Non-ferrous metals

Securing Mineral Resources through Recycling

May, 2025

Industry Research Department
Mizuho Bank

Summary

- The Japanese government has designated critical minerals as specified critical products under the Economic Security Promotion Act.
- As Japan works toward carbon neutrality, demand for storage batteries and motors is increasing, and Japan relies entirely on imports for the critical minerals necessary to manufacture them, creating a situation of dependence on supply from specific countries.
- To secure stable procurement of critical minerals, investments in overseas mines and research on rare metal and rare earth conservation have been conducted. However, as demand for lithium-ion batteries and neodymium magnets is expected to expand in the medium to long term and waste volumes are projected to increase, there are expectations of securing mineral resources through recycling.
- Lithium-ion battery recycling is currently limited to scrap materials and similar waste, but with increasing waste volumes in the future, it is estimated that by 2040, approximately 30% of demand could be met from waste lithium-ion batteries collected from the market.
- Challenges include high recycling costs, securing a sufficient volume of waste lithium-ion batteries, and compliance with European battery regulations.
- The following measures are conceivable to address high recycling costs: (1) Selecting leading intermediate processing facilities by area and collecting from nearby vehicle dismantling sites to reduce transportation costs; (2) Effectively utilizing heat from existing processes to reduce energy costs in intermediate processing and hydrogen fluoride treatment costs; (3) Pursuing volume benefits through inter-company collaboration and establishing schemes that reduce refining costs by receiving waste treatment fees and processing charges for refining operations.
- The following measures are conceivable to secure a sufficient volume of waste lithium-ion batteries: (1) Establishing schemes to collect used EVs exported overseas, set up black mass recovery and rare metal refining facilities in local areas, and re-export to Japan; (2) Creating mechanisms that utilize recovery schemes by the Japan Auto Recycling Partnership to implement not only intermediate processing but also refining processes.
- For compliance with European battery regulations, strengthening traceability through public-private collaboration is required.
- (Supplementary note) Like lithium-ion batteries, neodymium magnets are currently limited to recycling of scrap materials and similar waste. To commercialize waste neodymium magnet recycling, developing refining technologies with low environmental impact is essential.

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd.

Securing stable supply of critical minerals is an important issue for economic security

- As we work toward carbon neutrality (CN) and demand for storage batteries and motors increases, there is increased demand for critical minerals such as rare metals (lithium, cobalt, nickel) and rare earths necessary for manufacturing. Japan imports almost all of these materials and needs to ensure stable procurement.
- Under the Economic Security Promotion Act, the Japanese government designated critical minerals as specified critical products in December 2022. In January 2023, it formulated an approach for ensuring stable supply and designated 35 mineral types, mainly rare metals, as critical minerals subject to policy measures.

List of Designated Specified Critical Products

"Enforcement Order of the Act on the Promotion of Ensuring National Security through Integrated Implementation of Economic Measures" (February 2024)

1. Antibiotics
2. Fertilizers
3. **Permanent magnets**
4. Machine tools and industrial robots
5. Aircraft parts
6. Semiconductors
7. **Storage batteries**
8. Cloud programs
9. Natural gas
10. **Critical minerals**
11. Marine equipment
12. Advanced electronic components

Critical Minerals

Rationale for designation

- Critical minerals are used for various purposes and economic activities depend on them. In particular, as we work toward carbon neutrality, **demand is expanding for critical minerals** such as battery metals (lithium, nickel, cobalt, etc.) and rare earths necessary for **manufacturing storage batteries, motors, etc.**
- **Japan is almost entirely dependent on critical mineral imports from overseas**
- As competition for resource acquisition intensifies, there is an **urgent need to ensure stable supply** to **counter the monopolization of resource interests through massive overseas investments and oligopolization of supply chains**

Storage Batteries

Rationale for designation

- **Storage batteries are key to achieving CN by 2050**. They are **essential materials for maintaining the foundation of future electrification and the digital society** as **power sources for EVs, 5G base stations, etc.,** and for **power supply-demand adjustment toward making renewable energy the main source of power**. A **shortage of storage batteries would significantly impact major industries** as they are incorporated into various products and the market is expected to expand significantly. Foreign companies are significantly expanding their supply of storage batteries, backed by government support.
- **Japan possesses high-level technology for developing and manufacturing battery cells and component materials**, but **Japan's market share has declined significantly. There is a high risk that external dependence on storage batteries will further increase, which requires urgent measures**

Permanent Magnets

Rationale for designation

- With the progress of electrification and digitalization, we use semiconductors (brain) and batteries (heart), as well as **motors (muscles), which hold important elements, and permanent magnets determine their performance**. **These have a wide range of applications from electric vehicles, generators, and home appliances to military use, and continued market growth** is expected.
- **As Japanese companies' market share declines (23% in 2013 → 15% in 2021), external dependence is expected to increase further**. Also, **some types of rare earth raw materials are entirely dependent on external sources**.
- In addition to ensuring stable domestic supply, the US is also carrying out investigations under Section 232 of the Trade Expansion Act, showing high security interest. **Urgent measures are also necessary from an economic security perspective**.

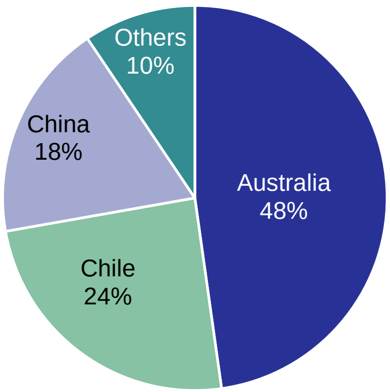
Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on Cabinet Office materials

Minerals required for lithium-ion batteries and neodymium magnets face procurement risks

- Rare metals (lithium, nickel, cobalt) used in lithium-ion batteries and rare earths used in neodymium magnets, which are motor components, face supply chain risks.

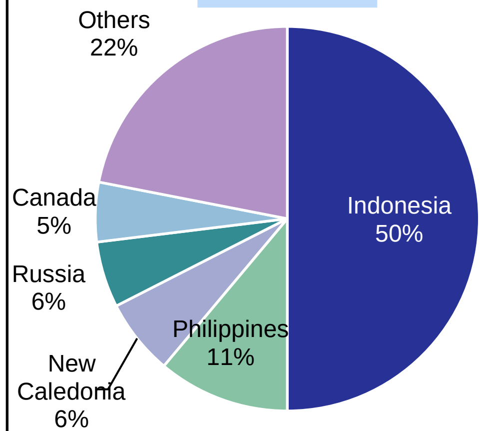
Production Volume Share of Lithium, Nickel, Cobalt, and Rare Earths (2023)

Lithium



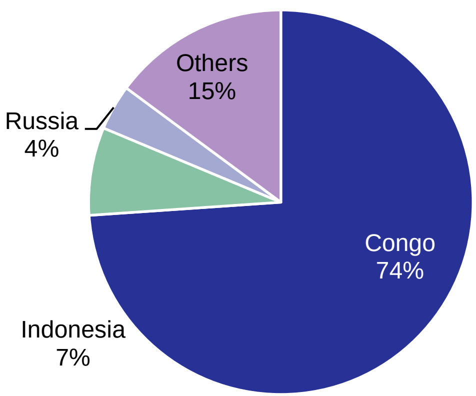
- Australia accounts for approximately half of lithium production
- However, China dominates chemical product manufacturing, holding more than an 80% share in lithium hydroxide

Nickel



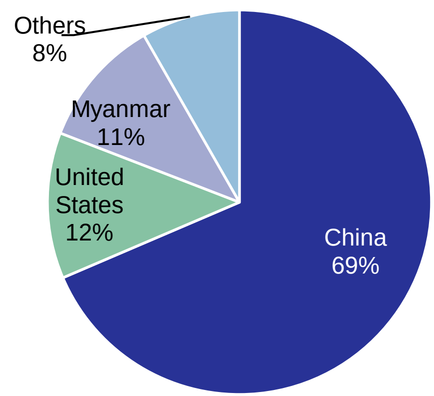
- In Indonesia, which accounts for half of nickel production, resource nationalism movements such as nickel ore export bans are intensifying

Cobalt



- Congo, which accounts for over 70% of cobalt production, has high country risk
- China controls much of the cobalt resource interests and accounts for more than half of metal production

Rare Earths



- China accounts for 70% of rare earth production
- Deposits containing heavy rare earths are particularly concentrated in China. 90% of refining capacity is concentrated in China

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on U.S. Geological Survey (USGS) materials

(Reference) Designation status of critical minerals in major countries and regions

- Governments in various major countries and regions are concerned about mineral procurement risks. They are moving toward strengthening procurement by designating "critical minerals" and similar categories.
- Minerals necessary for lithium-ion batteries and neodymium magnets are designated as critical minerals in Japan, the EU, and the United States.

