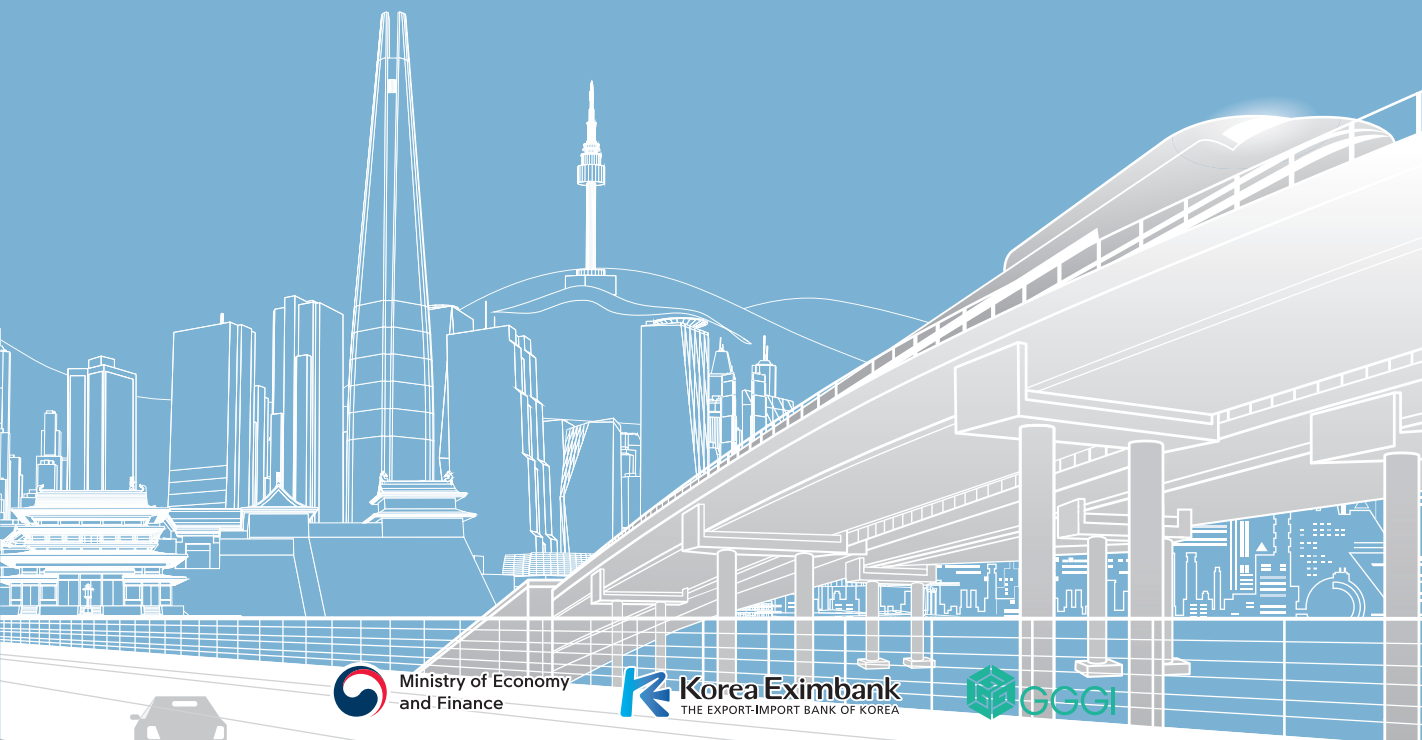


2024/25 KSP-GGGI Joint Consulting Report

Indonesia Policy Framework for Strengthening EV Battery Recycling Capacity in Indonesia



Ministry of Economy
and Finance



Korea Eximbank
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JEJU TECHNOPARK

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2024/25 KSP-GGGI Joint Consulting Report
Policy Framework for Strengthening EV Battery
Recycling Capacity in Indonesia

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List of Abbreviations

Abbreviation	Full Description
AMDAL	Analisis Mengenai Dampak Lingkungan(Environmental Impact Assessment)
BAPPENAS	The Ministry of National Development Planning Indonesia
BRIN	Badan Riset dan Inovasi Nasional
BSN	Badan Standardisasi Nasional
EOL	End of Life
ESS	Energy Storage System
EU	European Union
EPR	Extended Producer Responsibility
EV	Electric Vehicle
IBC	Indonesian Battery Corporation
ICE	Internal combustion engine
IEC	International Electrotechnical Commission
IESR	Institute for Essential Services Reform
ISO	International Organization for Standardization
KC	Korea Certification
LFP	Lithium Ferrous Phosphate
LCO	Lithium Cobalt Oxide
NCM	Lithium Nickel Cobalt Manganese
NCA	Lithium Nickel Cobalt Aluminum
ENDC	Enhanced Nationally Determined Contribution
NEP	National Energy Policy

Abbreviation	Full Description
OEM	Original Equipment Manufacturer
PT IBI	PT Industri Baterai Indonesia
SNI	Standar Nasional Indonesia

List of Terms

Terms	Definition
Battery	A device that stores and provides electrical energy through electrochemical reactions
Primary Battery	A general term that refers to all types of batteries that are discarded after a single use
Secondary Battery	A general term that refers to all types of batteries that are used multiple times by reversing its chemical reactions
Lithium ion Battery	A type of secondary battery that uses lithium ions as the primary charge carrier and is widely used for its high energy density and long cycle life
Lithium Ferrous Phosphate Battery, LFP Battery	A type of lithium-ion battery that uses a lithium-iron-phosphate compound
Lithium Cobalt Battery, LCO Battery	A type of lithium-ion battery that uses a lithium-cobalt-oxide compound
Lithium Nickel Cobalt Manganese Battery, NCM Battery	A type of lithium-ion battery that uses a lithium-nickel-manganese-oxide compound
Lithium Nickel Cobalt Aluminum Battery, NCA Battery	A type of lithium-ion battery that uses a lithium-nickel-cobalt-aluminum-oxide compound
Black mass	A powdery substance containing valuable metals, produced before the metal extraction stage
End-of-life battery (EOL Battery)	A battery that has completed its service in an electric vehicle and can not be no longer suitable for its original purpose
Battery Reuse	Repurposing used batteries with remaining capacity for secondary applications, such as energy storage systems
Battery Recycling	Processing end-of-life batteries to recover valuable materials such as lithium, cobalt, and nickel
B3 substance	Substances and items designated under Indonesian law and subject to legal control regarding their handling
B3 waste (Hazardous Wastes)	A translation of the Indonesian term 'Limbah B3', referring to specific categories of waste containing B3 substances that require strict management, including discarded batteries and end-of-life batteries from electric vehicles
Waste containing B3	Waste containing B3 substances that are generated from household sources. Its official term in Indonesian is 'Sampah yang Mengandung B3'. As there is no established English translation, this report refers to it as "Waste containing B3".

Terms	Definition
Extended Producer Responsibility, EPR	A policy approach that holds producers responsible for the collection, recycling, and proper disposal of products after their use
Jeju	An island in South Korea south of the Korean Peninsula

Summary

Summary

This report aims to support the establishment of a sustainable resource circulation system in response to the anticipated surge in used electric vehicle (EV) batteries as EV adoption continues to expand in Indonesia. It highlights the urgent need to enhance infrastructure and strengthen the legal and institutional frameworks to ensure the safe and efficient management of used batteries.

Currently, Indonesia classifies batteries as Limbah B3 (B3 waste, hazardous waste) but there remain gaps in infrastructure for systematic collection, transportation, and storage of used batteries, as well as in clearly defining responsible entities and implementing traceability systems. While some private companies in Indonesia are capable of incinerating or landfilling used EV batteries, the infrastructure required for safe discharge and for recycling-related pre-treatment, such as disassembly, black mass production, and metal recovery, is still insufficient for building a functioning circular economy for EV batteries.

By strengthening both institutional and technological foundations, Indonesia can pave the way for the effective implementation of various treatment options for used batteries, including reuse, recycling, and Extended Producer Responsibility (EPR). To this end, it is necessary to establish short-, medium-, and long-term policy directions, and to implement pilot projects that assess the feasibility of regulatory systems and the application of relevant technologies.

The proposed policy directions are as follows:

Short term: Establish technical guidelines and legal frameworks for the collection, transport, and storage of used batteries.

Medium term: Evaluate the feasibility of recycling and EPR systems, and lay the groundwork for introducing relevant technologies.

Long term: Build an integrated traceability system and develop standards and certification schemes to complete a circular economy ecosystem for batteries.

In conjunction with these efforts, pilot projects are proposed to support infrastructure development and policy refinement.

With this report, we hope Indonesia will be able to respond to the challenges of used battery management in a timely manner and build a solid foundation for the sustainable growth of its EV industry, while also increasing its capacity to meet international environmental regulations.

01

CHAPTER

Project Overview

1. Project Background and Objectives
2. Project Activities and Expected Results
3. Project Implementation Plan

Project Overview

1. Project Background and Objectives

1.1. Background of the Project

The Government of Indonesia outlined its long-term energy policy in the National Energy Policy (NEP) in 2017, setting a strategic vision up to the year 2050. The newly inaugurated Prabowo administration in 2024 is expected to maintain the existing policy direction and continue accelerating the transition from internal combustion engine (ICE) vehicles to EVs. According to the NEP, the Indonesian government aims to increase the share of renewable energy to at least 23% by 2025, while capping oil at 25%, gas at 22%, and coal at 30%. This policy is aligned with broader strategic goals to reduce dependence on fossil fuels and expedite the achievement of carbon neutrality.

On the global stage, the adoption of low-carbon transportation systems is being actively pursued as a means to realize carbon neutrality.¹⁾ In line with this trend, the Indonesian government announced its Enhanced Nationally Determined Contribution (EENDC) in October 2022, committing to reduce greenhouse gas emissions by 2030. The ENDC includes the promotion of low-emission vehicles and the improvement of related institutional frameworks.

As EV adoption accelerates both domestically and internationally, the Indonesian EV market continues to expand steadily. However, considering the average lifespan of EV batteries (approximately seven years), the replacement cycle for the earliest EV batteries is approaching. This makes the management of end-of-life batteries an urgent issue. Despite the expected increase in end-of-life battery volumes, Indonesia still lacks adequate

1) UNEP, 2023

recycling infrastructure, collection systems, qualified personnel, and incentive mechanisms. Therefore, in order to establish a national system that facilitates a natural battery circulation ecosystem, it is critical to proactively strengthen policy and institutional capacity before large-scale battery disposal begins.

Recognizing this need, the Government of Indonesia issued “Governmental Regulation No.55/2019(PP No.55 Tahun 2019)”, which outlines plans to revise existing transportation-related laws, including those governing ICE and EVs, by 2026. The Ministry of National Development Planning (BAPPENAS) intends to use the outcomes of this KSP project to coordinate roles among ministries and align relevant laws, while incorporating best practices and lessons learned from countries such as Korea during the policymaking process.

Korea, for example, began establishing its legal and institutional framework for end-of-life battery collection, evaluation, and resale procedures in 2020. Since 2021, Korea has actively implemented a battery circulation policy that includes: ① collection, ② reuse, and ③ the development of a battery data platform²⁾.

These experiences may serve as valuable references for Indonesia in designing its battery circulation ecosystem and responding to global regulatory trends such as the EU Battery Regulation. Drawing on Korea’s experience, the KSP project will provide policy direction that enables Indonesia to eventually design and implement a comprehensive framework, including mandatory battery recycling.

1.2. Objectives of the Project

With the 2024/25 KSP Policy Consultation Program, this project aims to develop policy measures that enhance Indonesia’s capacity for EV battery recycling. Ultimately, the project seeks to improve Indonesia’s policy, institutional, and human resource capacities related to battery recycling. In preparation for the anticipated increase in end-of-life EV batteries driven by the expansion of EV adoption in Indonesia, the project also supports the development of a battery recycling and resource circulation system. This will contribute to environmental protection and the creation of a sustainable EV ecosystem.

By analyzing best practices in battery recycling from Korea and other global cases, the project will propose recycling technologies, regulatory frameworks, and incentive systems tailored to Indonesia’s policy landscape and industrial conditions. These recommendations are expected to facilitate the timely establishment of a circular economy for EV batteries in Indonesia.

2) KDB Future Strategy Research Institute, 2022

In Korea, full-scale sales of electric vehicles began in 2015, and noticeable quantities of end-of-life batteries started to be generated around 2021. Based on Korea's data, an estimate can be made for the generation of end-of-life batteries in Indonesia, as shown below. Based on sales of 7,200 electric vehicles in 2015, Korea generated end-of-life batteries equivalent to about 400 electric vehicles in 2021. Calculations using the cohort-lag method suggest that significant quantities of end-of-life electric vehicle batteries may begin to be generated in Indonesia around 2026 or 2027.

<Table 1-1> Annual electric vehicle sales and end-of-life battery generation in South Korea and Indonesia³

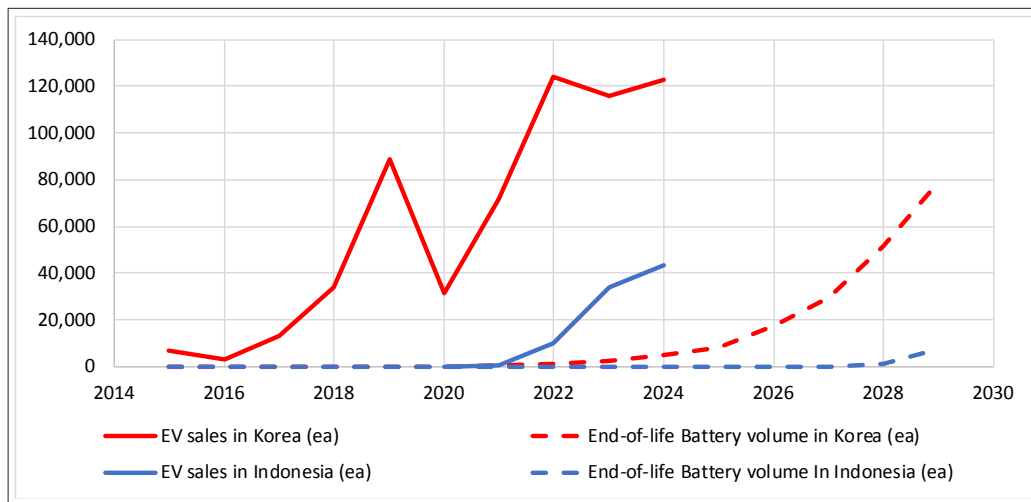
Unit: ea

Year	EV sales in Korea	End-of-life Battery volume in Korea	EV sales in Indonesia	End-of-life Battery volume In Indonesia
2015	7,200	0		0
2016	2,896	0		0
2017	13,300	0		0
2018	34,000	0		0
2019	88,909	0		0
2020	31,329	0	125	0
2021	71,517	440	687	0
2022	123,920	1,099	10,327	0
2023	115,817	2,355	34,108	0
2024	122,528	4,831	43,188	0
2025		8,321*		0
2026		17,426*		13*
2027		29,508*		119*
2028		51,500*		1,345*
2029		78,981*		7,766*

* : Estimation

Source: refer to footnote 3

[Figure 1-1] Annual electric vehicle sales and end-of-life battery generation in South Korea and Indonesia³⁾



Source: refer to footnote 3

1.3. Key Components of the Project

<Table 1-2> Key Components of the Project

Category	Detailed Description
Analysis and Diagnosis of the Current Status of EV Battery Management and Regulation in Indonesia	<ul style="list-style-type: none"> Analyze the current status of EV battery management in Indonesia, focusing on battery manufacturing, importation, end-of-life battery collection, retail, and recycling based on a review of existing documents and reports. Conduct market analysis to identify the potential demand for EV battery recycling in Indonesia. Review the existing policies and legal, institutional (including relevant agencies), and financial frameworks that govern the full life cycle management of EV batteries in Indonesia. Identify key barriers and challenges that may hinder the development of EV battery recycling initiatives in the country.
Case Studies on Best Practices and Latest Technologies in EV Battery Recycling	<ul style="list-style-type: none"> Investigate the latest technologies related to EV battery recycling. Analyze performance evaluation systems and map potential industrial users to maximize reuse, remanufacturing, and recycling of end-of-life EV batteries. Study best practices in EV battery recycling from Korea and other countries, including the role of local governments. Assess the feasibility of introducing advanced EV battery recycling technologies and systems in the Indonesia context.

3) KAMA, Annual Vehicle Sales Statistics (2015–2024)
 MOLIT, Republic of Korea, Automobile Registration Statistics
 MOTIE, MOE, Republic of Korea, Policy Reports on EV Battery Recycling and Resource Circulation, 2021–2024
 KISTI, Lee, Jeong-Gu, End-of-Life Batteries from Electric Vehicles, ASTI Market Insight 04, 2021
 KSMER, Kim, Young-Hwan et al., Trends in End-of-Life Battery Resource Circulation and Recycling Policy and Technology, 2023
 KOITA, Issues and Strategies for Activating End-of-Life Battery Reuse and Recycling Industry, KOITA Webzine, 2023
 GAIKINDO, Annual Vehicle Sales Statistics (2020–2024)

<Table 1-2> continue

Category	Detailed Description
Development of a Roadmap and Policy Recommendations for Effective End-of-life Battery Management in Indonesia	<ul style="list-style-type: none">• Propose policy strategies encompassing legal, regulatory, and financial measures to improve the effectiveness of Indonesia's battery management system and promote the growth of the recycling industry.• Present a preliminary framework for standardization and certification approaches for compliance and quality assurance in the reuse and recycling of EV batteries.• Develop short-, medium-, and long-term action plans and a roadmap to achieve specific objectives in EV battery recycling, including stakeholder analysis.• Recommend two pilot project models based on the developed roadmap and action plans.
Capacity-Building Workshops	<ul style="list-style-type: none">• Enhance the capabilities of Indonesian government officials and experts with lectures, training programs, and knowledge-sharing sessions.• Organize site visits to Korean institutions and companies involved in EV battery management and recycling.

Source: Prepared by the author

2. Project Activities and Expected Results

2.1. Project Scope

<Table 1-3> Project Scope

Category	Detailed Description
Geographic Scope	<ul style="list-style-type: none"> Indonesia
Thematic Scope	<ul style="list-style-type: none"> Current Status Analysis (As-is): <ul style="list-style-type: none"> - Conduct an analysis of Indonesia's EV battery production, distribution, and end-of-life management systems. - Review relevant laws, regulations, and policy frameworks; identify challenges and compare them with global regulatory frameworks. - Assess the current status of collection and recycling infrastructure, operational management systems, and the response levels of local businesses. - Evaluate end-of-life battery treatment methods and environmental impacts to determine the applicability of recycling and circular economy models. Knowledge Sharing: <ul style="list-style-type: none"> - Case studies on best practices and latest technologies in EV battery recycling - Research and benchmark battery recycling policies and technologies from leading countries such as Korea, the EU, and the United States. - Analyze technologies and the commercial viability of battery reuse, remanufacturing, and recycling. - Study key players in the battery recycling industry and innovative technologies, and examine processes for metal extraction and recovery. - Assess the feasibility of introducing applicable recycling technologies and infrastructure in Indonesia. Strategic Roadmap Development (To-be): <ul style="list-style-type: none"> - Policy recommendations and roadmap for effective end-of-life battery management in Indonesia. - Propose legal and institutional improvements and guidelines for policy formulation in battery recycling. - Develop short-, medium-, and long-term policy roadmaps, and set recycling targets and implementation plans for each stage. - Propose frameworks for cooperation among government, industry, and research institutions, and define stakeholder roles. - Recommend strategies such as incentive policies, regulatory reforms, and technical standardization to promote battery recycling. Capacity Building: <ul style="list-style-type: none"> - Conduct training programs for Indonesian policymakers and approximately seven experts in battery recycling. - Organize a final dissemination workshop in Indonesia to share key project findings.

Source: Prepared by the author

2.2. Expected Outcomes

Korea has established an institutional framework that covers the entire life cycle of batteries from cell manufacturing to reuse and recycling. This approach offers a valuable benchmark for Indonesia as it works toward building a circular battery economy.

As the currently deployed EVs in Indonesia reach the end of their service life, the volume of end-of-life batteries will inevitably increase, raising environmental concerns related to battery disposal. Given that EV deployment has only recently begun in Indonesia and the average battery life has not yet been reached, now is an opportune time to prepare relevant policies. Doing so will allow Indonesia to address future environmental risks in advance, while also capturing the economic potential of battery reuse and recycling.

Furthermore, battery recycling can contribute to the reduction of carbon emissions generated throughout the EV production and disposal process. This effort will support Indonesia in achieving its ENDC targets for greenhouse gas reduction. It will also help the country respond to the tightening of international environmental regulations and lay a strong foundation for active participation in global cooperation on carbon neutrality.

<Table 1-4> Expected Outcomes of the Project

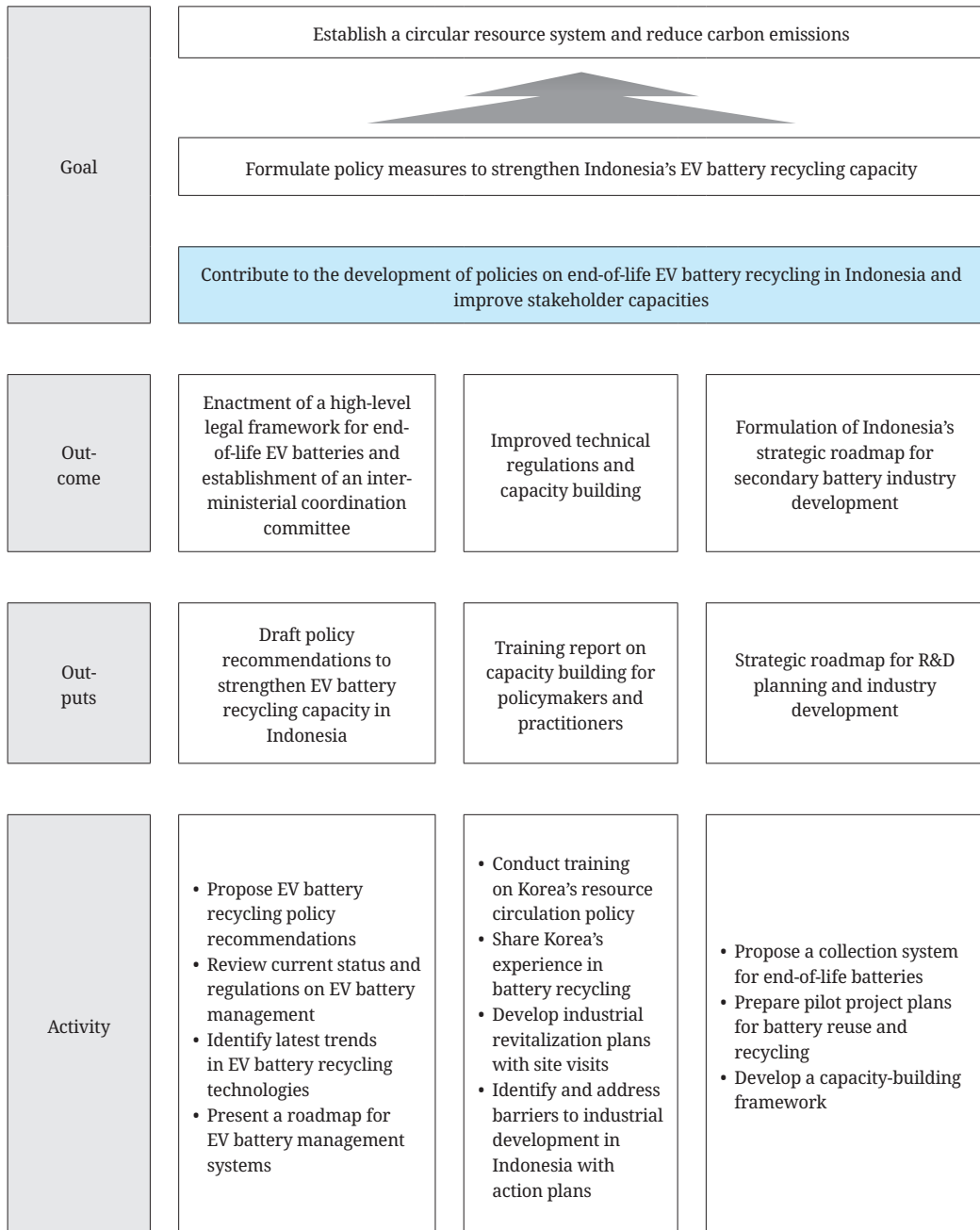
Category	Republic of Korea	Indonesia
Technical Impact	<ul style="list-style-type: none"> Facilitates knowledge sharing with the Indonesian government and relevant institutions on battery types, supply status, future demand forecasts, and recycling methods and lays the groundwork for potential collaboration with Korean companies. Advances in battery reuse and remanufacturing technologies strengthens the global technological competitiveness of Korean companies in the battery recycling sector. 	<ul style="list-style-type: none"> As technologies for battery disassembly, sorting, and metal extraction are introduced and developed, Indonesia can improve its technological competitiveness in the global EV battery recycling market. Advancements in battery state-of-health assessment and residual value analysis promote reuse and remanufacturing, while establishing standardized recycling processes and certification systems can increase industrial reliability and global competitiveness.
Economic Impact	<ul style="list-style-type: none"> Technological developments in battery reuse and recycling expand economic opportunities for Korean companies through exports of equipment, technical consulting, and system solutions. The emergence of new industries focused on battery recycling attracts private investment and has a positive ripple effect on the broader Korean economy. 	<ul style="list-style-type: none"> Recycling of waste batteries can reduce raw material procurement costs, and battery reuse can lower manufacturing costs. Social costs previously incurred for battery disposal can be converted into economic gains with efficient resource utilization and reuse of end-of-life batteries.
Social and Environmental Impact	<ul style="list-style-type: none"> Establishing a circular economy framework fosters a sustainable, eco-friendly industrial structure and positions Korea as a global leader in green industries. As battery recycling projects linked to EV and renewable energy policies expand, technologies for energy storage systems (ESS) and renewable energy integration advance, thereby reinforcing the foundation for sustainable energy transition and green growth. 	<ul style="list-style-type: none"> The reuse and recycling of end-of-life batteries can maximize the effectiveness of government incentives. Recycling end-of-life batteries based on standards to recover nickel, cobalt, and other metals, or reusing batteries deemed viable with proper inspection, contributes to carbon emission reduction and environmental protection.

Source: Prepared by the author

3. Project Implementation Plan

3.1. Implementation Objectives

[Figure 1-2] Implementation Plan



Source: Prepared by the author

3.2. Detailed Implementation Approach

<Table 1-5> Detailed Project Implementation Strategy

► Implementation Direction 1: Analysis and Diagnosis of EV Battery Management and Regulatory Status in Indonesia	
Current Status Analysis in Indonesia	<ul style="list-style-type: none"> • Legal and Institutional Aspects: Investigate the legal frameworks and responsible authorities for managing end-of-life EV batteries in Indonesia, and identify gaps by comparing with Korea and other countries • Operational and Management System: Assess whether a collection and recovery system is in place for end-of-life batteries and examine the level of awareness regarding Extended Producer Responsibility (EPR) among EV manufacturers • Technical and Infrastructure Aspects: Evaluate the infrastructure capacity for safe collection and recovery of end-of-life batteries, and visit facilities operated by private entities for end-of-life battery treatment
Implementation Method	<ul style="list-style-type: none"> • Policy, Legal, and Institutional Review: Analyze Indonesia's battery management policies, regulations, and laws, and compare with global standards and derive potential institutional improvements • Field Interviews and Surveys: Collaborate with the Indonesian government, industry, and research institutions to conduct field surveys and identify challenges in battery management and recycling systems

► Implementation Direction 2: Case Studies on Best Practices and Latest Technologies in EV Battery Recycling	
Case Studies from Korea	<ul style="list-style-type: none"> • Analyze pilot recycling projects led by local governments (e.g., Jeju, Gwangju) and infrastructure such as centralized collection centers for future battery waste. • Examine national R&D projects on lithium/nickel recovery and the policy support for commercialization • Investigate past challenges prior to the stabilization of battery reuse/recycling businesses and how they were overcome
Case Studies from Other Countries	<ul style="list-style-type: none"> • Study practices and systems for end-of-life battery management in leading EV countries such as the United States, China, and Japan
Implementation Method	<ul style="list-style-type: none"> • Global Benchmarking: Analyze battery recycling policies and technologies from Korea, the EU, and the United States, and propose strategies tailored to the Indonesian context • Technology and Market Assessment: Review recycling processes, rare metal recovery technologies, and second-life applications for end-of-life batteries and analyze the potential for industrial development

► Implementation Direction 3: Roadmap Development and Policy Recommendations for Effective end-of-life Battery Management in Indonesia	
Direction for Development of Indonesia's Policy Framework	<ul style="list-style-type: none"> Review Indonesia's current status identified under Implementation Directions 1 and 2, together with case studies from Korea and other countries Develop policy recommendations tailored to Indonesia, taking into account its legal, institutional, and infrastructural characteristics and current conditions
Implementation Approach	<ul style="list-style-type: none"> Present short-, mid-, and long-term roadmaps and action plans: establish policy directions to promote battery reuse, and develop phased strategies including legal and institutional improvements, technology development, and incentive schemes Establish a stakeholder cooperation framework: develop collaboration models among government, industry, and research institutions to build an institutional foundation for activating battery reuse Based on policy recommendations and institutional frameworks developed through this KSP project, and considering implementation feasibility, propose pilot ODA projects related to infrastructure that can support the collection or reuse of end-of-life batteries

► Implementation Direction 4: Operation of a Capacity-Building Program and Holding of a Final Seminar	
Policy Sharing and Capacity Enhancement	<ul style="list-style-type: none"> Share policy recommendation and action plan by holding a final workshop with the Indonesian government and stakeholders to improve the impact of policy consultations Share domestic and international accident cases to emphasize the importance of safe battery collection, transport, and disposal
Implementation Method	<ul style="list-style-type: none"> Tailored Training Programs: Provide practical training and workshops for Indonesian officials and experts, share Korean policy and technology cases, and strengthen field-level capacity Final Dissemination Workshop: Present project outcomes, policy recommendations, and the roadmap to Indonesian government officials and stakeholders to assess feasibility and gather feedback

Source: Prepared by the author

3.3 Technical Review Plan

This component will analyze the current status of battery recycling technologies in Indonesia and review the efficiency and limitations of existing recycling processes. It will also evaluate the technical and economic feasibility of these processes by comparing them with technologies currently implemented in Korea and other advanced countries.

In order to accurately predict the performance and assess the residual value of end-of-life batteries, the project will examine battery condition diagnostics and data management technologies. Based on this, recommendations will be made for establishing a battery traceability and management system suitable for Indonesia.

02

CHAPTER

Diagnosis of Indonesia's EV Battery Management and Regulatory Framework

1. Current Status in Indonesia
2. Status of Waste Recycling and Treatment in Indonesia
3. Legal, Policy, Institutional, and Financial Status of EV Batteries in Indonesia
4. Barriers and Challenges in EV Battery Recycling in Indonesia

Diagnosis of Indonesia's EV Battery Management and Regulatory Framework

1. Current Status in Indonesia

1.1. Indonesia's National Strategies for Carbon Neutrality

1) National Energy Policy (NEP)

To reduce its reliance on coal and facilitate a transition toward natural gas and renewable energy, Indonesia has established a national energy mix vision through 2050. The target is to increase the share of renewable energy to 23% by 2025 and 31% by 2050.

Unlike centralized energy generation, renewable energy typically relies on decentralized production between regions and localities. Therefore, the deployment of microgrids and energy storage systems (ESS) is needed to support this transition.

Repurposing end-of-life EV batteries as ESS can be an effective strategy. By re-integrating these batteries into renewable energy facilities, it is possible to reduce waste while also contributing economically to the implementation of renewable energy policies.

2) RUPTL 2021–2030 (Electricity Supply Business Plan)

This plan, formulated by the state-owned electricity company PLN and commonly referred to as the Green RUPTL, targets approximately 52% of new power generation capacity to come from renewable sources, thereby surpassing fossil fuels in the national energy mix.

3) Enhanced Nationally Determined Contribution (ENDC)

Indonesia's Enhanced NDC, submitted to the UNFCCC, sets an official GHG reduction target of 32% through domestic efforts and up to 43% with international support by 2030. Key focus areas include the land use, land-use change and forestry (LULUCF) and energy sectors.

4) LTS-LCCR 2050 (Long-Term Strategy for Low Carbon and Climate Resilience)

This strategy presents three development scenarios to achieve net-zero emissions by 2060 or earlier: business as usual (BAU), emission reduction pathway, and carbon neutral pathway. It focuses on five main sectors: energy, industry, agriculture, waste, and forestry.

5) Transport and Mobility Transition Strategy

A roadmap for Indonesia's transition to electric vehicles is being established based on "Government Regulation No.79/2023 (PP No.79 Tahun 2023)", which amends the "Government Regulation No.55/2019 (PP No.55 Tahun 2019)". The roadmap focuses on expanding electric vehicle production and charging infrastructure, particularly to promote the adoption of electric buses in urban areas. The regulation also includes provision to expand biodiesel distribution to decarbonize the transportation sector, and to set customs duties for electric vehicle imports at 0% as a policy incentive. The expanded adoption of electric buses will result in the generation of end-of-life batteries. The preparation of treatment methods such as reuse and recycling for these batteries will be needed to ensure the sustainability of the electric vehicle transition roadmap.

6) FOLU Net Sink 2030 Roadmap

This roadmap aims to achieve a net sink status in the Forestry and Other Land Use (FOLU) sector by 2030. Key measures include forest fire prevention, illegal logging control, degraded land restoration, and sustainable forest management.

7) Introduction of Carbon Tax and Carbon Market Mechanisms

Since 2022, Indonesia has begun imposing a carbon tax of approximately IDR 30,000 per ton (around USD 2) on coal-fired power plants, while also piloting a domestic carbon trading system. Additionally, demonstration and pilot projects for carbon capture, utilization, and storage (CCUS) technologies are underway.

8) RPJMN 2025–2029

The RPJMN 2025–2029 is Indonesia's national medium-term development plan and is the first five-year roadmap to realizing Indonesia Emas 2045, which is a plan to elevate Indonesia to a top-five global economy. The plan is centered on eight national priority agendas and emphasizes economic growth, infrastructure development, and human capital improvement, and identifies environmental and climate action as key strategic pillars.

In particular, energy transition, green industry development, and EV expansion are highlighted as critical means to lay the foundation for carbon neutrality. The promotion of EVs is presented as a key strategy for building a low-carbon transportation system and advancing industrial transformation.

Accordingly, a circular economy framework encompassing the entire battery life cycle from production and use to end-of-life management must be established in parallel. The end-of-life battery recycling industry is also directly linked to the development of Indonesia's green industry. This plan is an intermediate step in establishing the institutional foundation for Indonesia's transition to a low-carbon society.

9) RPJPN 2025–2045

RPJPN 2025–2045 is Indonesia's 20-year national long-term development plan, aiming for sustainable development with a specific target of achieving net-zero emissions by 2060. Based on a four-phase implementation roadmap, the plan is designed to integrate green economy, climate resilience, and energy and industrial transitions.

The EV strategy is outlined with a transition to renewable energy-based transportation, reduction of ICE vehicles, and the development of the domestic EV industry. Policy coherence in EV production and deployment is emphasized as a key success factor.

This plan positions EVs not merely as a mode of transportation, but as a strategic instrument for transforming the national economic structure into a green economy.

10) Strategic Linkages with End-of-Life Batteries

Indonesia's major carbon neutrality policies and strategies, such as NEP, ENDC, RPJMN, and RPJPN, aim to reduce greenhouse gas emissions with the expansion of EVs and renewable energy. In line with this direction, comprehensive life cycle management of batteries, a core component of EVs, should be regarded as a critical strategic element.

In particular, the increasing volume of end-of-life (EOL) batteries resulting from EV expansion presents the following strategic opportunities:

- **Energy Sector:** Reusing EOL batteries as ESS can be a complementary solution to address the intermittency of renewable energy sources.
- **Resource Circulation:** Recycling can help secure domestic supply chains of critical minerals such as lithium and nickel.
- **Industrial Strategy:** Battery recycling emits less carbon than virgin material extraction, offering a strategic advantage in responding to future carbon pricing mechanisms.
- **Greenhouse Gas Reduction:** Recycling and reuse contribute indirectly to GHG mitigation by reducing waste and avoiding new resource extraction.

Therefore, there is a structural linkage among the policies: EV deployment → generation of EOL batteries → reuse/recycling → GHG reduction and resource circulation. Future strategies should ensure that EV and EOL battery systems are supported by corresponding legal frameworks and infrastructure development.

1.2. Current Status of the EV Battery Industry in Indonesia

1.2.1. EV Sales Trends in Indonesia

Indonesia's EV market has experienced rapid growth since official statistics began in 2020. Starting with just 125 units sold in 2020, the number increased to 687 units in 2021. With the government's active EV promotion policies and the introduction of EV incentives in 2022, sales surged to 10,327 units that year. In 2023, the figure further rose to 17,051 units. In 2024, due to the influx of low-cost Chinese EV models and the impact of government subsidies, sales increased sharply to 43,188 units—marking a 153% increase year-on-year and accounting for 4.98% of the total automobile market⁴⁾.

4) Gabungan Industri Kendaraan Bermotor Indonesia, Laporan Tahunan 2024, Business Indonesia, "Car Sales in Indonesia Decline Amid Rising EV Popularity", June 2025, MarkLines, "Indonesia vehicle sales trend (2024)"

<Table 2-1> Annual EV Sales Trends in Indonesia

Year	EV Sales Volume
2020	125
2021	687
2022	10,327
2023	17,051
2024	43,188

Source: refer to footnote 4

Electric two-wheelers in Indonesia also began to be distributed around 2021 with approximately 10,000 units, and it is estimated that more than 60,000 units are currently in operation. Since electric two-wheelers are relatively small, have lower energy capacity, and feature structures that make battery replacement and collection easier, they require less direct government intervention compared to electric vehicle batteries. In contrast, EV batteries are larger in size, pose higher fire risks, and are more difficult to handle, thus necessitating systematic collection and recycling management measures at the national level.

1.2.2. Detailed Overview of EV Sales in Indonesia

Chinese-made electric vehicles have rapidly gained in Indonesia's EV market since 2022, and have become a dominant force. In particular, Wuling Motors and BYD have hold the largest share. Beyond passenger vehicles, Chinese EV brands have also expanded into public transportation. Models from BYD, Skywell, Zhongtong, and Golden Dragon have been widely adopted for Jakarta's electric bus fleet. At the end of 2024, a total of 300 electric buses were in operation in the Jakarta metropolitan area.⁵⁾

5) Gabungan Industri Kendaraan Bermotor Indonesia, "2024 Annual Electric Vehicle Sales Breakdown by Brand (Indonesia)", MarkLines, "Indonesia EV Sales Trends 2024 – Chinese Brands 90% Share", Gabungan Industri Kendaraan Bermotor Indonesia, "Best-selling EV Brands Monthly Report" (Mar 2025)

<Table 2-2> EV Sales in Indonesia by Manufacturer (2024)

Manufacturer (Country)	EV Sales Volume	EV Sales Share
BYD (China)	15,243	35.3%
Wuling Motors (China)	13,117	30.4%
Hyundai Motor (Korea)	2,757	6.4%
Chery Automobile (China)	1,771	4.1%
MG Motor (China)	1,082	2.5%
Neta (China)	1,000	2.3%
GAC Aion (China)	861	2.0%
Other Brands	7,357	17.0%

Source: refer to footnote 5

1.2.3. EV Battery Types and Characteristics in Indonesia

1) Chinese EV Manufacturers: Battery Types and Characteristics

Wuling Motors pioneered the Indonesian EV market with its locally produced mini electric vehicle, Air EV, starting in 2022. In that year, more than 8,000 units of the Air EV were sold, accounting for more than half of the annual EV sales. The model continued to enjoy steady popularity in 2023, with 5,575 units sold. Although sales slightly declined to around 4,000 units in 2024, the introduction of the larger and longer-range Binguo EV in the second half of the year led to 5,156 units sold, boosting Wuling's overall brand performance. Additionally, Wuling expanded its product lineup by launching the five-seater mini MPV Cloud EV and sold 3,521 units in 2024.

BYD made a full-scale entry into the Indonesian market in 2024. Within just six months, it sold 6,124 units of its midsize seven-seater electric MPV M6, ranked as the year's best-selling single EV model. Other BYD models also saw strong sales in 2024, including 4,828 units of the Seal electric sedan and 3,291 units of the compact SUV Atto 3. One key feature of BYD's lineup is its consistent use of lithium iron phosphate (LFP) batteries in both passenger vehicles and electric buses, which improves both safety and battery lifespan.

Other Chinese manufacturers have also entered the market. Chery's SUV model Omoda E5 achieved strong initial results and sold 4,425 units in 2024. The MG4 electric hatchback, part of the SAIC group, sold 2,340 units, ranking among the year's top 10 bestsellers. In the

commercial vehicle segment, DFSK's electric van Gelora E has seen limited cumulative sales since 2021. Meanwhile, Chinese-made electric buses from brands such as BYD continue to operate in Jakarta's public transportation network.

<Table 2-3> Battery Types and Features of Chinese EV Brands in Indonesia

Brand	EV Model	Battery Type	Battery Capacity (kWh)	Sales Volume (2024)
Wuling Motors	Air EV (Mini SUV)	LFP	17.3 / 26.7	4,440
Wuling Motors	Binguo EV (Small Hatchback)	LFP	31.9 / 37.9	5,156
Wuling Motors	Cloud EV (Compact MPV)	LFP	50.6	3,521
BYD	M6 (Midsize MPV)	LFP	55.4 / 71.8	6,124
BYD	Seal (Midsize Sedan)	LFP	61.4 / 82.5	4,828
BYD	Dolphin (Small Hatchback)	LFP	45 / 60.4	approx. 1,000
BYD	Atto 3 (Compact SUV)	LFP	49.9 / 60.5	3,291
Chery	Omoda E5 (Compact SUV)	LFP	61	4,425
MG	MG4 EV (Compact Hatchback)	NCM	51 / 64	2,340

Source: otomotif.bisnis.com, 2025; official websites of manufacturers

2) Korean EV Manufacturers: Battery Types and Characteristics

South Korean EVs, led by Hyundai Motor Group, entered the Indonesian market in 2020. That year, Hyundai's Ioniq Electric accounted for 81 out of the 125 EVs sold, with the Kona Electric selling 38 units, establishing Hyundai as an early market leader. In 2021, Hyundai's combined sales of the Ioniq and Kona reached 588 units, comprising around 85% of total EV sales that year.

In 2022, Hyundai launched the Ioniq 5, produced at its Indonesian manufacturing plant. The model sold 1,829 units, placing second in annual EV sales behind the locally manufactured Air EV by Wuling. Bolstered by government subsidies, the Ioniq 5 exceeded 7,000 cumulative units sold by 2023, which enabling Hyundai to reach a total EV sales volume of 7,482 units and maintain its position as the leading brand.

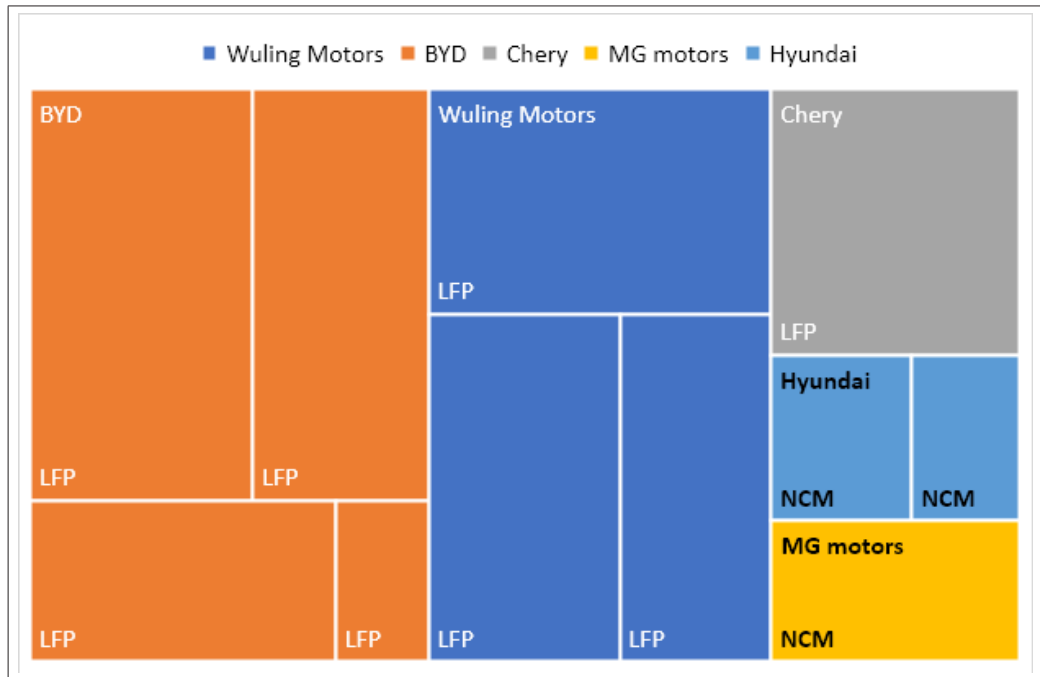
However, sales dropped sharply in 2024 due to strong competition from low-priced Chinese models. Hyundai EVs are equipped with nickel cobalt manganese (NCM) batteries, which offer higher energy density compared to LFP batteries, but tend to be less cost competitive.

