (conversion factor) = 3.94 kg Li certificates
- Nickel:
  14% × 350 kg × 0.9 = 44.1 kg Ni certificates
- Manganese:
  6% × 350 kg × 0.9 = 18.9 kg Mn certificates
- Cobalt:
  10% × 350 kg × 0.9 = 31.5 kg Co certificates
- Aluminium:
  22% × 350 kg × 0.9 = 69.3 kg Al certificates

(Note: The conversion factors (0.75 for Li, 0.9 for Ni/Mn/Co/Al) are drawn from CPCB's calculation method to account for practical recovery efficiency - i.e., producers do not assume 100% recoverability. These come from CPCB's guidance on EPR obligations.)

D Recycler generates certificates

- A registered recycler processes waste EV batteries and recovers metals.
- Suppose the recycler sells 50 kg of pure nickel to a downstream customer.
- According to CPCB's certificategeneration rule:
  EPR certificates (kg) = Weight of key metal sold

Thus, the recycler gets 50 kg Ni certificates in its portal wallet

E. Certificate transfer and compliance

- The producer buys 44.1 kg of nickel certificates from the recycler's portal wallet.
- The producer also obtains certificates for lithium, manganese, cobalt, and aluminium from recyclers in the market.
- All required certificates are submitted on the CPCB Battery EPR Portal with the annual EPR return (due by June 30, 2030).
- This confirms the producer has met its 202930 EPR obligations.

While India's Battery Waste Management Rules (BWMR) provide a robust foundation for Extended Producer Responsibility (EPR), producer accountability, and critical mineral recovery, achieving end-to-end battery circularity will require targeted, incremental regulatory enhancements. The EU Battery Regulation (EU 2023/1542) offers a suite of concrete and enforceable mechanisms that can inform future refinements to India's BWMR, subject to appropriate contextualisation.

A Recycled content mandates

The Battery Waste Management Rules, 2022 introduce phased recycled material obligations for producers. From 2027–28 onwards, new lithium-ion batteries placed on the market must contain a minimum proportion of recycled materials, beginning at 5% and increasing to 20% by 2030-31 (MoEFCC, 2022). However, the rules do not specify that these materials must originate from recycled batteries. Instead, they may be sourced from other recycled waste streams containing relevant metals.

In addition, the recycled content obligation is defined in terms of the aggregate share of recycled metals, rather than specifying minimum recycled content thresholds for individual materials. This approach provides flexibility for producers but may limit incentives for the recovery and reintegration of critical battery minerals such as lithium, cobalt, and nickel, which are central to resource security and battery circularity objectives.

In contrast, the European Union Battery Regulation (EU) 2023/1542 mandates minimum recycled content thresholds for specific materials, including cobalt, lithium, and nickel (IEA, 2024b) (see Appendix E). These requirements are accompanied by detailed provisions on recycled content calculation, traceability, and verification across the battery value chain. By defining recycled content obligations for individual materials and establishing robust reporting and verification mechanisms, the EU framework is designed to provide stronger incentives for the recovery and reintegration of critical battery minerals within battery value chains.

Recommendations:

- As domestic recycling capacity matures and end-of-life battery volumes increase, policymakers could consider progressively strengthening recycled content provisions by introducing material-specific recycled content thresholds, particularly for critical battery minerals such as lithium, cobalt, and nickel.
- Future revisions could explore mechanisms that encourage the use of recycled materials recovered specifically from end-of-life batteries, thereby supporting the development of more circular battery value chains.
- To ensure the credibility and enforceability of recycled content claims, these provisions should be accompanied by robust traceability and verification systems that track the origin and quantity of recycled materials across the battery value chain. Digital traceability systems – such as the proposed battery Aadhaar or similar lifecycle data frameworks – could play a key role in enabling such verification while strengthening overall EPR compliance.

B. Enabling battery reuse, refurbishment and second-life pathways

In a circular battery system, end-of-life marks a decision-point. After an EV battery completes its first life in an automobile, it should undergo a standardized state-of-health (SoH) assessment to identify the highest-value pathway:

- Batteries with residual capacity above a certain threshold can be repurposed for second-life applications, such as stationary storage.
- Batteries with degraded components can be refurbished or undergo module/component replacement.
- Batteries unfit for second-life application or refurbishment can be routed to recycling for material recovery.