Designation Status of Critical Minerals in Japan, the EU, and the United States

	Japan	EU		United States	
	Critical Minerals	(1) Critical Raw Materials	(2) Strategic Raw Materials	(1) Critical Minerals	(2) Critical Materials
Lithium	○	○	○	○	○
Cobalt	○	○	○	○	○
Nickel	○	○	○	○	○
Rare earths (heavy/light rare earths)	○	○	○	○	○
Platinum group metals	○	○	○	○	○
Graphite (natural)	○	○	○	○	○
Gallium	○	○	○	○	○
Fluorine (fluorite)	○	○		○	○
Magnesium	○	○	○	○	○
Silicon (metal)	○	○	○		○
Titanium	○	○	○	○	
Vanadium	○	○		○	
Manganese	○	○	○	○	
Germanium	○	○	○	○	
Niobium	○	○		○	
Antimony	○	○		○	
Hafnium	○	○		○	
Tantalum	○	○		○	
Tungsten	○	○	○	○	
Bismuth	○	○	○	○	
Beryllium	○	○		○	

Lithium, cobalt, and nickel are used in batteries
Rare earths are used in magnets

	Japan	EU		United States	
	Critical Minerals	(1) Critical Raw Materials	(2) Strategic Raw Materials	(1) Critical Minerals	(2) Critical Materials
Helium		○			
Boron	○	○	○		
Coking coal		○			
Bauxite, alumina		○	○	○	○
Phosphorus	○	○			
Scandium		○			
Chromium	○			○	
Rubidium	○			○	
Copper		○	○		○
Zinc				○	
Arsenic		○		○	
Strontium	○	○			
Zircon	○			○	
Molybdenum	○				
Indium	○			○	
Tin				○	
Tellurium	○			○	
Cesium	○			○	
Barium (barite)	○	○		○	
Terbium	○				
Feldspar		○			

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on JOGMEC materials

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To secure stable procurement of critical minerals, recycling of lithium-ion batteries and neodymium magnets is necessary

- Investments in overseas mines and research and development of rare metal and rare earth conservation technologies are conceivable as initiatives to secure stable procurement of critical minerals, but challenges would remain with these initiatives alone. Possible effective countermeasures to secure critical mineral resources include utilizing domestic resources and implementing recycling of lithium-ion batteries and neodymium magnets.
- Expanded demand is expected as we move toward CN, along with increases in waste volume, creating expectations for new recycling business sectors.

Countermeasures for Securing Stable Supply of Critical Minerals

#	Countermeasures	Overview	Challenges
(1)	Overseas Mine Investment	✓ The Japanese government deploys corporate support measures focused on upstream operations such as exploration, mine development, and refining operations	✓ Investment recovery periods may be prolonged ✓ Mine operations may be disrupted by political risks and social risks in resource countries
(2)	Promotion of Rare Metal and Rare Earth Conservation	✓ Development of cobalt-reduced lithium-ion batteries and rare earth-reduced neodymium magnets is advancing at various companies	✓ Substantial costs and time required for research and development with unclear profitability ✓ Even if cobalt-reduced lithium-ion batteries are commercialized, lithium and nickel remain essential ✓ Uncertain whether they will have performance equivalent to rare metals and rare earths
(3)	Promotion of Lithium-ion Battery and Neodymium Magnet Recycling	✓ Recycling research for commercialization is advancing at various companies ✓ NEDO is promoting research and development of neodymium magnet recycling	✓ Technology development needed for efficient separation ✓ Profitability is unstable as revenue is subject to resource price fluctuations *Current status and challenges are detailed on subsequent pages

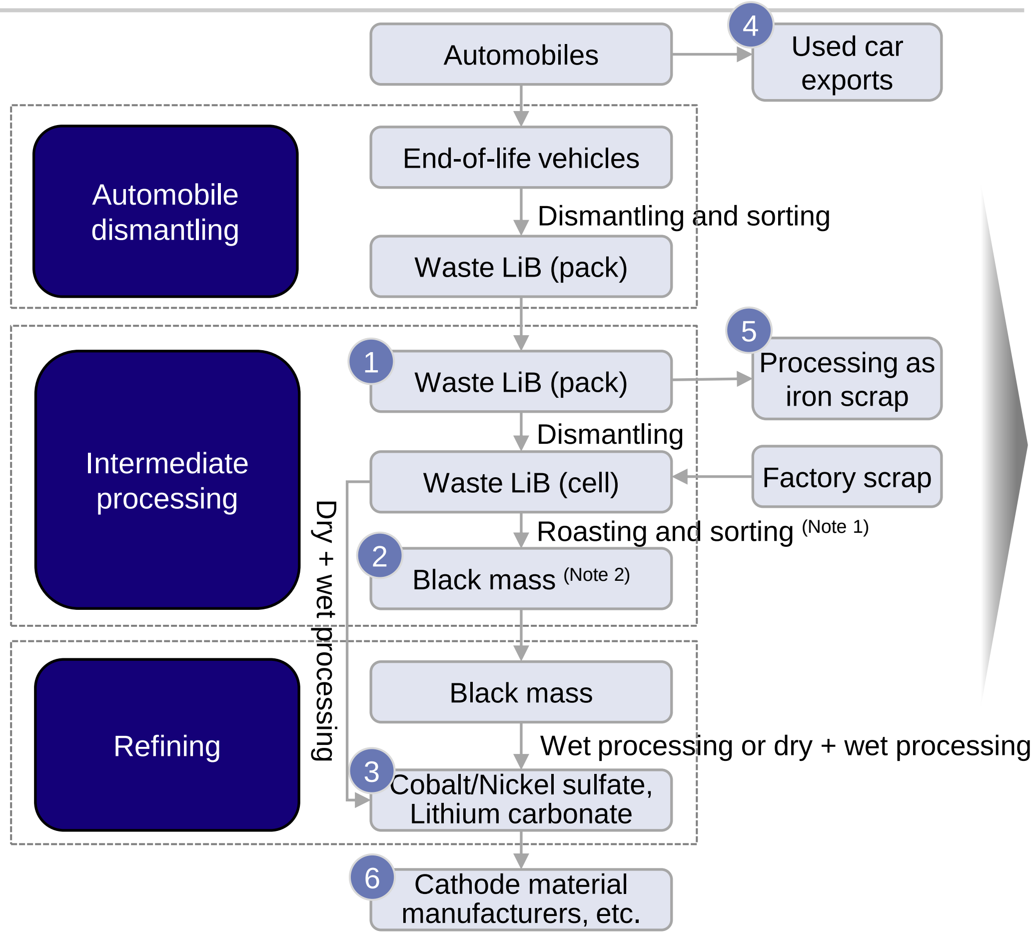
Medium-term expectations for lithium-ion battery recycling as a new business sector
Neodymium magnet recycling requires assessment of commercialization from a long-term perspective (explained in supplementary note)

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd.