<Table 2-4> Battery Types and Features of Korean EV Brands in Indonesia

Brand	EV Model	Battery Type	Battery Capacity (kWh)	Sales Volume (2024)
Hyundai	Kona Electric (Compact SUV)	NCM	39.2 / 64.0	1,196
Hyundai	Ioniq 5 (Midsize CUV)	NCM	58 / 72.6	1,561

Source: otomotif.bisnis.com, 2025; official websites of manufacturers

[Figure 2-1] EV Sales in Indonesia by Manufacturer and Battery Type



Source: otomotif.bisnis.com, 2025; official websites of manufacturers

3) Characteristics and Adoption Trends by Type of Electric Vehicle Battery

The current electric vehicle battery market is being reorganized around two main chemistries: NCM (Nickel-Cobalt-Manganese) and LFP (Lithium Iron Phosphate). NCM-type batteries offer high energy density and power performance, making them the preferred choice for premium and high-performance vehicle lines. They also ensure stable driving range under both high and low temperature conditions.

In contrast, LFP batteries have relatively lower energy density but are more affordable and safer, making them well-suited for mass-market and economy vehicles. Recently, as

major countries have reduced EV purchase subsidies and manufacturers face greater cost pressures, the economic advantages of LFP batteries have become increasingly prominent. In particular, rapid advancements in LFP production technology—driven mainly by China—have led global automakers to expand the adoption of LFP in mid- to low-priced models.

As a result, LFP's market share has risen from less than 10% of the total battery market in 2020 to around 50% in 2024. However, since LFP batteries do not contain nickel or cobalt, their metal recovery value is low, and the phosphate-based structure makes recycling processes more complex and technically demanding. Consequently, LFP recycling now focuses less on simple metal recovery and more on improving process efficiency, reducing energy consumption, and minimizing by-products. As a consequence, recent industry trends indicate that in the LFP battery recycling sector, not only technological advancement but also inter-company collaboration is becoming increasingly important. As recyclers work more closely with precursor producers and battery manufacturers to directly supply recovered materials, the value chain is being streamlined and intermediate margins are being reduced.

2. Status of Waste Recycling and Treatment in Indonesia

2.1. Legal and Institutional Framework for Waste Management in Indonesia

1) Basic Legal Structure

In Indonesia, B3 waste is managed under an independent legal regime and is considered a core element of environmental protection policy. The two primary legal foundations are:

- Law No.32/2009 (UU No.32 Tahun 2009) on Environmental Protection and Management
- Law No.18/2008 (UU No.18 Tahun 2008) on Waste Management

The Environmental Protection Law defines hazardous waste and outlines key principles for its management, including prevention, reduction, recycling, and safe treatment. It also provides enforcement mechanisms ranging from environmental impact assessments (AMDAL) to permit revocations and criminal penalties.

A subordinate law, “Governmental Regulation No.22/2021 (PP No.22 Tahun 2021)”, provides classification rules for B3 substances and related wastes.

- B3 substance (Bahan Berbahaya dan Beracun): Refers to the hazardous and toxic substances themselves, which require strict management during their storage, use, and transportation. Examples include sulfuric acid, lead, and mercury.
- Waste containing B3 (Sampah yang Mengandung B3): Refers to waste containing B3 substances, such as mercury-containing fluorescent lamps and pesticide containers.
- B3 waste (Limbah B3): Refers to specific categories of wastes containing B3 substances that are officially designated for B3 management, such as discarded batteries, including end-of-life batteries from electric vehicles.

2) Implementing Regulations and Detailed Provisions

“Governmental Regulation No.22/2021 (PP No.22 Tahun 2021)” also sets out detailed procedures for the classification, storage, transportation, and treatment of hazardous waste.

According to this regulation, hazardous waste is considered harmful to human health and the environment due to its biological or chemical properties. Businesses generating such waste are required to prepare and submit a hazardous waste management plan (RPLB3) to the Ministry of Environment.

Furthermore, “Ministry of Environment Regulation No.18/2018 (Permen LHK No.18 Tahun 2018)” categorizes more than 5,000 types of hazardous waste based on their physical/chemical properties, sources, and required management protocols. It also includes classification codes, labeling standards, storage facility requirements, and transportation vehicle specifications. Businesses that generate or handle B3 waste must report to and register with the national online system (SIPT B3).

3) Key Procedures and Recent Trends in B3 Waste Management

All companies that handle hazardous waste must obtain the relevant permits from the Ministry of Environment, and the maximum storage period is limited to 90 days. Waste transportation must be conducted using certified vehicles and professional operators, with prior submission of transportation plans and post-reporting requirements. Waste can be treated by incineration, stabilization, or recycling, but only at licensed facilities. Waste generators are obligated to report monthly and annual data, which are managed through the national environmental information system.

Recently, new high-risk waste categories such as EV batteries, medical waste, and e-waste have been added to the B3 waste classification, expanding its scope. However, the current legal system remains heavily disposal-centric and lacks flexibility for waste streams with high recycling or resource recovery potential.

In particular, in the case of lithium secondary batteries, which may still have a remaining lifespan that enables reuse or use as raw materials for recycling, there have been calls to establish a new legal status for such materials as ‘circulating resources’, reclassify hazardous waste that meets certain conditions as resources, or introduce exception systems under strict controls among designated B3 waste.

2.2. Status of Waste and Hazardous Material Management in Indonesia

1) Overview of National Resource Circulation Policy

Driven by rapid population and industrial growth, Indonesia is facing a steady increase in waste generation, making recycling (daur ulang) and the circular economy (ekonomi sirkular) increasingly critical. The National Medium-Term Development Plan (RPJMN 2020–2024) identifies “sustainable environmental management” as a key priority, and explicitly emphasized the 3Rs: Reduce, Reuse, Recycle.

However, the current recycling system remains structurally weak, and there is a heavy reliance on informal collection networks. More than 60% of municipal solid waste (MSW) is directly disposed of in landfills (TPA), and both public and private source separation systems often fail to function effectively. To address this, the government is gradually introducing waste-to-energy (WtE) policies, pilot circular economy models, and a producer responsibility scheme (EPR).

2) Waste Management System and Recycling-Related Regulations

Indonesia’s waste management system is governed by “Law No.18/2008 (UU No.18 Tahun 2008)” on Waste Management, which differentiates between household waste and hazardous waste. Local governments are responsible for the collection and treatment of household waste, while the central government provides guidance and technical standards.

Although there are limited direct laws on recycling, the government has been gradually introducing the EPR system. The Ministry of Environment has released pilot EPR guidelines for plastics, electronics, and batteries, and encouraged voluntary participation from private companies. However, these remain policy recommendations without legal enforceability, and current recovery rates and material quality assurance are limited.

3) Management of B3 waste including E-waste

In Indonesia, hazardous materials that require careful handling and the wastes containing them are categorized as B3 substances, waste containing B3, and B3 waste. Among these, wastes classified as the B3 waste category are subject to legally prescribed procedures and methods for handling, recycling, and disposal. B3 wastes are managed under separate legal frameworks, particularly “Law No.32/2009 (UU No.32 Tahun 2009)”

and “Government Regulation No.22/2021 (PP No.22 Tahun 2021)”, which cover classification, storage, transport, and treatment. B3 waste can only be handled by government-certified operators. Batteries, medical waste, and metal-based sludge are all classified as high-risk B3 waste.

Some types of e-waste generated from households are classified as B3 waste. E-waste management is gradually progressing, but no comprehensive national strategy has been established. Pilot collection programs are underway in cities such as Jakarta and Bandung, but collection volumes remain low, and post-collection processing often takes place in informal sectors.

4) Roles of the Private and Informal Sectors

Much of Indonesia’s recycling industry is driven by the informal sector. Informal waste pickers (pemulung) collect plastics, metals, and paper at waste collection sites and sell them to intermediaries. These transactions often occur outside the scope of national data systems and form unregulated value chains.

Although there are officially licensed private recycling firms, expansion is hindered by the lack of legal incentives, tax benefits, and technical guidance. Due to low-quality recyclables and limited collection infrastructure, the recycling business tends to focus on basic sorting and shredding rather than high-value recovery.

5) Future Policy Directions and Implications

The Indonesian government is currently exploring the formulation of a national circular economy roadmap and is developing a policy framework to support recycling as a strategic industry. Indonesia, in collaboration with international organizations (e.g., GIZ, ADB, World Bank), is promoting pilot projects for Extended Producer Responsibility (EPR) implementation, e-waste collection models, and certification schemes for B3-related waste recycling.

To institutionalize and effectively implement these policies, the following steps are necessary:

- Digitalization of waste information systems
- Clear definition of legal responsibility structures

- Standardization and certification systems
- Redefinition of roles between central and local governments

In particular, to enable the recycling of high-risk waste such as batteries and electronics, a paradigm shift from a “hazard-based approach” to a resource circulation–based approach is required.

2.3. Waste Collection Systems and Processing in Indonesia

Indonesia’s recycling system operates with a dual structure comprising informal collection networks and government-managed formal infrastructure. However, disparities between regions and limitations in processing technologies remain significant challenges to achieving a circular economy.

2.3.1. Current Status of Collection Systems

1) Formal Collection System

Waste generated in Indonesia is broadly categorized into general household waste, specific types of waste (such as e-waste and construction waste), and B3 waste.

General household waste is generated from homes, stores, and offices and is transported by village-level cleaning crews or private collection companies to temporary collection points (TPS, Tempat Penampungan Sementara). The TPS serves as a temporary collection site in the community where residents can directly dispose of their waste or where waste collected by trucks is brought together. Subsequently, this waste is loaded onto large transport vehicles and sent to integrated waste treatment facilities (TPST, Tempat Pengolahan Sampah Terpadu) or to recycling-focused TPS 3R (Reduce, Reuse, Recycle) sites. At this stage, recyclable items are separated and processed, while the remaining residues after treatment are transported to final disposal sites (TPA, Tempat Pemrosesan Akhir).

Meanwhile, B3 waste follows a distinct management system separate from general household waste. B3 waste generated by industries, hospitals, laboratories, or products containing hazardous components such as batteries must be temporarily stored for a specified time in a TPS Limbah B3 (temporary B3 waste storage facility) within business premises. They are then transported to designated treatment facilities by specialized carriers authorized by the Minister of Environment where they undergo physical, chemical,

or biological neutralization and stabilization processes, or are finally disposed of in specialized landfills, if necessary. Moreover, specific wastes classified as Sampah Spesifik, such as e-waste (discarded electronic products), used batteries, and used tires, are separately collected and stored. During this process, certain items, such as used batteries, are ultimately integrated into the designated B3 waste treatment framework.

2) Informal Collection Sector

Informal waste pickers, known as pemulung, collect recyclable materials directly from streets, markets, and residential areas and resell them. Bank Sampah (Waste Banks), largely community-based and informal, allow residents to regularly deposit and sell segregated recyclables. These are sometimes jointly managed by local governments and NGOs. Although this informal channel contributes significantly to the overall recycling recovery rate, transporting or collecting end-of-life EV batteries without proper safety measures poses serious safety risks.

<Table 2-5> Characteristics by Waste Collection Stakeholder

Collector Type	Main Target Items	Characteristics	Institutionalization	Value Focus
Pemulung (Informal Pickers)	PET, HDPE, paper, metals, cans, wires	Focus on high-value recyclables	Informal	High-value items
Bank Sampah (Waste Banks)	PET, HDPE, paper, metals, cans, wires	Community-based, point-accumulation system	Semi-formal (varies by region)	-
DLH (Local Environmental Agency)	Mixed waste (including e-waste)	Operates collection vehicles; connects to landfills	Formalized	Mostly disposal
TPST (Integrated Waste Processing Facility)	Mixed waste (including e-waste)	Focus on sorting and classification; some direct collection	Public facility	Mostly disposal
EPR (Extended Producer Responsibility)	Recovered by companies: beverage PET bottles, HDPE containers	Buy-back programs and refill stations	Pilot phase	High-value items

Source: Prepared by the author

2.3.2. Collection Flows by Major Waste Categories

1) General Waste Collection Flow

Indonesia's waste collection system is differentiated based on the economic value and collection complexity of each item. Waste that is relatively easy to collect and has high recycling value is efficiently recovered through the informal sector, while low-value or high-risk waste is typically handled by public agencies such as DLH.

Materials with high recycling value such as paper, metals, PET, and HDPE (high-density polyethylene) are primarily collected through informal networks. Other types of waste are collected and processed by DLH or official waste management agencies. Recyclable materials are immediately directed to appropriate recycling facilities, while non-recyclable waste is transported to TPSTs or directly to DLH facilities for further sorting and eventual disposal.

2) Pilot Implementation of the Extended Producer Responsibility (EPR) System

Indonesia has launched pilot programs for EPR focused on specific plastic types such as PET and HDPE. Plastic producers are required to fulfill EPR obligations with the following steps:

Submit recycling and collection targets to the government

- Establish refill stations, buy-back centers, and link with waste banks
- Partner with private recycling companies to obtain documented proof of collection
- Report the quantity of materials recycled and the recovery rate to the government

2.3.3. Collection System for B3-related waste including E-waste

1) Legal and Institutional Framework

In Indonesia, certain types of electronic waste are classified as B3 waste. This includes batteries that contain heavy metals, CRT monitors, and printed circuit boards (PCBs), which fall under the B3 waste classification code A402-1.

The key legal instruments governing e-waste are:

- Government Regulation No.22/2021 (PP No.22 Tahun 2021), which outlines the general management framework for B3 waste

- Ministry of Environment No.27/2020 (Permen LHK No.27 Tahun 2020), which provides guidelines to waste banks on small household e-waste management

However, a legally binding EPR framework that assigns collection responsibilities to manufacturers or importers has not yet been fully introduced.

2) Collection and Processing System

Most e-waste in Indonesia is collected through informal networks. Items such as used mobile phones, rice cookers, and radios are gathered by pemulung (informal waste pickers), lapak (small-scale dismantlers), and pengepul (intermediary traders). In this process, certain components may be reused or resold.

Formal collection programs have been introduced in cities such as Jakarta, Bandung, and Surabaya. In these cities, the local Environmental Agencies (DLH) collaborate with private companies to install drop-box systems that encourage voluntary disposal by residents. For example, the Jakarta city government is currently operating the “Drop Box Sampah Elektronik” program under the leadership of DLH.

Among the collected e-waste, high-value components are separated and recovered, while residues containing hazardous substances are transported to licensed B3 waste treatment facilities such as PPLI or PT Wastec for final disposal.

3) Key Issues

Currently, a significant portion of e-waste is collected and processed through informal networks, which often results in the direct exposure of workers to hazardous substances during solder removal or open burning of circuit boards. This poses serious risks to environmental and human health, especially since most informal workers operate without proper safety equipment.

In addition, there is limited infrastructure for collecting household e-waste, and the absence of a formal EPR framework linking responsibility to manufacturers means that many e-waste items are left uncollected or are disposed of with general waste. Most officially licensed processors operate through business-to-business (B2B) contracts, making it difficult to address household e-waste at scale.

4) Future Improvement Directions

The Indonesian government is in the process of developing a formal EPR system, with institutional design being led by Ministry of Environment and BAPPENAS. A nationwide e-waste management roadmap is being prepared to establish a systematic approach for the entire value chain from collection and sorting to recycling and final treatment.

To support this, the government is considering the implementation of a registration system and technical training for informal collectors and recyclers, and aims to integrate them into the formal management system. In partnership with local governments, discussions are also underway to expand public drop-off points as pilot projects and to establish certified e-waste processing centers.

2.3.4. Treatment Technologies

Treatment processes vary depending on the waste type: recyclable waste, non-recyclable waste, and specific B3-regulated categories such as e-waste, PCBs, and used batteries.

Currently, most e-waste, PCBs, and used batteries are treated with high-temperature incineration followed by landfilling. In some cases, especially for PCBs, incinerated residues are exported for further processing abroad.

<Table 2-6> Classification by Treatment Characteristics

Category	Example Items	Treatment Technology
Recyclable	Paper, PET, Steel	Shredding, Washing, Compression
Conditionally Recyclable	E-waste, etc.	Manual Disassembly, Metal Recovery
Difficult to Recycle	Mixed Plastics	High-Temperature Incineration, Landfilling
Hazardous Waste	Waste Oil, Waste Acid, Medical Waste	High-Temperature Incineration, Landfilling
General Waste	Organic Waste, etc.	Landfilling

Source: Prepared by the author

1) Recyclable Waste

- Paper

Newspapers, books, and cardboard are primarily collected through informal networks (pemulung, pengepul), and some are transferred to official recycling companies. The

collected paper undergoes washing and pulping to be reprocessed into recycled paper. High-quality paper has higher recovery rates, while contaminated paper is excluded from recycling.

- Plastics (PET, HDPE, etc.)

PET bottles and HDPE containers are sorted, shredded, and washed before being processed into pellets for use in recycled plastic products. This process is carried out by TPSTs or private companies in urban areas such as Jakarta. However, LDPE and composite films have low profitability and are mostly landfilled or disposed of as general waste.

- Metals (Iron, Aluminum, Copper, etc.)

Iron cans, aluminum cans, and wires are sorted by magnetism or density differences, then melted and reused as metal raw materials. While metals from large construction waste are processed through official channels, small household metals often pass through informal collection networks.

- Glass

Some bottles and containers are washed, crushed, melted, and remolded. However, due to the lack of dedicated glass collection systems, most glass ends up in landfills mixed with general waste.

2) Difficult-to-Recycle or Hazardous Waste

- Composite Materials (Mixed Plastics, Coated Paper, etc.)

Snack wrappers, Tetra Paks, and coated paper are composed of multilayer materials that cannot be separated or melted mechanically. Some are used as refuse-derived fuel (RDF), but most are categorized as general waste at TPSTs and sent to landfills. Many are not collected at all.

- Industrial Hazardous Waste (Waste Oil, Acid, etc.)

Industrial waste such as waste oil and acids/alkalis is incinerated at high temperatures or neutralized and stabilized by licensed B3 waste handlers such as PPLI. However, small manufacturers sometimes dispose of such waste illegally, which requires stronger supervision.

- Municipal Waste (Including Organic Waste)

Organic waste, plastic bags, and food scraps from households are generally transported from TPSTs to final disposal sites (TPAs) without proper sorting. This generates leachate and methane and exacerbates landfill saturation problems. Bantar Gebang landfill in Bekasi, the largest in the country, is facing unavoidable expansion.

3) Difficult-to-Recycle B3 waste including E-waste

E-waste is manually dismantled into wires, circuit boards, and metal parts. Valuable components are sold, while low-value or hazardous parts are sent to licensed B3 waste handlers for incineration or stabilized landfilling.

4) PCBs: Difficult-to-Recycle or Hazardous Waste

High-value metals are removed from PCBs manually and exported, or are crushed/incinerated in Indonesia before export. PCBs contain lead, brominated flame retardants, and organics, making direct export impossible without prior treatment. Most PCB dismantling is done informally using methods such as acid leaching, open burning, and solder removal, which are very harmful to the environment and human health. Workers lack protective gear, and toxins such as dioxins, lead, and brominated compounds are released. Extracted precious metals are sold to scrap dealers or urban mining specialists.

High-value PCBs from industrial electronics (servers, communication equipment) are sometimes exported intact without physical damage.

- Process: Collection → Composition Analysis (Li, Au, Pd ppm) → Ministry of Environment Export Approval → Basel Convention Documents → Direct Export to Refiners (e.g., Korea, Malaysia)

5) Used Batteries: Difficult-to-Recycle or Hazardous Waste

- Treatment by Battery Type

Lead-acid batteries follow a relatively structured recycling process. After collection, they are separated into acid and lead plates, and the lead is refined and reused. In contrast, small batteries such as lithium-ion, NiCd, and NiMH lack dedicated collection systems and are mostly disposed of with household waste, leading to low recovery rates.

- Treatment Process

Some batteries, whether collected or imported, are manually dismantled to extract metals, while electrolytes are left untreated or leaked. Officially transferred batteries are incinerated at high temperatures to produce metal sludge, which is sometimes sent to refineries for precious metal recovery. However, this process is costly and rarely applied. Overall, battery processing infrastructure is lacking, and EPR systems are underdeveloped.

2.4. Current Status of Waste Treatment Facility Operations in Indonesia

2.4.1. Public Waste Treatment Facilities

According to “Ministry of Environment Regulation No.9/2024 (Permen LHK No.9 Tahun 2024)”, the key waste treatment facilities are as follows:

- TPS (Tempat Penampungan Sementara): A temporary storage facility where waste is temporarily collected before being transported to the final disposal site.
- TPST (Tempat Pengolahan Sampah Terpadu): An integrated waste treatment facility that carries out various pretreatment processes, such as recycling, composting, and compaction, to reduce the overall waste volume.
- TPA (Tempat Pemrosesan Akhir): A final disposal facility for landfilling non-recyclable waste.
- TPS 3R (Tempat Pengolahan Sampah Reduce, Reuse, Recycle): A small-scale facility specialized in waste segregation and recycling.
- FPSS (Fasilitas Pengolah Sampah Skala Komunal): A community-scale waste treatment facility designated to treat waste within a specific area and reduce the volume sent to TPA.
- TPS Limbah B3 (Tempat Penyimpanan Sementara Limbah B3): A facility that safely stores designated B3 waste before it is sent to specialized treatment facilities.
- Pengolah Limbah B3 (Designated B3 Waste Treatment Facility): A facility that treats hazardous waste with chemical, physical, or thermal (incineration) processes to render it non-hazardous.

2.4.2. Private Waste Treatment Companies

1) Major Companies and Roles

- **PT Prasadha Pamunah Limbah Industri (PPLI):** PT PPLI is a leading integrated waste management company in Indonesia, established in 1994. It is 95% owned by Japan's DOWA Eco-System and 5% by the Indonesian government. The company provides comprehensive solutions for the collection, transportation, analysis, treatment, and final disposal of both B3 waste and non-hazardous industrial waste. PPLI maintains high standards of safety and reliability with its ISO 17025-certified laboratory, GPS-based tracking systems, and various treatment technologies. The company is also equipped with capabilities for treating high-risk waste such as PCBs and mercury batteries, and employs waste-to-energy (WtE) technologies to produce fuel from waste. PPLI holds various international certifications including ISO 9001, 14001, and 45001, and actively engages in ESG initiatives such as promoting the 4R (Reduce, Reuse, Recycle, Replace) approach and environmental cleanup campaigns.
- **PT Wastec International:** PT Wastec International is a private waste management company headquartered in Jakarta, Indonesia. Established in 2004, it has more than 20 years of experience and specializes in integrated waste management services, particularly for B3 waste. Its main services include legal transportation of B3 waste, treatment of solid, liquid, and sludge waste, industrial wastewater treatment, waste services for the oil and gas sector, contamination remediation, tank cleaning, environmental engineering, and on-site cleaning solutions.
- **PT Tenang Jaya Sejahtera (TJS):** PT Tenang Jaya Sejahtera, founded in 2008, is a comprehensive waste management company based in Karawang, West Java. It provides integrated environmental services, including collection, transportation, storage, treatment, and recycling of both B3 waste and general industrial waste. The company operates multiple storage and intermediate treatment facilities throughout Indonesia, with licensed facilities located in five regions including Karawang, Sukaluyu, and Adiarsa for wide geographic coverage. Its treatment methods include electrocoagulation for liquid waste purification, incineration of solid waste, and recycling into products such as bricks, paving blocks, and fill material. TJS also possesses field-level technical capabilities for medical waste treatment, tank sludge management, and IPAL (wastewater treatment plant) maintenance. It holds official permits for incineration and waste treatment facilities, along with environmental impact assessment (AMDAL) certification. The company is registered with the Indonesian Ministry of Environment

and Ministry of Transportation as a licensed hazardous waste transporter and processor. Furthermore, TJS integrates the Reuse-Reduce-Recycle (R3) principle into its operations and makes practical efforts to realize resource recovery and a circular economy.

- PT ARBA (PT Arah Environmental Indonesia): Established in 2008, PT ARAH is a specialized waste management company headquartered in Setiabudi, Kuningan, South Jakarta. Since its founding, the company has focused on B3 waste and medical waste and offers integrated services covering the full process of collection, transportation, treatment, and incineration with its own in-house systems. ARAH's main clients include hospitals, laboratories, pharmaceutical companies, commercial facilities, and public institutions. Using its national network, the company has expanded its services from Jakarta to West, Central, and East Java. A key feature of ARAH is its strict control of waste movement and treatment, achieved with real-time GPS and CCTV-based tracking systems and its own incineration facilities. The company has established quality and environmental management systems in accordance with international standards and holds multiple certifications including ISO 9001 (Quality), ISO 14001 (Environment), and ISO 45001 (Occupational Health and Safety). These standards are applied throughout all operations and procedures, which increases trust in the company's service quality and regulatory compliance.

2) Actual Operational Status

Companies such as PPLI and Wastec have obtained ISO certifications and possess advanced technological capabilities, including high-temperature incinerators and stabilization facilities. The consortium led by the Korea Testing Laboratory (KTL) conducted a site visit and interview with PT PPLI, where it was confirmed that the company had previously handled EV batteries in response to requests from vehicle manufacturers operating in Indonesia.

While the incineration of end-of-life EV batteries may be possible with additional safety measures, establishing recycling processes will likely require further infrastructure development.

2.5. Governance of EV Battery Recycling in Indonesia

2.5.1. Policies and Legal Framework Related to EV Battery Recycling

Indonesia has not yet established a dedicated law or system specifically for the recycling of EV batteries. These are classified as B3 waste, and general environmental regulations indirectly apply to their management. The relevant legal framework includes the following:

- Basic Law: Law No.32/2009 (UU No.32 Tahun 2009, Environmental Protection and Management Law)
- Waste Management Law: Law No.18/2008 (UU No.18 Tahun 2008, Waste Management Act)
- Government Regulation on B3 Waste: Government Regulation No.22/2021 (PP No.22 Tahun 2021, includes provisions on Limbah B3)
- Ministerial Regulation: Ministry of Environment Regulation No.101/2018 (Permen LHK No.101 Tahun 2018, Specifies classification, storage, transportation, and treatment of B3 waste)

Under these regulations, EV batteries are treated as B3 waste, and only licensed and registered entities are permitted to handle their storage, transport, incineration, or treatment after disposal, with appropriate environmental permits.

On the other hand, regulations related to EV promotion are governed by “Government Regulation No.55/2019 (PP No.55 Tahun 2019)”, which outlines the roadmap for accelerating EV development. This regulation focuses primarily on the production and deployment of EVs, but does not comprehensively cover the collection, treatment, or recycling of end-of-life batteries. It only mandates the management of used EV batteries through recycling and/or treatment (no specific methods) and the parties eligible to do so.

In summary, the current governance framework treats batteries solely as hazardous waste and provides guidance on treatment methods, but lacks a circular economy perspective that includes management before and after use, collection systems, and recycling infrastructure.

2.5.2. Challenges and Institutional Gaps

1) Unclear Responsibility for End-of-Life Battery Management

Current Indonesian regulations do not clearly define the party responsible for the collection and recycling of end-of-life EV batteries. There are no established criteria indicating whether producers, importers, sellers, or consumers are obligated to handle battery collection and recycling. This lack of clarity may lead to confusion in policy design and implementation. Notably, Indonesia has not adopted an EPR system, which is being implemented in countries such as the United States and China. As a result, there is a risk that the system may have to rely solely on voluntary collection efforts.

2) Absence of a Collection and Tracking System

There is no comprehensive system in place to track the full life cycle of EV batteries from production and use to disposal and recycling. Key information such as manufacturer, chemical composition, state of health (SOH), and usage history is not centrally managed, and there is no national-level registration system. As a result, it is difficult to verify collection and recycling history, assess suitability for recycling, and ensure safety. This also limits the potential for reuse.

3) Ambiguity in the Application of B3 Waste Regulations

Currently, only a few companies in Indonesia extract metals from used EV batteries. Many companies stop at producing black mass, a precursor to metal extraction. These companies may bury the black mass or sell it to firms capable of extracting the metals. Although EV batteries are classified as B3 waste in Indonesia, the applicable standards and regulatory scope for such business activities remain unclear. In the future, the government may need to revise B3-related regulations to support the smooth operation of EV battery disposal and recycling businesses.

4) Lack of Inter-Ministerial Policy Coordination

Several ministries, including the Ministry of Environment, Ministry of Industry, Ministry of Energy and Mineral Resources, National Standardization Agency, and Ministry of Transportation, are involved in EV and battery-related policies. However, coordination and division of roles among these ministries are lacking. The absence of an integrated policy framework or coordination mechanism for the complex task of EV battery collection and

recycling has resulted in inefficiencies on the ground and policy gaps.

5) Awareness Among EV and Battery Manufacturers Regarding End-of-Life Batteries

Interviews with domestic EV manufacturers and recycling companies revealed that Hyundai Motor Company, which manufactures EVs in Indonesia, is not currently considering end-of-life battery recycling as a major agenda item. However, Hyundai uses nickel-cobalt-manganese (NCM) cathodes, which contain valuable metals and offer high recycling potential. In fact, Korean companies such as Hyundai Glovis Co., Ltd., L&F Co., Ltd., and Evacycle Co., Ltd. have shown a strong interest in commercializing logistics and recycling businesses for EV batteries in Indonesia. However, concerns remain regarding the ambiguity of permits, legal frameworks, and the current infrastructure for handling end-of-life batteries in the country, which may hinder the implementation of these business plans.

3. Legal, Policy, Institutional, and Financial Status of EV Batteries in Indonesia

3.1. A Legal Framework

3.1.1. Legal Analysis of All Stages of the EV Battery Life Cycle

Indonesia is making concerted efforts to nurture its battery manufacturing industry and improve its production competitiveness.⁶⁾ These efforts are part of a broader strategy to establish the country as the EV hub of Southeast Asia and to scale up the production capacity of EVs and batteries.⁷⁾

The Indonesian government has set a target to increase the production of four-wheeled electric vehicles to 2.5 million units by 2030. This strategy aligns with President Prabowo Subianto's vision to accelerate vehicle electrification and achieve net-zero emissions (NZE) before 2060. In line with this vision, the legal and regulatory frameworks covering all stages of the EV battery life cycle, including production, importation, distribution, and recycling, have been examined. Furthermore, the roles and current status of the relevant ministries and regulatory agencies have been analyzed as follows.

1) Laws Related to EV Battery Production

Indonesia systematically manages the procurement of raw materials necessary for battery production, such as nickel, a key battery component, with regulations on the mining and refining of its abundant mineral resources. Among these, the battery cell manufacturing process is subject to laws related to concerning environmental impact assessments and industrial standardization, which are designed to control both product quality and environmental effects.

EV battery production in Indonesia is primarily regulated under the Mineral and Coal Mining Law, Environmental Impact Assessment Law, and laws related to industrial standards. The legal foundation for mining activities in Indonesia is provided by “Law No.3/2020 (UU No.3 Tahun 2020)” on Mineral and Coal Mining, which governs the extraction of key battery materials, including nickel. In addition, “Law No.32/2009 (UU No.32 Tahun

6) Hanin Post, February 2025, “Indonesia Aims to Produce 2.5 Million Electric Vehicles by 2030... Concerns Over Overheated Competition Raised”.

7) Yonhap News Agency, June 2023, “Electric Vehicle and Battery Investments Flood into Indonesia... 12 Trillion KRW from Glencore and Others”.

2009)” on Environmental Protection and Management establishes the regulatory framework for Environmental Impact Assessments (EIAs⁸⁾), which are required to evaluate and mitigate the environmental impact of battery production projects.

<Table 2-7> Laws Related to EV Battery Production

Law Title	Key Provisions
Mineral and Coal Mining Law (Law No.3/2020 (UU No.3 Tahun 2020))	Governs the mining and refining of battery raw materials, such as nickel
Environmental Protection and Management Law (Law No.32/2009 (UU No.32 Tahun 2009))	Mandates the prior assessment and management of potential environmental pollutants that may arise during the battery cell manufacturing process
Industrial Standardization Law (No formal law number assigned)	Regulates quality standards and manufacturing requirements for battery cell production

Source: Prepared by the author

2) Laws Related to the Imports of EV Batteries

Indonesia enforces strict regulations on the importation of EV batteries. The procedures and criteria for battery imports are governed by the Ministry of Trade’s import licensing system (PI, *Persetujuan Impor*), which allows the ministry to control the importation of specific goods and requires importers to obtain prior approval.⁹⁾ With regard to certificates of origin and the tariff system, importers are required to submit a certificate of origin (C/O)¹⁰⁾ to clearly identify the origin of the product. This official document certifies the country where the exported or imported product was manufactured, and it affects customs duties and clearance procedures. It is also operated in conjunction with international trade agreements.¹¹⁾ These regulations function as mechanisms not only to protect domestic industries, but also to ensure the quality and safety of imported products.

In relation to the import licensing system, the Indonesian Ministry of Trade enacted “Ministry of Trade Regulation No.16/2025 (Permendag No.16 Tahun 2025)”, replacing the previous framework and restructuring import policies. Under the new regulation, certain prior import approval requirements have been relaxed, the conditions for converting Importer Identification Numbers (API) have been adjusted, and the reporting system for

8) A regulatory system established to assess and minimize the environmental impacts of development projects in advance.

9) KOTRA Dream, “Recent Trends in Indonesia’s Strengthened Import Regulations”, December 2023.

10) An official document certifying the country of origin of exported or imported products.

11) Korea Customs Service, Embassy of the Republic of Korea in Indonesia, Customs Attaché, “Indonesia’s Customs Clearance System and Precautions”, April 2012.

import realization has been simplified. At the same time, sanctions for non-compliance have been clarified, making the supervision of import procedures more systematic and transparent.

In addition, Indonesia has enacted and implemented laws on rules of origin based on international trade agreements, including the ASEAN Free Trade Agreement (FTA). Importers may receive tariff benefits by submitting a certificate of origin. Furthermore, Indonesia flexibly adjusts its import regulations through various international trade agreements, such as the Regional Comprehensive Economic Partnership (RCEP) and the Korea-Indonesia Comprehensive Economic Partnership Agreement (CEPA).

In particular, Indonesia has established specific rules regarding the importation of used lithium batteries. “Ministry of Trade Regulation No.24/2025 (Permendag No.24 Tahun 2025)” is a comprehensive framework for managing the import of used goods and non-B3 wastes, under which used lithium batteries are also regulated. The regulation sets out detailed requirements for the importation of used lithium batteries, and importers are required to obtain prior approval not only from the Ministry of Trade but also from the Ministry of Environment. With this framework, Indonesia aims to secure raw materials for the domestic EV battery industry while at the same time minimizing the potential impacts of imported products on local industry and the environment, thereby conducting stricter oversight and control.

Fundamentally, used lithium batteries may only be imported by companies possessing a valid Import Identification Number for Producers (API-P),¹²⁾ which is given to companies that import raw materials or components for manufacturing purposes in Indonesia. To import such batteries, companies are also required to obtain a Certificate of Used Lithium Battery Manufacturer and Importer, which must be presented as part of the import clearance documentation. Consequently, used batteries are classified as regulated import goods. Under “Ministry of Trade Regulation No.16/2025 (Permendag No.16 Tahun 2025)”, certain exemptions apply for non-commercial imports such as new goods classified as freely importable or new goods for non-commercial use. Regulations on the importation of batteries for energy storage Systems (ESS), designed to store electricity generated from renewable sources such as solar or wind, also fall under these rules. The regulation applies the HS Code 3557,¹³⁾ used by Indonesian customs to classify used batteries and related products. While non-commercial imports of new lithium batteries may be exempt

12) A unique identification number given to companies that import raw materials or components into Indonesia for manufacturing purposes.

13) Product classification codes used by Indonesian customs to identify used batteries and related products.

from import restrictions, the non-commercial importation of used lithium batteries is not permitted, as such batteries may only be imported for commercial purposes. Additionally, importers of used batteries must be registered as Indonesian manufacturers and must obtain approvals from multiple government agencies, reflecting the strict regulatory oversight of this process.

<Table 2-8> **Laws and Regulations Related to EV Battery Imports**

Law/Regulation Title	Key Provisions
Import Licensing System (Ministry of Trade Regulation No. 36 of 2023 (Permendag No.36 Tahun 2023))	Expansion of goods subject to prior import approval, stricter import procedures and requirements, mandatory reporting obligations, and strengthened import controls
Mandatory Submission of Certificate of Origin	Clarifies the origin of products through submission; enables eligibility for preferential tariff benefits
Import Regulations Based on International Trade Agreements	Establishes rules of origin and provides tariff benefits through agreements such as ASEAN FTA, RCEP, and Korea-Indonesia CEPA
Regulation on the Import of Used Lithium Batteries (Ministry of Trade Regulation No.100/2020 (Permendag No.100 Tahun 2020))	Import permitted only for companies that have an API-P; Certificate of Manufacturer and Importer is required
Import Exemption Rules for Used Batteries (Ministry of Trade Regulation No.36 of 2024 (Permendag No.36 Tahun 2024))	Exemption applies only to new, non-commercial goods; used batteries can only be imported for commercial purposes; import clearance requirements are reinforced
ESS System Import Regulations (Application of HS Code 3557)	ESS-related products are classified under HS Code 3557; new products for non-commercial use may be exempt from import restrictions
Ministry of Trade Regulation No. 25 of 2022 (Permendag No.25 Tahun 2022)	Discusses the requirements for importing used lithium batteries that can be used for EVs

Source: Prepared by the author

3) Laws Related to EV Battery Distribution

At the distribution stage, standards for product safety and quality management are applied through the Consumer Protection Law and the Industry Regulation Law. In addition, regulations concerning distribution network management and logistics standards aim to improve distribution efficiency and maintain market order.

Laws governing product safety standards and quality management related to distribution and sales are primarily categorized under the Consumer Protection Law and the Industry Regulation Law. Indonesia’s Consumer Protection Law, enacted as “Law No.8/1999 (UU No.8 Tahun 1999)” on Consumer Protection, stipulates that products used by consumers must be safe and accompanied by accurate information. It legally defines requirements

such as labeling, quality assurance, and performance guarantees for battery products in distribution. Indonesia’s regulations on distribution networks, under “Law No.5/1984 (UU No.5 Tahun 1984)”, serve to maintain product quality and market order through compliance with quality standards, industrial licensing, and control of distribution channels for all industrial products, including battery products.

<Table 2-9> Laws and Regulations Related to EV Battery Distribution

Law Title	Key Provisions
Consumer Protection Law (Law No.8/1999 (UU No.8 Tahun 1999))	Includes provisions to protect consumer rights and ensure product safety in the distribution and sale of battery products
Industry Regulation Law (Law No.5/1984 (UU No.5 Tahun 1984))	Provides the legal basis for regulating distribution networks, including licensing, supervision, and quality standards related to the distribution and overall industrial activities of battery products
Minister of Industry Regulation No. 37/2024 (Permenperin No.37 Tahun 2024)	Regulates industrial verification for import and delivery incentives of BEV four-wheelers, including checks on technical specifications, production quantities, brand, and Domestic Component Level (TKDN)

Source: Prepared by the author

4) Laws Related to EV Battery Recycling

Indonesia’s legal framework for EV battery recycling¹⁴⁾ is established under “Government Regulation No.55/2019 (PP No.55 Tahun 2019)”,¹⁵⁾ and later amended by “Government Regulation No. 73/2023 (PP No.73 Tahun 2023). Although this regulation does not include specific provisions on battery recycling, Indonesia enforces recycling-related regulations through hazardous waste management laws governed primarily by the Ministry of Environment.

The key legislation in this area is “Law No.32/2009 (UU No.32 Tahun 2009)” on Environmental Protection and Management, which is the fundamental legal basis for environmental governance in Indonesia. These regulations are linked to the management of B3, or hazardous and toxic substances under “Government Regulation No.22/2021 (PP No.22 Tahun 2021)”. This law differentiates between B3 substances and B3 waste. A comparison between the two categories is outlined as follows.

14) When batteries can no longer be reused, critical rare metals such as lithium, cobalt, and nickel are recovered by dismantling, crushing, or incineration processes.

15) Government Regulation No. 55 of 2019 officially permits the recycling of EV batteries and aims to accelerate the electric vehicle battery program by reducing dependence on natural resources such as mining materials, thereby helping to prevent resource depletion.

<Table 2-10> Comparison Between B3 Substances and B3 Waste

Category	B3 Substance	B3 Waste
Governing Regulation	<ul style="list-style-type: none"> Government Regulation No.74 of 2001 on Management of Hazardous and Toxic Materials (PP No.74 Tahun 2001) 	<ul style="list-style-type: none"> Government Regulation No.22/2021 on Management of Hazardous and Toxic Waste (PP No.22 Tahun 2021)
Management Objective	<ul style="list-style-type: none"> Safe use, storage, and transportation 	<ul style="list-style-type: none"> Safe collection, transportation, recycling, and disposal
Content	<ul style="list-style-type: none"> Procedures for the use, storage, transportation, and handling of hazardous/toxic substances in use or in circulation 	<ul style="list-style-type: none"> Methods for managing hazardous/toxic waste after use (including contaminated materials), such as collection, storage, transportation, treatment, and final disposal
Responsible Authority	<ul style="list-style-type: none"> Ministry of Environment + Ministry of Industry (partial) - Basic registration, labeling, transportation control: Ministry of Environment-led - Management/use of B3 substances for industrial purposes: in coordination with Kemenperin 	<ul style="list-style-type: none"> - Ministry of Environment only - Full authority over licensing, tracking, and reporting
Examples of Relevant Substances	<ul style="list-style-type: none"> Lithium, nickel, cobalt, lead, cadmium, organic solvents, etc. 	<ul style="list-style-type: none"> Waste batteries, spent solvents, waste acids, waste alkalis, end-of-life lead-acid batteries, etc.
Involvement of Ministry of Industry	<ul style="list-style-type: none"> Relevant for industrial chemical substances (e.g., solvents, catalysts, paint raw materials) 	<ul style="list-style-type: none"> Not applicable (entirely under Ministry of Environment jurisdiction)
Obligations	<ul style="list-style-type: none"> B3 substance registration - Packaging/labeling - Provision of MSDS - Incident notification 	<ul style="list-style-type: none"> - Registration of waste generators - Transfer to licensed operators - Completion of manifest (tracking document) - Recycling or proper disposal
Licensing Requirements	<ul style="list-style-type: none"> License for use, transport, and storage of B3 substances 	<ul style="list-style-type: none"> License for collection, transport, recycling, and disposal of B3 waste

Source: "Government Regulation No.22/2021 (PP No.22 Tahun 2021)"

The Indonesian government has established strict legal standards for the management of B3 waste. The B3 regulations apply comprehensive controls throughout all stages of the waste life cycle, including its generation, collection, transportation, storage, and treatment. According to "Government Regulation No.22/2021 (PP No.22 Tahun 2021)" on the Management of B3 Waste, administered by the Ministry of Environment, all entities handling B3 waste are required to obtain a special permit¹⁶⁾ from the government. Prior

16) Special Permit.

to commencing operations, these entities must also conduct an Environmental Impact Assessment (AMDAL).¹⁷ Because the treatment of B3 waste may have a significant impact on the environment, the preparation and approval of this assessment is a mandatory part of Indonesia's environmental protection policy. Additionally, businesses must implement a waste tracking system to monitor the movement of B3 waste, accompanied by mandatory periodic reporting. These regulatory measures are designed to minimize the environmental and human health risks associated with hazardous waste and to maintain transparency and safety throughout the treatment process. In Indonesia, batteries are classified as designated B3 waste and require compliance with B3 waste regulations upon disposal. In particular, end-of-life batteries are fully classified as designated B3 waste and are subject to legal control.