Key BWMR provisions in India currently focus on the material recovery pathway, not so much on the other two pathways – second-life applications and refurbishment – that feature higher in the waste hierarchy.

- Under BWMR, refurbishment delays the classification of a battery as end-of-life and therefore temporarily defers the associated recycling obligation. However, this deferral is not accompanied by any permanent compliance credit or tradable instrument, meaning that refurbishment postpones – but does not reduce – the producer's ultimate recycling liability. For the refurbishers, revenue is only from sale of refurbished batters – no EPR certificate revenue stream.
- Traceability via the EPR portal is limited to collection, processing, and metals sales. Current mechanisms do not provide visibility into second-life pathways.
- India lacks dedicated technical standards or certification protocols for second-life or refurbished EV lithium-ion batteries. While the Battery Waste Management Rules (BWMR) recognise refurbishers procedurally through registration and reporting requirements, they specify no state-of-health thresholds, performance benchmarks, or application-specific criteria – creating a regulatory grey zone in which second-life batteries operate without formal technical governance.
- Emerging battery passport systems in India have the potential to underpin lifecycle traceability and EPR integrity. However, unless they are linked to standardised health assessment, mandatory decision checkpoints, and open access for second-life actors, they risk reinforcing recycling-centric compliance rather than enabling reuse-first outcomes. Given the globally integrated nature of battery supply chains and the cross-border movement of batteries, components, and secondary materials, such systems will also need to be aligned with emerging international battery traceability standards.

Recommendations:

Future-State EV lithium-ion battery regulations in India should address the gaps identified above through a combination of technical standards, digital traceability, and compliance controls. Key recommendations are as follows:

- Define standardised battery health parameters, supported by clearly specified testing protocols and threshold values that determine eligibility for refurbishment and second-life applications.

- Design emerging battery passport systems to capture and maintain critical battery health information, including parameters required to assess residual performance, safety, and suitability for second-life use at the end of first automotive application.
- Integrate battery passport data into the EPR compliance logic of the CPCB portal, such that traceability and health data actively inform compliance outcomes. For example, where battery passport records indicate that a battery meets defined thresholds for refurbishment or second-life use, its direct routing to recycling should not generate EPR certificates. This would establish a data-backed control mechanism that disincentivises premature recycling and prioritises higher-order pathways when technically viable.
- Define technical standards and certification requirements for refurbished and second-life EV lithium-ion batteries, including safety, performance, labelling, and disclosure obligations. A standardised certification and labelling framework should clearly communicate the battery's status (refurbished or repurposed), residual performance characteristics, and intended application, thereby providing confidence to consumers, insurers, and downstream users and enabling legitimate second-life markets.
- EV lithium-ion battery packs must incorporate design for disassembly (DfD) or repairability and modularity to operationalise the waste hierarchy, because current tightly integrated and welded pack architectures significantly increase disassembly time and cost, block module-level repair or second-life assessment and limit safe access for recycling and reuse. Research shows that poorly serviceable battery designs force long, labour-intensive teardown operations, increasing disassembly costs and inhibiting reuse and recycling workflows (Ran et al., 2022). Design for disassembly (DfD) in EV lithium-ion battery packs will take off only when tied to producer-level compliance and economics. For example, producers with repairability score below a certain threshold can be disqualified for production-linked incentive (PLI) schemes. Or their EPR targets can be increased by a certain multiple.

CONCLUSION

This study began with a focus on circularity in two emerging waste streams – EV lithium-ion batteries and solar PV modules. While the analysis focuses on these two technologies, many of the insights apply more broadly to the design of circular systems for complex electronic products. The findings therefore point to a broader set of principles for building scalable and sustainable electronics management systems.

Across the analysis presented in this report, a recurring theme is that circularity cannot be achieved through end-of-life waste management alone. Instead, it requires coordinated interventions across the entire lifecycle of products – from how they are designed and placed on the market, to how consumers interact with them, and finally how they are collected, repaired, refurbished, or recycled after use.

FIGURE 10 | **From Waste Management to Lifecycle Circularity**

Production

Design & Producer Responsibility

Circularity must begin at the production stage. Product design choices – such as repairability, modularity, material composition, and traceability—determine whether devices can realistically be repaired, refurbished, repurposed, or recycled at later stages. Producers must therefore embed circular design principles, establish clear lifecycle pathways for products placed on the market, and assume responsibility for their end-of-life management through mechanisms such as Extended Producer Responsibility (EPR).