Current status of lithium-ion battery recycling

- Lithium-ion battery recycling technology has been established, but currently remains limited to recycling factory scrap materials and similar waste.
- There are challenges in the commercialization of lithium-ion battery recycling: high recycling costs, securing sufficient volume of waste batteries, and establishing systems to evaluate the value of recycled materials.

Expected Recycling Flow for Used Lithium-ion Batteries



Challenges in Recycling

Challenge 1

High recycling costs

1. Transportation costs for heavy batteries
2. Energy costs and hydrogen fluoride treatment costs in intermediate processing
3. Refining costs in refining processes

Challenge 2

Securing sufficient volume of waste lithium-ion batteries

4. End-of-life vehicles in Japan are decreasing, with concerns that used EVs may also be exported in the future
5. Concerns that batteries may not be sent to refining processes after intermediate processing

Challenge 3

Systems to evaluate the value of recycled materials

6. Need for systems that can prove compliance with European battery regulations

Note 1: Roasting and sorting processes are mainstream in Japan, but overseas methods such as underwater crushing and nitrogen atmosphere crushing also exist
Note 2: Black mass: Black powder containing metals such as Ni, Co, Li, etc.
Source: Both figures were compiled by the Industry Research Department, Mizuho Bank, Ltd. based on various materials

[Reference] Each company's initiatives and business areas in lithium-ion battery recycling

- While numerous companies are entering lithium-ion battery recycling technology, their business areas differ. In the refining process, major non-ferrous smelting companies including Sumitomo Metal Mining, JX Advanced Metals, and Mitsubishi Materials are advancing development toward commercialization.

Each Company's Initiatives in Lithium-ion Battery Recycling

Representative Company Names	Initiative Status
Sumitomo Metal Mining Kanto Denka Kogyo	• Developed processes to recover Ni and Co as battery materials from waste LiB and intermediate materials • Collaborated with Kanto Denka Kogyo to establish technology for horizontal recycling of Li compounds as LiB materials (February 2022) • Announced construction of commercial-scale LiB recycling plant and concluded partnership agreement for building recovery network (April 2024)
JX Advanced Metals	• Developed basic technology for recovering Ni and Co as sulfates • Also achieved Li recovery as lithium carbonate (with prospects for battery grade) • Established new company in Tsuruga, aiming to establish technology for intermediate processing (May 2021)
Mitsubishi Materials	• Currently researching high-efficiency recovery of Li, Co, and Ni from black mass; announced pilot plant construction toward technology establishment (June 2023) • Also aims to acquire deterioration diagnosis technology and enter reuse business
Asaka Riken PPES	• Adopted proprietary chemical solution circulation process with lower CO2 emissions, higher recovery rates, and lower processing costs than other methods • Plans to recycle batteries equivalent to 15,000 EVs by 2030 from waste materials generated at PPES battery factories
Envipro Holdings	• Leveraged waste treatment technology to gain manufacturing know-how up to black mass (refining process technology also under development at subsidiary) • Announced establishment of new factory in Hitachinaka (March 2023)
DOWA	• Focuses on intermediate processing. Sells Fe/Al/Cu to recyclers

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on various materials

Major Companies' Business Areas in LiB Recycling

	Automobile Dismantling	Intermediate Processing	Refining
Sumitomo Metal Mining Kanto Denka Kogyo			△
JX Advanced Metals		△	△
Mitsubishi Materials	○ (Note 1)		△
Envipro Holdings	○	○	
DOWA		○	
Tsuruga Cement Matsuda Sangyo		○	
Nihon Kagaku Sangyo			△
Asaka Riken			△
JERA Sumitomo Chemical		△ (Note 2)	△ (Note 2)

○: Commercial operation level　△: Pilot level

Note 1: Implemented by equity-method affiliate Marc Corporation

Note 2: "Direct recycling" technology that regenerates cathode materials by repairing their structure without returning them to metals

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on various materials

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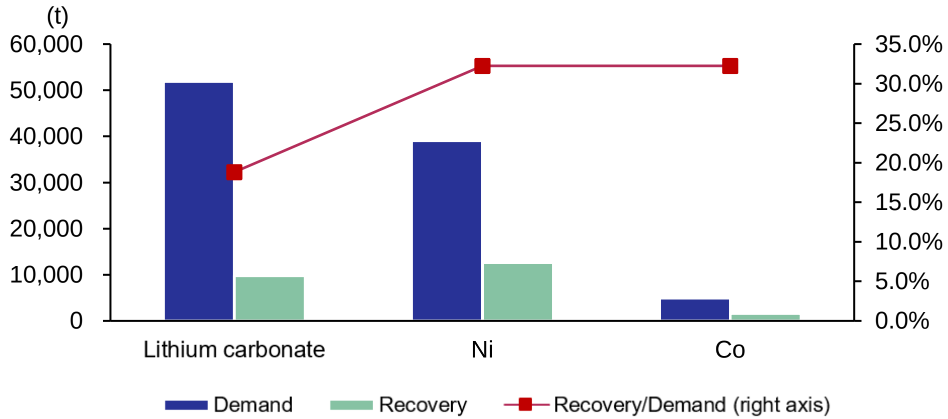
Automotive lithium-ion battery recycling volume and market scale

- While lithium-ion battery waste volumes will increase in the medium to long term, the recovery volume from lithium-ion battery recycling in 2040 is expected to meet approximately 20% of lithium demand, and approximately 35% of nickel and cobalt demand, assuming the used EV export ratio remains at the actual value of 35%,
- The recycling market scale (rare metal sales prices) fluctuates with rare metal prices, but at current price levels, it is expected to fall below costs, suggesting that the refining process alone may not be profitable.

Automotive lithium-ion battery demand and recovery volume (2040)



(Note) Assumptions:
<Automobiles>
・Automobile production and sales volumes are estimated by our bank
・Powertrain breakdown assumes 2040: ICE 10%, HEV 50%, PHV 10%, BEV 30%
・Assumes 65% of 2030 new vehicle sales will be recovered domestically and recycled in 2040
・Demand calculated by multiplying 2040 domestic automobile production by powertrain-specific unit consumption
・Recovery calculated by multiplying 2030 domestic end-of-life vehicle recovery by powertrain-specific unit consumption
<LiB>
・LiB breakdown assumes 2030: NMC 80%, LFP 20%; 2040: NMC 50%, LFP 50%
・All NMC assumed to be NMC 811
・LiB weight: HEV 25 kg, PHEV 120 kg, EV 300 kg
・Li volume expressed in lithium carbonate equivalent

Automotive lithium-ion battery recycling market scale (2040)

Rare Metal Price Level	LiB Recycling Market Scale	LiB Recycling Cost
Peak price	283.9 billion yen	248.6 billion yen
Current price	72.0 billion yen	80.2 billion yen
Lowest price	67.2 billion yen	76.5 billion yen