<Table 2-11> **Applicable Legal Frameworks (Primary, Secondary, Tertiary)**

Category	Name of Legislation	Key Provisions
Primary Law	Government Regulation No.74/2001 (PP No.74 Tahun 2001, Regulation on the Management of B3 Substances)	Establishes safety management standards for the use, storage, and transportation of B3 substances, including batteries
Secondary Law	Law No.32/2009 (UU No.32 Tahun 2009, Environmental Protection and Management Law)	Regulates the production, storage, transportation, and treatment of all B3 substances and waste
Tertiary Law	Government Regulation No.22/2021 (PP No.22 Tahun 2021, Regulation on the Management of B3 Waste)	Provides rules for the collection, transportation, temporary storage, recycling, and final disposal of battery waste (classified as B3 waste)

Source: Prepared by the author

Used batteries require authorization for all stages of handling, including collection, transportation, storage, recycling, and disposal. Waste generators must be registered as B3 waste generators. Furthermore, waste must be sent to licensed collectors, and transportation requires specific permits, along with the mandatory preparation of a waste tracking document (Manifest Form). The requirements for temporary B3 storage facilities must be fulfilled before recycling or final disposal, and waste-related records must be maintained for a minimum of five years.

In addition, it has been confirmed that recycling activities also require official permits, and the import and export of used batteries are subject to stricter regulations. In Indonesia, all batteries are classified as B3 substances during use and become B3 waste after use. Therefore, the entire life cycle of batteries, including manufacturing, importation, sale, use,

17) Environmental Impact Assessment (EIA): A system for analyzing and evaluating the potential environmental effects of development or industrial activities in advance.

disposal, transportation, and recycling, must comply with the permitting and registration requirements set by the Ministry of Environment.

According to “Government Regulation No.22/2021 (PP No.22 Tahun 2021)”, the Indonesian government has assigned a unique Waste Code to each type of B3 waste. Since different battery compositions are subject to different codes, it is important to obtain the appropriate permits based on the relevant Waste Code for battery collection and recycling. There is a specific B3 Code for products that contain lead, and lead-acid batteries are subject to import restrictions accordingly. Similarly, products that contain heavy metals such as cobalt and nickel are also designated under specific B3 Codes, and lithium-ion secondary batteries can be classified and regulated under comparable codes.

The Indonesian government is in the process of preparing a separate regulatory framework specifically for lithium-ion batteries. While this has not yet been formalized into legislation, the Ministry of Environment and the Ministry of Energy and Mineral Resources are currently drafting a “Guideline on Electric Vehicle Batteries and Lithium Batteries”. At present, lithium batteries are managed under the classification criteria for B3 waste. However, it is very likely that a separate management regulation will be established in the future that reflects the unique characteristics of these batteries, such as the risk of explosion and fire, in addition to their chemical composition.

Furthermore, the international transport of lithium batteries is subject to global standards, most notably the international regulations for the transport of dangerous goods. These regulations are particularly strict for air transport, and a clear understanding of the applicable requirements is essential. A summary of the relevant regulations is provided below.

<Table 2-12> Summary of Applicable Regulations

Category	Regulation Title	Description
1	UN Number: UN3480	Lithium-ion batteries (standalone)
2	UN Number: UN3481	Lithium-ion batteries contained in equipment (e.g., EVs, laptops)
3	UN Number: UN3090	Lithium metal batteries (standalone)
4	UN Number: UN3091	Lithium metal batteries contained in equipment
5	International Air Transport Association (IATA) Regulations	Mandatory packaging, labeling, and documentation for air transport
6	International Maritime Organization (IMO) Regulations	Compliance with hazardous materials regulations for maritime transport

Source: Prepared by the author

The following summarizes the previously mentioned procedures for licensing and the import/export flow of used batteries and lithium batteries in Indonesia. While Indonesia permits the import and export of used batteries, the fundamental principle is that export is prohibited without a special permit from the Ministry of Environment. Handling used batteries requires strict compliance with licensing procedures. Additionally, the export and import of lithium batteries must comply with UN regulations, including appropriate packaging, labeling, and complete documentation.

<Table 2-13> Procedures for Licensing and Import/Export

Category	Process
Used Battery Licensing	<ul style="list-style-type: none"> Establishment of legal entity → Application for B3 waste handling permit → Environmental impact assessment (AMDAL) → Facility inspection → Issuance of license → Registration in waste tracking system → Periodic reporting
Lithium Battery Import/Export	<ul style="list-style-type: none"> Identification of lithium battery type (UN3480/3481) → Use of UN-compliant packaging → Attachment of appropriate labels → Preparation of dangerous goods transport documentation → Obtaining import/export permit

Source: Prepared by the author

It is important to note that the standard principle for used batteries that cannot be recycled, such as end-of-life LFP batteries or severely damaged batteries, is that they must be treated at a government-authorized facility known as a B3 Waste Final Disposal Site. These batteries are required to undergo a specific treatment process involving discharging, shredding, and either special landfilling or incineration. Following treatment, it is mandatory to submit a Certificate of Destruction (Sertifikat Pemusnahan) and to fully comply with applicable legal requirements.

Therefore, the recycling and disposal of batteries are regulated under relevant laws, including the Waste Management Law and the Environmental Protection Law. These legal frameworks are grounded in the principles of circular economy and aim to promote sustainable resource utilization and environmental protection concurrently, thereby underscoring the significance of these regulatory systems.

5) Law of Hazardous Waste Management

The regulation of B3 waste in Indonesia is divided based on its source. If the B3 waste originates from households, it is classified as specific waste: household waste containing hazardous and toxic substances, and B3 waste generated from industrial activities.

a) Specific Waste (B3 Waste from Households)

B3 waste generated from households, referred to as specific waste, is governed under “Government Regulation No.27 of 2020 (PP No.27 Tahun 2020)” on Specific Waste Management. This regulation focuses specifically on hazardous household waste. Its technical implementation is outlined in “Minister of Environment Regulation No. 9 of 2024 (Permen LHK No.9 Tahun 2024)”. According to Articles 3 and 4, household B3 waste is classified into four categories.

<Table 2-14> Household B3 waste classification

Category	Description
1	Household products containing B3 that are no longer used
2	Packaging waste from B3-containing products
3	Electronic waste (e-waste), including used or damaged electrical items including waste EV batteries
4	Expired, spilled, or off-specification B3 substances

Source: Minister of Environment Regulation No.9 of 2024(Permen LHK No.9 Tahun 2024)

The waste management system for household B3 waste (Articles 5–9) consists of two core components: reduction and handling. Reduction efforts aim to minimize hazardous waste generation by encouraging the use of eco-labeled, recyclable, and environmentally friendly products. Handling involves a structured process comprising five critical stages for safe and compliant management of B3 waste as outlined in the table below.

① Sorting

Waste must be separated at the point of generation (households or management facilities). While detailed regulations may vary by region, it is generally sorted into designated color-coded containers as shown below.

- Red: Household products that contain designated B3 waste
- Yellow: Plastic waste
- Green: Organic or food waste
- Blue: Paper waste

- Black: General waste

② Collection

After sorting, the waste is collected and transferred to one of two types of interim facilities:

- TPS (Tempat Penampungan Sementara): Temporary collection point for general waste
- TPS 3R: Community-based resource circulation facility
- TPST (Tempat Pengolahan Sampah Terpadu): Integrated Waste Treatment Facility
- TPA (Tempat Pemrosesan Akhir): Final disposal site (landfill)
- TPS Limbah B3: Temporary storage facility for designated B3 waste
- FPSS: Government-provided facility for the segregation, collection, and treatment of specific or hazardous waste in Indonesia.

Collection is carried out by local governments (in residential areas) or by facility managers (in managed zones). These facilities must meet certain criteria as outlined in “Ministry of Environment Regulation No.9/2024 (Permen LHK No. 9/2024)”, including:

- Availability of emergency response equipment
- Accessible location and infrastructure for pollution prevention
- Clear signage, standard operating procedures (SOPs), and proper logbooks

Each facility must also appoint key personnel, including a responsible manager and officers for administration, finance, and operations. Facilities are required to report annually through the national waste management information system. In addition, comprehensive tracking logs must be maintained, documenting the type, source, and quantity of waste, dates of collection and processing, and the final disposal destination.

③ Transportation

Transport of B3 waste must comply with national regulations. All transportation activities

must be carried out by licensed entities, in accordance with “Ministry of Environment Regulation No.6/2021 (Permen LHK No.6 Tahun 2021)”, which specifies technical and administrative requirements for the safe transportation of hazardous waste.

④ Treatment

Treatment of B3 waste is regulated under “Government Regulation No.22/2021 (PP No.22 Tahun 2021)” on Environmental Protection and Management and further detailed in Ministry of “Environment Regulation No.6/2021 (Permen LHK No.6 Tahun 2021)”. These regulations require that:

- Treatment is conducted by licensed facilities
- Facilities meet technical design, construction, and operational standards
- Emissions and wastewater from the treatment process comply with environmental quality standards
- All activities follow approved licensing and technical procedures

⑤ Final Disposal

The final step in the management process is the disposal of B3 waste in a manner that ensures environmental and health safety. This must be done in accordance with both “Government Regulation No.22/2021 (PP No.22 Tahun 2021)” and “Ministry of Environment No.6/2021 (Permen LHK No.6 Tahun 2021)”, using licensed disposal facilities and following proper procedures to prevent contamination. This structured approach is essential to safeguard public health and protect the environment from the hazards posed by B3 substances.

b) B3 Waste from Industrial Activities

B3 waste generated from industrial activities is primarily governed by “Government Regulation No.22/2021 (PP No.21 Tahun 2021)”, which establishes the overarching legal framework for environmental protection and hazardous waste management in Indonesia. The technical requirements for managing industrial B3 waste are further elaborated in “Ministry of Environment Regulation No.6/2021 (Permen LHK No.6 Tahun 2021)”, which provides detailed guidelines for operational procedures, licensing, and monitoring. According to Annex IX of “Government Regulation No.22/2021 (PP No.22 Tahun 2021)” and

supporting provisions in “Ministry of Environment Regulation No.6/2021 (Permen LHK No.6 Tahun 2021)”, industrial B3 waste is classified into several categories: i) B3 waste from specific sources, such as waste generated by defined industrial processes; ii) B3 waste from non-specific sources, including general cleaning and maintenance activities; and iii) B3 waste from expired products, off-specification materials, and contaminated packaging. Furthermore, examples of B3 waste codes include i) A102d: Used batteries (including lead-acid and lithium-ion batteries from equipment or EVs); and ii) B107d: Electronic waste (including printed circuit boards, CRTs, lamps, and cables).

The industrial B3 waste management system also consists of two key components: reduction and handling.

① Storage

Industrial B3 waste must be temporarily stored before further processing. Storage must:

- Be conducted in designated areas with impermeable flooring and secondary containment systems
- Include proper labeling with B3 hazard symbols and information
- Storage duration limits: 90 days for most generators and 180 days for small-scale generators

② Collection

- Collection of B3 waste must be carried out by licensed B3 waste collectors, either internal to the company or through third-party service providers.
- All collection activities must be documented using Festronik, the electronic manifest system.

③ Transportation

B3 waste must be transported exclusively by licensed transporters, in accordance with:

- Ministry of Environment Regulation No.6/2021 (Permen LHK No. 6 Tahun 2021) – Technical and administrative requirements

- Ministry of Transportation No.60/2019 (Permenhub No. 60 Tahun 2019) – Safety and specification standards for hazardous goods transport
- All shipments must be traceable through the Silacak (B3 Waste Tracking) system.

④ Utilization

B3 waste that still contains recoverable value (e.g., solvents, oils, or metals) may be:

- Recycled or reused by licensed B3 waste utilization facilities
- Used as alternative raw materials or fuels (e.g., in cement kilns)
- Utilization is permitted only if the process complies with safety, environmental, and product quality standards.

⑤ Treatment

B3 waste must be treated at licensed B3 treatment facilities using approved technologies such as:

- Incineration, chemical stabilization, or physical separation
- Facilities must meet technical design, emission, and operational standards, and prevent leakage or hazardous byproducts.
- All treatment must be documented with pre- and post-treatment reports.

⑥ Final Disposal

B3 waste that cannot be reused or treated must be disposed of safely in engineered landfills (Sanitary Landfill B3), operated by certified final disposal facilities. The disposal process must meet environmental safeguards under “Government Regulation No.22/2021 (PP No.22 Tahun 2021)”, including leachate control, groundwater protection, and long-term monitoring.

⑦ Reporting and Documentation

All stages of B3 waste handling must be recorded and reported through the National B3

Waste Management Information System. Required documentation includes:

- Electronic waste manifest (Festronik)
- Storage and collection records
- Transport and treatment logs
- Annual reports submitted to the Ministry of Environment

This comprehensive and tiered regulatory framework ensures that industrial B3 waste is managed in a way that protects both public health and the environment, while maintaining alignment with international hazardous waste management standards.

3.1.2. Roles of Key Authorities in Policy Formulation, Regulation, and Enforcement

1) Regulatory Roles of Major Ministries

BAPPENAS is responsible for strategically guiding Indonesia's long-term growth objective for the battery and EV industries. Low-carbon, energy transition, and sustainability goals are integrated into national planning by BAPPENAS through programs such as the Long-Term National Development Plan (RPJPN) 2025-2045. The Indonesia Green Economy Index (IGEI)¹⁸⁾ is one of the tools the ministry uses to evaluate how the adoption of EVs affects the economy, jobs, and environment. The Bali E-Mobility Project is one such initiative. It is a pilot program that incorporates electric buses and associated infrastructure in order to prepare the way for broader nationwide adoption.

Road permits, registration, safety regulations, and EV integration into public transit systems are all under the jurisdiction of the Ministry of Transportation. It also oversees vehicle certification and supports EV conversion programs. "Ministry of Transportation Regulation No.45/2020 (Permenhub No.45 Tahun 2020)" sets safety requirements for light electric vehicles, such as e-bikes and scooters. While "Government Regulation No.79/2023 (PP No.79 Tahun 2023)" promotes local infrastructure development and conversion projects, especially those headed by MSMEs. The Ministry of Transportation is responsible for the registration of electric vehicles, road use permits, charging station standards, and transportation safety regulations. It also promotes EV product certification, operational

18) A set of comprehensive indicators jointly developed by the Indonesian government and international organizations (e.g., UN-PAGE, GGGI) for sustainable growth and socioeconomic-environmental transitions.

standards, and the electrification of public transportation.

The Ministry of Energy and Mineral Resources oversees the upstream segment of the EV battery supply chain, including the mining and processing of critical materials such as nickel and cobalt. It also establishes technical standards for public EV charging and refueling stations and leads the development of charging infrastructure. Under “Ministry of Energy and Mineral Resources Regulation No.1/2023 (Permen ESDM No.1 Tahun 2023)”, the ministry collaborates with PT PLN and other stakeholders to ensure the reliability and accessibility of energy infrastructure for EV users.

The Ministry of Environment is responsible for ensuring that the expansion of the EV and battery industries does not compromise environmental sustainability. The ministry coordinates battery recycling procedures, manages B3 waste, and oversees environmental impact assessments (AMDAL). Guided by “Government Regulation No.22/2021 (PP No.22 Tahun 2021)” as the overarching framework, it enforces specific technical standards through “Ministry of Environment Regulation No.6/2021 (Permen LHK No.6 Tahun 2021)” on B3 waste management procedures and “Ministry of Environment Regulation No.12/2021 (Permen LHK No.12 Tahun 2021)” on emission standards for lithium battery recycling facilities. Furthermore, under “Government Regulation No.5/2021 (PP No.5 Tahun 2021)—which introduced the risk-based licensing system—the ministry defines the roles and responsibilities of authorized operators.

2) The Importance and Limitations of the Roles of Major Regulatory Authorities and Agencies

The electric vehicle and end-of-life battery industries in Indonesia operate in a multi-ministerial system involving the National Development Planning Agency, Ministry of Industry, Ministry of Energy and Mineral Resources, Ministry of Environment, and Ministry of Transportation. These agencies are engaged across the entire spectrum of production, environmental management, distribution, and transportation.

To respond to emerging demands, the government has enacted and implemented a number of regulations, including “Government Regulation No.79/2023 (PP No.79 Tahun 2023)”, “Ministry of Industry Regulation No.6/2022 (Permenperin No.6 Tahun 2022), Ministry of Environment Regulation No.6/2021 (Permen LHK No.6 Tahun 2021)”, and “Government Regulation No.55/2019 (PP No.55 Tahun 2019)”, to respond to new demands. Nevertheless, inconsistencies in implementation and overlapping institutional jurisdictions remain persistent challenges. To effectively advance the development of Indonesia’s electric vehicle

ecosystem, clearly defined roles, improved inter-agency coordination, and consistent policy execution are essential.

3.2. Policy Framework

3.2.1. Analysis of Policies and Incentives to Promote Investment in the Battery Recycling Industry

1) Policy Directions for the Battery Industry in Indonesia's National EV Development Strategy

The Indonesian government has initiated the creation of a roadmap for the battery industry with a focus on developing a battery manufacturing ecosystem by 2035. Notably, the government's EV Development Master Plan, announced in 2019, outlined the direction for fostering electric vehicle and battery technology as core national industries. In its EV development strategy, the government has designated the battery industry as a key driver of growth and is currently pushing forward with medium- to long-term plans to support this. The government is particularly aiming to attract global companies such as Tesla, and is working on the development of EV and battery-related industrial infrastructure and the establishment of production hub clusters in pursuit of this. However, the development of technology and the provision of investment incentives for the battery recycling industry remain at an early stage, and there isn't a clear policy framework in this area.

Indonesia's EV and battery strategy is anchored by "Government Regulation No.55/2019 (PP No.55 Tahun 2019, Battery-Powered EV Acceleration Program)", recently updated by "Government Regulation No.79/2023 (PP No.79 Tahun 2023)", which makes domestic EV industry development a national priority.

To support the development of EVs, Indonesia has formed a state-owned company operating in the EV ecosystem called Indonesia Battery Corporation (IBC). IBC is a consortium of PLN (utility), Pertamina (energy), Aneka Tambang (nickel mining) and Inalum/MIND ID (mining holding). One of IBC's mission is to maximize the potential of Indonesian resources with the establishment of an integrated battery, EV, and ESS ecosystem from upstream to downstream and coordinating the national EV battery ecosystem.

Another key organization is the Indonesian Battery Association, idBattery, which carries out activities such as building a network of battery-related companies in Indonesia and conveying policy recommendations between the government and the private sector.

IBC is also one of the major member companies of idBattery and has announced plans to build a domestic lithium-ion battery recycling plant by 2031. In July 2025, it officially announced the completion of a recycling facility specifically for end-of-life EV batteries. Accordingly, the Indonesian government must provide timely policy support to guarantee the success of IBC's EV battery circular system while also safeguarding national interests and ensuring public safety.

3.2.2. Analysis of the Linkage Between Green Transition Goals and Industrial Policies

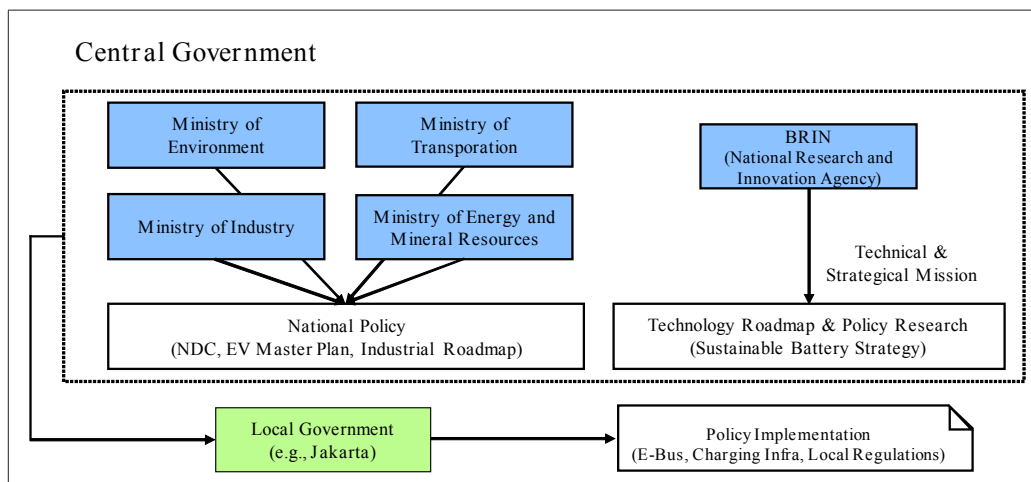
1) The Relationship Between Indonesia's Nationally Determined Contribution (NDC) and Battery Policy

Indonesia has a national vision to achieve carbon neutrality (net-zero emissions, NZE) by 2060, and this long-term goal is reflected in the country's greenhouse gas reduction commitments under ENDC.

In its initial NDC draft submitted in 2016, Indonesia set a goal to reduce greenhouse gas emissions by 29% compared to the business-as-usual (BAU) scenario by 2030. In response to the mandate of the Paris Agreement temperature goal by the end of 2022, Indonesia submitted its Enhanced NDC in September 2022 which increased the emissions reduction target from 29% in first NDC and updated ENDC to 31.89% unconditionally by 2030, and set the conditional reduction target at 43.20%. The 2022 updated version further specified the pathway to achieving this target, emphasizing the implementation of EV adoption and its supporting ecosystem, increased share of renewable energy, and improved energy efficiency. One of the key strategies outlined in the revision is the electrification of the transportation sector and the expansion of EV infrastructure.

While an implementation strategy to achieve the net-zero emissions goal is being developed at the central government level, actual execution is carried out through collaboration between local governments and individual ministries, reflecting Indonesia's decentralized structure.

[Figure 2-2] Indonesia Government EV Implementation System Structure



Source: Prepared by the author

As shown in the diagram above, local governments have the authority under Indonesia's decentralized administrative structure to independently pursue environmental and industrial policies. At the city government level, for example, Jakarta has implemented its own EV deployment program, which includes the introduction of electric buses and the expansion of charging infrastructure, intended to improve air quality and reduce transportation-related carbon emissions.

Additionally, as part of a science and technology-based policy design, the National Research and Innovation Agency (BRIN, Badan Riset dan Inovasi Nasional) leads policy research on the electric vehicle battery circular economy and recycling technologies. BRIN has published several strategic documents, including the National Technology Roadmap for EV Industry Transition¹⁹⁾ and the Action Plan for Sustainable Battery Life Cycle. These strategies are linked with the Battery Industry Roadmap 2020-2035 established by the Ministry of Industry and the central government's EV master plan,²⁰⁾ and they are also used to form joint roadmaps between relevant ministries. To support this strategy, the Ministry of State-Owned Enterprises (BUMN) established the Indonesia Battery Corporation under MIND ID, located in Jakarta. This company was formed to manage the integrated battery industry from upstream to downstream in the country.

Meanwhile, Indonesia's battery recycling policy is still in its early stages. To date,

19) National Research and Innovation Agency (BRIN), "Action Plan for Sustainable Battery Life Cycle", 2022, Badan Riset dan Inovasi Nasional, Indonesia.

20) Indonesia's central EV master plan refers to the "Battery Industry Development Roadmap 2020–2035" and "EV Development Master Plan" established by the Ministry of Industry, encompassing EV production expansion, battery technology development, and supply chain establishment.

the Ministry of Industry and the Ministry of Environment have individually developed relevant guidelines, but there is no comprehensive collection system or Extended Producer Responsibility (EPR) system in place. In particular, the absence of a collection system for waste batteries is considered the biggest policy challenge. Additionally, current regulations in Indonesia classify EV batteries as B3 waste, which further complicates the management and recycling processes.

Moreover, the issue of illegal disposal by informal recyclers, who handle electronic waste in general, is increasingly emerging, and it is necessary to address this along with other concerns. There has been criticism that collected waste batteries are not entering the official recycling system but are being processed irregularly in blind spots. This not only poses environmental pollution and human health risks but also distorts the formal distribution system.

The issue of ownership of waste batteries is also emerging as a significant concern. In particular, Chinese companies have established their own collection systems based on their dominance in the nickel supply chain, which may lead to recycling taking place outside the control of public institutions or local governments.²¹⁾ Given that Chinese companies hold an absolute advantage in the battery supply chain, the regulations regarding ownership in the reuse and recycling stages are likely to be a critical factor in shaping the battery circular economy system.²²⁾

There is also a lack of accurate predictions regarding the volume of waste batteries. According to published literature, with the expansion of EV adoption, it is expected that tens of thousands of tons of waste batteries will be generated annually by 2030.²³⁾ However, a significant issue is the lack of a practical collection forecast model that reflects various variables such as battery replacement cycles, driving distance, and climate conditions. This situation increases the uncertainty around decisions regarding the establishment of a collection system and related infrastructure investments. In addition, there is currently no regulation in Indonesia that specifically addresses the disposal mechanism of vehicles, further complicating the management and recycling systems for automotive waste.

According to the International Energy Agency (IEA) in *Global EV Outlook 2023 – Battery End-of-life Trends*, the volume of waste batteries is expected to reach thousands of tons annually by 2030 due to the growing adoption of EVs. The IEA's forecast model considers

21) The Jakarta Post, "China's Battery Dominance and the Challenge of Recycling in Southeast Asia", 2022.

22) CSIS Indonesia, "The Future of Battery Industry in Indonesia: Opportunities and Strategic Risks", 2023.

23) International Energy Agency (IEA), "Global EV Outlook 2023 – Battery End-of-life Trends", 2023.

the spread of EVs and battery replacement cycles as key variables, but it has limitations in providing sophisticated predictions that account for regional characteristics or replacement cycles. In its 2020 report *Critical Raw Materials Resilience: Charting a Path Towards Greater Security and Sustainability*, the European Commission predicted a significant increase in the volume of waste batteries in Europe by 2030 due to the rise in EV adoption. The report also highlighted the need for policy efforts to improve the recyclability of waste batteries.²⁴⁾ According to research by the Institute for Essential Services Reform, if EV adoption expands rapidly in ASEAN regions such as Indonesia, approximately 1,000 tons of waste batteries will be generated annually by 2030, with significant challenges anticipated in establishing collection systems in this region.²⁵⁾ Finally, the World Economic Forum (WEF) predicted in a 2022 report that waste battery volumes in Asia and Africa would surge due to the rise in EV adoption, with variations in these forecasts depending on battery replacement cycles and climate conditions.²⁶⁾

The major issue in these predictions is the lack of forecasting models that effectively reflect various variables such as battery replacement cycles, driving distance, and climate conditions. For example, climate conditions can affect battery performance and change the timing of waste battery generation,²⁷⁾ and the lifespan of EVs may vary, adding uncertainty to prediction models. Additionally, as battery technology advances, battery lifespans and replacement cycles may be extended, so there is a need to update current prediction models.

As the volume of waste batteries is expected to increase rapidly, the need to establish collection systems and invest in related infrastructure is being emphasized. Currently, there is no well-established system for the efficient collection and recycling of waste batteries, and policy supplementation is needed. The issue of illegal recycling is also rising, and legal and institutional measures are needed to establish an official recycling system.²⁸⁾

2) Industrial Clusters and Private Sector Collaboration Policies

In line with these policy directions, the Indonesian government is strengthening supply chains by developing industrial clusters and fostering private sector collaboration. A notable example of this is Morowali Industrial Park. This industrial park is an integrated supply chain system that connects nickel mining, refining, battery material processing, and cell manufacturing. It was established through cooperation between the Indonesian government

24) European Commission, "Critical Raw Materials Resilience: Charting a Path Towards Greater Security and Sustainability", 2020.

25) Institute for Essential Services Reform (IESR), "Battery Waste Management in Indonesia: Challenges and Policy Gaps", 2023.

26) World Economic Forum (WEF), "Battery Recycling and Circular Economy: A Global Perspective", 2022.

27) Wu, H., & Craig, M. T. (2024). "Climate Change Will Reduce the Durability of EV Batteries Globally". Center for Sustainable Systems.

28) Institute for Essential Services Reform (IESR), "Battery Waste Management in Indonesia: Challenges and Policy Gaps", 2023.

and multinational corporations. While it has successfully integrated the battery production value chain, it also faces challenges, particularly environmental risks and opposition from local communities.

Additionally, government-private sector joint ventures in EV battery production facilities have attracted significant investments from South Korean and Chinese companies, including Hyundai Motor Group and LG Group. The government supports foreign investment by offering tax incentives and regulatory easing. Hyundai Motor Group, in collaboration with LG Energy Solution, has established a 10 GWh annual battery cell production plant in Karawang, Indonesia, and supplies battery cells for Hyundai and Kia's EV models. This initiative has significantly contributed to the production of the first EVs in Indonesia equipped with domestically produced batteries. The government is also developing industrial zones near nickel mines to continue attracting foreign investment and promoting public-private partnerships (PPPs).

However, these developments and investments have led to concerns about environmental damage and local community opposition in certain areas, raising the need for further discussions on sustainability in the future. Furthermore, while the Ministry of Industry has introduced regulations and incentives to promote the development of the EV industry, these policies sometimes overlap or conflict with those of other ministries. Indonesia is implementing multiple policies to strengthen the supply chain of the EV and battery industry, but there are conflicts between industrial incentives, environmental regulations, and foreign investment restrictions, indicating the need for improvements in these areas. A significant issue contributing to investor uncertainty is the differing interpretations of regulations between the central and local governments, as well as a lack of consistency in laws. Therefore, to achieve a battery circular economy, it is important to design and regulate a consistent policy framework that covers recycling, production, and distribution. While multiple goals are being pursued simultaneously, it is critical to minimize conflicts arising from a lack of coordination between policies. Moving forward, there is a need to establish a coherent legal and institutional system that encompasses recycling, production, and distribution for consistency between potentially conflicting policies.

3.3. Institutional Framework

3.3.1. Analysis of Roles and Stakeholders Among Government Agencies, Industry, and Local Institutions

1) Key Regulatory Systems Related to the EV Battery Industry

Indonesia's EV battery industry has experienced rapid growth in recent years, and relevant regulatory systems and operational frameworks are gradually being established. The main regulatory systems currently applicable to this industry include: i) Battery Quality Management and Certification System; ii) Recycling and Waste Recovery Framework; and iii) Licensing and Registration System for Production and Distribution

The Battery Quality Management and Certification System ensures product safety and reliability with the adoption of the Indonesian National Standard (SNI, Standar Nasional Indonesia). Key certification bodies include the National Standardization Agency (BSN, Badan Standardisasi Nasional) and the Agency for the Assessment and Application of Technology (BPPT, Badan Pengkajian dan Penerapan Teknologi²⁹⁾, which are responsible for overseeing testing and certification processes at both the production and import stages.

In support of this certification framework, a number of detailed SNI standards have been issued to regulate battery safety, particularly for lithium-ion batteries used in electric vehicles. These standards focus on safety and technical performance, although gaps remain in guidance for battery reuse and recycling. The current standardization approach electric vehicle EV batteries has primarily focused on safety and performance, with limited coverage of battery reuse and recycling. Several Standar Nasional Indonesia (SNI) documents currently regulate the safety and technical specifications of lithium-ion batteries used in EVs as tabulated in <Table 2-3>.

SNI 8871:2019 and SNI 8872:2019 govern the safety requirements of rechargeable electrical energy storage systems (REESS) for four-wheeled (category M and N) and two/three-wheeled (category L) electric vehicles, respectively. These standards include provisions for thermal, mechanical, and electrical safety testing, but do not address reuse or recycling procedures.

For electric two-wheelers, additional standards have been established to support swappable battery and its standardization. SNI 8927:2020 outlines safety requirements for removable and swappable battery systems, while SNI 8928:2020 specifies standard dimensions, connector types, and communication protocols for these battery packs to ensure interoperability between vehicle models.

On the cell level, the SNI IEC 62660 series, comprising SNI IEC 62660-1:2017 (performance testing), SNI IEC 62660-2:2017 (reliability and abuse testing), and SNI IEC 62660-3:2016 (safety

29) Formerly a technology testing and application research institute, now integrated under BRIN, that performs roles such as certification testing, technical evaluation, and quality inspection.

requirements) adopted from the IEC international standards, provides rigorous testing procedures for secondary lithium-ion cells used in EV propulsion.

While these standards ensure product safety and reliability during use, none currently provide technical guidance detailed technical guidance for the reuse, second-life application, or recycling of spent EV batteries. As of now, Indonesia lacks a dedicated SNI specifically addressing battery end-of-life management, although there are policy signals and ongoing industry discussions pointing to the need for such standards in the near future.

<Table 2-15> Standards of battery in Indonesia

Type of Battery	Vehicle Category	Standard	Certification Focus
REESS (integrated system)	M & N (four-wheelers)	SNI 8871:2019	Safety
REESS (integrated system)	L (two, three-wheelers)	SNI 8872:2019	Safety and vibration/fire resistance
Swappable battery packs	L (motorcycles)	SNI 8927:2020	Removability, connector safety, EMC
Standardized pack specs	L (motorcycles)	SNI 8928:2020	Dimensions, voltage, communication
Lithium-ion cell (general)	All	SNI IEC 62660-1/2/3	Performance, reliability, safety

Source: Prepared by the author

The Recycling and Waste Recovery Framework is gradually being reinforced through the Extended Producer Responsibility (EPR) system, which mandates battery collection and recycling obligations for industry players. This system is emerging as a key mechanism for establishing a resource-circulating industrial ecosystem.

The Licensing and Registration System manages permits at all stages of the battery life cycle, including production, import, and distribution, with the One Stop Service (OSS) integrated licensing system. This centralized approach improves procedural efficiency and administrative transparency. The OSS platform represents a leading example of e-government innovation and offers fast and consistent services to both industrial stakeholders and public institutions.

<Table 2-16> Battery Quality Management and Certification System

Category	System Name	Description	Governing Body
1	Indonesian National Standard (SNI)	Battery quality and safety certification system	National Standardization Agency (BSN), National Research and Innovation Agency - Technology Assessment Division (BRIN)
2	Extended Producer Responsibility (EPR)	Obligation for companies to collect and recycle batteries	Ministry of Environment
3	One-Stop Service (OSS)	Integrated licensing system for production, import, and distribution	Investment Coordinating Board (BKPM)

Source: Prepared by the author

2) Operational Framework: Public and Private Actors

To improve the sustainability of Indonesia’s EV battery industry, the government emphasizes a regulatory framework based on public-private partnerships (PPP). The expansion of PPP projects is expected to contribute significantly to the development of a sustainable battery industry ecosystem in the country. In particular, regarding battery recycling and waste collection systems, Hyundai Glovis Co., Ltd. is collaborating with the local company PT Arah Environmental Indonesia to implement a project for the collection, treatment, and resource recovery of used batteries in Indonesia.

The case of Hyundai Glovis Co., Ltd. partnering with PT Arah Environmental Indonesia to collect, treat, and recycle end-of-life batteries in Indonesia is a practical example of a global private company jointly pioneering a market with local institutions in establishing a battery recycling ecosystem. Hyundai is also working closely with PT Prasadha Pamunah Limbah Industri (PPLI), a leading hazardous waste management company in Indonesia, to dispose of EV battery rejects and testing. PT TES AMM Indonesia, another company involved in waste management, also accepts used EV batteries for recycling. This company specializes in recycling electronic waste, including EV batteries, so that they are disposed of properly.

In addition, companies such as LG Energy Solution Co., Ltd. and Hyundai Motor Company are increasing their strategic ties with public agencies through investments in local battery cell production and materials processing clusters. Meanwhile, BRIN is supporting these initiatives by conducting policy research and establishing technical standards. This division of roles between public policies and private actors is emerging as a driving force in the transition of Indonesia’s battery industry.

The partnership between MIND ID and PT Nasional Hijau Lestari (NHL) exemplifies a crucial public-private collaboration to develop a sustainable EV battery waste management system in Indonesia. As electric vehicle adoption grows, this partnership addresses the challenge of managing battery waste. MIND ID supplies essential materials such as nickel for battery production, while PT NHL handles the recycling and disposal of used batteries. The project focuses on a circular economy, where valuable materials from old batteries are reused, to reduce environmental impacts and conserve resources. The partnership also benefits from collaboration with global companies such as CATL and LG Chem to bring advanced recycling technologies to Indonesia. Supported by the Ministry of Environment, this PPP aims to position Indonesia as a leader in sustainable battery management.

3) Establishment of Consultative Bodies and Governance Structures

Indonesia operates various consultative bodies and governance mechanisms to support the development of its EV industry. A representative institution is the Indonesia Battery Corporation (IBC³⁰⁾), established in 2021 as an integrated state-owned enterprise with joint participation from state mining company MIND ID, Antam, the state electricity company PLN, and the state oil company Pertamina. IBC functions as a key operator overseeing the entire battery value chain, including raw material extraction, cell production, and recycling. Its core objective is to facilitate technology transfer and local job creation through the formation of joint ventures with foreign investors.

In addition, the “Moving Indonesia” initiative, led by the World Economic Forum (WEF),³¹⁾ aims to establish a public-private cooperation network involving the government, industry, and research institutions. This initiative seeks to improve EV production capabilities and build a sustainable transportation ecosystem.³²⁾ It encourages the participation of various stakeholders in areas such as policy coordination, infrastructure investment, and vocational training, and is a strategic effort to position Indonesia as an EV manufacturing hub in the ASEAN region.

3.4. Financial Framework

3.4.1. Current Status of Financial Support for Promoting the Recycling Industry: Government’s Fiscal Support Direction and Policy Orientation

30) Indonesia Battery Corporation Official Website: <https://www.indonesiabatterycorp.com/>

31) World Economic Forum (WEF), “Moving Indonesia: Public-Private Strategies for Sustainable Mobility”, 2023.

32) World Economic Forum, Moving Indonesia: Public-Private Strategies for Sustainable Mobility, 2023.

The Indonesian government is providing various forms of financial support to foster the EV and battery industries as national strategic sectors. This support includes incentives, subsidies, and tax relief measures. In particular, investments made in industrial parks are given preferential treatment such as corporate income tax reductions and exemptions from import duties.

The legal framework serves as the foundation for the government to demand the active role and responsibility of producers in reducing and managing electronic waste. In Indonesia, the EPR policy is indirectly regulated under “Law No.18/2008 (UU No.18 Tahun 2008)” concerning waste management. Article 15 of the law states that producers are obligated to manage products that are non-biodegradable or difficult to decompose naturally. Based on this provision, every producer bears responsibility for managing the waste generated by their products. Currently, however, the implementation of EPR in Indonesia remains voluntary and has not yet become a mandatory obligation for producers.

The Indonesian government has actually established a waste reduction roadmap with “Ministry of Environment Regulation No.75/2019 (Permen LHK No.75 Tahun 2019)” which requires business actors in the manufacturing, food and beverage, and retail sectors to implement waste reduction measures. These include limiting waste generation, recycling, and reusing waste materials. Businesses that carry out these measures may be eligible to receive incentives in the form of awards, public recognition for good performance, and other forms of incentives aligned with scientific and technological advancements and applicable laws and regulations. This roadmap is in line with the government’s broader efforts to support the recycling industry. However, the regulation still needs to be followed up with more detailed policies, particularly regarding the specific requirements, conditions, and forms of incentives.

Studies in EVB waste recycling for Indonesia are mostly on an experimental basis, such as one by Yulamnda et al. (2025). However, Wasesa et al. (2022) conducted research that evaluates the economic and environmental feasibility of establishing a lithium-ion battery (LIB) recycling supply chain in Indonesia using a hybrid simulation approach (agent-based modeling, system dynamics, and metallurgical process simulation). The result show that recycling is not profitable when the lithium iron phosphate (LFP) content is high (e.g., 30%) and the collection rate is low (e.g., 10%). Recycling is more profitable when the black mass composition is rich in valuable metals such as cobalt (Co) and nickel (Ni), and LFP content is lower. To achieve profitability, the collection rate also has to be high (e.g., 90%). From the scenario analysis, the best-case scenario (0% LFP, 90% collection) offers a recycling cost of \$1,803/ton and the highest profitability. The research outcomes also highlight the importance

of national-level regulations and incentives to increase collection rates, as well as setting legal frameworks for safe transport, storage, and recycling of LIB waste. The Indonesian government also needs to prepare recycling plants, especially to cover the battery waste from high-density EV areas.

In terms of research and development, the Indonesian government also supports circular economy studies in a collaborative program with NTU, funded by the LPDP (Indonesia Endowment Fund for Education) under the Ministry of Finance. This includes exploring the circular economy potential for electric vehicle battery (EVB) recycling on a micro level (process), pilot scale, and macro level (Indonesian context).

3.4.2. Current Status of Financial Support for Promoting the Recycling Industry: Private Investment and Linkages with Foreign ODA/Funds

Institutional frameworks to encourage private investment are continuously being refined, and the government is improving the investment environment with various tax benefits and deregulation policies. Partnerships with major development cooperation agencies such as the Asian Development Bank (ADB), the Korea International Cooperation Agency (KOICA), and the Japan International Cooperation Agency (JICA) are expanding technical and financial support for renewable energy and EV-related projects. In addition, some projects are applying a blended finance³³⁾ approach that combines ODA funding with private investment. This enables private capital to participate in investment in a relatively stable structure.

3.4.3. Current Status of Financial Support for Promoting the Recycling Industry: Financial Institutions and Investment Attraction Platforms

Indonesia is expanding the participation of financial markets to foster the EV and related industries with a focus on sustainability. The country is gradually improving access to industrial finance with the issuance of green bonds (a bond used to fund environmentally friendly projects)³⁴⁾ and incentives for environmental, social, and governance (ESG)-based sustainable investments. Additionally, state-owned development banks are operating financial products specialized in EV-related industries, and some commercial banks are also strengthening their green finance product portfolios. The green finance system is a framework that allocates funds to projects that have a positive impact on the environment.

33) A financial mechanism that combines public sector funding (governments, international organizations, development aid agencies) with private sector capital to invest in development projects.

34) In 2018, Indonesia became the first country in the world to issue an Islamic Green Sukuk.

This system has been promoted by the government and financial authorities as part of efforts to achieve sustainable growth and carbon neutrality goals. Sectors such as waste management and energy transition are included in this system. Since 2014, the Financial Services Authority of Indonesia (OJK, Otoritas Jasa Keuangan) has been implementing a sustainable finance roadmap.

The first phase of the roadmap (2015–2019) focused on introducing the concept of green finance and establishing a regulatory foundation, while the second phase (2021–2025) aims to expand implementation by financial institutions and activate market mechanisms. Notably, the Green Taxonomy³⁵⁾ announced in 2022 categorizes projects in six major sectors—energy, agriculture, manufacturing, waste, transportation, and more—into green, transition, and brown (non-green) categories. This classification system guides banks and investment institutions to prioritize funding for environmentally friendly projects. This demonstrates the positive role of the green finance system and the Green Taxonomy in promoting the recycling industry. Green finance is directly linked to the activation of investments in the EV battery industry, recycling infrastructure, and green energy in Indonesia.

Indonesia's issuance of the world's first sovereign Islamic green sukuk provided funding for renewable energy, energy efficiency, and forest conservation projects, and has encouraged other private banks to issue green bonds. A notable example is Bank Negara Indonesia (BNI), which issued its first green bond, worth approximately IDR 500 billion, in 2022 for projects related to renewable energy, energy efficiency, green buildings, and waste management. This marked the first issuance of a green bond by a state-owned commercial bank in Indonesia. In 2023, BRI (Bank Rakyat Indonesia) issued a green bond worth around IDR 1 trillion for rural solar energy projects and eco-friendly agricultural financing, creating a “sustainability bond” that reflected both financial inclusion and environmental goals. At the end of the same year, Bank Mandiri issued a Green and Sustainability Bond to fund large-scale EV infrastructure development.

Furthermore, with the mandatory disclosure of ESG-related information, OJK has required listed financial institutions to publish sustainability reports so that their ESG performance can be evaluated by investors and the broader market.

35) Indonesia Green Taxonomy 1.0 provides classification criteria to determine which projects are considered “green” or environmentally sustainable.

4. Barriers and Challenges in EV Battery Recycling in Indonesia

4.1. Regulatory Barriers

4.1.1. Institutional Gaps

1) Lack of Legal Definitions and Scope of Management

EV batteries are classified as B3 waste, but their management standards vary depending on whether they are deemed reusable. However, the current regulatory framework lacks clear definitions for reused/recycled batteries, resulting in varying interpretations among government agencies and inconsistent policy implementation.