Consumption

Convenience, Clarity, & Incentives

Consumers rarely engage with products at the level of material composition or waste implications. Their disposal behaviour is shaped primarily by convenience, accessibility, and financial incentives. Effective systems must therefore simplify decision-making by creating clearly defined return pathways – communicated through mechanisms such as product coding or labelling – and supported by economic incentives such as deposit-refund or buy-back systems.

Post-Consumption Management

Second-Life Pathways & Complementary Recovery Networks

Once products exit the consumption stage, systems should prioritize higher-value circular pathways such as repair, refurbishment, and second-life applications before material recycling. Achieving this requires structured recovery networks that combine the strengths of formal recycling infrastructure with the extensive collection, repair, and aggregation capabilities of the informal sector. Clear institutional roles, traceability systems, and supportive policy frameworks can enable both environmentally sound material recovery and inclusive economic participation.

Source: Authors' illustration

Circularity must be approached as a system design challenge rather than a narrow waste management problem. Policies that operate only at the downstream stage, such as recycling targets or waste collection mandates, are unlikely to deliver durable circular outcomes if they are not supported by upstream design standards and consumer-facing return systems. Effective circular systems therefore depend on aligning responsibilities, incentives, and institutional roles across the entire value chain, including producers, consumers, informal and formal recovery networks, and recyclers.

A frequently expressed view is that waste challenges will resolve themselves once volumes become large enough to attract investment and market attention. Experience suggests otherwise. When systems are designed only after waste streams reach visible scale, recovery pathways are often fragmented, environmental risks become entrenched, and opportunities for value recovery are lost. For long-lived technologies such as solar PV modules and EV batteries, the time to shape circular systems is therefore well before large volumes of waste appear. Establishing repair ecosystems, second-life applications, collection networks, and recycling capacity in advance is not premature – it is a strategic necessity. The choices made today will determine whether the material flows created by the energy transition become future environmental liabilities or strategic reservoirs of value in an increasingly resource-constrained world.

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ACKNOWLEDGEMENTS AND DISCLAIMER

DISCLAIMER ON STAKEHOLDER CONSULTATIONS AND ATTRIBUTION

This report draws on consultations with a diverse range of stakeholders across industry, government, academia, civil society, and the informal sector. The consultations were conducted to inform the analysis and understand multiple perspectives.

The findings, interpretations, and recommendations presented in this report are solely those of the authors and do not necessarily reflect the views of any individual or organization consulted. The inclusion of any stakeholder in the consultation process does not imply endorsement of the report's conclusions or recommendations, nor should any recommendation be attributed to specific stakeholders.

NOTE ON ANONYMITY OF STAKEHOLDERS

For reasons of confidentiality and to avoid any perception of attribution or endorsement, individual stakeholders consulted are not named in this report. Consultations are reported in aggregated form.

NOTE ON SOURCES AND CITATIONS

All sources have been duly acknowledged to the best of the authors' knowledge, and any inadvertent errors or omissions in citation are unintentional.

ACKNOWLEDGEMENTS

The authors are grateful to the stakeholders who shared their time, insights, and perspectives during the course of this study. Their inputs helped inform the analysis and strengthened the robustness of the report.

Consultations were conducted with representatives from the following stakeholder groups:

- Formal recyclers operating in e-waste, lithium-ion batteries, and solar PV modules
- Informal sector workers and worker representatives
- Producer Responsibility Organizations (PROs)
- Non-profit organizations
- Policy experts, researchers, and civil society organizations
- Government and regulatory bodies

APPENDIX A:
STUDY METHODOLOGY

This study employs a macro-level, systems-oriented approach to examine circularity in solar PV modules and EV li-ion batteries. Instead of focusing on a single barrier, stakeholder group, or regulatory instrument, the methodology is designed to analyse the full spectrum of interacting levers that shape material flows and end-of-life outcomes in these emerging waste streams.

The assessment integrates insights across regulatory frameworks, market structures, user behaviour, technology pathways, and the role of informal actors, recognising that circularity outcomes are the result of interdependent policy, economic, and institutional dynamics. By mapping these interconnections, the methodology enables a holistic understanding of where value is lost, where leakage occurs, and which system-level interventions hold the greatest potential to improve take-back, recycling, and resource recovery.