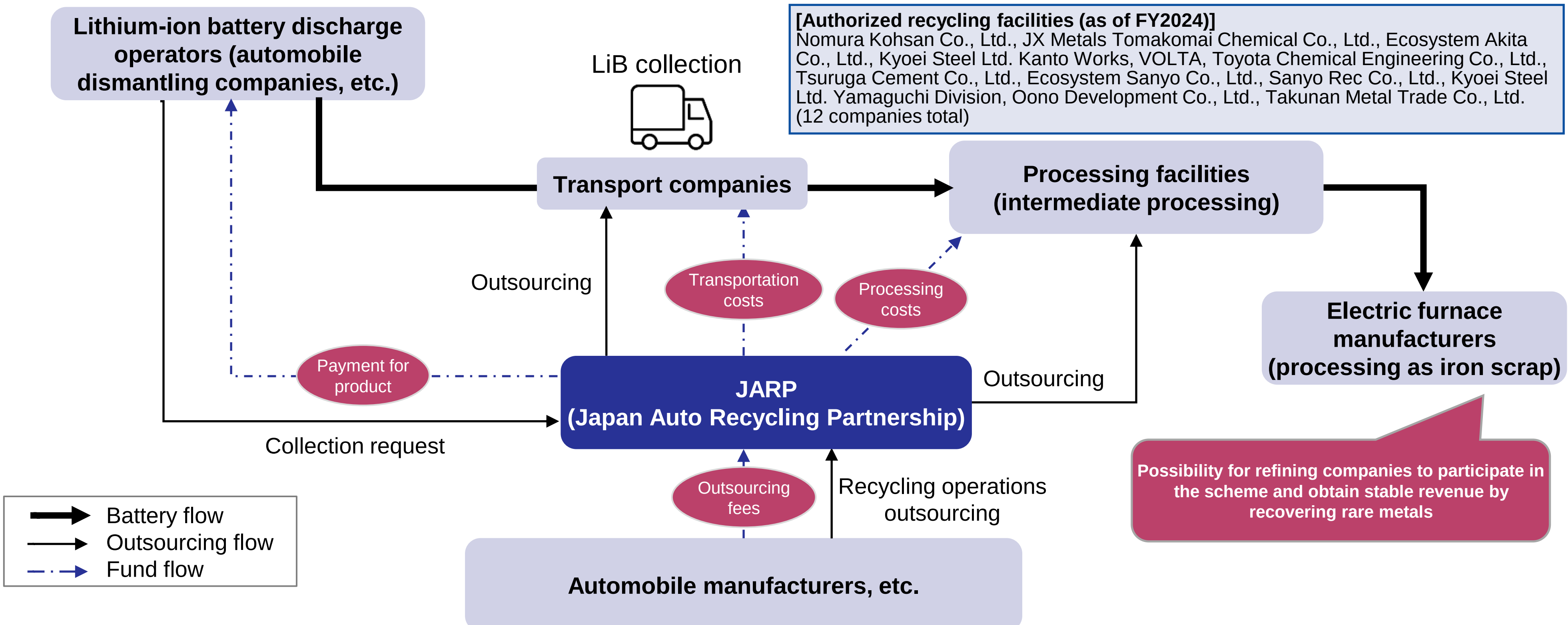
<Costs and Market Scale>
・Market scale and costs calculated for both scrap recycling and market-recovered battery recycling
・Market-recovered battery recycling costs include black mass purchase price and separation/refining costs
・Black mass purchase price assumed at 70% of metal sales price
・Separation/refining cost assumed at 136 yen/kg
・Market scale calculated by multiplying Li, Co, Ni market prices by recovery volumes. Calculated at 150 yen per dollar
・For rare metal prices, Ni and Co use LME prices, Li uses MIRU-calculated lithium carbonate prices
・Rare metal prices adopt peak and lowest values from 2021-2024. Current prices as of March 2025
・Rare metal recovery yield rates: Li 80%, Co 95%, Ni 95% (as obligated by the European Battery Regulation 2031)

Source: Both charts were compiled by Industry Research Department, Mizuho Bank, Ltd. based on Ministry of Economy, Trade and Industry (contractor: Deloitte Tohmatsu Consulting LLC) “FY2021 Critical Technology Management System Strengthening Project: Survey of Current Status of Mineral Resource Recycling in Automotive LiB and Challenge Identification Based on Actual Distribution Conditions - Final Report” (February 2022), Japan Science and Technology Agency Center for Low Carbon Society Strategy “Storage Battery System,” IRuniverse Co., Ltd./MIRU

Extension of joint collection scheme by Japan Auto Recycling Partnership to refining processes (our bank's hypothesis)

- In the dismantling and intermediate processing stages, the "LiB joint collection scheme" by the Japan Auto Recycling Partnership has been operating since October 2018.
  - Under the coordination of this organization, waste LiB generated from automobile manufacturers and others is collected and processed. This functions as an efficient scheme where stable revenue can be obtained from collection through to intermediate processing, with automobile manufacturers bearing the costs.
- However, at the moment, some batteries go on to electric furnaces as iron scrap after intermediate processing, so there may be a need to create mechanisms that utilize this scheme while guiding batteries to refining processes.

Joint collection scheme for automotive LiB by Japan Auto Recycling Partnership (JARP)

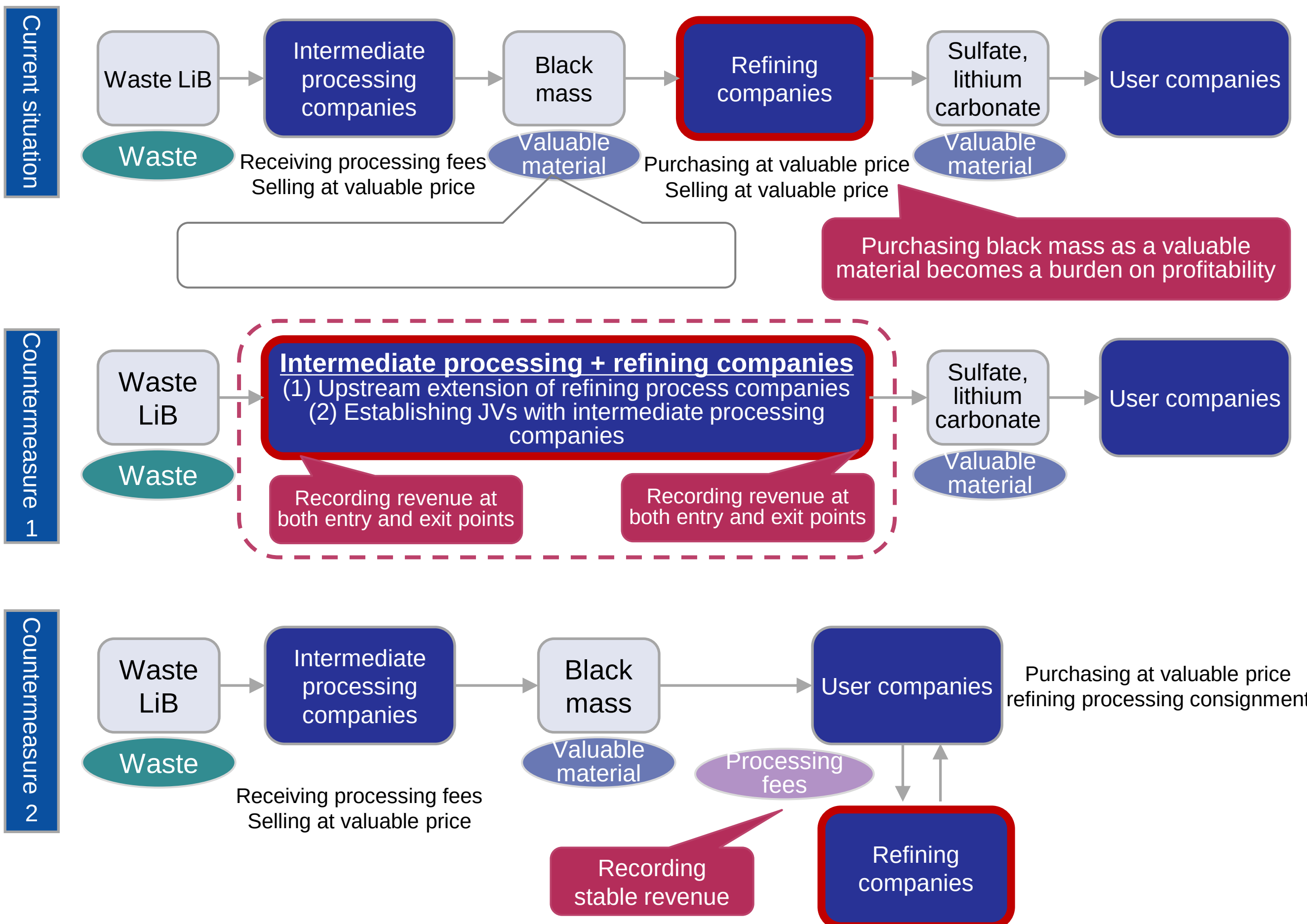


Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on materials from Japan Automobile Manufacturers Association and Japan Auto Recycling Partnership

Profitability of refining companies (our bank's hypothesis)

- Refining companies face unstable profitability and carry deficit risks, as refining costs are high while revenue is subject to rare metal prices.
- Since procurement costs of black mass account for the majority of refining costs, we believe it is necessary to transform the existing business model of procuring black mass at valuable prices. For example, we envision (1) extending into intermediate processing operations that can receive waste treatment fees, or (2) conducting refining processing by receiving processing fees from user companies.