2) Absence of Extended Producer Responsibility (EPR) Application

Indonesia has introduced initial EPR schemes for certain electronic appliances, but EV batteries are not yet included. Although some EV manufacturers have pledged to manage used batteries after sale, such pledges do not encompass obligations for collection or recycling. Without a dedicated collection mechanism, the implementation of an effective EPR system for end-of-life EV batteries remains uncertain. Responsibility among manufacturers, consumers, and the government is still unclear. Since EV battery retirement is not yet a widespread issue, the establishment of a policy-based collection system has been delayed. However, considering the life cycle of EVs, this will likely become a pressing issue for Indonesia in the near future.

4.1.2. Complex Administrative Structures and Export/Import Procedures

1) Unclear Export Regulations and Dual Oversight

Exporting end-of-life EV batteries from Indonesia for recycling involves multiple layers of regulation: B3 waste rules under the Ministry of Environment, hazardous materials export requirements by Customs, Ministry of Finance, and Ministry of Trade and Ministry of Industry, and the Basel Convention's notification and approval procedures from importing countries. These complexities are further exacerbated by unclear legal distinctions depending on whether batteries have undergone pre-treatment (e.g., incineration, shredding). This lack of clarity often results in administrative delays and rejections.

2) Overlapping Roles and Unclear Responsibilities among Institutions

Currently, multiple ministries, such as BAPPENAS, the Ministry of Environment, the Ministry of Energy and Mineral Resources, Ministry of Industry, and the Ministry of Transportation, are involved in EV and battery reuse/recycling policies. However, inter-ministerial coordination is lacking. Each institution has released only basic and separate guidelines, and the absence of an integrated governance structure has led to limited awareness among government officials, businesses, and users regarding proper treatment of end-of-life EV batteries.

4.2. Market and Economic Barriers

4.2.1. Low Profitability and Lack of Private Investment

Indonesia currently lacks advanced recycling facilities capable of recovering valuable metals such as lithium, cobalt, and nickel. In reality, incineration appears to be the only viable treatment technology for used EV batteries in the country. As a result, profit generation after collection is limited, reducing incentives for private sector entry. Without stable revenue streams, it is likely to be unsustainable to maintain such businesses.

4.2.2. Undeveloped Collection and Distribution System

The existing waste collection network mainly focuses on low-risk, low-value recyclables such as paper and plastics. Whether this system can be extended to cover high-risk and high-value items such as end-of-life EV batteries remains doubtful. There have already been cases of illegal dismantling or abandonment of used electric motorcycle batteries, raising concerns about fire hazards and toxic substance leakage.

4.3. Technical and Infrastructure Barriers

4.3.1. Lack of Recycling and Pre-Treatment Technologies

1) Absence of Physical and Chemical Recycling Facilities

As of now, Indonesia has very few pilot recycling facilities capable of extracting metal compounds from end-of-life batteries. However, it has been confirmed that some waste treatment sites, such as Indonesia's largest recycling company, PPLI have experience in incinerating and landfilling end-of-life EV batteries. Additionally, the Indonesian subsidiary of global recycling company SK Tes is currently operating a business that exports used

batteries to its Singapore branch for further processing.

Nonetheless, these activities primarily involve physical pre-treatment methods rather than actual material recovery. In reality, establishing full-scale recycling facilities that can support commercial operations in the short term would require significant economic investment and time.

2) Lack of Discharging and Safe Dismantling Systems

High-voltage lithium-ion batteries require full discharging prior to or immediately after dismantling to ensure safety. However, there is currently no standardized discharge equipment or procedures in Indonesia except a small-scale test facility under the Technical Material and Good Standardization Agency (Balai Besar Standardisasi dan Pelayanan Jasa Industri Bahan dan Barang Teknik/B4T) of the Ministry of Industry. This poses ongoing risks of fire, electric shock, or explosion, and makes safe collection and transport structurally difficult in most field conditions.

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4.3.2. Insufficient Collection and Management Infrastructure

1) Absence of Safe Collection and Transport Systems

In Indonesia, waste collection largely relies on informal collectors or the internal infrastructure of manufacturers. It has been reported that transportation often occurs without standardized storage containers or fire safety equipment. This lack of infrastructure poses potential risks of environmental pollution and safety incidents throughout the entire process. In the case of end-of-life EV batteries, safe handling, transportation, collection, and storage are critical. Without appropriate infrastructure or protocols in place, participation in the management of end-of-life batteries, both in the formal and informal sectors, may become unfeasible.

2) Lack of a Battery and Vehicle Information Database

There is currently no public or private database in Indonesia that manages information on battery type, manufacturer, or configuration by EV model. Even if EPR policies are adopted in the future, this lack of data will likely become a major obstacle in managing the full chain of used EV batteries from collection and transport to dismantling, reuse, or final disposal.

03

CHAPTER

Practices and Technological Cases in EV Battery Recycling

1. Korea's National Framework for Resource Circulation and Waste Recycling Policies
2. EV Battery Recycling Policies and Case Studies Overseas
3. Overview of Electric Vehicle Recycling Technologies
4. Feasibility of Introducing the Latest EV Battery Recycling Methods in Indonesia

Practices and Technological Cases in EV Battery Recycling

1. Korea's National Framework for Resource Circulation and Waste Recycling Policies

1.1. Korea's Master Plan for Resource Circulation

1.1.1. Background

South Korea has acknowledged that its traditional linear economic model “extraction → production → consumption → disposal” is accelerating both resource depletion and environmental degradation. Rapid economic growth and population increase have led to a surge in material consumption, pushing each stage of the resource life cycle—extraction, processing, and disposal—beyond the Earth’s capacity to absorb environmental impacts.

Volatile raw material prices and supply instability have undermined the competitiveness of the manufacturing sector, while rising landfill and incineration costs are placing increasing financial pressure on local governments. At the same time, international frameworks such as the EU Circular Economy Package (2015) and the UN Sustainable Development Goals (SDGs) have made circular economy transformation a key indicator of competitiveness. To remain resilient in global supply chains, Korea recognized the need for a proactive policy shift.

In response, the Korean government announced a structural transition from the conventional focus on “safe waste treatment” and “expanded recycling” to a fully integrated circular economy. To guide this shift, it introduced the First Master Plan for Resource Circulation, a top-level roadmap that serves not only as environmental policy but also as a comprehensive national growth strategy encompassing industry, trade, energy, and regional development.

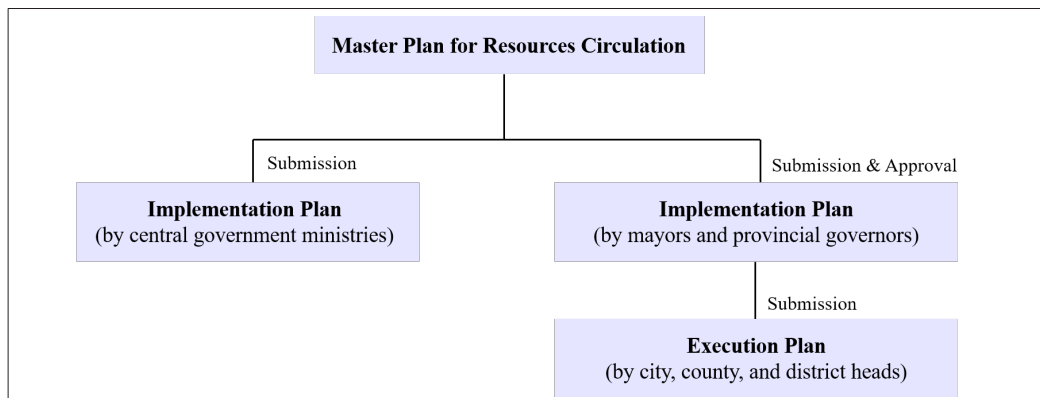
1.1.2. Legal Basis

This first plan is a 10-year national master plan (2018–2027) established under Article 11 of the Framework Act on Resource Circulation, which took effect in January 2018. It is led by the Korea Ministry of Environment, which oversees the master plan and manages waste reduction and recycling systems. The Korea Ministry of Trade, Industry and Energy is responsible for expanding the use of recycled raw materials and fostering the resource circulation industry, while the Korea Ministry of Land, Infrastructure and Transport manages construction waste and promotes the use of recycled aggregates. The Korea Ministry of Agriculture, Food and Rural Affairs and the Korea Ministry of Oceans and Fisheries handle the recycling of agricultural, livestock, and fishery byproducts, and the Korea Ministry of Economy and Finance supports these efforts through financial measures and tax incentives.

The Act consolidated previously fragmented legal frameworks covering waste management, recycling, and construction waste into a unified structure that promotes a circular economy at the national strategic level. As a result, the basic plan functions as the highest-level directive, binding all central ministries and local governments in the development and implementation of their respective action and execution plans.

The government defined the plan as the nation’s flagship project for the waste sector. Annual performance outcomes are jointly monitored and published by the Korea Ministry of Environment and the Office for Government Policy Coordination. In practice, this plan serves as a foundational framework for resource and waste policy in Korea—so much so that companies and local governments must align their budgets, policy priorities, and permitting processes to it. It plays a constitutional-level role in the country’s approach to circular resource management.

[Figure 3-1] Hierarchy of Resource Circulation Plans



Period	Key Law/Plan	Features
1986	Waste Control Act	Regulated generation, collection, transport, and disposal of municipal/industrial waste → focused on incineration and landfill
1992	Act on the Promotion of Saving and Recycling of Resources (Resource Recycling Act)	Introduced EPR system for packaging, electronics, tires, batteries, etc.; legal basis for recycling industry promotion
2003	Construction Waste Recycling Promotion Act	Required separation of construction/demolition waste and mandatory use of recycled aggregates
2000s–2010s	Waste Disposal Charges, Sectoral Plans (Comprehensive Waste Management Plan, Resource Recycling Basic Plan, etc.)	Discouraged landfill/incineration, promoted recycling
2018–2027	Framework Act on Resource Circulation & First National Master Plan (2018–2027)	Integrated waste/resource circulation policies; introduced a 10-year master plan with annual implementation plans; aimed at building a circular economy

Source: Prepared by the author

1.1.3. Strategic Objectives

The objective of the Basic Plan for Resource Circulation is to establish a sustainable circular economy through a virtuous cycle of resources. To this end, the Korean government has set out the following strategic targets to be achieved by 2027:

- Reduce the amount of waste generated per billion KRW of GDP by 20%, from 95.5 tons to 76.4 tons.
- Increase the resource circulation rate (the proportion of waste that is actually recycled) from 70.3% to 82%.
- Lower the final disposal rate (by landfilling and incineration) from 9.1% to 3%.

These targets were designed to exceed the average levels of advanced economies such as the EU and Japan. For effective implementation, the government will introduce enforcement measures including additional charges and strengthened regulatory requirements in the event of underperformance.

<Table 3-1> Resource Circulation Target Indicators

Indicator	Target	Remarks
Waste Generation Intensity (tons / billion KRW) Waste generated per unit of GDP	95.5% → 76.4% (20% reduction)	<ul style="list-style-type: none"> Improve resource productivity, reduce waste generated at the production and consumption stages
Resource Circulation Rate (%): Share of total waste that is actually recycled * Excludes byproducts in conventional recycling	70.3% → 82.0%	
	Sector	Recycling Rate (%)
	Household Waste	35.8 (2016) → 61.1
	Industrial Waste	69.1 (2016) → 83.1
	Construction Waste	79.5 (2016) → 88.9
	Designated Waste	51.6 (2016) → 51.6
Total		70.3 (2016) → 82.0
Final Disposal Rate (%): Share of waste that is landfilled or incinerated without recovery * Includes incinerated or landfilled waste after intermediate treatment	9.1% → 3.0%	
	Sector	Recycling Rate (%)
	Household Waste	19.9 (2016) → 7.7
	Industrial Waste	16.3 (2016) → 3.2
	Construction Waste	1.6 (2016) → 0.9
	Designated Waste	26.3 (2016) → 26.3
Total		9.1 (2016) → 3.0
Energy Recovery Rate (%): Share of combustible waste converted to energy	16.3% → 20.3%	<ul style="list-style-type: none"> Promote energy recovery (e.g., bio-gas, heat recovery) after maximizing material recycling

Source: Prepared by the author

1.1.4. Core Strategies

The Master Plan outlines three core strategies:

First, the establishment of a circular utilization system covering the entire life cycle from production and consumption to management and regeneration. This involves mandating circular design at the raw material input stage, increasing waste prevention and sorting efficiency during consumption, ensuring traceability during the management phase, and promoting high-value-added recycling in the regeneration phase. The goal is to realize a closed-loop system.

Second, the promotion of high-quality material recycling. Moving beyond low-value recycling or simple energy recovery, the strategy aims to refine waste materials into high-purity metals and polymers and reintegrate them as raw materials for advanced industries.

Third, an optimal treatment strategy based on regional governance. This entails building customized collection and recycling models linked to local economies and improving public acceptance to resolve the structural issue of local opposition to waste treatment facilities (not

in my backyard/NIMBY).

These three strategies are designed to work in a mutually reinforcing manner, simultaneously pursuing quantitative target achievement and qualitative system transformation.

1.1.5. Key Tasks by Life Cycle Stage

Production Stage: Resource productivity targets are established by industry sector. Products such as packaging materials and electronics are subject to mandatory “circularity assessments” so that recyclability is considered from the design stage.

Consumption Stage: Measures such as deposit schemes for single-use cups, restrictions on excessive packaging, and RFID-based pay-as-you-throw (PAYT) systems for food waste are introduced, with the aim of reducing household waste generation per capita by 15%.

Management Stage: Key efforts include upgrading the Allbaro tracking system, equipping 100% of food waste collection vehicles with GPS, and implementing a “zero landfill” roadmap. These aim to ensure full traceability and eliminate illegal waste handling.

Regeneration Stage: A major task is the establishment of regional collection centers for future waste streams. These centers will handle end-of-life electric vehicle batteries and discarded solar panels, both expected to increase significantly, by providing testing, refurbishment, and recycling support. Once the private market becomes viable, these waste streams will be incorporated into the Extended Producer Responsibility (EPR) system.

<Table 3-2> Key Tasks by Resource Circulation Stage

Stage	Representative Tasks	Key Ministries
Production	<ul style="list-style-type: none"> • Improve resource productivity by industry • Promote reduction in waste generation • Mandate circular design (Including EPR) 	<ul style="list-style-type: none"> • Ministry of Trade, Industry and Energy • Ministry of Environment
Consumption	<ul style="list-style-type: none"> • Suppress generation of household waste • Promote eco-friendly consumption • Expand resource circulation culture 	<ul style="list-style-type: none"> • Ministry of Environment • Fair Trade Commission • Ministry of Education / Local Governments
Management	<ul style="list-style-type: none"> • Reform waste collection, sorting, and separation • Establish zero-landfill targets • Strengthen safety management of hazardous/imported waste 	<ul style="list-style-type: none"> • Ministry of Environment • Ministry of Land, Infrastructure and Transport • Local Governments
Recycling	<ul style="list-style-type: none"> • Build base for future resource recycling • Promote high-value-added recycling through R&D and industry ecosystem development 	<ul style="list-style-type: none"> • Ministry of Environment • Ministry of Trade, Industry and Energy • Ministry of Agriculture, Food and Rural Affairs

Source: Prepared by the author

1.1.6. Implementation Evaluation Framework

Under Korea’s Framework Act on Resource Circulation, the government establishes a 10-year National Master Plan and each ministry sets sector-specific targets aligned with it. These targets are expressed in quantitative indicators such as waste reduction, recycling rates, and the use of recycled resources. Each ministry must also prepare and report annual implementation plans, which the Korea Ministry of Environment consolidates and manages. In addition, a mid-term evaluation is conducted every five years to assess progress and make adjustments if necessary. Finally, at the end of the 10-year period (e.g., 2027), the overall performance is quantitatively evaluated and reflected in the next master plan (2028–2037).

<Table 3-3> Roles of Stakeholders in Resource Circulation

Stakeholder	Core Role	Main Responsibilities and Actions
Government	Establishment of national-level policy and legal framework	<ul style="list-style-type: none"> Formulate and revise the Basic Plan for Resource Circulation and related legislation Monitor implementation performance of local governments and agencies Support market stabilization, infrastructure development, and R&D investment in recycling
Metropolitan Governments (Cities and Provinces)	Regional-level strategy and coordination	<ul style="list-style-type: none"> Develop regional implementation plans for resource circulation Set and manage local targets (e.g., reduction, circulation rate) Coordinate policies, budgets, and planning with cities, counties, and districts
Local Governments (Cities, Counties, Districts)	On-site execution and service delivery	<ul style="list-style-type: none"> Responsible for municipal waste treatment through execution plans Establishing a public system to operate collection, sorting, and disposal Implement tailored local models using community-based networks
Businesses	Producer responsibility and improving resource efficiency	<ul style="list-style-type: none"> Innovate production to improve resource productivity, reduce waste, and expand use of recyclables Design recyclable products and comply with Extended Producer Responsibility (EPR) obligations
Civil Society	Monitoring, participation, and cultural diffusion	<ul style="list-style-type: none"> Monitor implementation by government, local authorities, and companies; provide policy feedback Promote sustainable consumption and lead resource circulation practices

Source: Prepared by the author

1.2. Advanced Waste Recycling Programs

1.2.1. Circulation Resource Certification System

The Circulation Resource Certification System allows the government to reclassify certain waste materials originally designated as waste into circulating resources if they meet specific criteria. Once certified, these materials can be freely traded and used.

The system was originally established under the 2018 Framework Act on Resources Circulation, and its legal basis was transferred in 2024 to the Act on the Promotion of Transition to Circular Economy and Society. According to this framework, waste generators (individuals or corporations) may apply for certification through the relevant Regional or Local Environmental Offices.

The system aims to reduce regulatory burdens on high-quality waste materials, promote circular utilization, and lower dependence on imported raw materials.

To qualify for certification, the Minister of Environment has stipulated that a material must:

- pose no risk to human health or the environment;
- be tradable for value, with minimal risk of being discarded; and
- satisfy four detailed criteria prescribed by Presidential Decree.

Materials such as designated hazardous waste, substances with strong odor or leakage risks, and those intended solely for energy recovery are excluded from eligibility.

This ensures that potentially harmful substances—such as sewage sludge or steelmaking slag—remain regulated, while safe and verifiable materials such as spent coffee grounds, waste glass powder, and plastic flakes can be reintroduced into the market.

The certification process follows this sequence:“(recyclers or waste-generating businesses) application submission → technical review by the Korea Environment Corporation (KECO) → on-site inspection → certification issuance by the relevant environmental office”.

KECO evaluates the chemical properties, heavy metal content, and distribution pathway of the material, and reports its findings to the Minister of Environment. Once approved, the certified material is exempt from regulations under the Waste Control Act and acquires the same legal status as virgin raw materials.

Certified companies are relieved from administrative burdens such as mandatory waste reporting, storage time limits, and transport licensing. Furthermore, procedures for transport, storage, and import are streamlined to match those for general raw materials.

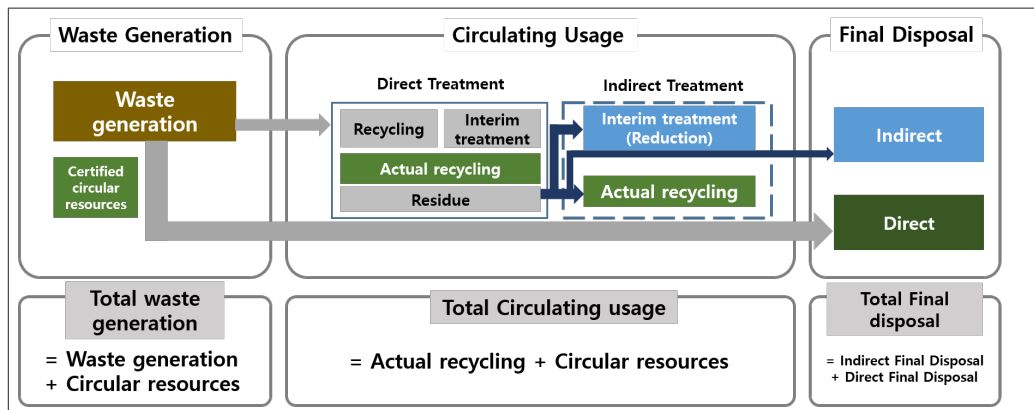
In addition to regulatory relief, the system provides economic incentives. Certified circulating resources are eligible for the Good Recycled (GR) Product certification administered by the Korea Ministry of Trade, Industry and Energy, which grants preferential treatment in public procurement. Tax and tariff benefits may also apply.

To promote active market use, the Korea Ministry of Environment operates the Resource Circulation Information Center, which provides real-time supply and demand data, e-bidding services, and price information. This platform facilitates transparent transactions by matching recyclers with end-users and has enabled the substitution of hundreds of thousands of tons of waste for raw materials annually, particularly in the steel and cement industries.

1.2.2. Circular Economy Performance Management System

The Circular Economy Performance Management System was introduced to help achieve the nation's mid- to long-term and phased goals for transitioning to a circular economy. In this system, local governments (cities and provinces) and major waste-generating businesses are required to establish and manage individual circular economy targets. The system monitors actual circulation volumes and final disposal quantities by tracking material flows from waste generation to final treatment. By doing so, it intends to improve resource circulation at all stages of the waste management process.

[Figure 3-2] Material Flow-Based Waste Management



Source: the Korea ministry of environment, 'Comprehensive Manual on the Resource Circulation Performance Management System', Apr. 2018.

The system is based on two key performance indicators:

- the Circulation Rate, calculated as $(\text{Actual Recycling Volume} + \text{Certified Circulating Resource Volume}) \div (\text{Total Waste Generation} + \text{Certified Volume})$
- the Final Disposal Rate, calculated as $(\text{Final Disposal Volume}) \div (\text{Total Waste Generation} + \text{Certified Volume})$.

These indicators are tracked annually at the national, provincial (city/province), and facility levels. The government has set the 2027 national targets at a circulation rate of 83.1% and a final disposal rate of 16.9%, with targets allocated using a top-down approach.

The scope of the system includes all waste streams, including municipal, industrial, construction, and hazardous waste. It is implemented by two primary stakeholder groups:

- Local governments are responsible for developing and executing 10-year targets tailored to regional conditions.
- Businesses are subject to performance management if they fall within one of 18 designated industry categories and have generated an annual average of more than 100 tons of designated waste or 1,000 tons of other waste over the past three years.

The system follows a structured five-step cycle: “Target allocation → Action plan development → Performance reporting → Evaluation → Follow-up measures”. Once the Korea Ministry of Environment and the Korea Ministry of Trade, Industry and Energy

finalize the proposed targets, the Korea Environment Corporation (KECO) distributes facility-specific targets through its integrated digital platforms: the Resource Circulation Information System and Allbaro.

Businesses are required to submit quarterly implementation plans detailing process improvements and recycling strategies, and report annual performance results at the end of the year. KECO then validates the data, conducts on-site inspections, evaluates the outcomes, and publishes the results by May of the following year.

<Table 3-4> Division of Roles in the Circular Economy Performance Management System

No.	Responsible Entity	Roles and Responsibilities
1	Korea Ministry of Environment	<ul style="list-style-type: none"> • Establish and revise guidelines for system operation • Evaluate implementation of performance targets • Provide incentives for local governments and businesses that exceed targets • Take necessary administrative or legal measures
2	Local Governments (Cities and Provinces)	<ul style="list-style-type: none"> • Set and implement regional performance targets • Submit progress reports • Coordinate and negotiate target values with stakeholders
3	Korea Environment Corporation (KECO)	<ul style="list-style-type: none"> • Select and announce target entities • Manage and assign performance targets • Review and evaluate implementation plans • Conduct site inspections and provide technical support
4	Target Entities (Businesses)	<ul style="list-style-type: none"> • Submit performance reports • Prepare and implement action plans • Take additional steps necessary for system compliance

Source: Prepared by the author

Clear incentives and penalties are in place. Entities that exceed their targets for either the circulation rate or the final disposal rate, classified as “high-performing target entities”, are eligible for various benefits, including:

- increased national subsidy rates,
- access to technical and financial consulting, and
- additional points in public procurement.

Conversely, if an entity fails to meet even one of the targets, the Korea Ministry of Environment may issue a compliance order that requires the shortfall to be added to the target for the following year. The ministry may also publish the underperformer’s results and name, conduct technical reviews and site guidance, and impose additional waste disposal charges as a penalty.

This system establishes a closed-loop governance framework by applying consistent indicators and a unified data platform at the national, local, and business levels.

It enables an integrated cycle of target-setting, reporting, performance evaluation, and fiscal linkage, while achieving the following outcomes:

- reducing dependency on large-scale landfilling,
- promoting higher-quality recycling and market growth, and
- strengthening accountability through data-driven public evaluations.

1.3. Institutional Framework for EV Battery Recycling

1.3.1. Legislative Improvements for the Circular Use of End-of-Life Batteries

With the expansion of electric vehicle (EV) adoption in Korea, the legal and institutional foundations for the safe collection, management, and reuse of end-of-life batteries have gradually been established.

The following is a chronological overview of the legislation established to build a full-cycle management system for EV batteries in Korea. As the adoption of electric vehicles expanded, Korea progressively developed a legal and institutional framework for the safe collection, management, and reuse of end-of-life (EOL) batteries. The major milestones are as follows:

In April 2013, the Air Quality Preservation Act (Article 58, Paragraph 5) was enacted, mandating that EVs that had received government subsidies must return their used batteries upon deregistration. This regulation was introduced to prevent illegal disposal or leakage of used batteries from the early stages of EV adoption.

In December 2018, a Public Notice on the Return of End-of-Life EV Batteries was issued. It specified detailed procedures for the separation, return, and storage of used EV batteries, and provided a more systematic and standardized basis for field-level battery collection and handling.

In January 2021, the Act on Resource Circulation of Electrical and Electronic Equipment and Vehicles was revised to include Article 20-4, which established the legal foundation for the installation and operation of regional collection centers. This aimed to promote the recycling of EOL products such as EV batteries and to build an efficient collection system.

In July 2021, the Enforcement Rules of the Waste Control Act (Annex 5) were amended to provide more detailed regulations on the transportation and storage of used batteries. These revisions were designed to prevent safety incidents during transport and to ensure safe and efficient logistics.

In January 2022, several institutional improvements were made to strengthen the management of EOL batteries.

The Waste Control Act Enforcement Rules (Article 10, Annex 16) were amended to establish legal grounds for the collection, transport, and storage of used batteries at designated centers.

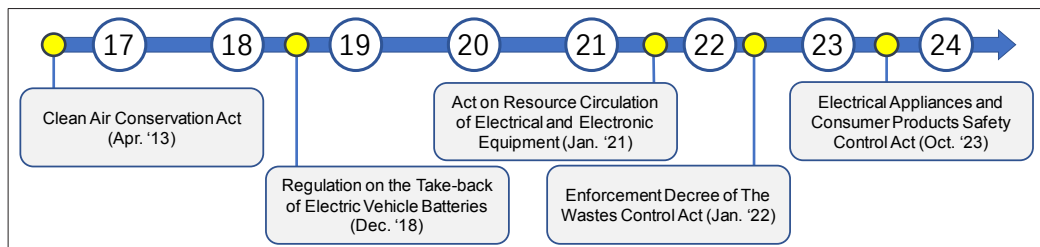
Annex 8 of the same rules clarified the mandatory measurement of the remaining capacity (SOH) of EOL batteries.

The Korea Ministry of Environment issued official guidelines for performance testing of EOL EV batteries to standardize the criteria and methods for evaluating battery condition, including remaining capacity.

The Public Notice on the Return of End-of-Life EV Batteries was also revised in January 2022, setting rules for the selling entity, pricing, and methods for EOL batteries. This provided a legal foundation for the fair and transparent sale and recycling of tested batteries.

Finally, in October 2023, the Electrical Appliances and Consumer Products Safety Control Act was amended to ensure the safety of reused batteries. A new certification standard (KC10031) for reused battery products was introduced and officially announced, laying the groundwork for safety assurance in battery reuse.

[Figure 3-3] Regulatory Framework for Electric Vehicle Battery Recycling



Category		Law	Details
Collection System	Collection	Clean Air Conservation ACT	<ul style="list-style-type: none"> EV subsidy-supported vehicles are required to return used batteries
	Dismantling	Regulation on the Take-back of Electric Vehicle Batteries	<ul style="list-style-type: none"> Rules on dismantling, return, and storage
	Transport	Wastes Control Act	<ul style="list-style-type: none"> Detailed rules on transport and storage of waste batteries
	Storage	Act on Resource Circulation of Electrical and Electronic Equipment	<ul style="list-style-type: none"> Legal basis for regional collection centers for safe storage and recycling
		Enforcement Decree of The Wastes Control Act	<ul style="list-style-type: none"> Establishment of grounds for collection, transport, and storage
Evaluation and Resale	Performance Evaluation	Wastes Control Act	<ul style="list-style-type: none"> Regulation requiring measurement of residual battery capacity
			<ul style="list-style-type: none"> Performance Evaluation Test Method for Used EV Batteries
	Resale Regulation	Regulation on the Take-back of Electric Vehicle Batteries	<ul style="list-style-type: none"> Specification of sales organizations, pricing, and methods
Reuse		Electrical Appliances and Consumer Products Safety control Act	<ul style="list-style-type: none"> Establishment of certification standards for reused battery

Source: Prepared by the author

1.3.2. Allbaro System

The Allbaro System is South Korea's official e-Manifest platform designed to digitally record and track the entire flow of industrial, construction, and designated waste from business sites. It performs real-time logging of waste data from the moment it is generated, loaded onto transport vehicles, and ultimately processed through recycling, incineration, or landfilling, on a centralized server. Each stakeholder—waste generator, transporter, and processor—logs in through a secure certificate to enter data on a web or mobile portal. Simultaneously, IoT devices such as GPS, RFID tags, weight sensors, and CCTV automatically transmit location, weight, and visual data to reduce manual errors and prevent false reporting. All transaction records are compiled into a real-time dashboard accessible by the Korea Ministry of Environment, Korea Environment Corporation (KECO), and local governments, enabling immediate detection of illegal dumping, unauthorized transport, or improper handling.

When EV batteries are disposed of or sold to recyclers, generators must pre-register the transaction in the Allbaro system before handing over the batteries. Transporters must

register the transfer within two days, and processors must confirm receipt within two days of delivery. After recycling, processors are also required to input the treatment volume and date for full traceability throughout the battery life cycle.

The system has significantly digitized millions of formerly paper-based transactions, reducing administrative burdens and disputes over weight discrepancies among stakeholders. Its accumulated big data makes it possible for the government to conduct time-series analysis of waste generation, recycling rates, and disposal volumes by region and sector. This provides a data-driven foundation for programs such as the Circular Economy Performance Management System and EV Battery Material Certification. For businesses, Allbaro serves as a compliance and competitive tool. Data from the system can be used for ESG reporting, green public procurement, and recycling certification to help companies meet regulations while strengthening their market standing.

Ultimately, the Allbaro system functions as a key pillar of Korea's circular economy infrastructure, increasing transparency, deterring illegal activities, and supporting evidence-based policymaking and industrial trust.

1.3.3. Promotion of Circular Use of Used Batteries

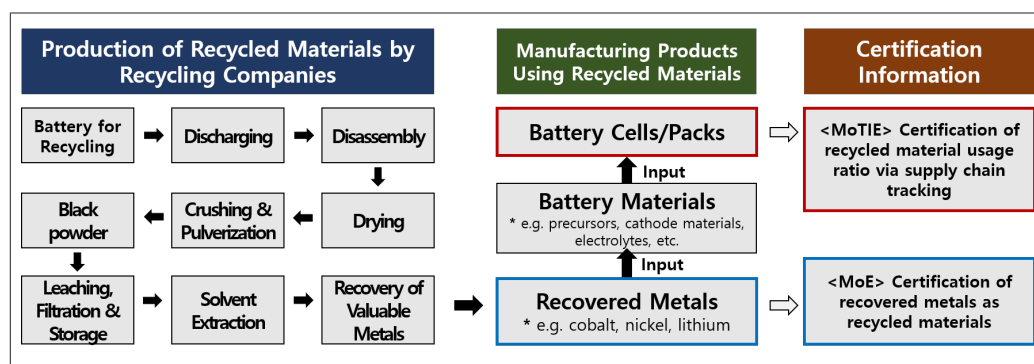
In anticipation of a significant increase in end-of-life batteries due to the electrification of mobility, such as electric vehicles, and the expansion of renewable energy, the Korea Ministry of Environment announced its "Action Plan to Promote Circular Use of Batteries". The plan aims to transform used batteries into high-value secondary resources and secure a stable supply chain for critical raw materials. It consists of 14 major policy tasks in four key areas to stimulate demand for recycled materials and reused battery products, while also responding to global environmental regulations such as the EU Battery Regulation. The four areas are as follows:

1) Development of a Circular Market

At the core of this area is the Recycled Material Certification System, which recognizes recovered substances such as nickel sulfate and lithium carbonate extracted from waste batteries and battery scrap as certified secondary raw materials. Legal grounds for this system will be established by 2025, with full implementation planned for 2027. The certification process will make transparent traceability of both origin and content possible. To boost early-stage demand for recycled materials, the government will introduce mandatory recycled content targets at the battery manufacturing and import stages,

and offer various incentives such as Extended Producer Responsibility (EPR) obligation reductions, and additional points in public procurement. In the battery recycled material certification system, the Korea Ministry of Environment is responsible for ensuring the environmentally safe management of the entire process of collecting and treating waste batteries, as well as certifying the quality and safety of recycled materials. In contrast, the Korea Ministry of Trade, Industry and Energy supports the development and advancement of recycling technologies and takes charge of standardization and the creation of an industrial ecosystem so that the recovered materials can be used effectively in industrial applications.

[Figure 3-4] Battery Recycling Process and Recycled Material Certification System



Source: Joint Ministries (MOEF, MOTIE, MOE, MOLIT), “Plans to Develop Laws, Institutions and Infrastructure to Foster the Used Battery Industry”, Oct., 2024.

2) Stabilization of Recyclable Resource Supply

To expand the scope of recyclable items, the number of EPR-covered products will be increased from the current 50 to all applicable products, thereby enabling broader battery recovery. In addition, support will be provided to recycling firms for leasing storage facilities and customs clearance for imported black mass and scrap. The government will also establish quality standards for cathode scrap and black mass by battery type, and extend domestic storage periods to help secure a stable supply of recyclable materials.

3) Technological Innovation and Competitiveness Enhancement

The Korea government will intensively support cutting-edge R&D in areas such as high-purity lithium recovery, recycling of separators and anodes, and automated battery sorting and dismantling technologies. A Battery Circular Economy Cluster, scheduled for completion in late 2025, and an inline automated performance evaluation center, set to begin operation in 2026, will provide integrated services for testing, certification, and safety inspections.

Regulatory rationalization efforts will also be made, including zero liquid discharge for saline wastewater, tailored technical consulting, and shortened timelines for marine toxicity assessments, to reduce the burden on industry.

4) Establishment of a Full-Cycle Management System

The Korea government plans to strengthen safety standards for battery transport and storage by 2026, and develop ultra-low-temperature cooling transport technologies to mitigate fire and explosion risks. A dedicated demonstration center for low-value LFP batteries will be considered, along with their potential inclusion in EPR scheme. In 2027, a comprehensive battery life cycle tracking system will be launched to integrate data in the manufacturing, use, and recycling stages. In addition, eco-design standards for battery packs and EVs, as well as a circularity assessment system, will be established to secure recyclability from the design stage onward. In this process, the goal is to continuously foster market participants for used battery recycling and develop a market that enables a circular economy for secondary batteries.

Within the framework of advanced battery recycling and the certification system for regenerated materials, the Korea Ministry of Environment is responsible for environmentally safe management of the entire process of collecting and treating waste batteries, as well as certifying the quality and safety of regenerated materials. Meanwhile, the Korea Ministry of Trade, Industry and Energy supports the development and advancement of recycling technologies, and takes charge of standardization and the creation of an industrial ecosystem to ensure that recovered materials can be effectively utilized in industrial applications.

1.3.4. Infrastructure for Used Battery Management

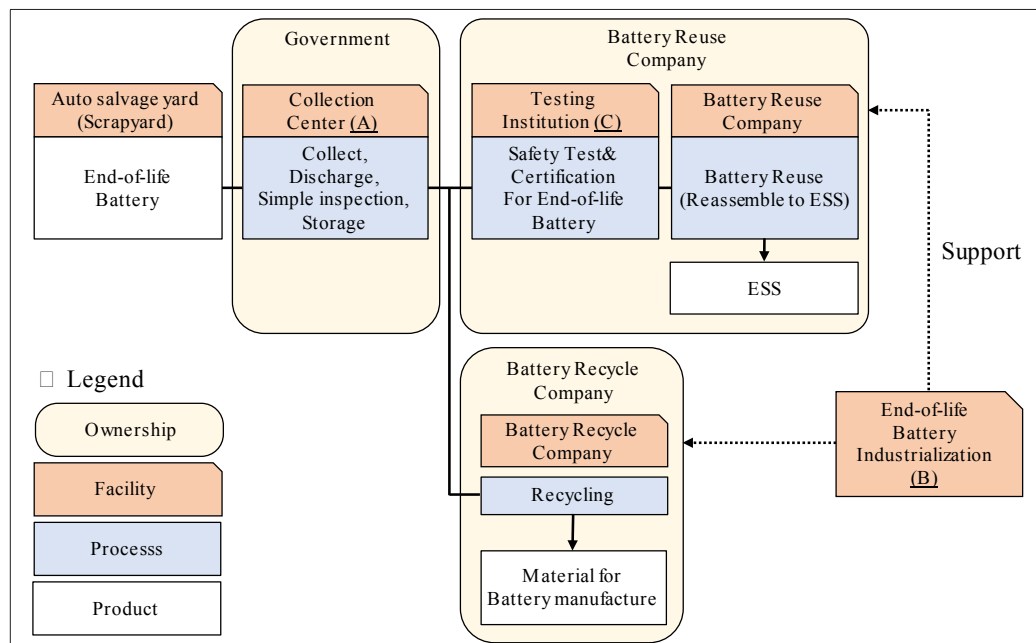
The Korean government is strategically establishing and operating three core hubs under a regulatory framework to foster the used battery industry as a national growth driver.

First, the Future Waste Resources Base Collection Center enables the public sector to lead in the centralized collection, storage, and standardized performance assessment of EV batteries retrieved from scrapped vehicles. These batteries are then sold in a transparent secondary distribution market. Second, the Used Battery Industrialization Centers provide one-stop support for companies with battery sorting, design, prototype development, and technical consulting, thereby accelerating the commercialization of reuse technologies. Third, the government designates Safety Inspection Institutions for Reused Battery so that

only batteries that pass rigorous tests, including charge/discharge, internal resistance, and capacity inspections, are allowed to enter the market. This secures consumer trust and improves market safety.

This tripartite structure of collection, industrialization support, and safety inspection simultaneously advances resource circulation and carbon neutrality while reinforcing Korea’s circular economy model as a leading infrastructure for attracting investment and setting global standards.

[Figure 3-5] Cooperation mechanism for end-of-life battery infrastructure



* A. Future Waste Resources Base Collection Center

B. End-of-life Battery Industrialization Center

C. Safety Inspection Institution for Reused Battery

Source: Prepared by the author

1) Future Waste Resources Base Collection Center

These regionally distributed centers, operated by the Korea Ministry of Environment, function as hubs for collecting, storing, evaluating, and auctioning used EV batteries. Batteries returned to local governments at the end of vehicle life are transferred to the centers for secure storage and performance evaluation, including assessments of residual capacity. Batteries deemed reusable or recyclable are auctioned to private companies to promote industrial reuse. Four core centers are currently operating in the Seoul metropolitan area, Chungcheong, Honam, and Yeongnam regions, with six in total including

locally operated facilities.

2) Used Battery Industrialization Centers

These centers, jointly operated by the Korea Ministry of Trade, Industry and Energy and local governments, support the development and commercialization of reuse, remanufacturing, and recycling technologies for used batteries. They offer performance evaluation infrastructure, classification and remaining lifespan diagnostics, new product development support using reused batteries, technical consulting, and workforce training. This one-stop support helps companies select suitable batteries by purpose, improve design and safety, and bring new products to market more efficiently.

3) Safety Inspection Institutions for Reused Battery

To reuse EV batteries removed from vehicles for other applications such as home energy storage systems (ESS) rigorous safety verification is needed. In October 2023, the Korean government amended relevant laws to mandate that only batteries certified by inspection may be distributed. Designated Safety Inspection Institutions for Reused Battery conduct comprehensive testing, including charge/discharge cycles, capacity measurements, and battery management system (BMS) safety checks, based on national safety standards (KC certification).

<Table 3-5> End-of-life Battery Hub Infrastructure

No.	Center Name	Location	Area	Storage Capacity	Center Type*			Operating Entity	Center Image
					A	B	C		
1	EV/ESS Used Battery Industrialization Center	Naju, Jeollanam-do	1,779m ²	-		√		Local Gov't	
2	EV Used Battery Industrialization Center	Ulsan	1,485m ²	-		√		Local Gov't	
3	Secondary Battery Management Center	Pohang, Gyeongbuk	3,549m ²	1,200 units	√	√		Local Gov't	

<Table 3-5> continue

No.	Center Name	Location	Area	Storage Capacity	Center Type*			Operating Entity	Center Image
					A	B	C		
4	Jeju EV Battery Industrialization Center	Jeju	2,345m ²	350 units	√	√	√	Local Gov't	
5	Future Waste Resources Base Collection Center (Seoul Area)	Siheung, Gyeonggi	1,480m ²	1,097 units	√			Ministry of Environment	
6	Future Waste Resources Base Collection Center (Honam Area)	Jeongeup, Jeollabuk-do	1,362m ²	1,320 units	√			Ministry of Environment	
7	Future Waste Resources Base Collection Center (Chungcheong Area)	Hongseong, Chungnam	1,075m ²	636 units	√			Ministry of Environment	
8	Future Waste Resources Base Collection Center (Yeongnam Area)	Dalseo, Daegu	1,456m ²	400 units	√			Ministry of Environment	

* A. Future Waste Resources Base Collection Center
 B. End-of-life Battery Industrialization Center
 C. Safety Inspection Institution for Reused Battery

Source: Prepared by the author

A representative facility for collecting, certification testing, and supporting private companies in the field of end-of-life EV batteries has been established at Jeju Technopark, and the details and construction costs of this facility are as follows.

<Table 3-6> Jeju Technopark End-of-Life Battery Infrastructure Project

No.	Center Name	Location
A. EV End-of-life Battery Reuse Center Construction Project	Period	Apr. 2017 – Dec. 2019 (33 months)
	Total Budget	USD 13.68 million (KRW 19.0 billion)
	Contents	<ul style="list-style-type: none"> Establishment of infrastructure for waste battery reuse and development of expansion models Buildings: Performance Evaluation Building (1,272m²), Safety Testing Building (666m²), Office Building (407m²) Performance evaluation capacity: Three packs/day, 24 modules/day Storage capacity: 350 units
B. EV End-of-life Battery Reuse Public Infrastructure Diversification Project	Period	Apr. 2020 – Mar. 2023 (36 months)
	Total Budget	USD 9.50 million (KRW 13.2 billion)
	Contents	<ul style="list-style-type: none"> Construction of a diversified platform for public infrastructure-linked battery reuse and equipment expansion Safety testing building 13 safety evaluation devices Temperature and humidity chamber, manual storage system (200 units) Battery performance evaluation system, test chambers
C. EV End-of-life Battery Remanufactured Product Testing and Certification Infrastructure Project	Period	Apr. 2022 – Dec. 2024 (33 months)
	Total Budget	USD 6.12 million (KRW 8.5 billion)
	Contents	<ul style="list-style-type: none"> Establishment of testing and certification infrastructure for remanufactured EV battery products to support application diversification Eight safety/reliability testing devices Forced discharge tester, crash/press machine, vibration tester, altitude tester, Water-cooled chiller, 3D vision system, X-ray scanner, salt spray tester, combustion tester, composite impact test system

* A. Future Waste Resources Base Collection Center,

B. End-of-life Battery Industrialization Center

C. Safety Inspection Institution for Reused Battery

Source: Prepared by the author

1.4. Best Practices in Battery Recycling in Korea

1.4.1. Proactive Measures by the Korean Government

Korea, as a country with a strong presence in both battery and EV manufacturing, has proactively implemented national-level measures to address the challenges associated with used EV batteries. In the late 2010s, the government began incorporating the mandatory return of used batteries into the eligibility criteria for EV purchase subsidies. However, due to an underdeveloped system, many used batteries ended up stockpiled in local government warehouses.