Given the constraints on resources and timelines, the study required a focused scope. Accordingly, in addition to Delhi, two districts were selected within each of the two in-scope states. The process for district selection was as follows.

A. Based on the project scope, three key parameters were identified for district selection:
- **Parameter 1:** Future li-ion waste potential from EVs
- **Parameter 2:** Future solar PV waste potential
- **Parameter 3:** Existing recycling infrastructure

B. Following the finalisation of the three parameters, proxies were identified to ensure that each parameter could be measured using nationally consistent and comparable data sources across all in-scope states.
- **Proxy 1:** EV sales in the last 5 years as reflected on the Ministry of Road Transport & Highway's Vahan dashboard
- **Proxy 2:** Installed solar (PV) capacity under PM Surya Ghar Yojana
- **Proxy 3:** Existing e-waste recycling capacity reported by registered recyclers on Central Pollution Control Board's E-Waste Extended Producer Responsibility (EPR) dashboard

C. All indicators were standardized to a 'per 100,000 population' basis to compare the density of indicators rather than absolute numbers. This ensured a fairer comparison and highlighted districts that might otherwise be overlooked.

D. The values were normalized to enable comparability across parameters and to allow calculation of a composite score for each district.

On top of this quantitative analysis, two qualitative filters were applied:

E. Selection of Gandhinagar and Chennai would give us the perspective from the state capitals which we hypothesize would be at the forefront of initiatives and infrastructure to manage these emerging waste streams and is the seat of government agencies and primary research organizations.

F. A population threshold of 2 million was applied to avoid distortions in per-capita comparisons; low-population districts are more susceptible to outliers (e.g., a single large recycler), which can skew composite scores.

It is important to note that the methodological steps described below were not implemented in a strictly linear sequence.

Study Methodology

CONDUCT PRIMARY SURVEYS

Assess knowledge, attitudes, and perceptions of households and organizations. These were augmented with insights from focus group discussions.

INTERVIEW STAKEHOLDERS

Gain insights on challenges and policy gaps from actors across the value chain – including formal recyclers, informal sector participants, researchers and academics, non-profit organizations, and government agencies.

REVIEW EXISTING LITERATURE

Examine relevant national and international studies, policies, and regulatory documents.

SYNTHESIZE & DEVELOP RECOMMENDATIONS

Integrate all findings to develop actionable recommendations and intervention pathways.

APPENDIX B:

PREDOMINANT LITHIUM-ION CHEMISTRIES

TABLE 2 | **Predominant Lithium-Ion Chemistries**

	Lithium Iron Phosphate (LFP)	Nickel Manganese Cobalt (NMC)
Key components	Lithium, iron, phosphate	Lithium, nickel, manganese, cobalt
Energy density	Lower	Higher
Cycle life	Longer (suited for frequent charging)	Shorter (compared to LFP)
Cost (relative)	Generally lower	Generally higher (driven by nickel and cobalt prices)
Recycling value	Lower	Higher (cobalt and nickel drive economics)
Dominant use cases in India	Electric two-wheelers (2W), three-wheelers (3W), buses, and entry-level passenger EVs	Premium cars and higher-range EVs
Current market share in India	Growing rapidly. Estimated to account for a significant and increasing share - especially in buses and 2W/3W segments	Still substantial, particularly in passenger cars, but declining share relative to LFP
Supply chain exposure	Lower exposure to cobalt and nickel supply risks	Higher exposure to global nickel and cobalt supply chains

Source: Authors' representation based on publicly available data.

APPENDIX C:

KEY COMPONENTS OF A LITHIUM-ION EV BATTERY

TABLE 3 | **Key Components of a Lithium-Ion EV Battery**

Battery component	Function	Typical materials used
Cathode (Positive Electrode)	During charging, the cathode releases lithium ions to the anode via the electrolyte; during discharge, it accepts lithium ions from the anode via the electrolyte, while electrons flow through the external circuit to generate electric current.	LFP (($LiFePO_4$), NMC ($LiNiMnCoO_2$), and other lithium-based compounds (varies as per cell chemistry).
Anode (Negative Electrode)	The anode performs the reverse role of the cathode: it stores lithium ions during charging and releases them during discharge.	Primarily graphite. Newer forms are incorporating silicon blends.
Electrolyte	Enables charge and discharge by conducting lithium ions between electrodes.	Lithium salt ($LiPF_6$) in an organic solvent.
Separator	Allows ion flow while creating a barrier between electrodes that prevents short circuits.	Polymer (example: polyethylene or polypropylene).
Current Collectors	Conduct electricity between electrodes via the external circuit.	Copper (anode), aluminium (cathode).
Binder	Holds active material to current collectors.	Typically, polyvinylidene fluoride (PVDF).
Cell Casing	Provides structural integrity.	Aluminium or steel.
Battery Management System	Monitors and controls individual cells for safety, performance, and longevity.	Microcontrollers, sensors, and switches.

Source: Authors' representation based on publicly available data.

APPENDIX D:

EPR TARGETS FOR FOUR-WHEELER EV BATTERIES

TABLE 4 | **EPR Targets for Four-Wheeler EV Batteries (Compliance Cycle: 2029-30 till 2042-43)**

<table>
<tr><th>No.</th><th>Year</th><th colspan="2">Mandatory waste battery collection target and 100% of refurbishment or recycling of the collection target (Weight)</th></tr>
<tr><td>I</td><td>2029-30</td><td>Minimum 70% of the quantity of Battery placed in the market in 2021-22.</td><td rowspan="14">Collection of 100% waste battery and of 100% of refurbishment or recycling shall be mandatory by end of fourteen-year compliance cycle (end of 14th year) against the battery placed in the market during fourteen-year compliance cycle. However, there may be a carry forward of up to 60% of the average quantity of battery placed in the market per year during the fourteen-year cycle to the next compliance cycle.</td></tr>
<tr><td>II</td><td>2030-31</td><td>Minimum 70% of the quantity of Battery placed in the market in 2022-23.</td></tr>
<tr><td>III</td><td>2031-32</td><td>Minimum 70% of the quantity of Battery placed in the market in 2023-24.</td></tr>
<tr><td>IV</td><td>2032-33</td><td>Minimum 70% of the quantity of Battery placed in the market in 2024-25.</td></tr>
<tr><td>V</td><td>2033-34</td><td>Minimum 70% of the quantity of Battery placed in the market in 2025-26.</td></tr>
<tr><td>VI</td><td>2034-35</td><td>Minimum 70% of the quantity of Battery placed in the market in 2026-27.</td></tr>
<tr><td>VII</td><td>2035-36</td><td>Minimum 70% of the quantity of Battery placed in the market in 2027-28.</td></tr>
<tr><td>VIII</td><td>2036-37</td><td>Minimum 70% of the quantity of Battery placed in the market in 2028-29.</td></tr>
<tr><td>IX</td><td>2037-38</td><td>Minimum 70% of the quantity of Battery placed in the market in 2029-30.</td></tr>
<tr><td>X</td><td>2038-39</td><td>Minimum 70% of the quantity of Battery placed in the market in 2030-31.</td></tr>
<tr><td>XI</td><td>2039-40</td><td>Minimum 80% of the quantity of Battery placed in the market in 2031-32.</td></tr>
<tr><td>XII</td><td>2040-41</td><td>Minimum 70% of the quantity of Battery placed in the market in 2032-33.</td></tr>
<tr><td>XIII</td><td>2041-42</td><td>Minimum 70% of the quantity of Battery placed in the market in 2033-34.</td></tr>
<tr><td>XIV</td><td>2042-43</td><td>Minimum 70% of the quantity of Battery placed in the market in 2034-35.</td></tr>
</table>

Source: Battery Waste Management Rules, 2022

APPENDIX E:

RECYCLED CONTENT REQUIREMENTS UNDER THE EU BATTERY REGULATION

TABLE 5 | **Recycled Content Requirements Under the EU Battery Regulation**

Material	Minimum recycled content	
	By Year 2031	By Year 2036
Cobalt	16%	26%
Lithium	6%	12%
Nickel	6%	15%

Source: European Parliament and Council (2023), Regulation (EU) 2023/1542 concerning batteries and waste batteries.

About Chintan Environmental Research and Action Group

Chintan, is a do-tank that works on the burning issues of circular economy, waste, air pollution, and climate change. Our interventions are at the intersection of environmental sustainability, social justice, gender equity, and climate resilience. We focus on the people most affected by these challenges.

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