Collaboration between intermediate processing and refining



- ✓ Under the current business model for refining processes, companies are exposed to risk of sales price fluctuations due to metal prices

- ✓ By implementing integrated processing from intermediate processing stages where waste treatment fees can potentially be received, metal price fluctuation risks can be minimized
- ✓ Cases of establishing JVs with intermediate processing companies seeking to enter LiB recycling may also be considered (majority ownership would be necessary to obtain revenue)

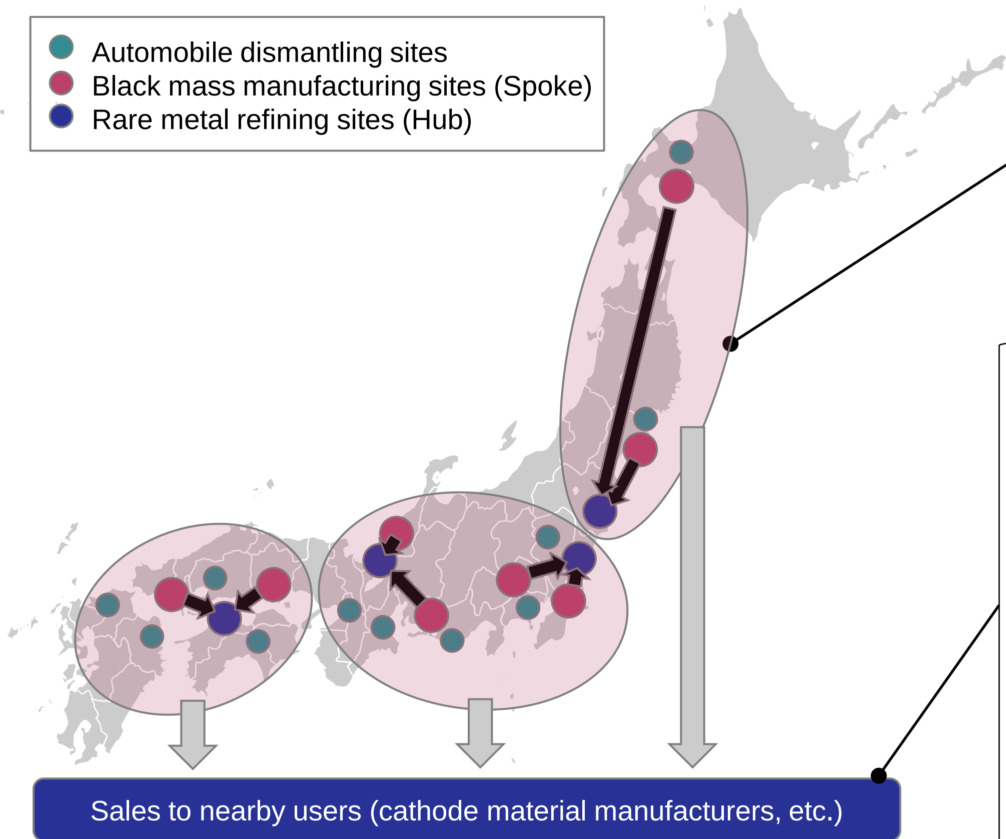
- ✓ User companies would own black mass and consign processing to refining companies
- ✓ While refining companies would be freed from metal price fluctuation risks, how to engage user companies becomes the key issue. Establishing stable battery material procurement networks will be a future challenge for user companies as well.

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd.

Hub & spoke concept in Japan through inter-company collaboration (our bank's hypothesis)

- To achieve efficiency across Japan, it would be effective to select intermediate processing companies and rare metal refining companies in each area and pursue scale expansion by increasing processing volume per site. We believe it is important for companies in close proximity to work together to minimize inter-process transportation costs for heavy batteries.

Hub & Spoke Concept in Japan (Image)



- ✓ Divide the country into several areas and select automobile dismantling sites with high end-of-life vehicle recovery capacity and leading intermediate processing facilities (it would be best for both to be in close proximity from the perspective of battery pack delivery)
- ✓ Maximize volume benefits by centrally recovering rare metals at one refining facility from black mass manufactured at multiple intermediate processing facilities

<Eastern Japan>

Cathode Material Manufacturers	Sites
Tanaka Chemical Corporation	Fukui
Nihon Kagaku Sangyo Co., Ltd.	Fukushima, Saitama
Nippon Denko Co., Ltd.	Toyama

<Western Japan>

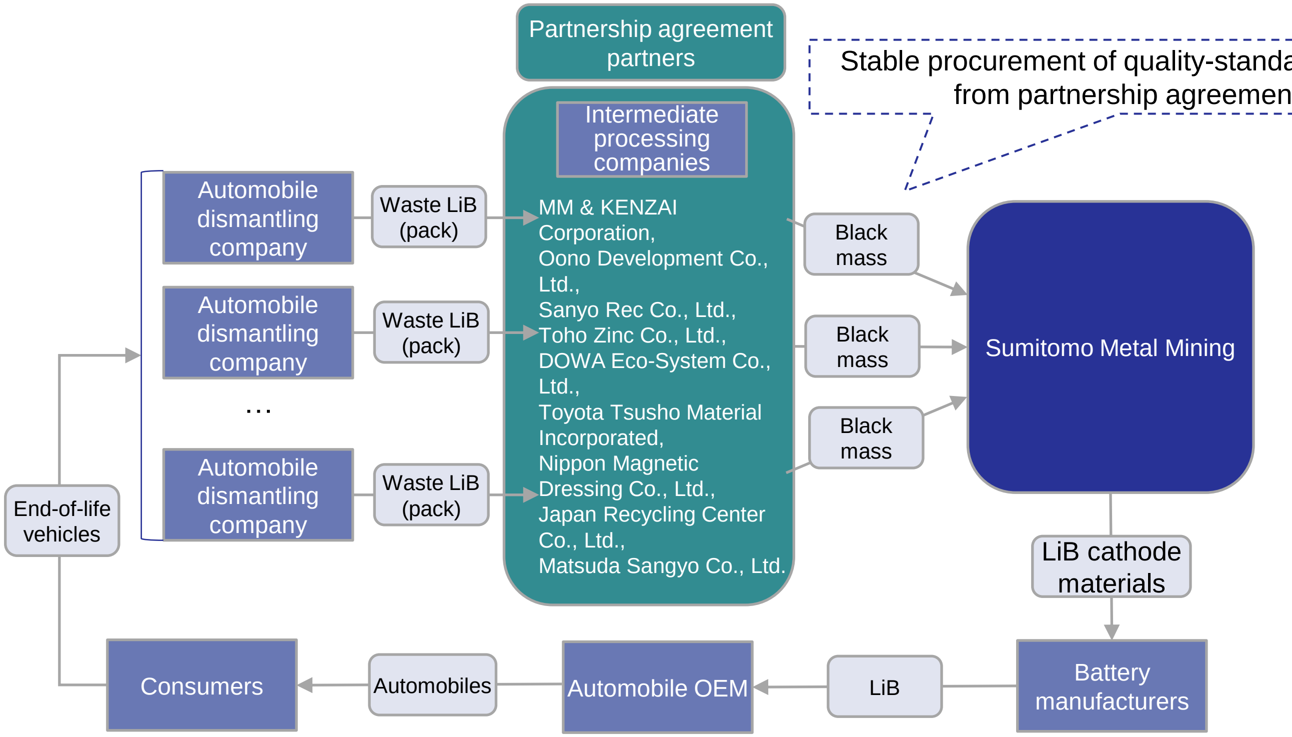
Cathode Material Manufacturers	Sites
Sumitomo Metal Mining Co., Ltd.	Ehime
Nichia Corporation	Tokushima
Mitsui Mining & Smelting Co., Ltd.	Hiroshima

Note: The locations of each site and divided areas are merely our bank's conceptual image
Source: Compiled by Industry Research Department, Mizuho Bank, Ltd.