In response, the Korea Ministry of Environment established the National Waste Resource Collection Center in 2020 to temporarily manage these batteries. In 2023, the government announced the “Measures to Strengthen the Competitiveness of Secondary Battery Life Cycle Industry”. Then in July 2024, a joint ministerial plan titled “Legislation, System, and Infrastructure Development Plan for Promoting the Used Battery Industry” was finalized in the Economic Ministers’ Meeting, marking the full-scale implementation of national policy.

When the central government establishes or introduces new policies or systems, local governments take on a practical implementation role in collaboration with private institutions. This includes initiatives such as operating a battery life cycle tracking system and launching public auction models to help create an early-stage market for used batteries.

1.4.2. Establishing a Circular System for EV Battery Resource Management

Jeju Province was the first in Korea to adopt EVs in 2011 and has since rapidly expanded their use. As a result, 682 used EV batteries were collected and stored as of the end of 2024, and the number is projected to rise to approximately 47,000 by 2035. To cope with this surge, Jeju has been developing a full-cycle management system since 2017 that integrates the recovery, disassembly and evaluation, reuse, and recycling of batteries into a single circular chain. In this system, EV batteries are first removed at designated dismantling facilities. The batteries are then collected and stored at the Battery Industrialization Center, where their performance and safety are assessed at the pack and module levels. Batteries deemed to be in good condition are reused in various applications such as ESS for streetlights, agricultural transport vehicles, and mobile UPS systems. Batteries with insufficient remaining capacity are crushed and pulverized into “black powder” for stabilization and sent to specialized inland facilities for metal recovery. Every step of the process is tracked using the battery’s unique identification code, and safety testing and certification procedures are managed through an integrated digital platform.

A comprehensive legal and institutional framework for the safe and efficient management of used batteries has been established and is in operation. There are clear regulations from relevant ministries for the entire process from the mandatory return of batteries to their separation, transport, storage, and finally recycling and reuse. With this system, used batteries are managed not as simple waste, but as “circulating resources” with new value.

1) Collection and Retrieval of Used Batteries

The first step in managing used batteries begins with their safe “collection” from owners. The government has laid the groundwork for a systematic retrieval system by imposing legal obligations and providing specific methods.

- **Mandatory Return:** Owners of subsidized electric vehicles are obligated to return the battery to the head of the local government when deregistering the vehicle for scrapping. This is a legal requirement specified in Article 58, Paragraph 5 of the 「Atmospheric Environment Conservation Act」.
- **Separation and Storage Methods:** Automobile dismantling and recycling operators must safely separate and store used batteries according to methods notified by the Minister of Environment, as per the Enforcement Decree of the 「Act on Resource Circulation of Electrical and Electronic Equipment and Vehicles」. Detailed procedures for this are laid out in the 「Notice on the Return of Electric Vehicle Batteries」 and the 「Detailed Regulations on the Separation and Storage Methods for Used Electric Vehicle Batteries」.
- **Operation of Collection Hubs:** To manage the collection, storage, and recycling of used batteries more professionally, the government established the legal basis to install and operate “Future Waste Resources Collection Centers” under the 「Act on Resource Circulation of Electrical and Electronic Equipment and Vehicles」. These centers play a pivotal role in handling not only collection and storage but also performance evaluation and sales of batteries.

2) Logistics of Used Batteries

Collected batteries are strictly managed according to safety regulations for transportation and storage. This is to prevent risks such as fires and explosions during transport and storage and to preserve their value as resources.

- **Specific Storage Methods:** The Enforcement Rule of the 「Wastes Control Act」 stipulates specific storage methods for used EV batteries. According to this rule, battery terminals and connecting cables must be insulated, and the batteries must be stored in a dry, well-ventilated place away from high temperatures, fire, direct sunlight, and moisture.
- **Adherence to Transport Methods:** For a used battery to be recognized as a “circulating resource” and not waste, it must be transported in compliance with the methods set forth in the 「Notice on the Return of Electric Vehicle Batteries」, as required by the

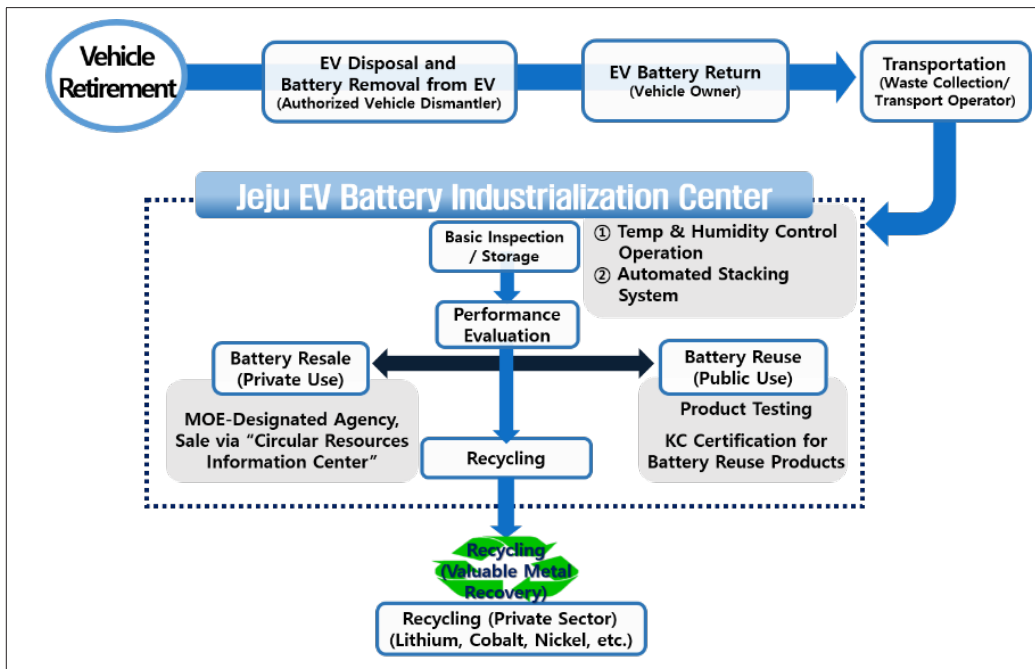
「Notice on Designation of Circulating Resources」. This shows that meeting safety standards is a prerequisite for resource circulation.

- **Jeju's Pioneering Case:** Jeju Special Self-Governing Province enacted the 「Ordinance on the Return and Treatment of Electric Vehicle Batteries」. With this, it has pioneered the establishment of a legal basis for the local government to directly handle related tasks such as battery separation, transport, storage, performance evaluation, and sales, thereby realizing systematic management.

3) Processing of Used Batteries

Batteries that have been safely transported and stored undergo performance evaluation to be either “reused” or “recycled”. The government actively supports the circulation of used batteries as resources in various ways with relevant laws.

[Figure 3-6] Circular System of the Jeju EV Battery Industrialization Center



Source: Prepared by the author

- **Waste Classification and Recycling:** The Enforcement Rule of the 「Wastes Control Act」 manages used EV batteries by assigning them a specific waste classification code, “51-41-05”. It also specifies the standards for facilities and technical capabilities that recycling operators must possess. For instance, if the operator creates a reused product such as an energy storage system (ESS), is required to have equipment capable of measuring

the battery's state of charge (SOC) and state of health (SOH).

- **Mandatory Performance Evaluation:** Recycling operators who intend to manufacture reused products must mandatorily measure the remaining capacity and other performance metrics according to methods jointly notified by the Minister of Environment and the Minister of Trade, Industry and Energy. This is an important procedure to maintain the safety and quality of reused batteries.
- **Safety Inspection for Reuse:** The 「Electrical Appliances and Consumer Products Safety Control Act」 introduced a system that designates reused battery modules and systems as “products subject to safety inspection”, and requires them to undergo safety checks before being distributed in the market. Through this, consumers can confidently use reused battery products whose safety has been verified.
- **Certification as Circulating Resources:** Notably, safe used batteries without damage from water, fire, or deformation can be recognized as “circulating resources” rather than waste according to the Act on the Promotion of Transition to a Circular Economy and Society (formerly the Framework Act on Resource Circulation). Once designated as a circulating resource, a battery is exempted from certain waste regulations and can be reused more freely, which contributes significantly to the growth of the related domestic industry.

4) Challenges in the Implementation Phase

The establishment of a full-cycle EV battery management system faced multiple challenges.

From an institutional perspective, the roles and responsibilities of the central government, local authorities, and private companies in all stages of collection, storage, reuse, and recycling were not clearly defined. The absence of standardized procedures for performance evaluation, grading, distribution, and safety certification also created administrative and industrial confusion.

Financially, the cost of building basic infrastructure, such as high-voltage battery disassembly equipment, dedicated storage facilities, and explosion-proof installations, was considerable. Yet private investment remained limited due to the lack of verified profitability and stable demand in the secondhand battery market.

On the technical front, there was a shortage of specialized facilities and skilled personnel

for disassembly, storage, performance evaluation, and recycling. Safety protocols for managing risks such as fire and explosion were also insufficient. In remote and island regions, additional logistics bottlenecks arose due to regulatory restrictions on transporting hazardous materials by sea.

Socially and environmentally, widespread reports of battery-related fires heightened public anxiety. Consumers lacked trust in the quality and safety of used batteries, leading to low market acceptance of reuse products.

5) Strategies to Overcome Challenges

To address these challenges, Jeju Province implemented a comprehensive strategy based on four key pillars: institutional reform, financial support, technological infrastructure, and public acceptance.

At the national level, the central government established unified guidelines for battery collection, transportation, and storage, while Jeju Province developed detailed local manuals for on-the-ground implementation. This led to the publication of manuals for EV battery disassembly and safety storage, which helped clarify responsibilities among stakeholders and reduce operational confusion.

In 2023, Jeju Technopark became the first officially designated institution for reused battery safety inspection and certification. This enabled the issuance of credible test data on battery performance and safety and built a stronger foundation of trust in the industry.

Financially, the provincial government provided subsidies for disassembly and lifting equipment, and conducted on-site safety training funded by local budgets. Jeju also invested in critical infrastructure, such as the Battery Industrialization Center, using national and local government funding to facilitate industry entry and expansion.

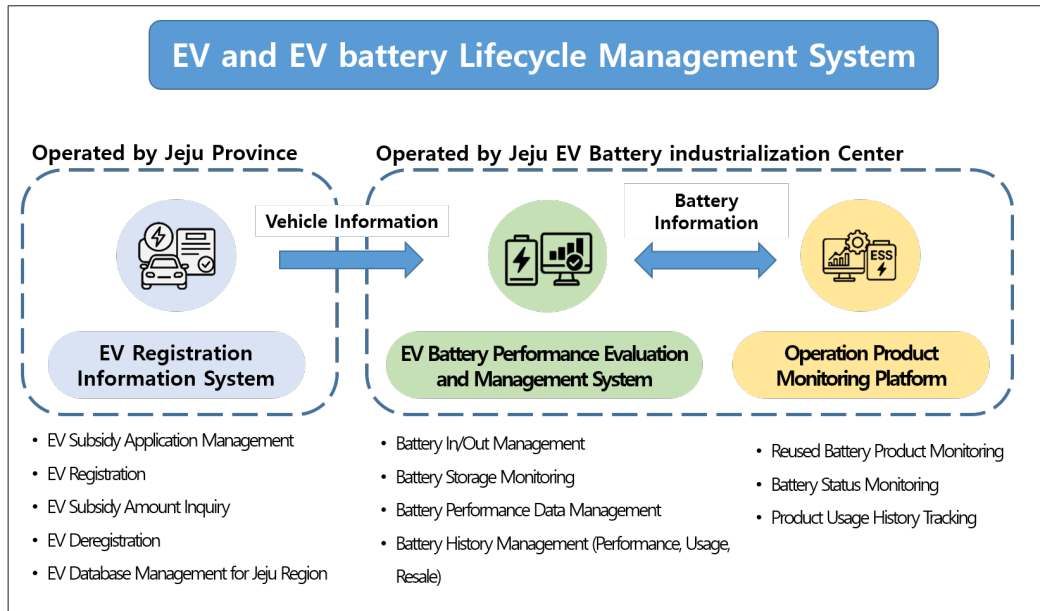
As part of its technology strategy, Jeju operated the Battery Industrialization Center as a testbed, rather than a mere storage facility. This allowed local companies to access support for technology demonstration, testing and certification, and product development.

To improve public acceptance, the province prioritized the application of reused batteries in home energy storage systems (ESS), agricultural transport vehicles, and similar products. This allowed residents to experience firsthand the safety and cost-saving benefits of reused batteries, which helped shift perceptions in a positive direction.

Through these efforts for legal and institutional reform, financial and technical support, and strategies for social engagement, Jeju has systematically built a full-cycle EV battery circulation model. In particular, the clear division of responsibilities between central and local governments, early activation of the market through public infrastructure, and public-private pilot projects have become key foundations for a sustainable circular economy.

1.4.3. Battery Life Cycle Management System

[Figure 3-7] Jeju EV and Battery Life Cycle Management System



Source: Prepared by the author

Jeju Province, where the adoption of EVs has progressed more rapidly than in any other region in Korea, has recognized the growing need for systematic management of used batteries. In response, the province has established a comprehensive, end-to-end management system that covers the entire battery life cycle from vehicle registration to dismantling, storage, reuse, recycling, and final sale.

First, a centralized database (DB) has been established for real-time tracking of EV distribution. At the time of subsidy disbursement, vehicle registration information is automatically recorded in the system for the integrated management of key data such as registration date, vehicle type, and battery specifications, thereby improving administrative efficiency. Each battery is assigned a unique identification number, which is recorded in the national vehicle registry together with the vehicle's registration information. When an electric vehicle is first registered, the battery identification number and basic

vehicle information are entered. During the vehicle's lifetime, major events such as maintenance, recalls, or battery replacement are recorded, and when a battery is replaced, the new identification number is also registered and linked to the vehicle. At the time of deregistration, the return of the used battery is officially documented, and this information is submitted to the Korea Ministry of Environment through a standardized return ledger.

In this process, local governments are responsible for collecting and recording field-level information. For example, they verify and document the return of batteries when vehicles are deregistered and report this information to the central government. They also carry out tasks such as managing subsidy payments and overseeing local collection and storage facilities. The central government, through the Korea Ministry of Environment and the Korea Environment Corporation, manages the centralized database, aggregates and verifies nationwide data, and connects it with other systems such as the vehicle registration database. This consolidated information is then used to design and implement policies on subsidies, recycling standards, and safety guidelines.

With this structure, Korea has established a system where local governments provide on-the-ground data while the central government integrates and manages it at the national level. This allows each battery to be tracked throughout its entire life cycle and enables safety and recycling regulations to be implemented consistently across the country.

In addition, Jeju has implemented a detailed tracking system to maximize the utilization of reusable batteries. Used batteries are sent to the "Used Battery Industrialization Center", and each battery is assigned a unique barcode for tracking. After undergoing dismantling, safety inspections, and performance evaluations, the batteries are classified into grades, and the results are registered in the system under their unique identifiers. When the batteries are later sold or repurposed for reuse or recycling, their ownership and usage history, as well as inspection records, are continuously tracked based on these identifiers.

This system functions not only as a tool for managing inventory and distribution, but also as a core data-driven platform for policy making, budgeting, logistics planning, and resource recovery. For example, the system allows the government to adjust the storage capacity of local facilities in advance based on projected volumes of used batteries, or to prioritize the allocation of high-grade reusable batteries to sectors with higher demand.

1) Vehicle Life cycle and Battery Return

A vehicle's life cycle begins with its new registration at the Korea Ministry of Land, Infrastructure and Transport, is operated by the owner, and finally concludes by undergoing the scrapping process at a scrapyards.

This “vehicle scrapping” stage is a crucial point where the battery management process begins. In accordance with relevant laws, the electric vehicle owner must mandatorily return the battery upon scrapping, and the scrapyards is the first gateway in this procedure. The final deregistration of the vehicle is also processed by the Korea Ministry of Land, Infrastructure and Transport, officially ending the vehicle's life cycle.

2) Battery Collection and Condition Diagnosis

When a vehicle enters a scrapyards, the battery enters a new management flow.

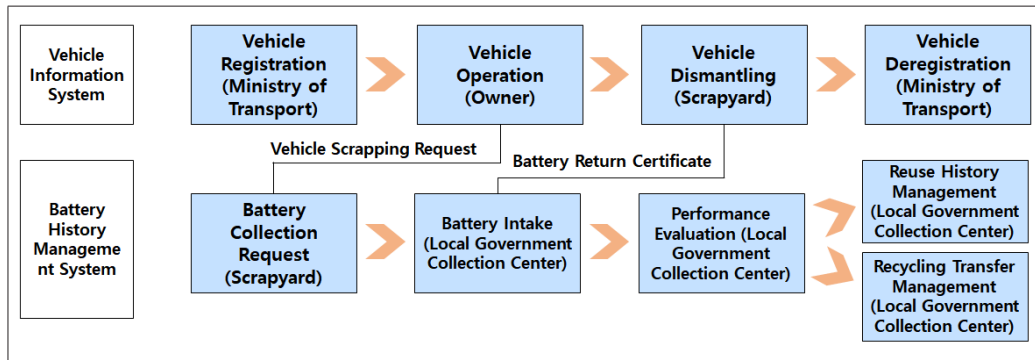
- **Collection Request:** The scrapyards separates the battery from the vehicle in compliance with safety regulations and then officially requests the collection of the battery from a collection center managed by the local government.
- **Receipt and Performance Evaluation:** Upon receiving the request, the collection center takes possession of the battery and registers it in the center. The received battery undergoes the most critical procedure, the performance evaluation. In this process, the battery's current value, including its remaining capacity (state of health - SOH), is precisely diagnosed using specialized equipment.

3) Determining the Battery's New Path and History Management

The results of the performance evaluation determine the battery's future, and all this information is recorded in the “Battery History Management System”.

- **Reuse Path:** If the performance evaluation results determine that the battery still has sufficient performance, it is classified as a target for “reuse”. These batteries are reborn as products such as energy storage systems (ESS) or small electric vehicles, and the “reuse history management” system transparently manages who reuses them and how.
- **Recycling Path:** If the battery's performance does not meet the criteria for reuse, it is classified as a target for recycling. These batteries are sent to specialized recycling facilities for raw material extraction, and the Allbaro system records this process to track and manage the resources.

[Figure 3-8] Interconnection of the Vehicle and Battery Management System



Source: Prepared by the author

1.4.4. Reuse Case - Secondary Utilization of Used Batteries in Jeju

Jeju Province is conducting a pilot project—the first of its kind in Korea—to reuse used EV batteries in energy storage systems (ESS) and electric agricultural machinery, which are then distributed free of charge to local communities. For example, battery modules recovered from electric vehicles are reassembled into ESS units for farm use and deployed in island and rural areas with limited power infrastructure to promote energy self-sufficiency. Additionally, electric utility vehicles made from used batteries are distributed to elderly farmers to improve agricultural work efficiency, forming what is now known as the “Jeju Model for EV Battery Circular Economy”.

In collaboration with the Korea Ministry of Environment and Jeju Technopark, the province plans to distribute approximately 300 reused battery products over the next three years with the aim to present a leading example that proves the viability of battery remanufacturing and reuse.

[Figure 3-9] Reuse Product Development Using Used Batteries (Jeju)



Source: Prepared by the author

1.5. Current Status of EV Battery Reuse and Recycling Industry in Korea

1.5.1. Status of the EV Battery Reuse Industry

In Korea, there are active efforts to reuse end-of-life EV batteries for new applications. Reuse is mainly carried out in the form of using retired batteries in energy storage systems (ESS) or in low-speed and small electric mobility devices. With recent institutional reforms, end-of-life batteries that have passed safety verification can now be certified and deployed in these fields. Major domestic reuse companies and cases are as follows.

1) Poen Co., Ltd.

Poen Co., Ltd., a startup spun out from Hyundai Motor Company's in-house venture program, is a leading domestic company in the remanufacturing and reuse of end-of-life EV batteries. It diagnoses and disassembles batteries that are damaged due to failure or accidents, or that have reached end of life, and then reassembles them into new battery packs. These repurposed packs are provided to customers for use in electric bicycles, electric two-wheelers, and ESS, thereby lowering battery replacement costs and contributing to the expansion of EV adoption.

2) Cases of Automakers and Battery Manufacturers

Automakers and battery manufacturers are also participating in pilot reuse projects through regulatory sandboxes.

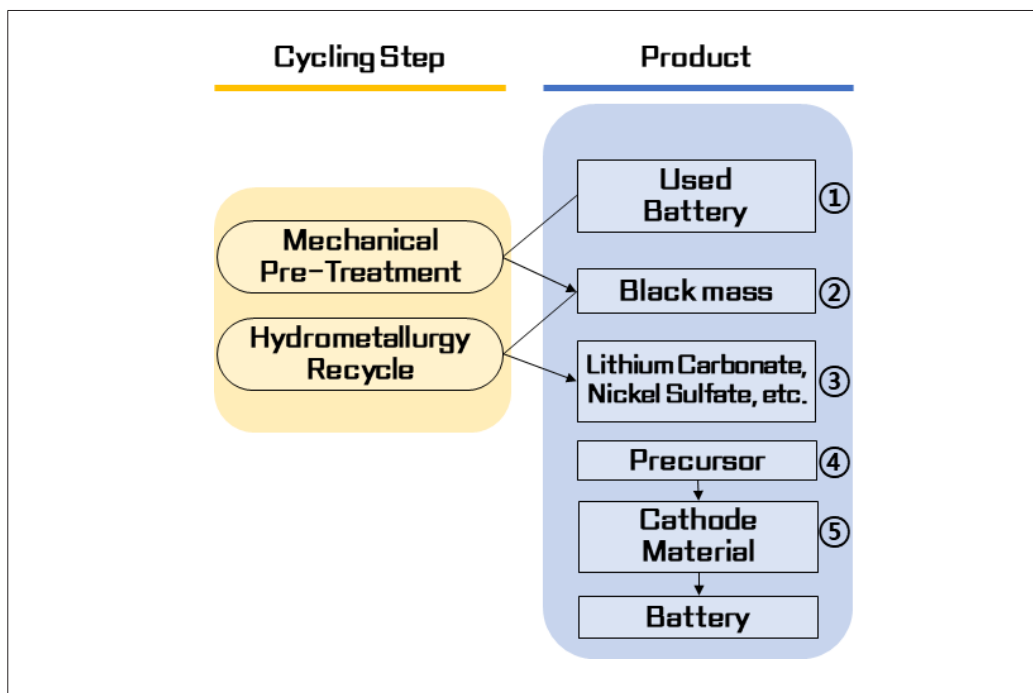
- Hyundai Motor Company: Received approval for a pilot project using its own retired batteries to build ESS containers connected to solar power generation, thus repurposing used batteries as large-scale ESS for solar energy storage.
- Hyundai Glovis/LG Chem/KST Mobility Consortium: In a pilot project in the battery rental business for electric taxis, the consortium is exploring a business model to reuse retired taxi batteries in ESS and other applications.
- SK On Co., Ltd.: In collaboration with the Korea Electrical Safety Corporation and SK ecoplant, SK On developed an ESS for construction sites, marking Korea's first case of using ESS made from retired EV batteries to supply temporary power at apartment construction sites.

Large corporations are accumulating safety data for reused batteries and working to establish reuse models to contribute to the formation of an early market. Korean reuse companies are focusing on diagnosis and grading technologies, as well as capabilities in producing small-scale ESS/packs. With the government's establishment of safety standards (KC 10031) and designation of certification bodies, second-life EV batteries are expected to be used in various fields such as building emergency power, renewable energy-linked storage, and portable power supplies. In addition, more business models are emerging that apply end-of-life batteries to low-speed vehicles such as e-bikes and electric carts, as well as industrial electric forklifts, to pursue both cost reduction and environmental benefits.

1.5.2. Status of the EV Battery Recycling Industry

The EV battery recycling industry aims to chemically process end-of-life batteries to extract key materials such as nickel, cobalt, and lithium, recover resources, and feed them back into the supply chain. In Korea, companies are active throughout the entire value chain from preprocessing (black mass production) to post-processing (metal refining), and even precursor and cathode material production. The value chain by stage is as follows, with notes on whether companies pursue each stage independently, through affiliated group companies, or through partnerships.

[Figure 3-10] Recycling Stages and Resulting Products of End-of-Life Batteries



Source: Prepared by the author

<Table 3-7> Business Status of EV Battery Recycling Companies in Korea

Company or Corporate Group	Stage ①~②	Stage ②~③	Stage ③~④	Stage ④~⑤
Evacycle	O	X	X	X
Sung-Eel HiTech	O	O	X	X
L&F	O	O	O	O
Posco Group	O	O	O	O
	(Posco HY Clean Metal)		(Posco FutureM)	
Ecopro Group	O	O	O	O
	(Ecopro CNG)		(Ecopro Materials)	(Ecopro BM)

Source: Prepared by the author

1) Preprocessing Stage (Black Mass Recovery)

- Business corresponding to stages ① to ② in [Figure 3-10]
 - In this stage, end-of-life batteries are collected, dismantled, and shredded, and valuable components are concentrated into black mass.
 - Evacycle Co., Ltd.: This is a Korean battery recycling startup founded in July 2023 as a spinoff from Hyundai Motor Company's in-house venture program. From its inception, major corporations such as Hyundai, POSCO, GS, and LX have participated as strategic investors. It currently operates two plants and two laboratories in Korea. The company's core business is recycling batteries generated from end-of-life EVs. Evacycle Co., Ltd. safely discharges the batteries, dismantles them into modules, then separates them into cells to recover black mass. The black mass is used as feedstock for extracting valuable metals such as nickel, cobalt, and lithium. The company maintains close ties with automakers and focuses not only on black mass recovery but also on process efficiency and improved safety. With backing from shareholders such as POSCO and GS, Evacycle Co., Ltd. also has the potential to connect into the precursor and cathode material production segments of the value chain.

2) Post-processing Stage (Production of Metal Compounds)

- Business corresponding to stages ① to ③ in [Figure 3-10]
 - At this stage, metal compounds such as lithium carbonate and nickel sulfate are produced from black mass.
 - Sung-Eel HiTech Co., Ltd. is an industry leader that has pioneered secondary battery recycling in Korea since 2008. The company collects end-of-life batteries and production scrap nationwide, processes them in its own facilities to produce black mass, and extracts metals in an integrated process. Sung-Eel HiTech Co., Ltd. has grown into one of the world's largest recyclers, capable of producing approximately 15,000 tons of nickel, 1,200 tons of cobalt, and 9,500 tons of lithium annually. With the completion of Phase 1 of its Saemangeum Plant 3, the company can now recover 600 tons of cobalt, 5,300 tons of nickel, and 6,000 tons of lithium carbonate per year. When Phase 2 is completed, it is expected to supply enough material for approximately 300,000 EVs.

3) Advanced Post-processing and Battery Material Production (Precursors and Cathode Materials)

- Business corresponding to stages ① to ⑤ in [Figure 3-10]
 - In this stage, black mass is produced from retired batteries and metal compounds are extracted, and these are used to produce cathode materials for EV batteries, completing the loop from recycling to new cathode material production. Some companies handle all stages independently, while others do so through affiliates or partnerships.
 - L&F Co., Ltd.: Originally a cathode material specialist, L&F Co., Ltd. has internalized precursor production through EV battery recycling, thereby achieving vertical integration from black mass production to cathode material production. The company also has recycling technology for LFP batteries and has commercialized this domestically, while considering projects abroad that involve black mass production overseas and precursor manufacturing in Korea.
 - POSCO HY Clean Metal and POSCO Future M: In POSCO Group, POSCO HY Clean Metal contributes to the completion of POSCO's full battery material value chain by recycling EV batteries and supplying raw materials to POSCO Future M for cathode production.
 - Ecopro CNG, Ecopro Materials, Ecopro BM: With group-level integration, Ecopro Group has established a vertical structure that spans black mass production, precursor production, and cathode material production.

4) Overall Industry Trends

In Korea, the major metal recovery rates of EV battery recycling companies are approximately 98–99% for nickel and cobalt, 90–95% for manganese, and 80–90% for lithium. In the case of LFP batteries, lithium recovery is more challenging. However, technologies to enhance lithium recovery efficiency are continuously being developed.

Alongside technological advancement, collaboration among companies to stabilize supply chains and improve efficiency has become increasingly important and active. Major Korean cathode-material manufacturers—such as Samsung SDI Co., Ltd., LG Chem Co., Ltd., POSCO Group, EcoPro Group, and L&F Co., Ltd.—are strengthening partnerships with recycled-

material suppliers in preparation for future regulations mandating the use of recycled raw materials (e.g., EU requirements). Furthermore, consortiums combining public institutions, private firms, and large corporations are making efforts to integrate the recycling value chain, from precursor production to cathode manufacturing.

Korean companies are developing their respective expertise across the entire process—from pretreatment to post-treatment and material refinement—while collaborating closely. Technologically, they are focusing on improving lithium recovery rates, developing low-energy and eco-friendly processes, and advancing next-generation battery recycling technologies. Ultimately, their goal is to enhance domestic self-sufficiency in critical battery materials and contribute to national carbon neutrality through the establishment of a circular battery economy.

2. EV Battery Recycling Policies and Case Studies Overseas

2.1. European Union (EU)

2.1.1. Circulation Strategies

1) Policy Overview

The European Union (EU) initiated its transition to a circular economy by adopting its first Circular Economy Action Plan (CEAP) in 2015. As part of the European Green Deal announced in 2019, the European Commission introduced a new CEAP in March 2020, positioning the circular economy as a central component of the EU's sustainability strategy. This plan aims to improve resource efficiency, prevent waste generation, and contribute to climate neutrality by 2050 and the preservation of biodiversity. The driving factors behind the EU's circular economy policies include reducing dependence on finite natural resources, mitigating environmental impacts from waste, and decoupling economic growth from resource consumption.

In line with the CEAP, the EU adopted the new Battery Regulation (EU) 2023/1542 in 2023, significantly strengthening regulations throughout the entire battery life cycle. This regulation mandates limitations on carbon footprints during production, minimizes the use of hazardous substances, and enforces the collection and recycling of used batteries. For instance, digital battery passports will be introduced for electric vehicle and industrial batteries starting in the 2030s, documenting material composition, carbon emissions, usage history, and recycling information. Manufacturers are also subject to Extended Producer Responsibility (EPR), which requires them to collect and process all used batteries and use a certain percentage of recycled materials.

The EU aims to achieve a harmonized regulatory framework among member states to establish a battery circular economy and reduce reliance on imported critical raw materials. Key targets include incorporating a minimum of 6% recycled lithium and nickel, and 16% recycled cobalt in new batteries by 2031, increasing to 12% lithium, 15% nickel, and 26% cobalt by 2036. Additionally, the EU has set specific recycling efficiency targets: achieving at least 65% for lithium-ion batteries by 2025 and 70% by 2030; recovering over 95% of cobalt, nickel, and copper, and 80% of lithium. These policies reinforce the principle that batteries must be collected and recycled as valuable resources.

2) Key Legislation

The EU has established a comprehensive legal framework for waste management, and is continuously updating laws to advance the circular economy. The Waste Framework Directive (2008/98/EC), amended by Directive (EU) 2018/851, provides the foundational structure for waste reduction and safe management. The 2018 amendment introduced new recycling targets, mandatory separate collection, and strengthened the EPR system. Under EPR, producers are responsible for the entire life cycle of their products, including end-of-life management, in various sectors such as packaging waste, electronic waste (WEEE), end-of-life vehicles (ELV), and used batteries. Member states are required to implement these EPR schemes. Furthermore, directives on packaging waste and single-use plastics impose recycling cost sharing on producers and promote the reduction and substitution of certain plastic products.

The EU has also set clear recycling and landfill reduction targets. For municipal waste, the recycling rate must reach 55% by 2025, 60% by 2030, and 65% by 2035. For packaging waste, the target is 65% recycling by 2025. Landfilling is to be reduced to a maximum of 10% of total waste by 2035. To combat illegal waste trade, the Waste Shipment Regulation (WSR), which generally prohibits the export of hazardous and unclassified plastic waste to non-OECD countries, was revised in 2023.

3) Recent Policy Developments

The EU's circular economy initiatives have accelerated following the 2020 CEAP 2.0. This updated plan emphasizes sustainable product design and improved circularity throughout product life cycles, with specific implementation strategies for resource-intensive sectors such as electronics, batteries and vehicles, packaging, plastics, textiles, construction materials, and food. Since 2020, the EU has introduced product-specific circular economy legislation, including the Battery Regulation (2023) and the proposed Packaging and Packaging Waste Regulation (2022). The Sustainable Products Initiative (SPI) mandates eco-friendly and circular design for all products. In 2023, the EU also improved its monitoring indicators for circular economy performance by introducing metrics such as material footprint and consumption footprint. In the European Green Deal, the circular economy is integrated with climate change mitigation and industrial strategies, positioning the EU as a global leader in promoting circular economy practices.

Notably, the EU has set ambitious quantitative targets for resource circulation. The new CEAP aims to double the circular material use rate (the proportion of recycled materials in

total resource consumption) by 2030 compared to 2020 levels and reduce per capita residual municipal waste generation by half by 2030. To achieve these goals, the EU is implementing policies to empower consumers (e.g., giving them the right to repair and promoting green consumption) and support regional and industrial transitions to a circular economy (e.g., establishing local circular hubs).

2.1.2. Polices and Regulations on EV Battery Recycling

As part of its Circular Economy Action Plan, the EU adopted the new EU Battery Regulation in 2023, which significantly strengthens regulations throughout the entire life cycle of batteries. This regulation establishes legal requirements for limiting carbon footprints during production, minimizing the use of hazardous substances, and mandating the collection and recycling of used batteries. Starting in the 2030s, the EU will introduce a digital battery passport for EV and industrial batteries. This passport will document and manage information such as material composition, carbon emissions, usage history, and recycling records for each battery. Additionally, manufacturers will be subject to EPR, which requires them to collect and process all used batteries and use a minimum proportion of recycled materials.

The EU's intent is not only to achieve a battery circular economy with harmonized regulations among member states, but also to reduce dependence on imported critical minerals and strengthen supply chain resilience. Specifically, all new batteries must contain at least 6% recycled lithium and nickel, and 16% recycled cobalt, by 2031. These targets increase to 12% lithium, 15% nickel, and 26% cobalt by 2036. Moreover, the regulation sets ambitious recycling efficiency goals: lithium-ion batteries must reach a minimum recycling efficiency of 65% by 2025 and 70% by 2030. Recovery rates must exceed 95% for cobalt, nickel, and copper, and 80% for lithium. With these measures, the EU establishes the principle that "batteries are resources that must be collected and recycled".

2.1.3. Status of the Battery Recycling Industry

The EU plans to completely ban the sale of internal combustion engine vehicles (such as gasoline and diesel cars) in all 27 member states starting in 2035. As a result, the EV battery market is expected to expand significantly in the coming years. In fact, the number of newly registered EVs in the EU was only 700 in 2010, but increased to approximately 550,000 in 2019, accounting for 3.5% of all newly registered vehicles.

According to the European Commission, approximately 40,000 tons of waste lithium-ion batteries were generated in 2020, and this number is projected to rise to 75,000 tons by 2025 and 240,000 tons by 2030. However, as of 2019, the total recycling infrastructure capacity for EV batteries in the EU was only 160,000 tons, indicating that the processing of waste batteries may not keep pace with demand in the near future.

To address this, the EU began implementing the New Batteries Regulation in 2022–2023 and is establishing institutional mechanisms to increase the rates of recycling and reuse. The current recovery rate for lithium-ion batteries is around 50%, but the EU plans to raise the target to 65% by 2025 and 70% by 2030. Notably, under the existing Batteries Directive (enacted in 2006 and revised in 2013), the EU had already set a goal to recover 45% of batteries placed on the market by 2016.

Additionally, the EU is preparing to introduce the battery passport system to systematically manage the reuse and recycling of EV batteries. This system is a technological platform designed to allow all stakeholders in the supply and value chain to share information and trace the life cycle of batteries. It is intended to maximize battery safety, enable optimal use throughout the battery's life cycle, and ensure responsible recycling at end of life. Battery minerals, packs, and key components (such as modules and cells) will be traceable in real time with the Internet of Things (IoT) using distributed ledger or blockchain technology among qualified stakeholders.

Furthermore, the EU will mandate the use of recycled raw materials in industrial and EV batteries starting in 2030, and plans to increase the required ratios by 2035. Specifically, by 2030, manufacturers will be required to use recycled materials at the following rates: cobalt 12%, lead 85%, lithium 4%, and nickel 4%. By 2035, these rates will be raised to cobalt 20%, lithium 10%, and nickel 12%, with lead remaining at 85%.

<Table 3-8> Major Companies Involved in EV Battery Recycling (EU)

No.	Company Name	Role & Responsibilities
1	Umicore (Belgium)	<ul style="list-style-type: none"> • Company Overview: A leading company in the production of a wide range of materials, including cathode materials for secondary batteries, and in recycling business operations. • Business Activities: Operates a “closed-loop business model” that recovers and recycles raw materials from used batteries.
2	Northvolt (Sweden)	<ul style="list-style-type: none"> • Company Overview: A battery cell manufacturer that has also entered the raw material recycling business through a joint venture with aluminum company Norsk Hydro. • Business Activities: Currently building a battery recycling plant called Revolt Ett. • Additional Notes: Signed large-scale battery supply contracts with BMW, Volvo, Porsche, and others.
3	Primobius (Germany)	<ul style="list-style-type: none"> • Company Overview: A joint venture founded by Neometals (Australia) and SMS Group (Germany). • Business Activities: Built a plant with an annual processing capacity of 20,000 tons for recycling battery cells.

Source: Prepared by the author

2.1.4. Best Practices in Battery Recycling

1) Volkswagen Battery Recycling Plant

A leading example of proactive compliance with EU regulations is Volkswagen in Germany. In 2021, Volkswagen launched a pilot battery recycling plant in Salzgitter capable of processing more than 3,600 EV battery packs annually. The facility combines mechanical shredding with an environmentally friendly hydrometallurgical process and achieves a metal recovery rate of more than 95%, including the recovery and refinement of lithium into lithium carbonate.

Volkswagen has established a closed-loop system, where end-of-life batteries from its own EVs are collected and recycled at this facility, and the recovered materials are reintegrated into the company’s battery cell production. According to the EU Battery Regulation, automakers are required to achieve 100% collection of end-of-life batteries by 2030. Volkswagen has taken early action by setting up an in-house logistics network and recycling process, thereby ensuring regulatory compliance while also securing economic advantages such as reduced battery production costs and stable raw material supply.

In addition to Volkswagen, Umicore, a company based in Belgium, has been operating a large-scale battery and scrap recycling facility since the 2010s, with an annual capacity of 7,000 tons. The company supplies recovered nickel and cobalt to European battery manufacturers.

Umicore's process combines pyrometallurgical and hydrometallurgical technologies for high recovery efficiency. Under the EU's EPR system, Umicore has established long-term contracts with automotive manufacturers for a stable and continuous supply of end-of-life batteries for recycling.

2.2. United States

2.2.1. Circulation Strategies

1) Policy Overview

The United States does not have a comprehensive federal circular economy law akin to the EU's framework; however, efforts to promote recycling and reduce waste have been ongoing for decades. Following the enactment of the Resource Conservation and Recovery Act (RCRA) in the 1970s, municipal-led recycling programs expanded across the country, and the national recycling rate steadily increased through the 1990s. The concept of a "circular economy" has only more recently entered the policy discourse, as interest has grown in resource efficiency and sustainable materials management. In response, the U.S. Environmental Protection Agency (EPA) and several state governments have begun to incorporate circular economy principles into their policies. In the federal system, waste management authority is decentralized, distributed between federal, state, and local governments. As a result, the United States faces challenges such as the absence of a unified national strategy and significant variation in policy implementation across regions. Recently, rising public demand for stronger environmental regulations and the increasing adoption of ESG management practices by businesses have led to greater attention to circular economy transitions. The federal government has begun to recognize this shift as a key factor in maintaining economic competitiveness and environmental leadership and is strengthening its response accordingly.

2) Key Legislation

The U.S. federal government has traditionally taken a supportive and advisory approach rather than imposing direct regulations in the field of waste management. While recycling mandates and Extended Producer Responsibility (EPR) systems are not legislated at the federal level, several states have recently begun introducing such frameworks. Since 2021, states such as Maine and Oregon have passed EPR laws for consumer packaging, and as of 2023, six states have implemented EPR legislation covering packaging and other waste streams. In addition, more than 10 states have enacted producer take-back and recycling

responsibilities for specific product categories, such as waste electrical and electronic equipment (WEEE), used tires, and paint containers. At the federal level, broader legislation aimed at reducing waste and promoting recycling indirectly contributes to these efforts.

Regarding recycling systems, the United States operates a decentralized, municipality-led collection model. Most major cities and counties run separate collection programs for paper, plastics, glass, and metals. To support these local efforts, the EPA provides technical guidelines and public outreach. However, recycling programs and acceptable material lists vary significantly by region, leading to a fragmented national system. At the federal level, the Save Our Seas 2.0 Act was enacted in 2020 to address marine debris, especially plastic waste. The law tasks the EPA with developing a national strategy to combat plastic pollution. Furthermore, in the 2020s, state- and city-level regulations on single-use plastics, such as bans on plastic bags and straws, have been expanding. Four states have also enacted legal requirements for minimum recycled plastic content in products. These various policy initiatives demonstrate a growing trend of state-led efforts in waste reduction across the United States

3) Recent Policy Developments

In recent years, the U.S. federal government has begun formulating strategic plans and setting targets to advance the circular economy. In 2020, the EPA announced a national recycling goal of achieving a 50% recycling rate by 2030. To support this, the EPA released the National Recycling Strategy in 2021, which aims to modernize the country's traditional municipal solid waste (MSW) recycling system and improve its efficiency. The strategy sets out five key objectives: expanding recycling markets, investing in collection and sorting infrastructure, reducing contamination in the recycling stream, strengthening policy support, and standardizing data. Building on this foundation, the EPA has released a series of strategic documents for establishing a circular economy. In 2023, it published the National Strategy to Prevent Plastic Pollution, which outlines measures to reduce plastic pollution throughout its entire life cycle—from production to disposal. These strategies are part of a broader plan to release sector-specific roadmaps for food waste, plastics, and critical materials through the mid-2020s. While not legally binding, they serve as comprehensive blueprints to guide federal efforts in promoting circularity.

On the legislative front, Congress has seen the introduction of bills related to the circular economy. For example, the Accelerating Circular Economy for Plastics Act, introduced in 2023, aims to support innovation in plastic recycling technologies. Additionally, the 2021 Bipartisan Infrastructure Law allocated \$350 million for recycling infrastructure

improvements, providing funding to help local governments upgrade their facilities. Public-private collaboration is also growing. Voluntary initiatives such as the U.S. Plastics Pact, which brings together companies, NGOs, and local governments, are working to shared targets for reducing plastic waste by 2025. These industry-led movements complement and reinforce federal circular economy initiatives.

2.2.2. Policies and Regulations on EV Battery Recycling

The United States does not yet have a comprehensive federal law specifically focused on battery recycling, but it is advancing a circular economy indirectly through legislation such as the Inflation Reduction Act (IRA) and multi-agency strategies. The IRA (2022) requires a certain percentage of critical minerals in EV batteries to be sourced either from North America or from recycled materials in order to qualify for EV tax credits. Starting at 50% in 2024, this threshold will rise to over 80% by 2027. Recycled lithium, nickel, and cobalt are considered domestic under this provision, which provides a significant incentive for automakers (OEMs) to use recycled inputs. This provision effectively acts as a de facto mandate for the use of recycled materials, stimulating growth in the United States battery recycling market. OEMs can receive up to \$3,750 in tax credits per vehicle when using qualifying recycled materials, leading companies such as Ford and GM to partner with and invest in domestic recycling startups.

In addition, the United States Department of Energy (DOE) has established the ReCell Center and is funding hundreds of millions of dollars in research and pilot projects to support the development of next-generation recycling technologies, including not only hydrometallurgical and pyrometallurgical methods, but also direct recycling approaches.

The U.S. EPA is also working to standardize battery recycling practices by developing national guidelines and collaborating with state governments on harmonized regulations, such as labeling for transport and standards for hazardous components in shredded material. Meanwhile, some individual states are pursuing their own Extended Producer Responsibility (EPR) legislation. For example, California has launched a task force on EV battery recycling to explore future manufacturer responsibility programs. Unlike the EU's regulation-driven model, the U.S. approach relies more on market incentives and public support to foster a voluntary circular economy. This strategy encourages private sector leadership, with companies such as Redwood Materials and Li-Cycle playing a key role in building domestic recycling infrastructure.