Sumitomo Metal Mining: Pursuing the merits of scaling through collaboration with intermediate processing companies

- Sumitomo Metal Mining has concluded partnership agreements with multiple intermediate processing companies in order to build supply chains for used LiB recycling.
  - In April 2024, the company decided to construct recycling plants within the Toyo Smelter and Refinery and the Niihama Nickel Refinery to recover copper, nickel, cobalt, and lithium from LiB and other sources. The company aims to promote efficient recycling leveraging the merits of scaling.

Value chain envisioned by Sumitomo Metal Mining



[Recycling Plant Overview]
- ✓ Main raw materials: Black mass
- ✓ Equipment capacity: 10,000 tons/year in LiB cell equivalent
- ✓ Construction sites: Dry process = within Toyo Smelter and Refinery; Wet process = within Niihama Nickel Refinery
- ✓ Schedule: Scheduled for completion in June 2026

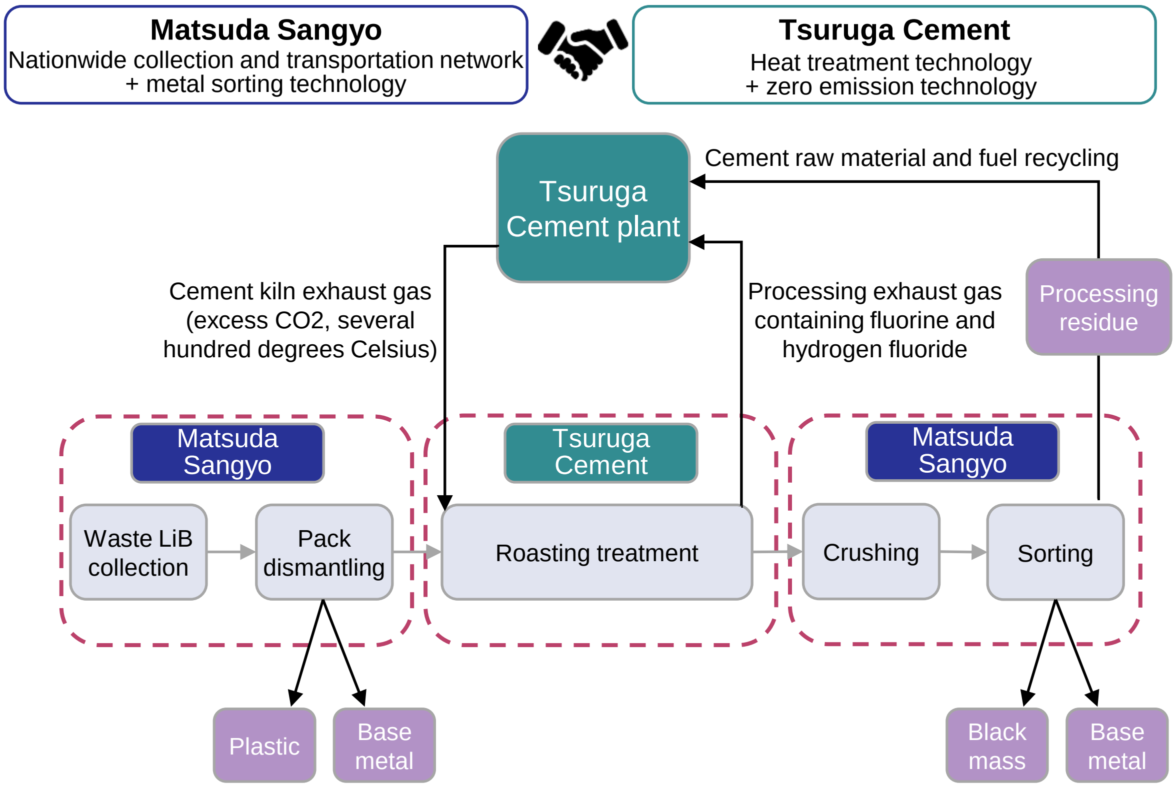
Aims to diversify black mass procurement routes through partnership agreements and promote efficient recycling leveraging the merits of scaling

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on Sumitomo Metal Mining IR materials

Tsuruga Cement + Matsuda Sangyo: Intermediate processing process utilizing cement manufacturing process

- In intermediate processing, it is necessary to heat the materials at high temperatures to evaporate the electrolyte; heating generates hydrogen fluoride gas and other substances, requiring exhaust gas treatment costs. There are also barriers to obtaining waste incineration permits.
- Tsuruga Cement and Matsuda Sangyo have developed a recycling process that returns fluorine gas generated during LiB roasting to the cement process for treatment, and utilizes exhaust gas generated in the cement manufacturing process for waste LiB roasting. This enables cost reduction in intermediate processing.

LiB recycling process by Tsuruga Cement and Matsuda Sangyo



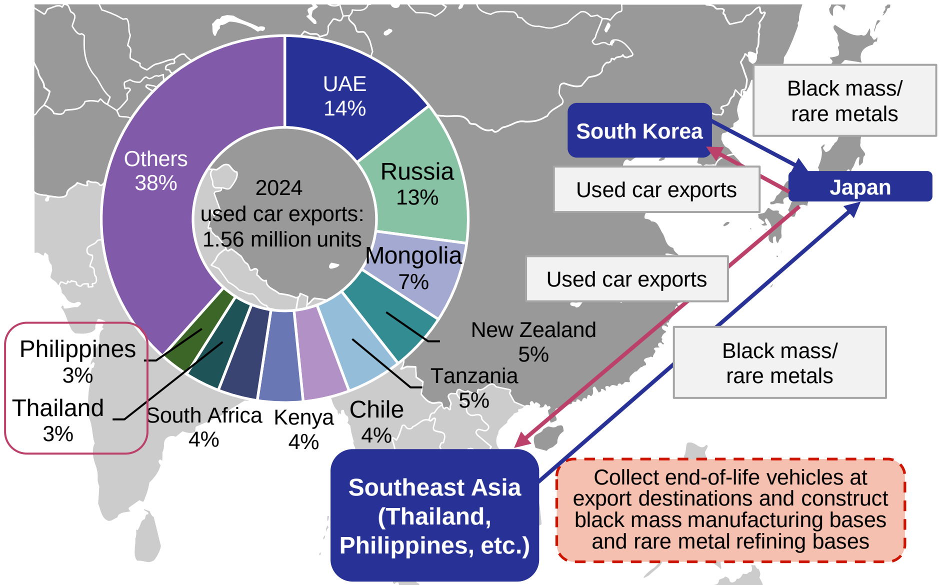
Fluorine gas is adsorbed by Ca and rendered harmless for use in cement material, while exhaust gas from the cement process is used as a heat source for battery roasting, thereby reducing intermediate processing costs

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on Japan Environmental Management Association for Industry Resources Recycling Promotion Center

Establishing overseas end-of-life vehicle collection bases to secure black mass and rare metals (our bank's hypothesis)

- To address battery outflow due to used EV exports, schemes could be constructed where local recyclers and domestic battery manufacturers in nearby regions such as South Korea and ASEAN collaborate to collect batteries, and re-import black mass or locally refined rare metals to Japan.
- DOWA HD is developing lithium-ion battery recycling operations in Thailand and Indonesia, while South Korea's SK Group has acquired TES, which operates a lithium-ion battery recycling business. Lithium-ion battery recycling in Southeast Asia is attracting attention.

Black mass recovery from used car export countries



- ✓ While 2.6 million end-of-life vehicles were generated in 2024, 1.56 million used cars were exported, indicating significant outflow of used cars overseas
- ✓ Even if recovery from the Middle East and Russia is difficult, enhancing collection in geographically closer Southeast Asia and South Korea is an important point for consideration
- ✓ If all used cars exported to Thailand, the Philippines, and South Korea could be recovered, this would be equivalent to 100,000 units annually (equivalent to 15,000 tons in black mass)(Note)

Examples of lithium-ion battery recycling companies in ASEAN

DOWA expanding LiB recycling business in Southeast Asia

- ✓ **In October 2019, DOWA HD announced that its Thai subsidiary BPEC would begin recycling lithium-ion batteries and other materials**
- ✓ **Its processing capacity is approximately 4 tons per day**
- ✓ **Subsequently, in 2021, it constructed a waste incinerator in Indonesia for use in lithium-ion battery recycling**

SK Group's acquisition of TES

- ✓ **In February 2022, SK Ecoplant of South Korea's SK Group acquired TES, a Singaporean company operating a lithium-ion battery recycling business, for approximately 115 billion yen**
- ✓ **TES has a maximum processing capacity of 14 tons per day**
- ✓ **This enables extraction of rare metals from used batteries for reuse in the Group's automotive battery companies**

Note: Assumes all recovered used cars are EVs
Source: Both figures were compiled by Industry Research Department, Mizuho Bank, Ltd. based on Japan Used Motor Vehicle Exporters Association, Japan Automobile Recycling Promotion Center, and various materials

Strengthening traceability for European battery regulations

- The European battery regulations were established to regulate the flow from the procurement and manufacturing of raw materials to the recycling of batteries sold in the EU, aiming to enable sustainable product supply. The regulations stipulate recycling and recycled material usage obligations for lithium, nickel, and cobalt, requiring Japanese companies to build compliant systems.
- In response to strengthening environmental regulations, including the European battery regulations, 14 domestic automobile manufacturers, the Battery Association for Supply Chain, and the Japan Auto Parts Industries Association established the Automotive and Battery Traceability Center in May 2024. Effective initiatives such as introducing battery passports are required.

Overview of European Battery Regulations

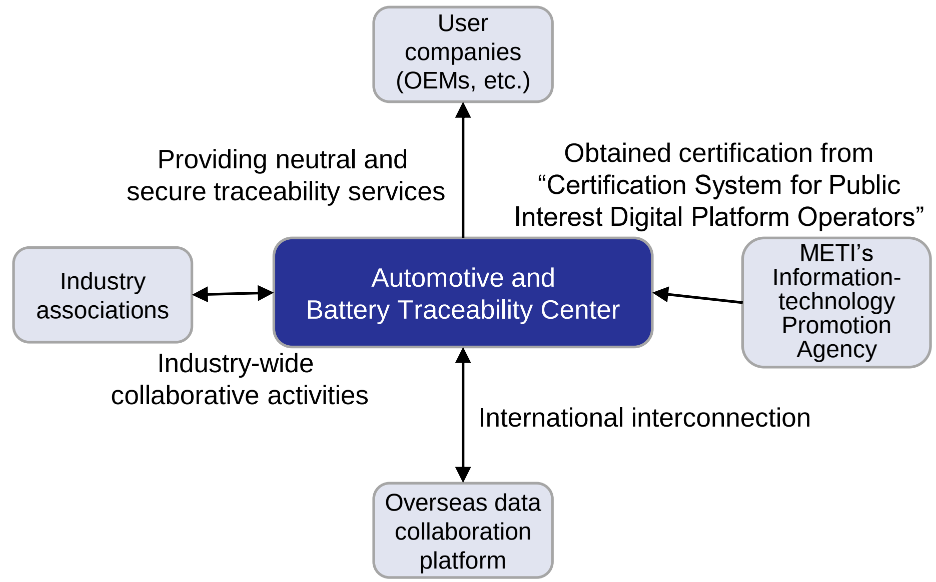
	Recycling Obligations Obligation to achieve recycling rates from used batteries		Recycled Material Usage Obligations Obligation to achieve recycled material usage rates in battery raw materials	
	By end of 2027	By end of 2031	From August 2031	From August 2036
Lithium	50%	80%	6%	12%
Cobalt	90%	95%	16%	26%
Nickel	90%	95%	6%	15%

- ✓ **Must achieve LiB recycling efficiency of 65% by end of 2025 and 70% by end of 2030 based on average weight**
- ✓ **Manufacturers are obligated to certify recycled material usage rates**
- ✓ **Prohibits landfill disposal and incineration of collected waste batteries**
- ✓ **Obligation to collect batteries embedded in waste equipment**

Battery Passport Introduction | **Label Display QR Code Introduction** | **DD Implementation Obligation**

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on various materials

Traceability management by Automotive and Battery Traceability Center



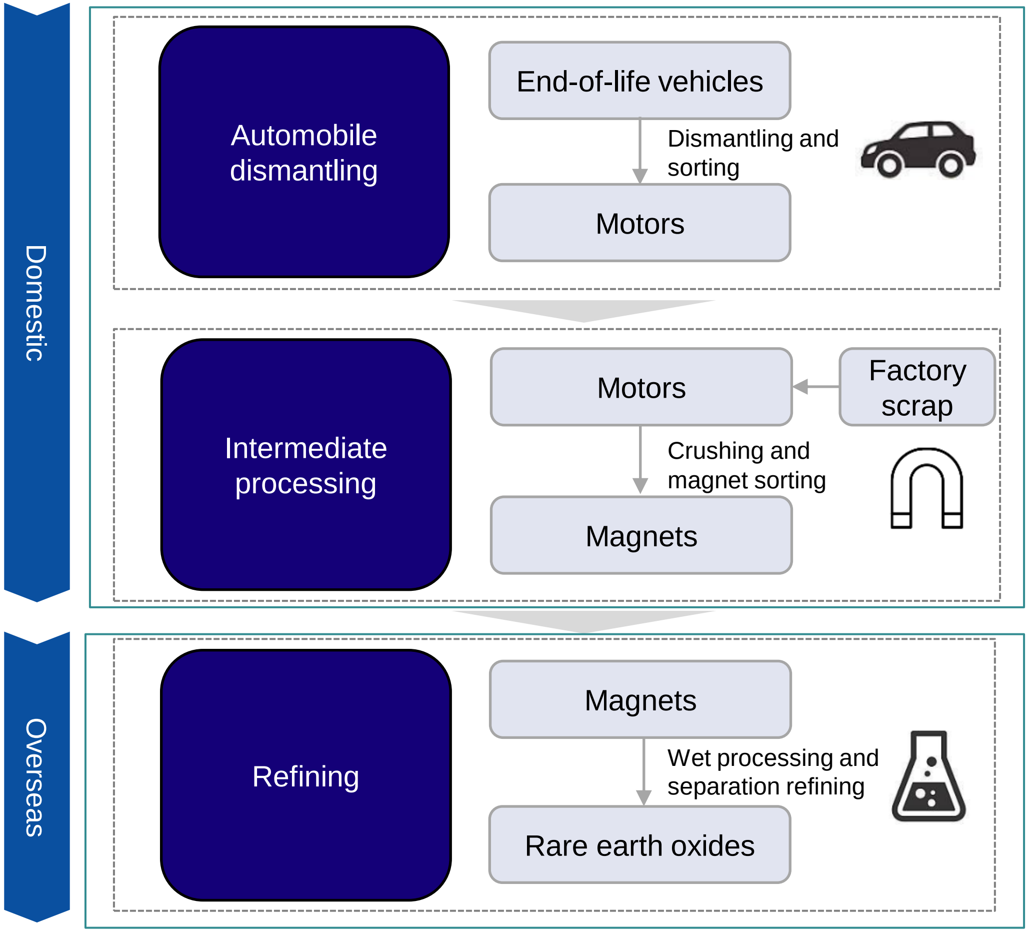
Note: Certification System for Public Interest Digital Platform Operators: A system that certifies private enterprises and others that meet certification standards among applicants who operate and manage data collaboration systems