2.2.3. Status of the Battery Recycling Industry

As part of its strategy to address supply chain vulnerabilities in key industrial sectors, including electric vehicles, the United States announced plans to boost domestic EV battery recycling, in addition to cooperating with allied nations in mineral mining. This follows the “100-day review of supply chains”, which identified battery recycling as a national priority.

According to a U.S. government report, if battery recycling is not implemented, the country could face around 8 million units of EV battery waste by 2040. This projection is closely linked to the rapid growth of the EV market in the United States, where annual EV sales are expected to exceed 10 million units by 2025, up from about 700,000 in 2021. The report also estimates that battery recycling could meet a significant share of the demand for critical battery metals by 2040, specifically 55% of copper, 25% of lithium, 35% of cobalt, and 35% of nickel. In response, the U.S. federal government announced a direct investment of \$20.5 million to establish battery recycling infrastructure on May 1, 2022, and pledged \$3.1 billion in support for EV and battery-related companies. In addition to direct financial support for recycling projects, the government is also funding research and development (R&D) aimed at reducing the use of heavy metals in batteries.

In particular, the Argonne National Laboratory, with support from the U.S. government, is conducting economic analyses and technical evaluations of battery recycling. According to the lab, reusing lithium recovered from spent batteries in the production of new batteries can reduce manufacturing costs by 10–30%, and potentially lower the cost per kilowatt-hour of EV batteries to around \$80. These policies and research findings represent a strategic move by the United States to ensure both sustainability and competitiveness in the global EV industry and battery supply chain.

<Table 3-9> Major Companies Involved in EV Battery Recycling (USA)

No.	Company Name	Roles and Responsibilities
1	Ultium Cells	<ul style="list-style-type: none"> • Company Overview: A joint venture between GM and LG Energy Solution for EV battery cell manufacturing. • Business Activities: Invested approximately KRW 60 billion in equity in cooperation with Li-Cycle to recycle up to 100% of battery manufacturing waste. • Additional Notes: Signed a supply agreement with Germany's Vulcan Energy to receive 45,000 tons of lithium hydroxide (LiOH) over five years starting in 2025. In addition to the battery cell plant in Lordstown, Ohio, plans are underway to build a second plant in Spring Hill, Tennessee.

<Table 3-9> continue

No.	Company Name	Roles and Responsibilities
2	Tesla	<ul style="list-style-type: none"> • Company Overview: Designs, develops, manufactures, sells, and leases EVs and energy generation/storage systems, and provides related sustainable energy services. • Business Activities: Working to recycle EV batteries at its Nevada plant and is reportedly considering establishing another recycling facility at its Gigafactory in Shanghai. • Additional Notes: Plans to include electric motors and other key EV parts in its recycling efforts.
3	Redwood Materials	<ul style="list-style-type: none"> • Company Overview: A battery recycling startup founded by former Tesla CTO JB Straubel. • Business Activities: Plans to recycle cells from the Envision AESC battery manufacturing plant located in Smyrna, Tennessee, which was sold by Nissan to the Envision Group. • Additional Notes: Redwood is expanding its recycling facility near its Gigafactory to 51,000 m², up from the current 14,000 m² site where waste batteries are already processed.

Source: Prepared by the author

2.2.4. Best Practices in Battery Recycling

1) Battery Resource Recovery by Redwood Materials

In the United States, Redwood Materials stands out as a leading company in battery resource recovery. Founded by a former Tesla executive, the company focuses on recycling lithium-ion batteries and recovering key materials such as lithium, nickel, and cobalt. Redwood operates large-scale facilities that collect used batteries from electric vehicles, consumer electronics, and industrial applications. The company employs advanced hydrometallurgical and pyrometallurgical processes to achieve high recovery rates and supply recovered metals back into the domestic battery manufacturing supply chain. Redwood Materials has established partnerships with major automakers and electronics manufacturers and contributes to a circular battery ecosystem in the United States. With strong policy incentives under the Inflation Reduction Act (IRA), including tax credits for recycled content in batteries, Redwood plays a vital role in reducing dependence on imported critical minerals while promoting a sustainable EV industry. The company's efforts exemplify the U.S. strategy of encouraging private sector leadership and innovation in building a domestic battery recycling infrastructure.

2.3. China

2.3.1. Circulation Strategies

1) Policy Overview

Faced with environmental pollution and resource depletion amid rapid industrialization and urbanization, China was relatively early in incorporating the concept of a circular economy into its national development strategy. The idea was officially adopted at the 16th National Congress of the Communist Party in 2002, where the goal of building a “resource-saving and environmentally friendly society” was first proposed. Following this, China enacted the “Circular Economy Promotion Law” in 2008, which came into force in 2009.

This law was China’s first comprehensive legal framework for promoting a circular economy. It institutionalized the 3R principles—reduce, reuse, and recycle—and established national goals for improving resource productivity and reducing pollution. The policy was driven by China’s need to sustain long-term economic growth despite limited resources. With more than 20% of the global population but relatively low per capita access to key resources such as arable land and energy, resource security emerged as a critical issue. At the same time, worsening environmental pollution and public health crises such as smog and water contamination brought environmental sustainability to the forefront. These challenges prompted China to pursue what it calls a “blue economy”, aiming for economic growth in harmony with environmental protection.

2) Key Legislation

China’s circular economy policy has been advanced through a combination of laws, plans, and guidelines. The cornerstone of this effort was the enactment of the Circular Economy Promotion Law in 2008, which defined the responsibilities of the government, enterprises, and citizens, while also introducing incentives such as tax benefits and the establishment of special funds to promote resource conservation and the recovery and utilization of waste. In 2013, the State Council released the “Circular Economy Development Strategy and Action Plan”, followed by the National Development and Reform Commission (NDRC) issuing a detailed implementation plan in 2016. During the 13th Five-Year Plan period (2016–2020), the circular economy was elevated to a core pillar of national economic strategy, with a strong focus on improving resource productivity and fostering the recycling industry.

During this time, pilot projects were launched in key industries, and systems such as green factory certifications and circular economy industrial park accreditations were introduced. Notably, the State Council announced a plan in 2016 to implement an Extended Producer Responsibility (EPR) system in four sectors: electrical and electronic products, automobiles, lead-acid batteries, and packaging materials. In this plan, manufacturers are required to engage in eco-design, use recycled materials, establish collection systems, and contribute to recycling funds. A key target is achieving a 50% standardized collection and recycling rate for major product categories by 2025. For example, electric vehicle battery manufacturers are mandated to set up take-back networks through sales channels and operate tracking systems for used batteries.

In terms of waste management, China has focused on improving household waste separation and treatment systems, as well as industrial waste recycling. In 2017, a phased rollout of mandatory household waste sorting was launched in major cities, with 46 cities enforcing waste classification regulations by 2020. Additionally, China banned the import of solid waste, including post-consumer plastics and mixed paper, and a full ban has been in effect since 2021. This move was intended to improve domestic waste management and stimulate the development of its recycling industry, significantly impacting global waste markets. Furthermore, China launched a pilot program for “Zero-Waste Cities” in 2019 that aims to minimize waste generation and maximize resource circulation at the city level.

3) Recent Policy Developments

During the ongoing 14th Five-Year Plan period (2021–2025), China continues to position the circular economy as a key pillar of its national development strategy. Prior to the adoption of the Plan in 2020, the Chinese leadership introduced the “dual circulation” strategy, which emphasized strengthening domestic resource circulation while reducing reliance on external sources. The 14th Five-Year Plan includes various targets to improve domestic resource circulation. By 2025, China aims to improve resource productivity per unit of GDP by 20% compared to 2020 levels, reduce energy and water consumption per unit of GDP by 13.5% and 16%, respectively, and achieve reuse rates of 86% for agricultural waste, 60% for large industrial solid waste, and 60% for construction waste. It also sets specific numerical targets, including annual utilization of 60 million tons of waste paper, 320 million tons of scrap steel, and 20 million tons of recycled non-ferrous metals, and the expansion of the resource recycling industry to 5 trillion yuan (approximately USD 773 billion). These goals reflect China’s intent to cultivate the recycling industry as a strategic emerging sector and to strengthen its national resource security.

As a strategic policy response, the “Development Plan for Promoting Circular Economy (2021–2025)” was jointly issued by the National Development and Reform Commission (NDRC) and related ministries in 2021. The plan outlines key tasks such as promoting circular production models, green design and cleaner production, large-scale recycling of waste resources, and establishing circular logistics systems. It also emphasizes urban mining (recovering metals from urban waste) and the improvement of reverse logistics systems for end-of-life vehicles and household appliances. Furthermore, according to the national carbon neutrality goal (by 2060), circular economy initiatives are increasingly linked to climate strategies, and carbon reduction from recycling is incorporated into policy performance indicators.

China has played a leading role in circular economy cooperation on the international stage, including its earlier leadership with Japan in launching the Asia 3R (Reduce, Reuse, Recycle) initiative. More recently, it has participated in global circular economy dialogues with organizations such as the United Nations Environment Programme (UNEP), and has voiced support for helping developing countries transition to circular economies. These efforts reflect China’s strategic intent to build global leadership in circular economy practices while addressing domestic challenges.

2.3.2. Policies and Regulations on EV Battery Recycling

① Full implementation of the EPR system (Measures for Promoting the Extended Producer Responsibility System, State Council General Office, Dec. 25, 2016.)

In 2016, China expanded the producer’s environmental responsibility to encompass the entire life cycle of design, distribution, collection, and disposal with the EPR promotion plan. The measures institutionalized manufacturers’ responsibilities for the collection and recycling of priority sectors such as batteries and automobiles. The government oversees implementation through mechanisms for target-setting, evaluations, and information disclosure. This plan later became the overarching policy framework for regulations governing the collection and utilization of electric vehicle batteries.

② Comprehensive regulations on post-use power battery collection and utilization (Interim Measures for the Management of New Energy Vehicle Power Battery Collection Utilization, jointly issued by seven ministries, Jan. 2018.)

Jointly issued by seven ministries, including the China Ministry of Industry and Information Technology and the China Ministry of Science and Technology, and the China

Ministry of Environment and Forestry, these measures provide comprehensive management of the design, production, use, collection, reuse, and recycling of electric vehicle batteries. The key points include: concretization of EPR (automotive manufacturers as the primary collection entities), standardization and design obligations for disassembly ease, restriction of recovery and recycling to qualified enterprises, and role-sharing and supervision among government departments. The goal is to balance safety, environmental protection, and resource collection, and to achieve efficient enforcement through market mechanisms.

③ Full-cycle traceability (Interim Regulation for Power Battery Recycling Utilization Management, the China Ministry of Industry and Information Technology, July 2018.)

This regulation mandates the use of a dedicated platform to digitally track the full-cycle movement of electric vehicle batteries from production to installation, replacement, collection, disassembly, reuse and recycling. Automobile manufacturers, vehicle dismantling companies, and recycling enterprises must upload data such as battery codes and movement and processing statuses to the government traceability platform regularly after registering accounts.

④ Management of electric vehicle battery reuse (NEV Power Battery Staircase Utilization Management Methods, five ministries, Aug. 2021.)

These measures establish quality and safety standards for the secondary use of electric vehicle batteries, such as for ESS. It requires standardized labeling of reused products with product barcodes and unified battery codes (GB/T 34014) and specifies procedures for performance selection, residual life evaluation, safety testing, product labeling and traceability, and product liability (e.g., recall) to support the institutional establishment of a reuse market.

⑤ Identification and standard infrastructure rules (GB/T 34014-2017 Code Rules for Automobiles' Power Batteries)

This standard defines a unique identification code system for battery packs, modules, cells, and reused batteries and enables data linkage and traceability across the stages of production, replacement, collection, and reuse/recycling. This standard also integrates with the remote management specification and recycling utilization standard group and serves as the technical foundation for government traceability platforms and reuse indications.

⑥ Industrial management and access control (whitelist) and promotion measures.

The China Ministry of Industry and Information Technology published a list of companies that meet the recycling standard conditions for batteries, and designed government support, OEM collaboration, and subsidy connections centered on qualified companies. This aims to create a standard-compliant industrial ecosystem for companies that meet equipment, technology, environment, and safety standards, and to promote the advancement of recycling such as black mass collection. According to publicly available data, numerous batches have been announced since the introduction of the system in 2019, and hundreds of companies have been registered, contributing to the establishment of market order.

In this way, China has established a full-cycle, data-based circular economy system, progressing from “EPR → Comprehensive Regulations (2018) → Traceability (Data) → Reuse Standards (2021) → Standards, List of Outstanding Enterprises”.

2.3.3. Status of the Battery Recycling Industry

China defines “power batteries” as batteries used not only in electric vehicles but also in various electric transport systems such as electric motorcycles and electric railways. Based on this broad definition, China continues to release related research and policy initiatives.

The country’s EV battery recycling industry has seen rapid development with strong government support. Notably, in a government report released during the 2021 “Two Sessions” (National People’s Congress and Chinese People’s Political Consultative Conference), accelerating the establishment of an EV battery recycling system was emphasized. Furthermore, on July 7, 2021, the “14th Five-Year Circular Economy Development Plan” was issued, which explicitly promoted the active advancement of waste battery recycling and the improvement of a traceability management platform, demonstrating that the Chinese government regards EV battery recycling as a matter of national importance.

The market size and adoption rate of EVs in China have also surged. In 2021, EV sales reached 3.4 million units, three times the previous year’s total, accounting for 51.5% of global EV sales. According to the “New Energy Vehicle Industry Development Plan (2021–2035)”, the goal is to increase the proportion of new energy vehicles (NEVs) to 20% of total new car sales by 2025. As of November 2021, the figure had already reached 17.8%.

Along with this rapid growth, the volume of end-of-life batteries is also sharply increasing. In 2021, the amount of used batteries was estimated at around 252,000 tons, and

it is expected to grow at an average annual rate of 28.3% over the next nine years and reach 2.373 million tons by 2030. The average battery lifespan in China is generally estimated to be 5–10 years; this projection assumes a 5-year lifespan. By 2030, lithium iron phosphate (LFP) batteries are expected to account for 1.531 million tons (64.5%) and nickel-cobalt-manganese (NCM) batteries for 842,000 tons (35.5%).

China’s EV battery recycling market is also expanding rapidly. The market size was about 5 billion yuan (approximately USD 700 million) in 2019, which doubled to 10 billion yuan (approximately USD 1.4 billion) in 2020. It is projected to reach 16.5 billion yuan (approximately USD 2.3 billion) in 2021 and exceed 28 billion yuan (approximately USD 3.9 billion) in 2022.

<Table 3-10> Major Companies Involved in EV Battery Recycling (China)

No.	Company Name	Roles and Responsibilities
1	CATL (Contemporary Amperex Technology Co., Limited)	<ul style="list-style-type: none"> • Company Overview: The world’s largest EV battery manufacturer. • Business Activities: Partnered with Guizhou Province to invest 6.2 billion yuan in a battery manufacturing industrial complex. Plans to build a comprehensive production facility capable of certification, sourcing, procurement, logistics, and recycling, aiming to begin operations in 2025. • Additional Notes: Signed cooperation agreements with German auto parts supplier ZF and chemical company BASF to collaborate on battery recycling.
2	BYD	<ul style="list-style-type: none"> • Company Overview: A leading Chinese EV manufacturer. • Business Activities: Partnered with GEM to establish a battery recycling and processing production line and signed MOUs with around 200 dealerships. Currently operating 40 battery recycling outlets across China. • Additional Notes: Completed the internal replacement of all EV batteries in its operations with lithium-ion batteries as part of its closed-loop system.
3	GEM (Green Eco Manufacturer)	<ul style="list-style-type: none"> • Company Overview: Established on December 28, 2001, and listed on the Shenzhen Stock Exchange in January 2010 as a small-to-medium enterprise. Specializes in battery recovery and processing. • Business Activities: Building a nickel resource facility in Indonesia and signed contracts with major mining firms and stable suppliers for nickel procurement. Plans include recovering 150,000 tons of nickel matte in 2022 (with 40% nickel content), 50,000 tons in 2025 (70% nickel content), and 100,000 tons in 2030 (100% nickel content).

Source: Prepared by the author

2.3.4. Best Practices in Battery Recycling

1) CATL’s Closed-Loop Battery Recycling System

CATL, the world’s largest battery manufacturer, has established a large-scale battery recycling operation through its subsidiary Brunp, in line with Chinese government policies. CATL partners with automakers to collect used EV batteries, which are then recycled

at Brunp's facilities to recover valuable metals such as cobalt, nickel, and lithium. As of 2021, CATL-Brunp has handled tens of thousands of tons of battery waste annually, and its processing capacity ranks among the top globally. The recovered materials are reintegrated into CATL's battery production lines to create a closed-loop resource circulation model. According to China's Extended Producer Responsibility (EPR) regulations, CATL has vertically integrated the entire value chain from production and sales to collection, regeneration, and remanufacturing, to enable cost reduction and operational efficiency. As a result of these efforts, CATL had already recycled more than 10,000 tons of cobalt and nickel by 2020, along with significant volumes of lithium, thereby reducing China's dependence on imported battery materials. CATL's case exemplifies how strict government enforcement of collection targets combined with proactive corporate investment can lead to a successful circular economy. In addition, Chinese recycling firms such as GEM are also demonstrating global leadership in recycling capacity by processing imported black mass from around the world.

2.4. Japan

2.4.1. Circulation Strategies

1) Policy Overview

Japan is regarded as one of the leading countries that adopted the 3R principles early on as part of its national policy to transition to a circular society. In the 1990s, waste management became a major social issue, and cases of illegal dumping drew public attention. In response, the Japanese government introduced the "Sound Material-Cycle Society Vision" in 1999 and enacted the Basic Act for Establishing a Sound Material-Cycle Society in 2000, which came into effect in January 2001. This foundational legislation laid the groundwork for Japan's circular economy transition, emphasizing three core principles: waste reduction, proper treatment, and resource recovery. Japan's swift action was driven by the country's geographic constraints, such as limited land area and severe shortage of landfill space. By the late 1990s, the rapid increase in waste generation led to growing concerns over the saturation of final disposal sites. At the same time, the post-Kyoto Protocol climate fostered a sense of national responsibility as an environmental leader and prompted Japan to pursue both environmental protection and economic development through resource circulation. Against this backdrop, Japan began implementing its circular economy strategy through government-led roadmaps and phased policy rollouts.

2) Key Legislation

Building upon this, Japan has implemented various product-specific recycling laws tailored to different waste streams: the Containers and Packaging Recycling Law (1995, effective 1997), the Home Appliance Recycling Law (1998, effective 2001), the Construction Material Recycling Law (2000, effective 2002), and the Food Waste Recycling Law (2000, effective 2001). In 2005, the End-of-life Vehicle (ELV) Recycling Law came into effect, establishing a comprehensive system that includes the recycling of dismantled vehicles and automobile shredder residue (ASR). Japan has continued to update its legal framework to reflect societal and technological changes, introducing the Small Home Appliance Recycling Law (effective 2013) and the Plastic Resource Circulation Act (effective 2022). These individual laws define the roles of producers, consumers, and local governments according to the characteristics of each waste category. They also establish structured collection and recycling systems and clearly outline funding mechanisms, such as Extended Producer Responsibility (EPR) schemes and recycling fees.

One of the defining features of Japan's circular economy (CE) legal framework is the extensive application of EPR. For example, under the Home Appliance Recycling Act, consumers pay a recycling fee when purchasing a new appliance, and manufacturers are responsible for collecting and recycling end-of-life products through a designated organization. Similarly, the Automobile Recycling Act mandates that recycling fees be prepaid at the time of new vehicle purchase, which covers the final treatment of recycling. Under the Packaging Recycling Act, manufacturers bear the responsibility for recycling packaging materials. After municipalities collect the waste, a designated organization performs recycling in bulk, and manufacturers fund the process with recycling fees. This EPR system, which combines financial responsibility for manufacturers and distributors with the obligation of consumers to separate waste, forms the foundation of Japan's circular economy policy.

Another core element of the system is the establishment of the Fundamental Plan. First formulated in 2003 and revised every five years, this plan sets national targets and priority measures for promoting a sound material-cycle society. The plan uses three key indicators: (1) resource productivity (domestic resource input per unit of GDP), (2) cyclical use rate (the ratio of recycled resources to total material input), and (3) final disposal amount (landfilled waste). For example, the Fourth Plan (2018–2022) set the following goals to be achieved by 2025: increase resource productivity to ¥490,000 per ton, raise the cyclical use rate to 18%, and reduce the final disposal amount to below 13 million tons. These targets represent a doubling of resource productivity, an 80% increase in the cyclical use rate, and a 77%

reduction in landfill disposal compared to the year 2000. With this data-driven approach, Japan continuously monitors and improves the performance of its circular economy policies.

3) Recent Policy Developments

Japan continues to upgrade its circular economy strategy to address emerging issues. In line with developments in the EU and other regions, Japan released the “Circular Economy Vision 2020”, a revised version of its original 1999 vision. This updated framework laid out a mid- to long-term direction that reflects new challenges such as plastic waste. Subsequently, in March 2023, the Japan Ministry of Economy, Trade and Industry (METI) launched the “Pro-Growth Resource-Independent Economic Strategy”, a policy linking resource circulation to economic growth. This strategy emphasizes the development of new industries, such as converting waste plastics into raw materials and recycling rare metals.

On the legislative side, the enforcement of the Plastic Resource Circulation Act in 2022 marked a significant shift. The law encourages companies to reduce plastic use and adopt recycled plastics, while requiring consumers to make behavioral changes such as paying for plastic bags, which became mandatory in 2020. The government also promotes reusable design and chemical recycling technologies in industries to establish a circular economy for plastics. In 2024, the Fifth Fundamental Plan for Establishing a Sound Material-Cycle Society was approved by the Cabinet. This plan outlines the resource circulation policy direction for the next five years, focusing on deepening the circular economy in connection with decarbonization and optimizing circular systems with digital technologies.

Japan has also played a leading role in international 3R discussions. In 2005, it proposed the 3R Initiative at the G8 Summit, and at the 2019 G20 Summit, it spearheaded the Osaka Blue Ocean Vision, which aims to eliminate marine plastic pollution by 2050. Through such efforts, Japan maintains its leadership in circular economy policy both domestically with comprehensive legislative execution and internationally by offering best-practice models.

2.4.2. Policies and Regulations on EV Battery Recycling

Japan has promoted hybrid and electric-drive vehicles from an early stage, and has developed an advanced automobile recycling system. Under the End-of-life Vehicle (ELV) Recycling Law, automakers are obligated to collect components such as batteries when vehicles are scrapped, and the government includes batteries in its goal of achieving a 95% recycling rate for automotive shredder residue. Recently, the Japanese government and private sector have begun collaborating on developing lithium-ion battery recycling

technologies and establishing relevant standards. For example, Toyota has long recovered precious metals from used nickel-metal hydride batteries and is now working to improve the recycling rate of EV lithium batteries by establishing internal battery recycling centers. In its 2023 Battery Industry Strategy, the Japan Ministry of Economy, Trade and Industry (METI) announced a goal to make 100% of new car sales electrified vehicles by 2035 and emphasized building a reuse and recycling system for used batteries.

To this end, the Japan Automobile Manufacturers Association (JAMA) leads a consortium for joint battery collection and recycling, while battery manufacturers such as Panasonic have set targets to source 10–30% of battery raw materials from recycled metals by the 2030s. Overall, Japan is integrating EV batteries into its existing vehicle recycling system and preparing technologies and infrastructure jointly through public-private collaboration in anticipation of a future surge in end-of-life batteries.

Japan's battery recycling policy is implemented within the existing framework of its automobile recycling law. A deposit system is in place, in which consumers pay a fee at the time of new vehicle purchase, which is later used to cover battery processing costs when the vehicle is scrapped. Designated contractors appointed by automakers are responsible for collecting used batteries. In its 2020 Resource Circulation Strategy, the government pledged to establish a lithium-ion battery recycling system by 2030. In 2023, METI also launched the Council for Promoting Second-Life Battery Use to gather input from the industry. Japanese automakers such as Toyota and Honda are now jointly operating pilot recycling plants for lithium-ion batteries, with plans to legislate based on the outcomes. Moreover, the Japanese government supports business models for second-life battery applications, such as using used EV batteries in power storage systems. These are increasingly being used as backup power sources and energy storage solutions, especially in preparation for natural disasters.

2.4.3. Status of the Battery Recycling Industry

The Japanese government has launched a support project involving an investment of approximately 100 billion yen (about USD 64 million) and subsidy provision to strengthen international competitiveness in the automotive battery industry. At the same time, private companies are actively cooperating with the government to build a domestic EV battery recycling ecosystem. For instance, the Battery Association for Supply Chain (BASC) was established in April 2021 with the participation of around 30 Japanese battery and parts manufacturers. The association advises the government on battery supply and recycling issues and promotes the development of regulations for refining and recycling rare metals.

Meanwhile, Japan is actively implementing pilot programs that reuse used EV batteries in everyday life. For example, Mitsubishi Motors repurposes used EV batteries from its plants as stationary ESS. In Shizuoka Prefecture, the Forest Control Club utilizes used EV batteries as a power source for electric golf carts. Seven-Eleven Japan has installed used battery-based storage systems at 11 stores in Kanagawa Prefecture. These systems generate electricity from solar panels during the day, store it in batteries, and use it at night. East Japan Railway Company (JR East) is piloting the use of used EV batteries to power railway crossings during blackouts. Einoth Holdings is using used batteries in household storage systems and as power sources for streetlights.

In addition, major Japanese trading companies view the reuse of secondhand EV batteries as a new business opportunity and are actively pursuing projects. Itochu is working on converting lithium-ion batteries collected from electric taxis and buses in China into storage systems for use in Japanese and overseas factories and logistics centers. Mitsui & Co., in collaboration with Renault SA in 2019, established an office in Bordeaux, France, and launched a battery reuse service for power companies in Germany.

<Table 3-11> Major Companies Involved in EV Battery Recycling (Japan)

No.	Company Name	Roles and Responsibilities
1	4R Energy Corp	Successfully developed various technologies, including simulation tools to estimate residual capacity, and established a product plant for battery reuse. The company currently processes batteries from approximately 1,500 EVs and plans to triple its processing capacity.
2	Sumitomo Corp	A non-ferrous metal refining company in the Sumitomo Group, and one of Japan's largest in the field. Uses expertise in copper smelting to recover valuable metals such as copper, nickel, cobalt, and lithium from used EV batteries.

Source: Prepared by the author

2.5. Comparison of National Policy Models and Implications

Policies on EV battery recycling have evolved differently across countries, depending on their institutional conditions, industrial capacities, and levels of social consensus.

The European Union has established a regulation- and standard-based model that governs the entire battery lifecycle—from production to disposal and recycling—through the “Battery Regulation (EU) 2023/1542”. This model has been supported by Europe’s strong institutional foundation, characterized by a unified market system, harmonized legal framework, and high level of social consensus.

The United States, in contrast, has developed its market primarily through private-sector technological innovation and investment competition rather than direct federal control. This approach has been made possible by the country's strong technological capabilities, robust capital markets, and vibrant startup ecosystem.

Meanwhile, China and Japan exhibit features of government-led models based on centralized administrative systems. Such models efficiently build full-cycle management systems by leveraging strong policy execution and industrial control from the central government. However, this model is difficult to replicate without a powerful centralized governance system and a well-defined national industrial strategy. Moreover, the success of these government-led systems has been underpinned by the technological capabilities of private enterprises.

Indonesia, on the other hand, is still in the early stages of developing its technological, industrial, and institutional foundations for EV battery recycling. Therefore, it would be challenging to directly adopt advanced-country models in the short term. A more realistic approach would be to establish a transitional system—one that utilizes EPR to delegate recycling operations—over the next three to five years, while gradually advancing technology transfer, localization, and infrastructure development.

In summary, advanced-country models have functioned effectively within their own social, economic, and institutional contexts. For Indonesia, rather than importing these models wholesale, it is crucial to design policies that build the necessary preconditions domestically and internalize the system gradually in alignment with the country's unique circumstances.

<Table 3-12> Comparison of Policy Models and Preconditions by Major Countries

Category	Type	Key Features	Preconditions
EU	Regulatory / Institutional	<ul style="list-style-type: none"> • EPR obligation • Recycled content requirement • Battery passport system • Operation of EU wide database and traceability system 	<ul style="list-style-type: none"> • Unified market and harmonized legal framework • High social acceptance of circular economy and environmental regulations • Established certification and legal system
U.S.	Private-sector led	<ul style="list-style-type: none"> • Technology development and investment driven by the private sector • State-level decentralized policies 	<ul style="list-style-type: none"> • Active private R&D and investment system • Federal structure with strong state autonomy • Public acceptance of environmental regulation
China	Government led	<ul style="list-style-type: none"> • Legalization of EPR system • Recycle responsibility assigned to producers and users • Life-cycle management through the NEV Traceability Platform • Integrated management of battery collection, recycling, and reuse 	<ul style="list-style-type: none"> • Strong administrative control of the central government • Targeted industrial policy and financial assistance • Development of digital governance and data infrastructure • Advanced technology and manufacturing base
Japan	Government led	<ul style="list-style-type: none"> • Legalization of EPR system • Recycle responsibility assigned to producers and users • Recycling Performance Management System for Producers • Cooperation between manufacturers and local governments 	<ul style="list-style-type: none"> • Strong central administrative control • Targeted industrial policy and financial assistance • Development of digital governance and data infrastructure • Advanced technology and manufacturing base • Social consensus and strong quality norms • Governance structure between government and industry

Source: Prepared by the author

3. Overview of Electric Vehicle Recycling Technologies

3.1. Stages and Material Flow in the Recycling of EOL EV Batteries

The recycling process of end-of-life EV batteries can be broadly categorized into the following stages:

“EV battery → removal of aluminum casings, copper wires, and other recoverable materials for recycling at aluminum and copper smelters → battery dismantling → black mass production → extraction of lithium carbonate, nickel sulfide, and other compounds through hydrometallurgical processes → reuse by battery material manufacturers”.

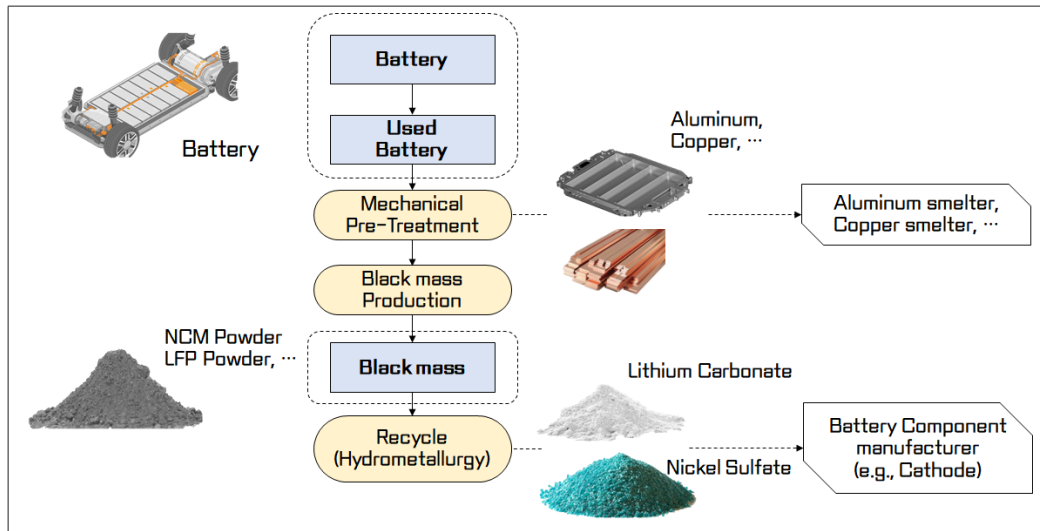
Although there are other extraction methods, the method most widely adopted today is hydrometallurgical processing, and the explanation below is based on that approach.

When an end-of-life battery is collected, detachable metal components such as the casing and wiring are removed and sent to metal smelters for recycling. The remaining battery, stripped of its outer components, is then dismantled and processed into black mass, which contains valuable active materials.

Key compounds such as lithium carbonate and nickel sulfide are extracted through hydrometallurgical treatment of the black mass. These compounds can be reused as raw materials in the production of cathode materials for new batteries.

This process can be illustrated as a flow diagram based on the stages: “Battery dismantling → Black mass production → Hydrometallurgical extraction of metal compounds”.

[Figure 3-11] Stages and Material Flow in EV Battery Circulation



Source: Prepared by the author

During this process, companies may organize themselves along the value chain to improve the efficiency of battery recycling, or a single company may perform multiple functions within the chain. Examples can be found among Korean companies.

SungEel HiTech Co., Ltd. began as a battery recycling company and now performs a wide range of functions, including the collection and dismantling of end-of-life batteries, as well as the extraction and sale of lithium carbonate and nickel sulfide.

L&F Co., Ltd., initially focused on producing cathode active materials for batteries, has since expanded upstream to secure raw materials. It now extracts lithium carbonate and nickel sulfide from end-of-life batteries and uses them in its own cathode material production.

Evacycle Co., Ltd. has commercialized the dismantling of used batteries and the production of black mass. These examples illustrate how each EV battery-related company defines its own scope and specialization in the recycling value chain.

3.2. Overview of Key Steps in EV Battery Recycling Technologies

The recycling of end-of-life EV batteries generally follows these steps:

- Mechanical pre-treatment, in which the battery is dismantled

- Black mass production, where the battery is ground into a powder containing active materials
- Metal recovery, typically using either pyrometallurgical (thermal) or hydrometallurgical (wet) processes

Although pyrometallurgical methods are used, they have limitations in the types of metal compounds that can be recovered. As a result, hydrometallurgy has become the most widely adopted method for extracting final metal compounds such as lithium carbonate and nickel sulfide.

1) Mechanical Pre-treatment

This is a general pre-processing stage that does not include metal extraction. It involves removing low-value components such as battery casings and dismantling the battery into its individual cells. In some cases, even the cell casings are removed to improve recycling efficiency.

2) Black Mass Production

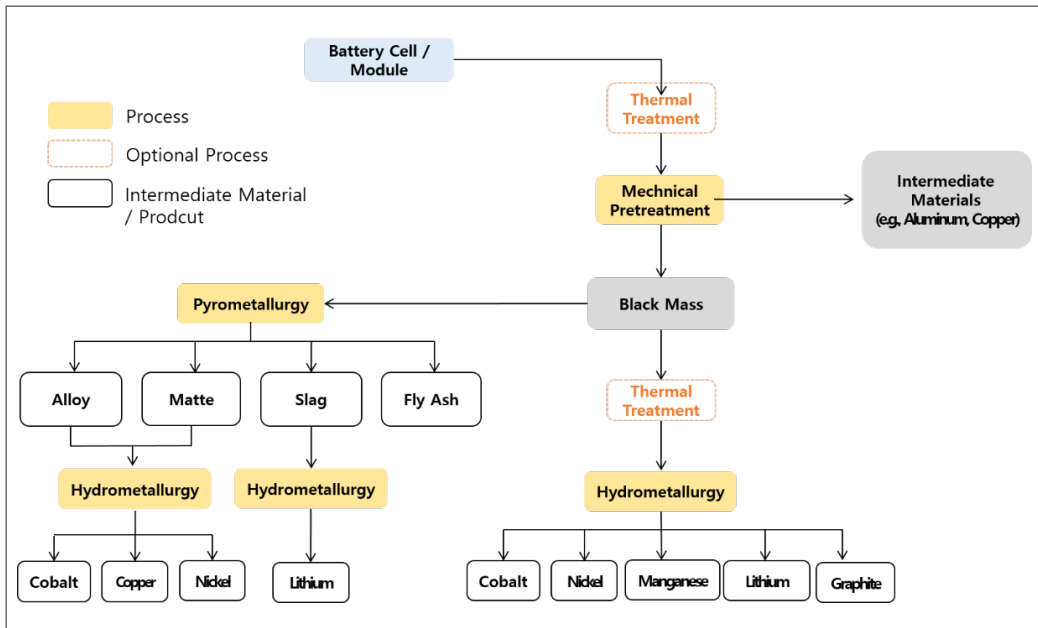
This process involves grinding battery cells into fine powder, known as black mass, to prepare for metal compound extraction. To improve extraction efficiency, companies specializing in black mass production have developed methods to effectively remove liquid components such as electrolytes and metallic materials such as aluminum and copper.

3) Hydrometallurgy

In the hydrometallurgical process, acidic solutions are used to dissolve metals, and target metals are selectively recovered through sequential steps such as leaching, solvent extraction, and precipitation. In this method, black mass is treated with acid to extract metallic components into solution, from which metal compounds are subsequently recovered. Major recoverable elements include lithium, nickel, and cobalt.

This process offers advantages such as relatively low greenhouse gas emissions and high recovery efficiency; however, it also requires proper treatment of waste solutions. The recovered metals—lithium, cobalt, nickel, and manganese—can be reused as precursor materials for battery cathodes.

[Figure 3-12] Battery Recycling Process



4. Feasibility of Introducing the Latest EV Battery Recycling Methods in Indonesia

4.1. Technical Feasibility Analysis

4.1.1. Technological Gaps in the Collection, Retrieval, and Storage Systems for Used Batteries

To fully implement battery recycling, it is important to first establish not only in-plant recycling technologies but also a preceding process for collecting and safely storing used batteries. This is because end-of-life batteries pose significant fire and explosion risks when physically damaged or overheated, and also present environmental hazards due to residual current and potential electrolyte leakage. Therefore, these front-end procedures must be in place regardless of the downstream policy, whether it be battery recycling or Extended Producer Responsibility (EPR). Technical implementation must precede any assessment of economic or environmental feasibility. Without this foundational infrastructure, the subsequent stages cannot be realized. The gap between Indonesia's current state and the technological requirements can be summarized as follows.

<Table 3-13> Infrastructure Gaps in Collection and Transportation of Used EV Batteries

Process	Required Technology/ Conditions	Status in Indonesia	Remarks
Collection	Battery Pack Disassembly Insulation Treatment	Not in place	Lack of standards for electrical/chemical hazard response
Transport (logistics)	Discharge Insulated Packaging Dedicated Transport for Hazardous Materials	Not in place	Lack of manual for End-of-life battery
Storage (temporary)	Temperature and Humidity Control Ventilation System Separated Storage Racks	-	Inadequate fire and explosion prevention facilities
Classification and Recording	Battery Type Manufacturer State of Charge (SOC) Recording	Not in place	Critical for black mass quality and process design

Source: Prepared by the author

4.1.2. Technology Gap for Black Mass Production

In situations where it is difficult to implement the full battery recycling process, a more realistic alternative is to focus first on producing black mass and exporting it to overseas refining facilities. Black mass refers to the concentrated powder extracted from cathodes and anodes of used batteries. It contains valuable metals such as lithium, nickel, and cobalt, making it a key intermediate material in the recycling process. The following outlines the technology requirements and existing gaps specifically related to black mass production.

<Table 3-14> Technological Gaps in Upstream Process of EV Battery recycling

Process	Required Technology/Conditions	Status in Indonesia	Remarks
Discharge and Dismantling	Discharge handling technology, safe dismantling technology	Not in place	-
Crushing	Shredder, suction collectors, metal separation devices	Not in place	-
Black Mass Separation	Sorting of active/inactive materials, combination with wet separation	Not in place	-

Source: Prepared by the author

4.1.3. Technological Gaps in Full Recycling Processes Including Metal Recovery

Ultimately, from a circular economy perspective, the most desirable scenario is to recover high-purity lithium, nickel, cobalt, and other critical metals from used batteries and reuse them as raw materials for new batteries. However, this process requires very advanced chemical refining technologies and purification facilities, which only a limited number of companies in Korea and other leading EV battery-producing countries are currently capable of operating. The table below outlines the gap between the technologies required for a full recycling process and the current situation. However, it is expected that the feasibility of implementation remains significantly low.

<Table 3-15> Technological Gaps in Downstream Process of EV Battery recycling

Process	Required Technology/Conditions	Status in Indonesia	Remarks
Hydrometallurgical Extraction	Leaching, purification, and neutralization based on sulfuric/nitric acid	Not in place	-

Source: Prepared by the author

4.2. Economic Feasibility Analysis

The economic viability of battery recycling is primarily determined by processing costs and the value of recovered metals. Based on battery type, the recycling cost per ton, the value of recovered metals, and potential profit were analyzed as follows

4.2.1. Lithium Ferrous Phosphate (LFP) Battery

As previously noted, LFP batteries contain few recoverable precious metals, resulting in a low recovered metal value of approximately \$3,170 per ton—significantly lower than that of NCM, LCO, or other cathode materials. However, the processing costs for collection, crushing, and extraction are relatively constant between battery types, ranging from \$1,500 to \$1,800 per ton. When additional costs are considered, the value of recovered metals from LFP batteries is insufficient to cover the total processing expenses. According to available data, traditional pyrometallurgical and hydrometallurgical methods make it difficult to generate profit from recycling LFP batteries. In fact, studies in Europe and the United States have found that recycling LFP/LMO-type batteries is often economically unviable.

However, with the recent surge in demand for LFP batteries, companies such as L&F Co., Ltd., a major Korean cathode material manufacturer, and CATL, China's largest battery producer, are making significant investments in recycling facilities specifically designed for LFP and other battery types. These developments indicate a growing interest in the recycling sector, and suggest that value can potentially be created by recycling, depending on positioning in the battery value chain.

4.2.2. Lithium Nickel Cobalt Manganese (NCM) Battery

NCM-series batteries have a high recovery value due to their nickel (Ni) and cobalt (Co) content. As of 2023, it is estimated that 1 ton of mixed NCM battery cells contains approximately \$8,700 worth of lithium, nickel, and cobalt—about three times the value of LFP batteries. In terms of recycling costs, the total expenses for collection, crushing, and hydrometallurgical extraction are lower than the value of the recovered metals, leading to a positive profit margin. In the United States and Europe, it is reported that recycling NCM batteries yields a net profit of about \$10 per kWh, while in Korea and China, profits can reach up to \$20 per kWh. Converting this into battery pack weight, an NCM battery with an energy density of about 250 Wh/kg can yield a net profit of more than \$2,500 per ton. In short, NCM battery recycling offers meaningful economic gains even after accounting for processing costs. Numerous studies and modeling analyses support the profitability of NCM

recycling. Although the prices of valuable metals such as cobalt and nickel are subject to market fluctuations, NCM waste batteries are generally considered economically viable.

4.2.3. Lithium Nickel Cobalt Aluminum (NCA) Battery

NCA batteries, like NCM batteries, are considered economically profitable for recycling due to their high nickel and cobalt content. Although NCA contains less cobalt than NCM, it has a higher nickel content, resulting in a similar total value of recoverable metals. Reports suggest that NCA recycling can generate \$10–20 of profit per kWh, which translates to several thousand dollars in net profit per ton. While aluminum has a small economic contribution, the high nickel content offsets this. Overall, NCA batteries offer profit margins comparable to NCM and play a significant role in the EV battery recycling business.

4.2.4. Lithium Cobalt (LCO) Battery

LCO batteries have the highest economic value among the four types due to their high cobalt content. Recycling costs are similar to those of other batteries, and profit is mainly driven by the value of cobalt. In fact, business models for collecting small waste batteries (e.g., from mobile phones and laptops) to extract cobalt have existed for years, solely based on the value of cobalt. Despite this profitability, the downside is that LCO batteries are primarily used in small electronics rather than electric vehicles, limiting the scalability and economy of scale in recycling operations.

<Table 3-16> Comparative Analysis of End-of-life EV Battery Types

Battery Type	Key Metals (Cathode)	Recovered Metal Value (USD / ton)	Recycling Profitability (Net Profit)	Environmental Benefit (e.g., Carbon Reduction)
LFP	Li	Approx. \$3,170	Low (Loss)	Low
NCM	Li, Ni, Co, Mn	Approx. \$8,700	High (Net profit of several thousand dollars per ton)	Very High (Significant carbon reduction compared to mining/refining)
NCA	Li, Ni, Co	Approx. \$8,000	High (Net profit of several thousand dollars per ton)	High (Significant carbon reduction compared to mining/refining)
LCO	Li, Co	Approx. \$11,130	Very High (Net profit of several thousand dollars per ton)	High (Significant carbon reduction compared to mining/refining)

4.3. Environmental Feasibility Analysis

Battery recycling provides significant environmental benefits by limiting the need for new mineral mining and refining. The production of EV batteries generates substantial carbon emissions and has an environmental impact, primarily during the extraction and refinement of raw materials such as lithium, nickel, and cobalt. Recycling these materials helps bypass such processes and results in a substantial reduction in carbon emissions.

4.3.1. Carbon Emissions Reduction Effect

Recycling 1 kg of lithium-ion batteries can reduce CO₂ emissions by approximately 2.7 to 4.6 kg. This reduction results from the difference in energy consumption between mining new materials and recycling existing ones. Notably, direct recycling has the greatest carbon footprint reduction potential and is capable of reducing greenhouse gas emissions from battery production by up to 61%. Hydrometallurgical recycling achieves a reduction of about 51%, while pyrometallurgical (thermal) recycling offers a reduction of around 17%. The relatively low effectiveness of thermal recycling is due to its high energy consumption and limited recovery of materials such as lithium, whereas direct and hydrometallurgical processes have higher recovery rates and lower energy input requirements. In summary, battery recycling has a carbon reduction potential of approximately 50%, making it a very impactful strategy for building sustainable and environmentally friendly material supply chains.

4.3.2. Differences by Battery Chemistry

The environmental benefits of battery recycling vary depending on the metals used in their composition. Metals such as nickel and cobalt, which have high energy consumption and carbon emissions during the refining process, offer greater environmental gains when recycled. For example, according to the International Energy Agency (IEA), 55% of the total carbon emissions generated during the production of NMC batteries come from the refining of key minerals such as nickel and cobalt. In contrast, this figure is about 35% for LFP batteries. This suggests that recycling NMC batteries can significantly reduce the carbon footprint associated with raw material production. On the other hand, while LFP batteries have a relatively lower environmental burden due to their material composition, recycling them still avoids emissions from lithium extraction and offers meaningful reductions. Additionally, cobalt mining is known for its significant environmental and human rights concerns. Recycling cobalt from LCO and NCM batteries can therefore substantially reduce associated issues such as mine wastewater and soil contamination.

4.3.3. Resource Circularity and Other Environmental Benefits

Beyond carbon reduction, battery recycling contributes to a circular economy by reusing valuable minerals and preventing secondary pollution from landfill disposal or improper handling. If used batteries are mismanaged, they may cause soil and groundwater contamination due to electrolyte leakage or heavy metal leaching and pose a fire risk. Thus, technologies that prevent these hazards are essential.

4.3.4. Battery Types with the Highest Economic and Environmental Value

Based on both economic and environmental indicators, batteries with higher cobalt content generally provide the greatest combined benefits. LCO batteries offer the highest profitability due to cobalt recovery and significant environmental benefits by reducing the need for cobalt mining. NCM and NCA batteries, which also contain nickel and cobalt, provide substantial recycling profits and environmental advantages. Since NCM and NCA batteries are widely used in current EVs, their recycling offers large absolute reductions in carbon emissions and strong commercialization potential.

Conversely, LFP batteries lag in terms of economic feasibility due to their low recovery value and offer comparatively modest environmental benefits. However, with LFP projected to account for up to half of the future battery market, innovation in recycling technologies may improve its economic and environmental impact over time.

In conclusion, when considering both economic feasibility and environmental benefits at the current stage, the most favorable battery types for recycling are lithium cobalt oxide (LCO), nickel cobalt manganese (NCM), and nickel cobalt aluminum (NCA) batteries due to their high content of valuable metals such as nickel and cobalt. While lithium iron phosphate (LFP) batteries are currently viewed as a target for Extended Producer Responsibility (EPR) systems, they may become a more viable target for the recycling industry in the future as technologies advance.

By actively promoting the recycling of such batteries, it is possible to achieve both resource security and carbon neutrality. In the long term, it will be necessary to continue developing recycling technologies for other battery chemistries, including LFP, in order to realize a comprehensive circular economy for all end-of-life batteries.

4.3.5. Environmental and Social Risks

Establishing recycling infrastructure for electric vehicle (EV) batteries requires

significant investment in facilities, logistics, and technical capacity. While these costs can be substantial, the absence or delay of such infrastructure may, in the long term, result in even greater environmental and social costs.

Without a systematic collection and recycling system, used batteries are often disposed of improperly or through informal channels, increasing the risk of leakage and waste. This can lead to soil and groundwater contamination, as well as risks of fire and explosion, ultimately posing health hazards to local communities.

Therefore, the establishment of recycling infrastructure should not be viewed solely as an economic choice, but as a necessary environmental safeguard. It plays a crucial role in preventing the leakage of hazardous waste and ensuring the safe and sustainable circulation of valuable resources through environmentally sound management.

4.4. Analysis of Case Studies and Recommendations for Improvement

Considering international case studies, economic feasibility by battery chemistry, and the current state of Indonesia's EV battery market, it may be more appropriate to first establish institutional foundations that support various recycling pathways, rather than immediately introducing a full-scale EPR system or comprehensive mandatory recycling legislation. As noted above, the value and technical complexity of recycling vary by battery type, and these factors are subject to change depending on global trends and technological advancements.

In addition, the KSP implementing organization plans to work with Korean companies that possess advanced EV battery recycling technologies, which are not yet available in Indonesia, to help build a complete local battery circulation system. During the course of this project, the KSP mission confirmed that several companies have shown a strong interest in pursuing projects in Indonesia. These include:

In this project, the KSP execution team has identified domestic companies eager to promote business ventures in Indonesia.

Poen Co., Ltd., operates a business that recycles used electric vehicle batteries into ESS by collecting end-of-life batteries, ensuring safety, and repurposing them into ESS. The business has expanded to Vietnam following operations in Korea, and it is planning ventures in collaboration with Hyundai Motor Company in Indonesia. Additionally, Evacycle Co., Ltd. is running a business that incinerates and shreds EV batteries to produce black mass both

domestically and internationally in collaboration with Hyundai Glovis Co., Ltd., while L&F Co., Ltd. plans to commercialize technology for the recycling of LFP batteries using value chains with domestic companies.

It is anticipated that the entry and commercialization of these Korean companies into Indonesia will significantly contribute to the circular economy of used electric vehicle batteries.

04

CHAPTER

Roadmap and Policy Recommendations for End-of-Life Battery Management

1. Strategies and Policies for End-of-Life Battery Management
2. Standardization and Certification Approaches
3. Proposed Pilot Project for EV Battery Recycling in Indonesia

Roadmap and Policy Recommendations for End-of-Life Battery Management

1. Strategies and Policies for End-of-Life Battery Management

1.1. Vision and Goals

1.1.1. Vision

To improve the effectiveness of Indonesia's electric vehicle battery management system and promote the sustainable development of the reuse and recycling industry in line with local characteristics.

1.1.2. Objectives

1) Establishing a legal and institutional framework for used battery management

Indonesia at present does not define used batteries as a separate resource, and as a result lacks a legal basis for their collection and utilization. Therefore, it is urgent to enact a basic law or subordinate legislation that covers the definition, classification, responsible entities, and disposal standards of batteries. In particular, the initial institutional framework should be established by the central government to lay the legal foundation for public-oriented infrastructure construction and expanded private participation in the future. Such institutionalization will be a key foundation for the institutionalization of all stages of collection, reuse, and recycling in the future by clearly distinguishing the implementation entities and roles for each scenario.

2) Establishing a regulatory-based implementation system

To ensure the safety of used batteries and prevent environmental damage, it is important to introduce battery health and residual value (SOH) evaluation criteria, certification system, and traceability management system. For this purpose, a technical and regulatory framework aligned with the Indonesian National Standard (SNI) should be established in stages and applied in the field through integrated support centers or mobile equipment. The implementation system should initially be led by the public, but in the long term, it should be designed in a structure that clearly defines the roles of the government and the private sector with the expansion of private certification organizations for policy effectiveness.

3) Establishing a recycling infrastructure model that reflects the geographical characteristics of island nations

Due to the geographical characteristics of Indonesia's many islands, it may be difficult to apply the policy nationwide by building a centralized recycling infrastructure. Therefore, a local government-led or jointly operated demonstration model centered on small-scale recycling facilities, mobile evaluation equipment, and a decentralized processing system that can be connected to maritime logistics may be an alternative. As in the case of Jeju Island's Carbon-Free Island (CFI) policy, a local energy self-reliant ESS construction model using used batteries is also likely to be employed in the long term. In this way, it is important to explore the direction of introducing a combination of demonstration model and ordinance-based operation system under the leadership of local governments.

4) Establishing a cooperation system between central and local governments and institutionalizing role division

Because the end-of-life battery policy is difficult to implement solely at the level of a single ministry or the central government, it is necessary to clearly define and institutionalize roles between the central and local governments. When roles and detailed plans are established for the overall recycling of end-of-life batteries, it is important to carefully reflect the current initiatives and capabilities of affiliated organizations and relevant local institutions in each central government ministry. For instance, the Ministry of Transport must review the installation of EV battery testing facilities in regional offices, and the Ministry of Industry should consider the expertise of its subordinate institutions concerning the standardization of electronics and transportation machinery. Thus, there is a need for a complementary system where the central government takes responsibility for policy making, financial support, and standard setting, while local governments handle

infrastructure management at the regional level and onsite execution. To this end, roles and responsibilities (R&R) between the central and local governments should be clearly established, and a collaborative platform incorporating annual evaluations and adjustment mechanisms should be implemented. Such a structure would contribute to increasing the regional suitability and sustainability of policies.

1.2. Implementation Strategy

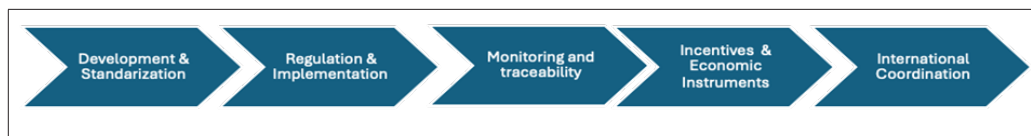
Indonesia does not currently have an integrated policy strategy for the reuse and recycling of used batteries, and the roles and responsibilities between ministries are unclear. Given these realities, the following strategic directions are proposed.

1.2.1. Policy governance in stages

As Indonesia is in the early stages of its end-of-life battery policy, a phased implementation structure is needed where the central government takes the lead in establishing the institutional framework and public infrastructure, and then private participation and local government implementation capacity is expanded in the mid- to long-term. In the short term, a centralized policy platform should be established under the leadership of the Ministry of National Development Planning (BAPPENAS) by preparing laws and regulations, coordinating roles, and establishing a national-level integrated support center, while in the medium term, local governments should be able to become empirically based policy implementers by directly operating base infrastructure or using mobile equipment. In the long term, a structure may be implemented in which the public focuses on standards, evaluation, and supervision, and certain functions (certification, collection, etc.) are transferred to the private sector. This transition process is similar to the CFI case in Jeju Island or the rebalancing of public-private roles after the introduction of the KC certification system in South Korea, and Indonesia needs to design a transitional governance strategy that is initially public led and later private led.

Below is the proposed framework of policy governance at the stage in Indonesia based on Jeju Island.

[Figure 4-1] Phased Policy Recommendation Framework



Source: Prepared by the author

<Table 4-1> Policy Tasks by Implementation Phase

Stage	Policy Focus	Key Governance Actions
1. Development and Standardization	Policy Design and Standards	<ul style="list-style-type: none"> Define end-of-life battery category (reuse, recycle, disposal) (Source: Kirti Richa, 2016) Create performance and safety standard - Establish EV battery utilization framework (Source: Jeju Case - 2024/25 KSP - GGGI, 2025)
2. Regulation and Implementation	Regulatory	<ul style="list-style-type: none"> Create Extended Producer Responsibility (EPR) - (Source: UNEP, 2020) Set mandatory collection and recycling targets and responsible (EU battery regulation, 2023) Certified recycler and logistic handlers - Standard battery handling and resale) - Create authority status for battery reuse - (Source: Jeju Case - 2024/25 KSP - GGGI, 2025)
3. Monitoring and Traceability	Eco-design and Tracking	<ul style="list-style-type: none"> Create eco label and design (digital IDs) - Eco-design (Picatoste et.al, 2025) Require reporting from manufacturer EV - Battery Passport Framework (Source: World Economic Forum (2020)) Establish national database for end-of-life (Source: Nurdiawati & Argawal, 2022)
4. Incentives and Economic Instruments	Incentives	<ul style="list-style-type: none"> Offer subsidies and incentives for recycler (Hao et.al., 2022) Penalize improper disposal (Hao et.al., 2022) Provide R&D (Source: Nurdiawati & Argawal, 2022)
5. International Coordination	Cross-border Harmonization	<ul style="list-style-type: none"> Align with Basel Convention (Source: OECD (2021) – Global Material Flows) Develop regional hub (Source: OECD (2021) – Global Material Flows) Share best practices and tech standards (Source: Korea National Strategies for EV Battery Recycling, 2021-2024)

Source: Prepared by the author

1.2.2. Guiding regulatory and incentive-based policies

Since used batteries are both a potential resource and an inherent safety and environmental hazard, it is important to design policies that link regulations and incentives. For example, batteries with residual performance above a certain threshold may be eligible for reused and remanufacturing, but this should be subject to a certification and grading system-based inspection. In other words, there should be a clear policy bifurcation to ensure that non-performing batteries are recycled and performing batteries are reused as ESS. To support this, tax incentives or technical subsidies should be provided to companies that obtain certification, and strong regulations should be applied to illegal collection and storage. By balancing regulations and incentives in this way, it is possible to simultaneously promote private sector responsibility and market revitalization, a policy mix proven effective with Korea's quasi-EPR system, the KC certification framework, and the European EPR model.

As EV adoption accelerates globally, managing end-of-life lithium-ion batteries has become a strategic environmental, economic, and industrial priority. Effective policy governance is needed so that batteries are reused, repurposed, or recycled safely and sustainably.

These are the proposed key regulatory and incentive-based policies in Indonesia based on a literature review.

1) Key Regulatory Policies

a) Extended Producer Responsibility (EPR)

Requires manufacturers to take full life cycle responsibility, including take-back and safe disposal. (Source: EU Battery Regulation (2023), Gaines (2014))

b) Mandatory Recycling Targets

Legal requirements for recovering lithium, cobalt, and other critical minerals. (Source: EC Proposal (2020), Binnemans et al. (2013))

c) Battery Passport and Traceability

Digital records of battery chemistry, life cycle, and ownership to support transparency (Source: Ghosh et al. (2021), WEF (2020))

d) Eco-Design Regulations

Promote battery designs that are easy to disassemble and recycle. (Source: Harper et al. (2019), EU Ecodesign Directive).

2) Key Incentive-Based Policies

a) Recycling Subsidies and Tax Incentives

Financial support for recyclers and circular business models to scale up operations. (Source: IEA (2022), Xu et al. (2020), U.S. IRA (2022))

b) Deposit Return Schemes and Take-Back Programs

Boost consumer participation in battery return and safe disposal. (Source: UNEP (2020), State-level regulations (e.g., California))

c) Support for Second-Life Battery Markets

Encourage reuse in stationary energy storage before recycling. (Source: World Economic Forum (2020), Ghosh et al. (2021)).

3) Recommendations for Policymakers and Industry

a) Combine regulations (EPR, standards, traceability) with incentives (subsidies, tax breaks, take-back programs).

b) Promote public-private collaboration to scale up infrastructure for collection, repurposing, and recycling.

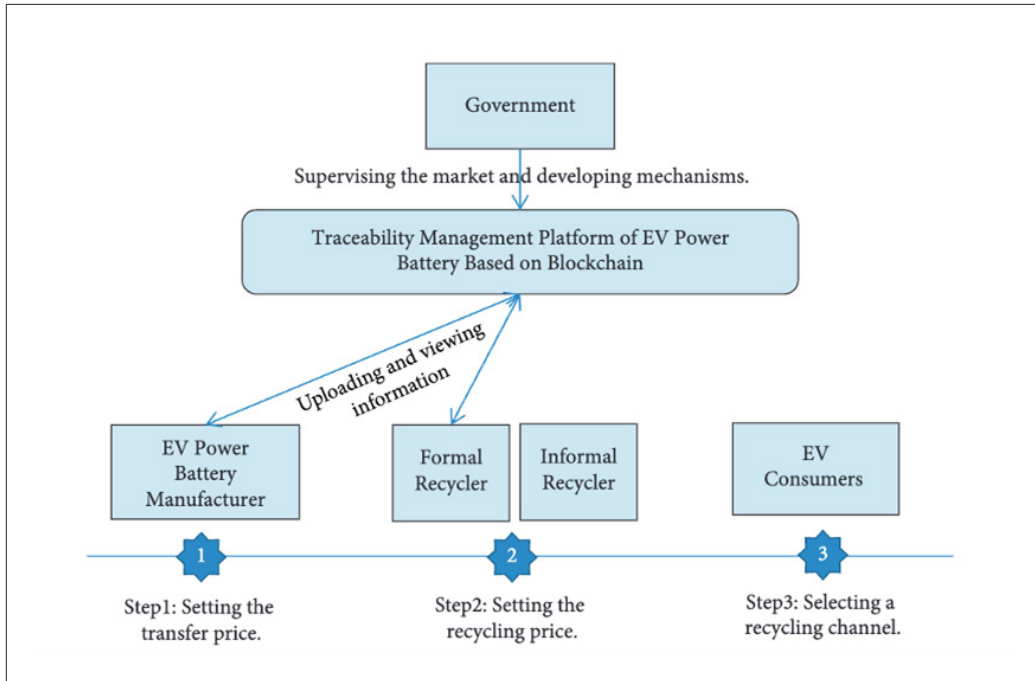
c) Ensure cross-border policy alignment to support a global circular battery economy.

1.2.3. A model that reflects geographical decentralization

Since Indonesia is an island nation, it would be inefficient to build a collection and recycling infrastructure based on a single centralized location. Therefore, a centralized model, such as an integrated support information/data center, is required in the center, while local governments on the islands are required to operate a decentralized strategy tailored to the region with small storage facilities, mobile diagnostic equipment, etc. As in the case of Jeju Island, it is possible to transition to a local energy independence model based on ESS using waste batteries, and a local power grid using reused batteries can be a strategic alternative, especially considering the limitations and high cost structure of high-voltage direct current (HVDC) submarine transmission. In this way, a nationwide circular economy system can be realized by designing an infrastructure model that considers the differentiation of functions and organic linkages between the central and local levels according to local conditions.

Alternatives for this model are to fill the gap regarding developing long-lasting, secure technologies that help build decentralized systems. At the same time, new technologies such as battery storage and electric vehicles disrupt consumer habits where renewable energy is favored, and a decentralized energy market is promoted. It includes the aspect of fine access control provided by blockchain in addition to decentralization; a permission system is vital for entities that require strict access control due to the nature of the data they hold (Chinnaperumal et al., 2025). Figure 18 shows the topological diagram structure of the model. The government has the power to supervise the market and develop a mechanism for a traceability management platform with blockchain (Cheng, Hao, Tao, & Zhou, 2021).

[Figure 4-2] Topological Diagram Structure of the Decentralization Model



Source: Prepared by the author

1.3. Legal, regulatory, and financial policy proposals

Indonesia’s end-of-life battery recycling system is in a nascent stage with a weak institutional foundation and lack of technical infrastructure, which requires a systematic approach to legal, regulatory, and financial aspects. These aspects should not be pursued in isolation, but should be interlinked with each other through legal definitions, standards, certification, and financial incentives, accompanied by a multi-ministerial collaboration and stakeholder consultation structure centered on the National Development Planning Agency (BAPPENAS) to ensure policy alignment.

1.3.1. Legal aspects

Indonesia does not yet categorize used batteries as an independent resource or have legislation to do so. Therefore, the first step is to clarify the definition and legal status of used batteries. This will enable their categorization as a resource with reusable potential, and is the basis for establishing future legal responsibilities and management schemes. Second, a basis for mandatory battery take-back and recycling is needed. Legislation for collection and recycling, such as Korea’s Basic Resource Circulation Act or Europe’s EU Battery Directive, provides both legal responsibility and opportunities for market actors. Such legislation may

serve as a basis for the integration of national battery management systems. In the long term, a step-by-step legislation roadmap from “public responsibility to private transfer” as in the Jeju Technology Park case needs to transition to a private-led system based on the Extended Producer Responsibility (EPR) system. In this process, a regulatory moratorium or grace period using a regulatory sandbox system³⁶⁾ can be key to mitigate the shock of the policy transition period.

<Table 4-2> Legislative Timeline of Korea’s Legal Framework for End-of-Life EV Batteries

Category		Regulation	Detailed Provision	Description
Collection System	Collection	Framework Act on Air Quality (MoE)	Article 58-5 of the Framework Act on Air Quality (Jan. 2016)	Mandates the collection of end-of-life EV batteries to help prevent air pollution.
	Dismantling	EV Battery Return and Collection Notice (MoE)	Detailed procedures for the separation and storage of end-of-life electric vehicle batteries (Dec. 2018)	Increases safety in battery dismantling and provides criteria for collection and storage.
	Transportation	Waste Management Act (MoE)	Annex 5 of the Enforcement Rule of the Waste Management Act (Jul. 2021)	Establishes transport safety and operational standards for used batteries.
	Storage	Electrical Appliances and Consumer Products Safety Control Act (MoE)	Article 20-4 of the Act on Resource Circulation of Electrical and Electronic Equipment and Vehicles (Jan. 2021)	Sets storage safety standards for reused batteries and fire prevention measures.
			Enforcement Rule of Waste Management Act (MoE)	Article 10 and Annex 16 of the Enforcement Rule of the Waste Management Act (Jan. 2022)
Evaluation & Auction	Performance Evaluation	EV Battery Reuse Performance Evaluation Method (MoE)	Annex 8 of the Enforcement Rule of the Waste Management Act (Jan. 2022)	Supports reuse potential assessment of batteries.
			Performance Evaluation Guidelines for End-of-Life EV Batteries (Jan. 2022)	Establishes testing procedures and evaluation criteria.
	Auction Standards	EV Battery Return and Collection Notice (MoE)	Public Notice on the Return of End-of-Life EV Batteries (Jan. 2022)	Sets standards for return pricing by the state and municipalities.

36) sandbox system: a framework that enables companies to test innovative product or services under relaxed regulatory requirements for a limited period'

<Table 4-2> continue

Category	Regulation	Detailed Provision	Description
Reuse	Electrical Appliances and Consumer Products Safety Control Act (MOTIE)	Enforcement of Public Notice Following the Newly Enacted Provisions of the Electrical Appliances and Consumer Products Safety Control Act (Oct. 2023)	Reinforces safety management standards for reused batteries.

Source: Prepared by the author

1) Clear Definitions and Legal Framework

The legal foundation for battery recycling must start with clear definitions and responsibilities for handling end-of-life batteries. Indonesia currently lacks specific legislation for end-of-life battery management. Drawing from global practices, including the EU's Batteries Directive and Korea's EPR model, Indonesia can introduce legislation that categorizes used batteries as a resource with significant potential for reuse and recycling. This would create legal obligations for manufacturers and consumers so that the life cycle of batteries is properly managed from production to disposal (Su et al., 2025; Farmer & Watkins, 2023).

2) Extended Producer Responsibility (EPR)

EPR is a critical component of many global systems, including the EU and Japan. This model mandates that manufacturers bear responsibility for the disposal and recycling of the batteries they produce. By adopting an EPR system, Indonesia can make sure that manufacturers are incentivized to design batteries that are easier to recycle and are responsible for financing and managing their recycling at the end of the product's life (Su et al., 2025; Feng, Guo, & Xu, 2024).

3) Battery Passport

The concept of a battery passport, seen in the EU's regulatory framework, would be a vital legal tool for tracking the life cycle of each battery from production to disposal. By incorporating such a system, Indonesia could mandate that all batteries are recycled properly and that manufacturers adhere to agreed-upon recycling targets. This traceability system ensures greater accountability, efficiency, and transparency in the recycling process (Farmer & Watkins, 2023; Su et al., 2025).

4) Clarifying Recycling Obligations

Clear legal definitions and obligations regarding the collection, recycling, and reuse of batteries will help reduce environmental hazards. This would include clear guidelines on the steps manufacturers and consumers must take at different stages of the battery life cycle for compliance with national recycling targets and promoting a circular economy (Su et al., 2025; Farmer & Watkins, 2023).

1.3.2. Regulatory aspects

Indonesia currently lacks a core management system for used battery condition assessment criteria, quality assurance procedures, and traceability systems, so it is important to introduce a four-step regulatory system consisting of “assessment, grading, certification, and traceability” to ensure the safety of used batteries and minimize environmental hazards. First, state of health (SOH)-based condition diagnosis criteria should be established, as well as a grading system to categorize the suitability for reuse and recycling. Second, a certification system based on these standards should be included in the national standardization (SNI) system to secure legal enforcement. Third, design a structure that enables integrated inspection, certification, and registration centered on public certification bodies, as in the case of Jeju Technopark (Jeju TP) and Korea Testing Laboratory (KTL), and fourth, establish a digital-based history management system (battery passport) that can accumulate and link certification results and battery history information. The regulatory framework should be designed to work in both central government-led and local government or private sector-led models, and it is critical to legally specify who is responsible for each step and for the data.

1) Recycling Technology Standards

A well-established regulatory framework for battery recycling technologies is crucial. As highlighted by China’s recycling practices and the EU’s Batteries Directive, effective regulations ensure that only the safest and most efficient recycling technologies are used. For Indonesia, adopting and enforcing standards for recycling processes such as direct cathode regeneration and hydrometallurgical processing would improve recovery rates of valuable metals such as cobalt, nickel, and lithium, thus reducing the need for new raw material extraction (Su et al., 2025; Jose et al., 2024). In particular, Korea has made various efforts to standardize battery recycling technologies. As part of this initiative, the Korean Agency for Technology and Standards (KATS) launched a standardization council for EV battery recycling in 2022, bringing together experts from industry, academia, and research

institutions. In 2023, KATS further advanced the standardization of the entire life cycle of used batteries by announcing the “Standardization Strategy for Used EV Batteries”.

2) Integrated Collection and Recycling System

Indonesia needs to establish an integrated collection and recycling infrastructure. Global examples from Japan and China highlight the importance of centralized recycling facilities supported by local collection points. The EU’s Batteries Directive mandates that batteries be collected separately and sent to designated recycling facilities so that batteries are not mixed with general waste, which could lead to environmental contamination (Farmer & Watkins, 2023; Su et al., 2025). To promote the efficient collection and recycling of used batteries, Korea is establishing a Used Battery Resource Circulation Cluster in the Pohang Blue Valley National Industrial Complex. Additional facilities such as an inline automated evaluation center and a dedicated LFP battery demonstration center are also under construction. These developments aim to create a central hub where the entire process of battery recovery, diagnosis, disassembly, and recycling can be carried out in one location.

3) Incentivizing Recycling through Legislation

To foster private sector participation, Indonesia can introduce policies that provide financial incentives for companies to engage in the recycling industry. Financial incentives, such as subsidies for setting up recycling facilities or tax credits for manufacturers that recycle their products, are key strategies used in countries such as the EU and China (Feng, Guo, & Xu, 2024). The Korean government is also providing various legal incentives to promote the battery recycling industry. In particular, a recycled material certification system will be introduced in 2025 to certify materials such as cobalt and nickel extracted from used batteries as recycled resources. The system will encourage their use above a certain percentage in the production of new batteries. Additionally, the government is promoting private sector participation by offering tax credits and subsidies to recycling companies. These policies will not only encourage greater participation from private companies but also help lower the financial burden of establishing the necessary infrastructure for battery recycling (Farmer & Watkins, 2023).

4) Multi-Stakeholder Approach

A collaborative approach between governments, industries, consumers, and researchers is essential for the successful implementation of an end-of-life battery management system. Insights from Japan and China demonstrate that involving multiple stakeholders ensures

that the battery life cycle is efficiently managed from initial design to recycling. Korea has also been making various efforts to establish a used battery management system with multilateral cooperation. For example, a public-private Battery Alliance has been formed to secure supply chains for key minerals and materials, and to collaborate on strengthening competitiveness in areas such as battery management systems, investment, workforce development, and research and development (R&D). In Indonesia, it would be vital for the Ministry of Environment, EV manufacturers, and recycling companies to collaborate in developing policies that incentivize innovation and enforce regulations (Feng, Guo, & Xu, 2024).

1.3.3. Financial aspects

The establishment of a battery recycling infrastructure requires significant upfront costs, and financial support from the government is essential to encourage private sector participation. First, national financing is needed for the establishment of a centralized center and demonstration facility, including collection and storage infrastructure, inspection equipment, and operating costs. Second, market participation should be encouraged with a variety of incentive designs, including tax incentives for private companies, subsidies for equipment introduction, and preferential contracting rights. Third, co-investment schemes with international partners such as KOICA and GGGI can be used to diversify financing. These financial incentives will increase the likelihood of success of the demonstration project and form the basis of a public-private role-sharing structure.

1) Government Financial Support

Establishing a battery recycling infrastructure also requires significant investment, which may initially be a barrier for the private sector. The EU and China provide financial incentives such as grants, subsidies, and low-interest loans to support the establishment of recycling facilities. Indonesia can adopt a similar model to ease the financial burden on recycling companies and make it easier for them to scale up operations (Farmer & Watkins, 2023; Su et al., 2025).

2) Public-Private Partnerships (PPP)

PPPs have proven to be an effective way to finance large-scale recycling infrastructure. In China, government support has been pivotal in funding recycling projects, while the private sector has provided the technical expertise and operational capacity to manage these projects. Indonesia could also encourage PPPs to leverage both public funding and private

sector expertise to build a sustainable recycling infrastructure (Jose et al., 2024; Feng, Guo, & Xu, 2024).

3) Recycling as a Market-Driven Industry

The financial viability of recycling will depend largely on the recovery of valuable metals from used batteries. Global estimates suggest that the market for lithium-ion battery recycling could reach USD 31 billion by 2040. Indonesia can help create a profitable market for battery recycling by facilitating the recovery of metals such as cobalt, nickel, and lithium, all of which are critical for new battery production and in high demand globally. Financial mechanisms such as tax incentives, export credits, or market guarantees can stimulate the recycling market and encourage more players to enter the sector (Farmer & Watkins, 2023; Su et al., 2025).

4) Reducing Costs through Recycling Incentives

The costs associated with battery recycling, particularly in Indonesia, can be high without appropriate financial incentives. Countries such as Japan have addressed this by creating voluntary schemes where manufacturers are incentivized to establish efficient recycling systems. Indonesia can build on these experiences by introducing similar incentives, particularly for domestic companies involved in battery production and recycling (Feng, Guo, & Xu, 2024; Jose et al., 2024).

1.4. Phased action plan and roadmap

A roadmap for strengthening Indonesia's end-of-life battery recycling capacity needs to be approached from an integrated perspective that encompasses intergovernmental cooperation, private sector participation, institutionalization, and infrastructure development. Currently, Indonesia has a strong interest in battery manufacturing and export, but limited investment in end-of-life battery recycling infrastructure and a lack of clear safety standards and guidelines for steps such as collection, transportation, and storage. Therefore, the following strategy and roadmap needs to be implemented in phases. These roadmaps should be linked to Indonesia's circular economy strategy and battery industry development strategy in the medium to long term, and the possibility of commercializing KSP projects as a follow-up policy should also be considered.

The key characteristics of the two policy frameworks are summarized in the table follow:

<Table 4-3> Characteristics of Phased Action Plans and Roadmap Scenarios

Category	Policy Framework 1: Government-led	Policy Framework 2: Private sector-led
Legal Basis	Government-led legislation enactment, specification of public responsibility, EPR legislation in the form of returning to companies after government inspection (Government-inspected return model)	Operation of sandbox, EPR legislation in the form of immediate return to companies upon end-of-life battery generation (Immediate return to producer model)
Infrastructure	Establishment of public integrated support centers	Centered on private recycling facilities
Certification	Led by public certification bodies, later expanded to private sector	Registration-based system for private certification bodies
Funding	Government budget and matching with international funds	Private investment promotion and policy financing support
Long-term Strategy	Nationwide expansion followed by transfer to private sector	Independent private operation with government oversight

Source: Prepared by the author

1.4.1. Government-led Policy Framework Model

In this scenario, the central government directly leads the entire process of policy implementation, and all key elements such as legislation, financial investment, infrastructure construction, and establishment of technical standards are designed and implemented by the government. As in the case of Jeju Island’s initial end-of-life battery project, the government takes the lead to resolve institutional uncertainties and create a technological and industrial foundation, leaving room for private expansion. It is suitable for countries such as Indonesia, where the system for used batteries is still in its early stages. This model is well-suited for Indonesia to design institutional frameworks and implement pilot projects in the early stages, while also facilitating the establishment of a foundation for future private sector expansion. Moreover, it allows for a smooth transition to a hybrid scenario in the long term.

1) Structural Features and Policy Directions

The core of the government-led model lies in institutionalization and infrastructure development. First, end-of-life batteries must be defined not as waste, but as recyclable circular resources, and this definition should be stipulated in law to clarify administrative responsibility. Based on this legal foundation, relevant ministries such as the Ministry of Environment, the Ministry of Industry, and the Ministry of Transportation can revise subordinate regulations concerning the designation of collection entities, standards for

temporary storage facilities, prohibited actions, and associated penalties. Furthermore, as demonstrated by the early case of Jeju Province, it is important to establish the principle that the state bears the responsibility for handling used batteries as public resources. This is an institutional precondition for the eventual transfer to the private sector and becomes a critical measure for clarifying administrative responsibility for end-of-life batteries in Indonesia as well. Additionally, the Indonesian Ministry of Environment must establish policies and guidelines for the management of hazardous waste, including spent EV batteries. The ministry plays a key role in addressing the environmental issues associated with battery disposal and recycling, and is responsible for ensuring that appropriate policies are put in place and effectively monitored. It also oversees the enforcement of regulations, ensures that industry and stakeholders comply with proper disposal and recycling procedures, and promotes the widespread adoption of environmentally sustainable practices in the battery handling process.

Second, a certification and classification system must be established. A state of health (SOH) standard and a grading system are required to assess battery condition and determine whether they are suitable for reuse or recycling. These can be developed under the leadership of the National Standardization Agency (BSN) or the National Research and Innovation Agency (BRIN), based on international standards such as those of the International Electrotechnical Commission (IEC), UN 38.3 for battery safety, and Korea's KC certification standards. International guidelines and regulations provide useful references for designing testing, grading, and certification systems. For example, IEC standards provide globally recognized benchmarks for battery safety and performance. The UN 38.3 guidelines, which focus on the safety and stability of batteries during transport, must also be taken into account in the grading process. The EU's Waste Electrical and Electronic Equipment (WEEE) Directive and the regulations of the U.S. EPA also offer policy frameworks that can be applied to the development of battery recycling and disposal systems. However, these standards must be adapted to suit Indonesia's technical capabilities and testing environment. Certification results should be registered in the form of a battery passport, and uncertified batteries should be restricted from distribution and reuse. Over time, the system should evolve into a more diversified structure through partnerships with private testing institutions. In particular, a robust traceability mechanism, a battery passport, should be developed to prohibit the reuse and circulation of uncertified batteries and to track the entire life cycle from post-collection to resale.

Third, infrastructure development based on public financing is required. In a central government-led business model, the most important element is investment in public infrastructure. The government must design integrated support centers and establish

regional hubs where collection, storage, inspection, and registration are carried out in a single process. Infrastructure budgets can be sourced not only from the national budget but also through linkage with international funding agencies such as KOICA and GGGI. As in the case of Jeju Technopark (Jeju TP), it is effective to design a structure in which testing, grading, and database registration are conducted simultaneously within the integrated support center. Jeju TP provides a model where batteries are thoroughly inspected, graded, and registered in a database after collection in order to track the entire process leading to reuse or recycling. This model is applicable to Indonesia as well, and a system can be established so that all batteries are properly graded and then reused or recycled for new purposes. In the early stages of implementation, the public sector should take the lead in operations. However, in the longer term, after the model is stabilized, certain functions such as testing, storage, and resale can be monetized or delegated to the private sector for a gradual transition. In particular, by gradually introducing an EPR scheme, the government can initially assume full responsibility for infrastructure operation, but later transfer responsibilities for collection, reuse, and recycling to battery manufacturers and importers. This evolution enables the institutionalization of circular economy principles even in a government-led model and serves as a key policy tool to promote private sector participation. Support measures such as tax credits or VAT exemptions for certified reuse operators can be introduced in parallel to facilitate private sector participation.

Fourth, coordination and overarching governance should be led by the Ministry of National Development Planning (BAPPENAS), which would be responsible for coordinating the division of functions among the Ministry of Industry, the Ministry of Environment, the Ministry of Transportation, local governments, and BRIN. Learning should be taken from the Coordination Committee EV Road Transport Program Acceleration established under Presidential Regulation 55/2019. This is a core governance mechanism for ensuring the medium- to long-term consistency and sustainability of policies. In this scenario, BAPPENAS, as the lead agency, must coordinate the roles of relevant ministries in accordance with their respective mandates. As the authority responsible for national development planning, BAPPENAS plays a central role in integrating the management of end-of-life batteries as circular resources into Indonesia's medium- and long-term national development plans. It must lead the formulation of a comprehensive policy that includes the efficient management of battery waste, the development of recycling infrastructure, and the participation of the private sector and civil society. If this collaborative coordination is carried out effectively, the scenario can be implemented smoothly and contribute positively to Indonesia's environmental governance and carbon emission reduction targets.

2) Key Case Study and Policy Implications: Korea's Government-Led Integrated Management System

Korea is a country that actively piloted a government-led integrated management model from the early stages of establishing a system for the recycling of end-of-life EV batteries. A notable example is the pilot project centered on Jeju Province. In a policy framework jointly designed by the Ministry of Environment and the Ministry of Trade, Industry and Energy, this model establishes an integrated system that covers battery collection, storage, grading, database registration, reuse, and recycling.

Since 2019, Jeju Province has established a system in which used batteries collected from local public infrastructure are transferred to the End-of-Life Battery Integrated Management Center operated by Jeju Technopark (Jeju TP). Upon receipt, the center conducts visual inspection and performance diagnostics, classifies the batteries based on the state of health (SOH) criteria, and registers the results in the national integrated tracking system. Batteries with a remaining capacity of 60% or higher are reused for ESS, while those below 60% are sent to private recycling companies for metal extraction processes.

This model is classified as a typical government-led system, in which the government directly designed the battery tracking system and led the development of initial infrastructure and certification standards. In particular, under the Ministry of Environment's Notification on the Return of End-of-Life EV Batteries (2022), the national and local governments are responsible for collecting and storing such batteries and supplying them to private businesses, thereby establishing a structure in which the public sector controls and coordinates the entire path from collection to reuse and recycling.

The system is currently evolving into a decentralized structure that induces private sector participation under public leadership. In the future, certain profit-related functions such as battery auctions and private distribution are expected to be gradually transferred to the private sector. As a region-based integrated hub model, the Jeju TP model can be an effective reference for designing pilot projects led by local governments in Indonesia.

The Jeju TP case is evaluated as a successful government-led model in which the central government directly designed and implemented the institutional and infrastructural foundation, enabling the stable establishment of the end-of-life battery management system in its initial phase. In particular, the integrated operation of the entire cycle from collection, diagnostics, and grading to reuse/recycling in a single hub has contributed to simplifying coordination among complex stakeholders and increasing policy credibility. This provides a

valuable reference for countries such as Indonesia, where the institutional framework and industrial ecosystem are still in their infancy. It offers key lessons for the early-stage policy design, such as conducting pilot projects led by local governments and public institutions, developing integrated support centers, and establishing a national-level tracking system. In the long term, it is desirable to design a public–private partnership model that anticipates the eventual transfer of responsibilities to the private sector, as seen in the Jeju case.

1.4.2. Private-led Policy Framework Model

This scenario is a policy framework that shifts the center of gravity for end-of-life battery management from the public to the private sector, specifically producers (end-use vehicle and battery manufacturers), distributors, and recycling specialists. Similar to the European Union’s EPR system, which requires producers of products to take responsibility for the environmental impacts of their products when they are disposed of after use, Korea is currently in the process of phasing in EPR in some areas. This model may be an important transition direction for Indonesia to build a market-friendly and sustainable circular economy ecosystem in the long term.

1) Structural Features and Policy Directions

The core of the private sector–led model lies in the transfer of responsibility and the provision of incentives. To this end, it is necessary to enact a special law or amend existing resource management legislation to include EPR as a key provision for EV batteries. Specifically, EPR legislation should be introduced so that manufacturers, sellers, and importers bear legal responsibility for the collection and recycling of end-of-life batteries. The four key principles of EPR are: (1) the obligation to prevent pollution, (2) a life cycle approach to product management, (3) the polluter pays principle, and (4) internalization of environmental costs (UNEP, 2020). However, considering Indonesia’s current institutional capacity, a regulatory sandbox may be introduced during the transitional or initial phase to pilot the system, followed by the formal institutionalization of requirements such as collection rates, reporting obligations, and penalty provisions.

Second, it is necessary to permit a decentralized structure for the registration of certification bodies and the management of battery tracking systems. Private testing laboratories, diagnostic centers, and recycling companies that meet government-defined standards could be authorized to conduct self-certification. In this model, the role of the government would focus on oversight and monitoring. To enable the private sector to autonomously handle the collection, inspection, reuse, and recycling of end-of-life batteries,

public regulatory intervention must be minimized while establishing a market-driven quality assurance system. The government would set only the fundamental safety and environmental standards and guidelines for the collection system, while the certification and evaluation bodies could be operated by the private sector. For this, a certification body registration system or a post-evaluation–based certification framework should be introduced.

Third, Indonesia may consider introducing mandatory standards on the utilization rate of recycled batteries, following the European model. For instance, policies could require a certain proportion of recycled materials in EV batteries or provide tax reductions and export incentives for companies that meet specific collection targets. These mechanisms can be linked to ESG-based “green product certification” schemes. For example, requiring that at least 30% of the materials in imported or domestically produced EV batteries consist of recycled content could serve as a powerful policy tool to promote both battery recycling and resource circularity.

<Table 4-4> Recovery target of EU countries

Measure	Option 2 – medium level of ambition	Option 3 – high level of ambition	Option 4 – very high level of ambition
Collection rate for portable batteries	65% collection target in 2025	70% collection target in 2030	75% collection target in 2025

Source: EU battery regulation (2023)

As shown in the table above, the EU has mandated clear collection targets and minimum recycled content requirements for specific battery types through the Battery Regulation (EU) 2023/1542, adopted in July 2023. The regulation, effective from February 2024, outlines differentiated scopes and core obligations for companies based on five main battery categories: portable batteries, SLI batteries, LMT batteries, electric vehicle batteries, and industrial batteries. In particular, the mandatory minimum recycled content rates and their respective implementation dates for each battery type under the regulation are summarized follow.

<Table 4-5> Minimum Recycled Content Requirements by Battery Type

Implementation Date	From 18 August 2031	From 18 August 2036
Applicable Batteries	Industrial batteries (>2 kWh) EV batteries SLI batteries	Industrial batteries (>2 kWh) EV batteries LMT batteries SLI batteries
Minimum Recycled Content	Cobalt: 16% Lead: 85% Lithium: 6% Nickel: 6%	Cobalt: 26% Lead: 85% Lithium: 12% Nickel: 15%

Source: EU battery regulation (2023)

Fourth, initial private sector-led pilot projects should begin in areas where private sector capabilities are concentrated, such as Jakarta and Bali, while establishing a collaborative framework with local governments to secure implementation capacity. For the private-led model to function successfully, a certain level of market entry incentives and policy-based financial support must be provided during the early introduction phase. For example, companies that meet battery collection targets may be given incentives such as tax reductions or R&D subsidies. In the longer term, incentives should also be introduced for the domestic distribution or export of recycled battery raw materials (e.g., black mass). Granting green product certification to manufacturers that use a certain percentage of recycled nickel, cobalt, and manganese can be both a gateway to the ESG market and a driver to improve the sustainability of the recycling industry.

2) Key Case Study and Policy Implications: EU Regulation on Batteries and Waste Batteries

In 2023, the European Union (EU) officially adopted the comprehensive Regulation (EU) 2023/1542 on Batteries and Waste Batteries, which replaces the previous Battery Directive (Directive 2006/66/EC). This new legal framework has direct applicability to all member states and imposes binding obligations throughout the entire life cycle of batteries. It applies to all battery types, including EV batteries, industrial batteries, SLI batteries (starting, lighting, ignition), and light means of transport (LMT) batteries. Its core objectives are to promote a circular economy and ensure environmental and social sustainability.

The most critical provision of the regulation is the legal institutionalization of the EPR system. According to this regulation, all battery producers are legally responsible for the environmental impact of their products once they reach end-of-life, and are

obliged to establish and operate the necessary infrastructure for collection and recycling. Accordingly, each member states is required to set battery collection targets and impose specific compliance responsibilities on producers. For example, the collection rate targets for portable batteries must reach 63% by 2025 and 73% by 2030, while LMT batteries must achieve 51% by 2028 and 61% by 2031.

In addition, the battery passport system, which requires unique digital passports for industrial and EV batteries, will be introduced in February 2027. These passports will track and manage essential data such as material composition, origin, carbon footprint, life expectancy, usage history, and recycling rate. Moreover, the regulation mandates a minimum percentage of recycled content in battery manufacturing, to be implemented in phases. From 2031, EV and industrial batteries must contain at least 6% lithium, 16% cobalt, 6% nickel, and 85% lead sourced from recycled materials, and by 2036, these thresholds will increase to 12% lithium, 26% cobalt, 15% nickel, and 85% lead.

While these regulations increase the burden on producers, they also act as incentives for participating in the circular economy market. Private companies with certified recycling technologies can meet the EU's market access requirements and gain a competitive advantage in the high-value recycled materials market. In parallel, national governments are deploying various policy tools such as subsidies and tax benefits to stimulate private investment.

The EU case demonstrates a governance model in which the private sector acts as the primary agent for battery collection and recycling, while the government plays a facilitating and supervisory role through clear regulations and market incentives. In particular, in conjunction with the EPR system, Regulation 2023/1542 provides a legally binding yet economically incentivized framework. It also aligns with ESG standards and international trade norms through instruments such as the battery passport and mandatory recycled content requirements. This serves as an important reference point for Indonesia as it seeks to support the growth of its private sector ecosystem and align with global market standards. However, for stable private sector operation, it is important to accompany this transition with initial policy-based financial support, tax incentives, and the establishment of a reliable certification system. A gradual implementation strategy tailored to Indonesia's institutional characteristics and private sector capacity is also necessary.

3) Integrated Roadmap Based on a Phased Action Plan

a) Integrated Roadmap

To establish a system for recycling end-of-life batteries in Indonesia, it is necessary to develop a phased action plan that spans the entire recycling value chain. The implementation approach may vary at each stage depending on the lead actor—whether it is the government or the private sector. Accordingly, based on case studies from Korea and other key countries, this study has derived two scenarios categorized by the leading actor. The integrated roadmap matrix below outlines the common procedural steps, while highlighting the differentiating elements by actor in each phase.

The government-led scenario is a model in which public institutions such as the Ministry of National Development Planning (BAPPENAS), the Ministry of Industry, the Ministry of Environment, the Ministry of Transportation, local governments, and the National Research and Innovation Agency (BRIN) play a central role in directly operating traceability systems, collection mechanisms, and recycling certification schemes based on public infrastructure. In this model, systems for technical certification, storage, and reuse are designed at the central level and applied at the local level, as exemplified by the case of Jeju Province.

In contrast, the private sector-led scenario is centered on OEMs, battery manufacturers, and private recycling companies, which oversee the entire process of collection and recycling based on market-driven demand. In this model, the government performs only minimal roles in setting basic standards and conducting oversight. This approach is reflected in key examples from the EU and the United States.

<Table 4-6> Integrated Roadmap Matrix

Phase	Core Function	Government-led Scenario	Private-led Scenario
1. Battery Registration and Traceability	Establishment of a traceable database from production to disposal; mandatory registration	Government-led development of a centralized database platform; mandatory registration by producers	OEMs and battery manufacturers build proprietary databases linked to government standards
2. Collection and Retrieval System	Collection of batteries at the point of vehicle dismantling or repair	Public collection system operated by local governments/Ministry of Environment (e.g., Jeju TP model)	Collection based on contracts among OEMs, distributors, and logistics providers

<Table 4-6> continue

Phase	Core Function	Government-led Scenario	Private-led Scenario
3. Storage, Transport, and Safety Management	Transport of hazardous materials, temporary storage, and compliance with safety standards required	Operation of government-certified transport companies and public storage facilities; operation of diagnostic and classification centers with issuance of certifications	Transportation based on contracts with private logistics providers; self-storage permitted if government standards are met
4. Diagnosis and Classification	Assessment of reusability and performance classification		Operation of diagnostic centers by private entities or OEM-affiliated facilities; third-party certification possible
5. Determination of Proper Treatment Route (Reuse/ Recycling)	Routing to secondary use (reuse) or metal recovery (recycling) based on diagnostic results	Public sector-led reuse model; operation of a government-run recycling certification scheme	Reuse, distribution, and recycling carried out by private sector operators
6. Metal Recovery and Recycling Process	Recovery of lithium, cobalt, etc. from waste batteries	Recycling plants operated by state-owned enterprises or with government investment	Introduction of high-efficiency recycling processes by private sector
7. Certification and Post-Market Management	Quality assurance, compliance with environmental regulations, and control of imports/exports	Government-led certification system (e.g., KC, SND); mandatory reporting framework	Private sector self-certification through accredited agencies; government provides standards and oversight

Source: Prepared by the author

b) Korean Reference Cases for Estimating Projected Costs

The establishment of integrated infrastructure for the safe collection, storage, diagnosis, reuse, and recycling of end-of-life batteries requires a significant level of initial investment. The case of Jeju Province in Korea serves as a representative precedent for such infrastructure development, and the actual scale of public financial investment and breakdown by component offer valuable reference points for policy design in Indonesia.

Jeju TP established the Jeju EV Battery Industrialization Center through three phases of government-funded projects. The total project duration spanned approximately seven years (2017–2024), and total funding reached approximately KRW 40.7 billion (equivalent to around USD 30 million). The first phase (2017–2019) focused on building physical facilities for the collection and storage of used batteries, while the second and third phases (2020–2024) concentrated on building infrastructure for battery reuse certification and testing equipment.

<Table 4-7> Status of the Jeju EV Battery Industrialization Center

Location	241 Cheomdan-ro, Jeju-si
Scale	Building (total floor area: 2,345.4m ²) (Performance Evaluation Building: 1,272.43m ² , Safety Testing Building: 666.23m ² , Office Building: 406.74m ²)
Storage Capacity	Up to 350 EV batteries
Operating Body	Jeju Technopark (Energy Center)
Opening Date	June 26, 2019
Main Roles	Collection and storage of EV batteries Battery safety testing Public utilization and sale of EV batteries
Major Milestones	<p>2017: Launch of the “Global EV End-of-Life Battery Recycling Center” project (~2019, Ministry of Trade, Industry and Energy)</p> <p>2019: Opening of the EV Battery Industrialization Center (June 25, 2019) Implementation of the “Special Regulatory Free Zone for EV Charging Services” (~2022, Ministry of SMEs and Startups)</p> <p>2020: Establishment of the Energy Convergence Center organization (Performance Evaluation Team, Utilization Technology Development Team) Enforcement of the “Jeju Special Self-Governing Province Ordinance on the Return and Treatment of EV Batteries” Promotion of the “Diversification Project for Public Infrastructure-Based EV Battery Utilization” (~2022, Ministry of Trade, Industry and Energy)</p> <p>2021: Designated as the official EV Battery Specialized Institution of Jeju Special Self-Governing Province</p> <p>2022: Completion of the Battery Safety Testing Building (Oct. 11, 2022) Accredited as a KOLAS Testing Laboratory (IEC 62619, 62620 / Oct. 20, 2022) Launch of the “Infrastructure Project for Testing and Certification Support of Remanufactured EV Battery Products” (~2024, Ministry of Trade, Industry and Energy)</p> <p>2023: Designated as Korea’s first authorized institution for reused battery safety inspection (Oct. 19, 2023)</p>

Source: Prepared by the author

The following table summarizes the investment components and budget allocations by major infrastructure development project led by Jeju TP.

<Table 4-8> Summary of Project Budget for End-of-Life Battery Infrastructure Development at Jeju TP

Project Title	Implementation Period	Total Budget (KRW 100 million)	Key Description	Established Facilities
<ul style="list-style-type: none"> EV Battery Reuse Center Establishment Project (System Industry Hub Support Project) 	Apr. 2017 – Dec. 2019 (33 months)	190	<ul style="list-style-type: none"> Establishment of infrastructure for reuse of end-of-life batteries and development of a dissemination model 	<ul style="list-style-type: none"> Storage Capacity: 350 units Battery Performance Evaluation Capacity: three packs/day, 24 modules/day
<ul style="list-style-type: none"> Diversification Project for EV Battery Reuse Linked to Public Infrastructure (Smart Specialization Infrastructure Project) 	Apr. 2020 – Mar. 2023 (36 months)	132	<ul style="list-style-type: none"> Development of a diversified platform and equipment expansion for reuse of batteries linked to public infrastructure 	<ul style="list-style-type: none"> Safety Testing Building: Equipped with 13 safety evaluation devices
<ul style="list-style-type: none"> Establishment of Testing and Certification Infrastructure for Remanufactured Products Using End-of-Life EV Batteries (Smart Specialization Infrastructure Project) 	Apr. 2022 – Dec. 2024 (33 months)	85	<ul style="list-style-type: none"> Establishment of a foundation for diversification of application fields through testing and certification of reused EV battery products 	<ul style="list-style-type: none"> Battery Testing and Certification Diversification: Equipped with eight devices for product safety and reliability evaluation

Source: Prepared by the author

In the case of Indonesia, while the penetration rate of electric vehicles and the industrial base remain lower compared to Jeju Province, the country possesses significant potential demand for battery recycling due to its abundance of mineral resources. Therefore, infrastructure development should begin with a scaled-down model and be designed with gradual expansion in mind.

For instance, simplified pilot centers focused primarily on collection, storage, and initial diagnostics may be established in major cities such as Jakarta and Bali in the short term.

In the medium to long term, as functions such as reuse certification and metal recovery preprocessing are added, additional investments will be required for advanced equipment and workforce training. In this regard, the Indonesian government may consider adopting a fund-matching mechanisms to actively attract mobilizing not only national... but also external but also through bilateral and multilateral cooperation projects.

c) Challenges

There are technical and economic challenges in the process of establishing and expanding a used-battery recycling system in Indonesia. For example, lithium iron phosphate (LFP) batteries, whose share in the secondary battery market has recently been increasing, contain a lower proportion of high-value metals compared to nickel–cobalt–manganese (NCM) batteries. Due to their chemical characteristics of containing mainly lithium, iron, and phosphate, the pace of technological development for recycling processes has been relatively slow. This hinders improvements in recovery rates and makes it difficult to achieve cost efficiency in recycling operations. In addition, products derived from recycled LFP materials generally have lower economic value, which weakens market competitiveness and may even lead to higher environmental treatment costs. These structural limitations make it difficult for the private sector to secure profitability on its own, and a stable recycling system is unlikely to take root without public intervention. Therefore, the Indonesian government needs to provide policy support to offset part of the environmental treatment costs, expand investment in R&D for LFP recycling technologies and recovery rate improvements, and strengthen related laws, regulations, and international cooperation. By doing so, it can compensate for the limitations of a market-driven approach and secure the sustainability of the overall recycling ecosystem, including LFP batteries, in the long term.

4) Comprehensive Policy Recommendations

Given Indonesia's industrial structure, the functional capacity of local governments, and the policy implementation capabilities of BRIN, a mixed approach appears most suitable rather than a model led by a single actor. For example, functions such as battery traceability registration, certification, and the formulation of quality standards may be led by the government, while collection, logistics, diagnostics, and parts of the recycling process may be delegated to the private sector. This would help maximize resource efficiency while reducing the fiscal burden on the government.

In particular, a decentralized hybrid governance model in which the government provides the normative framework and minimum infrastructure, while the private sector undertakes commercialization based on profitability, especially through recycling hubs linked with local governments, would be appropriate. This mixed model should follow a time-sequenced implementation approach and can be designed with a time-sequenced implementation strategy divided into short-term, mid-term, and long-term phases.

a) Short-Term: Government-led Institutional Framework Development and Public Pilot Projects

In the short term, the focus is on the government laying the foundational groundwork for the overall system. The core objective is to establish an implementation framework centered on public pilot projects, accompanied by legal and regulatory reforms.

<Table 4-9> Short-Term Action Plan

Phase	Implementation Details
1. Battery Registration and Traceability	<ul style="list-style-type: none"> Design of a registration system led by BAPPENAS, Ministry of Industry, and Ministry of Environment; mandatory producer registration
2. Collection and Retrieval System	<ul style="list-style-type: none"> Implementation of public collection pilots led by the Ministry of Environment and local governments
3. Storage/Transport and Safety	<ul style="list-style-type: none"> Selection of candidate sites for local recycling hubs; establishment of standards for transport and storage of hazardous materials
4. Diagnosis and Classification	<ul style="list-style-type: none"> Development of diagnostic protocols based on BRIN certification; designation of government-led evaluation institutions and budget allocation
5. Determination of Proper Treatment Route	<ul style="list-style-type: none"> Design of public-based reuse pilot project, Pilot application of classification process into recycling, reuse, and EPR based on diagnostic results
6. Metal Recovery and Recycling	<ul style="list-style-type: none"> Planning of pilot recycling facilities led by public research institutes or state-owned enterprises; exploration of potential cooperation with private technology companies
7. Certification and Post-Market Management	<ul style="list-style-type: none"> Drafting of SNI-based reuse and recycling certification guidelines led by BRIN and BSN; preparation for introduction of safety standards and environmental regulations

Source: Prepared by the author

A battery traceability registration system should initially be designed under the leadership of the Ministry of Environment and the Ministry of Industry, and mandatory registration for OEMs can be piloted based on this system. For the battery collection system, BRIN and local governments may cooperate to implement public collection pilots in areas such as remote islands. Regarding storage and transport, the selection of candidate sites for regional recycling hubs and the establishment of public safety standards are priority tasks.

In addition, diagnostic and classification standards should be established by government-certified evaluation centers led by BRIN. It is also necessary to pilot public reuse projects

using ESS (e.g., battery-based models for supplementing rural electrification) to verify both technical and policy feasibility. Even in public-based reuse projects, the design should incorporate the concept of Extended Producer Responsibility (EPR) and take into account the long-term transition of responsibilities to manufacturers and importers. The project should include partial participation from private companies from the pilot phase. This is a critical preliminary step in establishing a foundation for transitioning to a privately led reuse and recycling system during the institutionalization process. For the certification system, BSN and related institutions should take the lead in introducing initial safety standards based on SNI and preparing a draft guideline for performance certification.

b) Mid-Term: Institutionalization of Private Investment Incentives and Role-Sharing Mechanisms

In the mid-term, the primary objective is to refine the institutional framework to enable more active participation by the private sector and to formalize a structure for sharing roles between public and private actors.

<Table 4-10> Mid-Term Action Plan

Phase	Implementation Details
1. Battery Registration and Traceability	<ul style="list-style-type: none"> Link private registration systems with government platforms; prepare for the introduction of the EU-style battery passport system
2. Collection and Retrieval System	<ul style="list-style-type: none"> Permit private collection networks to enter the market; establish standard contract models and compensation mechanisms
3. Storage/Transport and Safety	<ul style="list-style-type: none"> Implement a registration system for certified private transport and storage operators; connect regional hubs with private logistics providers
4. Diagnosis and Classification	<ul style="list-style-type: none"> Authorize private diagnostic institutions or OEM-affiliated centers to operate; expand government certification schemes
5. Determination of Proper Treatment Route	<ul style="list-style-type: none"> Expand distribution channels for reused batteries managed by private sector
6. Metal Recovery and Recycling	<ul style="list-style-type: none"> Promote entry of private recycling firms; foster SMEs based on technology transfer
7. Certification and Post-Market Management	<ul style="list-style-type: none"> Expand the number of private certification bodies; the government provides standards and performs an oversight role

Source: Prepared by the author

The traceability system will be further developed into a structure in which private

databases are linked with government systems, and a gradually integrated information platform similar to the EU's battery passport may be introduced over time. For the collection system, private sector collection mechanisms such as those linked to private platforms or electronics distribution channels will be permitted. These should be accompanied by standardized contract frameworks and incentive schemes.

Transport and storage should be opened to private logistics providers, with certification and contracting permitted only for entities that meet predefined technical and operational criteria. Diagnosis and classification will be carried out by manufacturers or independent diagnostic institutions, while the government acts as a certifying authority that establishes a dual-track system for the public credibility of private sector assessments.

In the reuse and recycling sectors, product development linked not only to public ESS systems but also to the private ESS market will be expanded. In the recycling industry, the government should encourage the participation of capable small and medium-sized enterprises (SMEs) by offering technical and fiscal support. The certification system will be fully transitioned to private actors (e.g., testing and consulting agencies), while the government focuses on standard setting and post-market supervision.

c) Long-Term: Establishment of a Market-Driven, Private Sector-Led Ecosystem

In the long term, a market-driven structure should be established in which the majority of the value chain is led by the private sector, and the government limits its role to setting minimum standards and performing oversight functions.

With the full-scale introduction of Extended Producer Responsibility (EPR), manufacturers and sellers will be held accountable for battery traceability and collection, and technologies such as tracking systems may be gradually implemented.

Collection, storage, and transport will be transitioned to private sector leadership, while local governments will provide only complementary support in underserved areas. Diagnosis and testing will be carried out in a self-regulated private ecosystem, and the government's role will be limited to monitoring the operation of certification bodies and advancing related technologies through policy. The reuse and metal recovery (recycling) sectors will be fully privatized, with the government shifting its role to supporting the industry with the promotion of R&D, deregulation of import/export controls, and investment incentives.

Finally, the certification and post-market management system will also be led by private certification agencies, while the government focuses solely on ensuring alignment with global standards and performing institutional oversight. This long-term vision can be developed with reference to the EU battery regulation framework, Korea’s industrialization center model, and the private sector–driven recycling systems of North America.

<Table 4-11> Long-Term Action Plan

Phase	Implementation Details
1. Battery Registration and Traceability	<ul style="list-style-type: none"> • Full implementation of EPR and establishment of a manufacturer/importer-led battery traceability system
2. Collection and Retrieval System	<ul style="list-style-type: none"> • Stabilization of a private sector–led collection system
3. Storage/Transport and Safety	<ul style="list-style-type: none"> • Opening of the private logistics market and promotion of hazardous materials transport sector; the government performs legal standard setting and oversight
4. Diagnosis and Classification	<ul style="list-style-type: none"> • Establishment of a private diagnostic ecosystem; the government oversees certification bodies and advances standards
5. Determination of Proper Treatment Route	<ul style="list-style-type: none"> • Promotion of market-driven battery trading and reuse
6. Metal Recovery and Recycling	<ul style="list-style-type: none"> • Expansion of private recycling facilities and application of high-efficiency recovery technologies
7. Certification and Post-Market Management	<ul style="list-style-type: none"> • Institutionalization of private certification systems; the government manages export/import regulations and responds to international standards

Source: Prepared by the author

2. Standardization and Certification Approaches

2.1. Reuse and Recycling Criteria for End-of-Life EV Batteries

End-of-life EV batteries can be managed through three primary routes: reuse, recycling, or direct disposal. Among these, both reuse and recycling require the establishment of national standards and technical guidelines for industrial stability.

The criteria for reuse should be based on objective indicators such as state of health (SOH) and direct current internal resistance (DCIR), which assess residual capacity and rapid charge-discharge performance. In contrast, recycling is predicated on full destruction and material recovery and focuses on dismantling methods, hazardous material handling, and environmental impact mitigation.

While many countries leave reuse and recycling to market discretion, some governments actively provide market formation support or incentives to promote reuse markets.

2.2. Quality and Safety Verification

Before repurposing used EV batteries for new applications, it is important to ensure durability and safety. Key verification elements include:

- SOH diagnostics: Evaluating residual performance based on collected battery data, and verifying charge/discharge efficiency
- Cell voltage imbalance check: To prevent thermal hazards
- Physical inspection for damage: Detecting shock, leakage, swelling, or deformation
- Insulation resistance and leakage current measurement: Ensuring electrical safety
- Safety tests: Including vibration, high-temperature, and short-circuit tests to determine suitability for second-life applications

These evaluations should be conducted by accredited certification bodies or third-party evaluation agencies following standardized testing protocols.

2.3. International Standard Alignment

In Indonesia, there are certification systems for electric vehicles (EVs) and electric two-wheelers, as shown in <Table 2-15, p.80>, but there are currently no established standards for the reuse of end-of-life (EOL) batteries installed in expired mobility assets. To prepare for future reuse of such batteries in energy storage systems (ESS), it is important to establish a certification system, while also ensuring international compatibility and mutual recognition frameworks to support the formation of a global battery reuse market.

- KC10031 (Korea): A Korean standard for evaluating the performance and safety of EOL EV batteries to determine their suitability for reuse in ESS and other applications.
- IEC 63330 (International): An international standard specifying methods for measuring residual performance and procedures for assessing the reusability of EOL EV batteries.
- UL 1974 (United States): A U.S. certification standard that provides criteria for assessing the safety and performance of EOL EV batteries at the module level for reuse.
- GB/T 33598 (China): A Chinese national standard that defines a stepwise utilization pathway for EOL EV batteries based on residual capacity, including reuse in vehicles, ESS, low-speed vehicles, and recycling.

Indonesia currently has not adopted a national standard (SNI) aligned with such international frameworks. Going forward, collaboration with Badan Standardisasi Nasional (BSN) will be required to adopt and adapt IEC- or UL-based standards.

2.4. Establishment of a Certification System

To commercialize reused batteries, a credible certification system is needed. The system should be structured as follows:

- Designation of a national certification agency with functions similar to Korea Testing Laboratory (KTL) or TUV Rheinland
- Pilot programs based on public-private cooperation: Public institutions should lead demonstration projects and work with private sector stakeholders to institutionalize the certification system

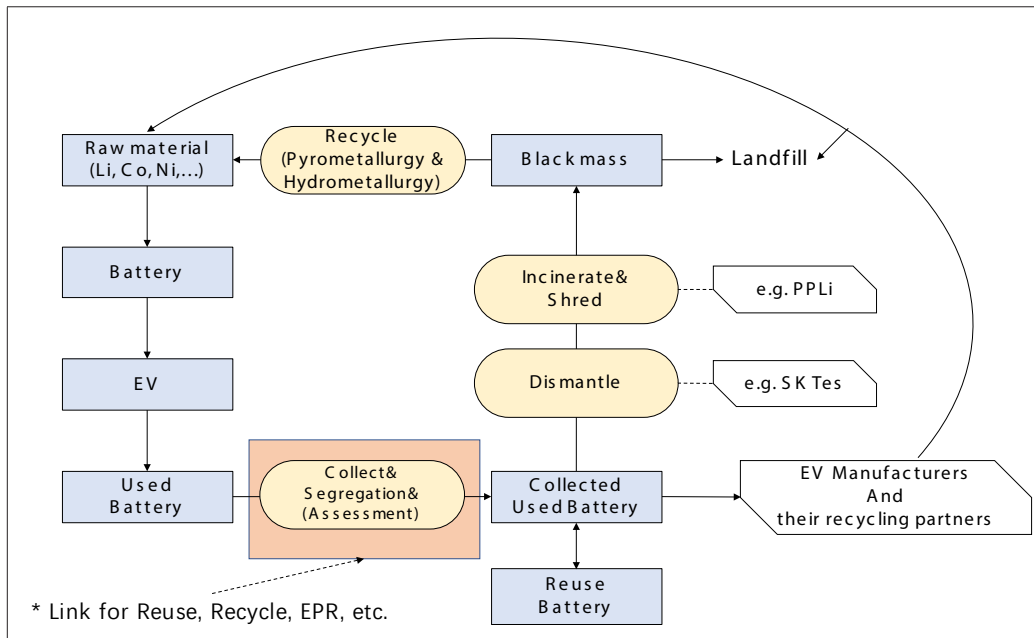
3. Proposed Pilot Project for EV Battery Recycling in Indonesia

3.1. Pilot Project for Used EV Battery Collection Center

3.1.1. Background and Rationale

In the first and second field studies, the consortium led by the Korea Testing Laboratory (KTL) identified the national circumstances of Indonesia, the status of EV deployment, and the country’s current capacity to manage used EV batteries. During this process, it was observed that discussions around the Extended Producer Responsibility (EPR) system had taken place between government ministries and EV manufacturers. Furthermore, it was confirmed that Indonesian government agencies have shown interest in introducing an EPR system. Accordingly, Indonesia will need to develop a policy framework that encompasses the recycling of used EV batteries and the implementation of EPR within the broader vision of a circular economy.

[Figure 4-3] Battery Life Cycle Structure and Missing Links



Source: Prepared by the author

In this context, the collection and safe storage of used EV batteries represent essential foundational steps, regardless of whether the batteries are to be reused, recycled, or managed under an EPR system.

Given its technical expertise and experience in the management of used batteries, the KTL consortium is well-positioned to support the establishment of a safe and efficient Used EV Battery Collection Center through bilateral cooperation. This pilot project would serve as a foundational model to support Indonesia in developing a sustainable battery circulation system and preparing for the expected surge in used battery volumes in the near future.

3.1.2. Functions and Processes of the Collection Center

1) Transfer and Transportation

When a certain quantity of used batteries is accumulated, or at regular intervals, transportation from major battery disposal sites such as dismantling yards is initiated. The necessary permits must be obtained from relevant authorities prior to transportation. The batteries are then packaged as hazardous materials, and a certified transport company moves them to the collection center in compliance with established safety protocols. The collection center records the receipt of each battery shipment.

[Figure 4-4] Explosion-proof Equipment for the Safe Transportation of Used Batteries



* Illustrative image

Source: Seoul Economic Daily and The Energy, "Mercedes-Benz Korea delivers 'Battery Safety Box' to local business site", December 27, 2023.

2) Receiving and Initial Inspection

Upon arrival, the batteries undergo an initial inspection to check for physical deformation, external damage, signs of leakage, or swelling. Battery identification numbers and relevant historical information are also recorded.

3) Insulation Resistance Measurement

The insulation resistance between the battery pack's terminals and outer casing is measured to verify electrical isolation. This procedure helps assess the risk of leakage current due to internal damage. A dedicated insulation resistance tester is used, and if the measured resistance is below the acceptable threshold, additional safety measures must be taken.

[Figure 4-5] Battery Inspection and Insulation Measurement



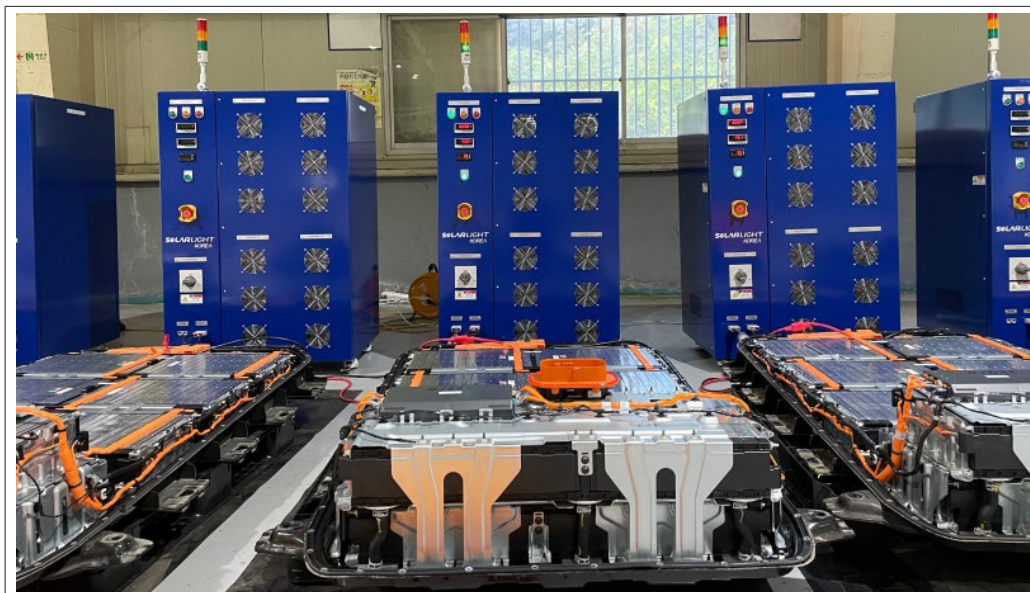
* Illustrative image

Source: SK echo plant Co., Ltd. Website (<https://news.skecoplant.com/plant-tomorrow/15551/>)

4) Residual Energy Discharge

Any remaining energy in the battery pack is fully discharged using a discharge device. Since fully charged lithium batteries pose significant safety risks, complete discharge is strongly recommended. The discharge device adjusts the current based on the battery's voltage and capacity, and any heat generated during the discharge process is managed using cooling fans or similar equipment. This procedure brings the battery's actual voltage close to 0 V to reach a safer state and significantly reduce the risk of fire during subsequent physical handling by workers.

[Figure 4-6] Complete Battery Discharge



* Illustrative image

Source: Solarlight Co., Ltd. Website (<http://www.solarlightkorea.com>)

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5) Safe Packaging, Labeling, and Storage

Once fully discharged, batteries are sealed and isolated in dedicated storage containers or racks. To prevent terminal short circuits, insulating tape or protective terminal covers are applied as needed. Each battery is labeled with identification information, including battery type, processing date, and condition. This allows for effective traceability for future transport or recycling.

6) Handover and Outbound Transport

When a certain volume of used batteries is accumulated, or at regular intervals (e.g., quarterly), they are transferred to recycling facilities or EV manufacturers for further processing. The collection center maintains records of all battery shipments and handovers for traceability.

3.1.3. Key Equipment

To ensure the safe operation of the collection center, the following equipment and facilities are required:

1) Battery Discharge Device

A device designed to rapidly discharge EV batteries of various voltages. It should support up to approximately 1000 Vdc and be equipped with multiple safety features such as overvoltage, overcurrent, short-circuit, and reverse polarity protection. A touchscreen control panel is recommended so that workers can monitor and control the discharge process in real time.

2) High-Voltage Insulation Resistance Tester

This instrument evaluates the insulation performance of battery packs and modules by applying a test voltage ranging from 500 V to 1000 Vdc. It determines whether the insulation resistance complies with safety standards based on IEC regulations.

3) Fire-Resistant Battery Storage Container

Dedicated containers or rack systems should be used to store individual used batteries safely. These should be constructed with thick steel plates and insulating materials to protect the batteries from external fire hazards and prevent the spread of flames in case of internal battery explosions. Some containers include ventilation valves and explosion-proof functions to release excess pressure safely. Each container should also be labeled with the battery type and date of storage for easy inventory tracking.

4) Logistics Equipment

To handle EV battery packs weighing several hundred kilograms, the center must be equipped with small forklifts, electric hoists, and cranes. The facility should have flat flooring for smooth transport, charging stations, and threshold-free paths. Roller conveyors may also be installed to improve efficiency.

3.1.4. Safety Facilities

1) Fire and Gas Detection Systems

The center should be equipped with smoke detectors, temperature sensors, and gas detectors (e.g., for hydrogen) to monitor environmental conditions in real time. Multi-gas detectors capable of detecting harmful gases such as hydrogen fluoride, which may be emitted during thermal runaway of lithium-ion batteries, must be installed. When threshold levels are exceeded, alarm lights and sirens should be triggered. All detection systems should be linked to a control room for 24/7 monitoring.

2) Fire Suppression Systems

A multi-tiered fire suppression system should be in place. Automatic sprinklers must be installed in battery storage areas for rapid response in case of a fire. ABC-class fire extinguishers and lithium-ion battery-specific extinguishers (e.g., Class D dry powder) should also be available. Firewalls and fire-resistant doors should be installed, and the storage containers themselves must be built with fireproof materials.

3) Personal Protective Equipment (PPE) and Tools

To ensure worker safety, PPE such as insulated gloves rated for over 1000 V, insulated boots, helmets, and face shields must be provided and their use strictly enforced.

3.1.5. Cooperation and Sustainability

1) Institutionalization and Policy Integration

Manuals, safety protocols, and operational data developed through the collection center can be shared with Indonesian authorities as national guidelines. If the Indonesian government adopts EPR or similar systems, this center could serve as a model for a nationwide collection network.

2) Expansion of Additional Centers and Network Formation

If the pilot center near Jakarta proves successful, similar centers can be built in other major cities. This can be done through joint investment or technical partnerships between Korea and Indonesia. A network of centers can be established to share best practices and operational information.

3) Strengthening Recycling Linkages

Collected used batteries can be transferred to recycling facilities in Indonesia or Korea under contractual arrangements. By integrating the collection center with a pilot recycling facility, a complete closed-loop process from collection to shredding can be established. When a large-scale recycling facility is built in Indonesia, it can be supplied through this system to complete the end-to-end battery recycling ecosystem.

4) Human Resource Development and Research Collaboration

The operation of the center will help train skilled professionals in the battery reuse and recycling sectors. These experts can support future R&D cooperation between Korea and Indonesia on topics such as second-life battery applications and improving recycling efficiency. This ongoing knowledge exchange will strengthen the technological capabilities and industrial competitiveness of both countries and promote a virtuous cycle of cooperation.

3.2. Pilot Project for Recycling of Used EV Batteries

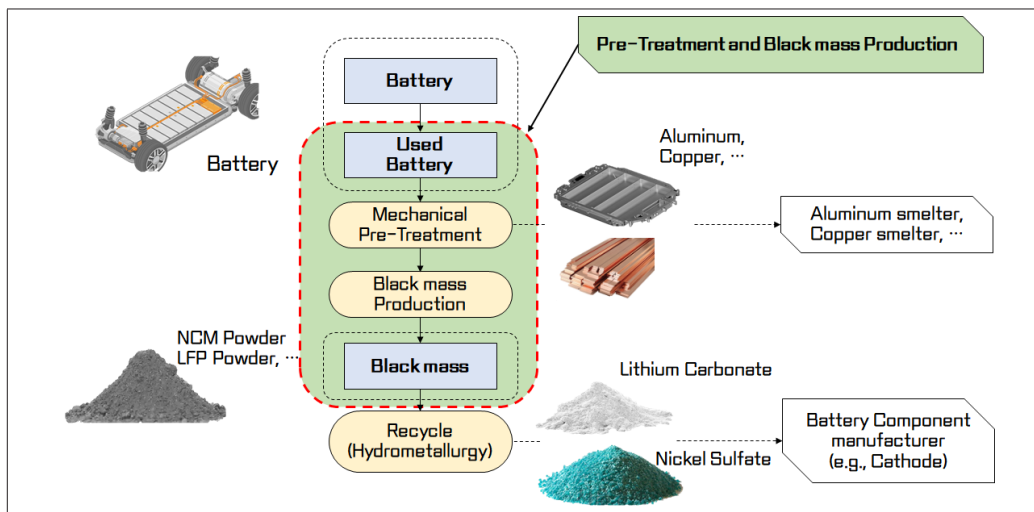
3.2.1. Background and Rationale

The Korea Testing Laboratory (KTL) consortium aims to establish a pilot-scale EV battery recycling center using its accumulated experience in the field of used EV battery recycling. This initiative will enable practical verification of the business potential of used EV battery recycling and contribute to strengthening the policy framework for permitting and commercialization in this sector.

As a result of the consortium's review by the Korea Testing Laboratory (KTL), it was confirmed that domestic companies such as L&F Co., Ltd. and Evacycle Co., Ltd. have plans to enter the Indonesian market. They expressed their intention to produce black mass in Indonesia and to pursue commercialization through this initiative.

3.2.2. Scope and Key Features of the Project

[Figure 4-7] Scope and Key Features of the Pilot Project



Source: Prepared by the author

The scope of the project will be limited to the first-stage physical processing of used EV batteries, specifically the shredding of battery packs to produce black mass. Second-stage chemical processes, such as hydrometallurgical metal extraction, will not be included. This approach is based on the following considerations:

- In the early pilot stage, focusing on mechanical shredding rather than complex chemical processes helps reduce investment costs and environmental risks and makes faster operational readiness possible.
- Hydrometallurgical processing requires complex environmental permitting due to the generation of wastewater and exhaust gases, whereas black mass production is primarily based on physical processes, making regulatory approval and operations easier.
- Some Korean companies are already operating business models in which they export black mass production equipment abroad and locally recycle used batteries. These existing players may enable rapid implementation of the pilot project.

Based on this approach, Indonesia can carry out the black mass production stage domestically, while downstream processing (e.g., metal refining) can be conducted in Korea or other countries. The black mass generated by this process can be used as a recyclable material, contributing to compliance with battery passports or recycled content regulations.

3.2.3. Required Equipment and Infrastructure

1) High-Voltage Battery Discharge Device

A device designed to rapidly discharge EV batteries of various voltage levels. It should support models capable of handling up to approximately 1000 Vdc. The equipment must include multiple safety features such as overvoltage, overcurrent, short-circuit, and reverse polarity protection. It should have a touchscreen control panel so that the operator can monitor the battery condition and control the discharge process to the desired level.

2) Battery Module/Pack Disassembly Workstation

This is a workstation for disassembling battery packs into modules using either skilled technicians or automated equipment. It should be equipped with insulated tools, robotic arms, or electric torque wrenches. With proper PPE use (e.g., insulated gloves, safety goggles), the operator should be able to safely separate high-voltage busbars and extract battery modules.

3) Industrial Shredder

A key piece of equipment used to crush battery modules into fine particles to obtain black mass. To prevent fire hazards, the shredding chamber should be designed to operate in an inert gas atmosphere or underwater environment. For example, enclosed shredders filled with nitrogen or other inert gases can reduce oxygen concentration during shredding, or shredding can be performed in water to immediately suppress sparks and thermal runaway.

4) Separation and Powder Processing Equipment

This equipment is used to separate metals (such as iron, aluminum, and copper) and plastics from the crushed material and to collect the black mass powder. Magnetic separators are used to remove ferrous metals, and sieving or cyclone classifiers are applied to sort particles by size. These steps improve the purity of the black mass as well as the efficiency of downstream refining processes.

[Figure 4-8] Powder Processing Equipment



* Illustrative image

Source: SK echo plant Co., Ltd. Website (<https://news.skecoplant.com/>)

5) Ventilation and Dust Collection System

Dust and volatile gases may be generated during the shredding and separation processes. To address this, local exhaust systems and air filtration units must be installed. Fine graphite dust should be collected using dust collectors to prevent accumulation in the workspace,

while harmful gases such as electrolyte vapors should be purified through activated carbon filters or equivalent technologies to ensure compliance with air emission standards.

6) Safety Equipment

The same safety equipment required for the Used EV Battery Collection Center pilot project should also be applied to this facility. This includes fire detection and suppression systems, gas monitoring devices, and personal protective equipment (PPE) for the safety of personnel and facility operations.

3.2.4. Expected Outcomes and Bilateral Benefits

With this pilot facility, Indonesia will gain the capacity to process its growing volume of used EV batteries, while also securing economic benefits from the recycling process. Furthermore, the project will significantly improve the country's technical expertise and management capabilities in battery recycling.

The initiative will support the development of a circular economy by enabling the reuse of resources and is expected to create new jobs and promote the formation of an industrial ecosystem in the battery recycling sector. This aligns with Indonesia's long-term strategy for eco-friendly industrial development.

Importantly, the pilot project will help fill current policy and infrastructure gaps faced by the Indonesian government in addressing the management of used EV batteries. It will be a valuable reference for future regulation development and policy formulation.

For Korea, this collaboration strengthens the strategic partnership with Indonesia and creates an opportunity for technology export and brand recognition with the operation of the pilot facility. In the long term, the project may also contribute to securing recycled resources such as black mass generated in Indonesia.

In fact, some battery recycling companies are already exporting black mass to countries such as Korea for reuse in EV battery production. Therefore, the project may support Korea's efforts to diversify its supply chain for battery materials, improve critical mineral security, and serve as a leading example of bilateral cooperation in addressing global environmental challenges. It also has the potential to open avenues for broader cooperation and raise the international standing of both countries.

05

CHAPTER

Conclusion

Conclusion

With the rapid growth of the EV market in Indonesia, a sharp increase in end-of-life batteries is expected in the near future. Prompt institutional and technological responses are required for proper treatment and integration into a circular economy. This report has proposed policy directions to strengthen Indonesia's capacity in EV battery recycling, based on international case studies (including Korea), current condition assessments, policy gap analysis, and technical feasibility reviews.

At present, Indonesia classifies used EV batteries as B3 waste, and only limited procedures such as storage, transport, and incineration are in place. There is no formal collection or recovery system, no recycling infrastructure, and no battery tracking mechanism. Legal responsibilities for battery recovery are unclear, inter-agency coordination is weak, and certification and standard systems are lacking.

On the technical side, advanced capabilities for metal extraction, performance evaluation, and residual life diagnostics are not yet available. While it may be possible to produce black mass (a pre-extraction intermediate material), the necessary infrastructure and expertise are absent.

Accordingly, this report recommends a three-phase policy roadmap:

- Short-term: Develop legal frameworks and practical guidelines for the safe collection and transportation of used EV batteries.
- Mid-term: Conduct pilot projects to assess the applicability of EPR systems and local recycling technologies.
- Long-term: Build a comprehensive circular battery ecosystem that includes standardization, certification, institutional role coordination, and stakeholder collaboration.

If Indonesia can adopt support systems similar to those used in Korea, such as a data-based battery tracking system, performance evaluation procedures for reuse and recycling, and incentive mechanisms for industrial participation, it will not only promote environmental protection but also contribute to localizing critical battery materials and achieving its ENDC for carbon neutrality.

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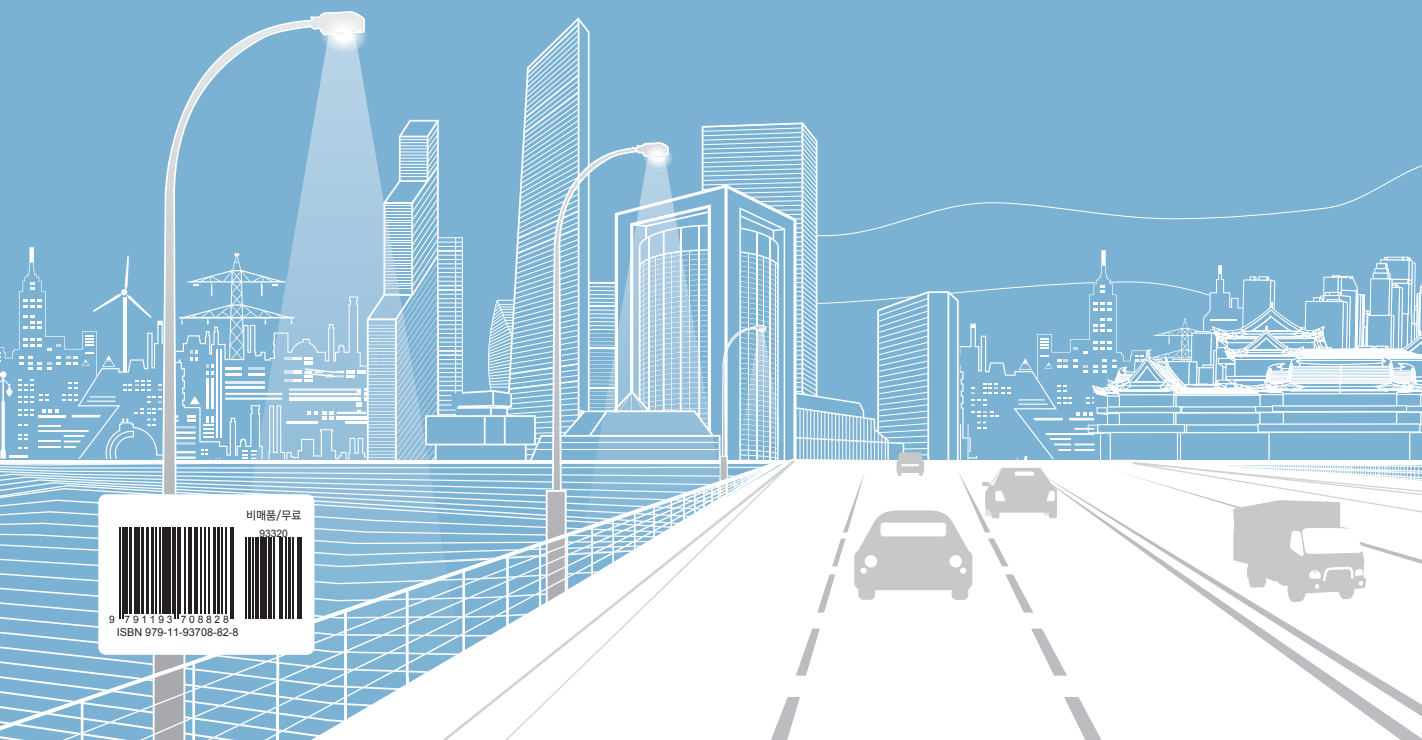
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