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on Automotive and Battery Traceability Center and Ministry of Economy, Trade and Industry materials

Current status of neodymium magnet recycling

- Neodymium magnet recycling technology is at the research stage. While factory-generated scrap is collected and recycled, used neodymium magnets are exported overseas, and recycled rare earths processed locally are re-imported.
- To secure volume, similar approaches to lithium-ion batteries are envisioned. Used wind turbines will also become promising targets in the future.
  - — However, implementing recycling in Japan requires development of refining technology with low environmental impact.

Expected recycling flow for used neodymium magnets (Example: Automobiles)



Issues in commercializing neodymium magnet recycling

Issue 1

How to collect used magnets necessary for recycling

- ✓ EV drive motors make up the majority segment
  - Similar approaches to LiB are envisioned
- ✓ Per 1 MW of wind power generation, offshore wind uses 106 kg of neodymium magnets and onshore wind uses 70 kg, with low risk of used wind turbines flowing overseas
  - Used wind turbines will become targets in the future

Issue 2

Can refining processes currently conducted overseas due to environmental regulations and costs be performed domestically?

- ✓ Existing mixer-settler technology in refining processes violates Japan's environmental standards. However, there are risks of stricter environmental regulations in Vietnam in the future
- ✓ To implement domestic refining, development of low-cost refining technology that suppresses waste liquid generation is required

Source: Both charts were compiled by Industry Research Department, Mizuho Bank, Ltd. based on Ministry of Economy, Trade and Industry and various materials

[Reference] Each company's initiatives and business areas in neodymium magnet recycling

- Santoku and Shin-Etsu Chemical wet-process grinding powder and other materials to recover rare earths. Additionally, Envipro Holdings and Nissan are advancing research using methods other than conventional approaches. While each company's initiatives are progressing, prospects for commercializing used neodymium magnet recycling have not been established. To develop refining technology with low environmental impact, research and development through inter-company and industry-academia-government collaboration is required.

Each Company's Initiatives in Neodymium Magnet Recycling

Representative Company Names	Initiative Status
Santoku Corporation	• Collects grinding powder from neodymium magnets and recovers rare earths through wet processing for reuse in magnets • Participates in NEDO's "Development of Technologies for Separation and Refinement of Heavy Rare Earths." Collaborates with multiple companies and universities on separation and refining technology development (2023-2027)
Shin-Etsu Chemical Co., Ltd.	• Recovers rare earths from grinding powder generated during magnet production through wet processing for reuse in magnets • Initiated magnet recycling efforts with Toyota Motor Corporation, regenerating magnets recovered from scrapped Prius vehicles into new magnets
Envipro Holdings HyProMag	• Signed MOU with UK's HyProMag regarding rare earth magnet recycling (June 2024) • Their technology requires no demagnetization, crushing, or chemical processing, attracting attention as a low-cost, low environmental impact recycling method • Plans to recycle waste neodymium magnets collected by Envipro in Japan
Nissan Motor Co., Ltd. Waseda University	• Melts rotors as-is at 1,400° C or higher without disassembly, oxidizes rare earths in molten liquid, and recovers compounds • Can recover 98% of rare earths used in motors. Reduces work time by half as magnet extraction is unnecessary • Aims for practical application in mid-2020s (September 2021)
Toyota Metal Co., Ltd.	• Ahead of HV proliferation, established recycling process to recover neodymium magnets from motors

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on various materials

Each Company's Business Areas in Neodymium Magnet Recycling

	Automobile Dismantling	Intermediate Processing	Refining
Santoku Corporation			○
Shin-Etsu Chemical Co., Ltd.			○
Daido Electronics Co., Ltd.			○
Envipro Holdings HyProMag	○	△(Note 1)	△(Note 1)
Nissan Motor Co., Ltd. Waseda University		△(Note 2)	△(Note 2)
Mitsubishi Materials Corporation	○	△	
Asahi Pretec Corporation		△	
Toyota Metal Co., Ltd.		○	

○: Commercial operation level (refining targets scrap recycling) △: Pilot level

Note 1: Uses hydrogen embrittlement waste magnet recycling technology that does not require existing intermediate processing and separation refining processes

Note 2: Recovers rare earth compounds by firing rotors as-is

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on various materials

R&D trends toward domestic commercialization of refining processes

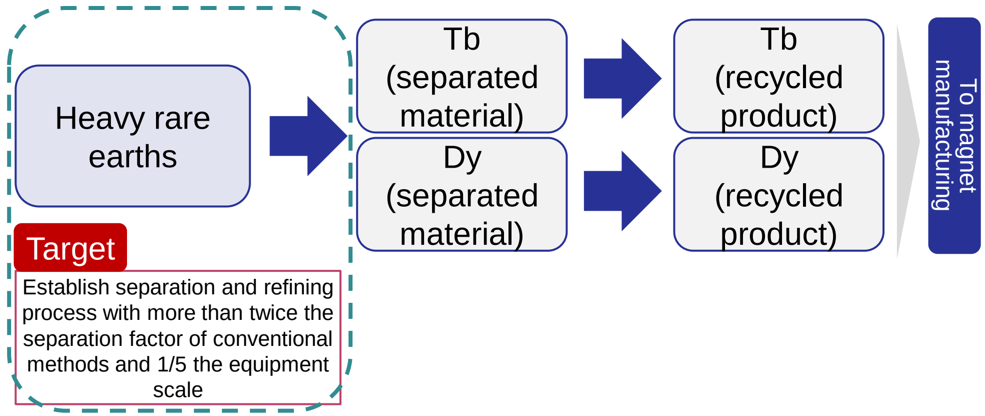
- The emulsion flow method significantly reduces the amount of solvents used, making it an attractive technology for refining with reduced environmental impact in Japan, where environmental regulations are strict.
  - Compared with conventional solvent extraction equipment (mixer-settlers), CAPEX is significantly reduced through reduction of solvent extraction process steps and plant miniaturization, with the advantage of being able to process different types of waste magnets in the same plant.
- NEDO is working on technology development to separate dysprosium (Dy) and terbium (Tb) using the emulsion flow method.

Refining process using emulsion flow method

- ✓ Basic technology developed by Japan Atomic Energy Agency
- ✓ Enables low-cost, high-purity element separation compared with conventional solvent extraction equipment (mixer-settlers). Also enables environmental impact reduction through significant reduction in solvent usage due to miniaturization of solvent extraction equipment

	Mixer-Settler	Emulsion Flow
Solvent extraction process	Mixing → Standing → Separation	Liquid feeding only
Solvent extraction plant size (rare earths)	1	1/10 or less
Plant type	Need to design individual plants according to waste magnet types; new plant design required when raw materials change	Can process and operate different types of waste magnets in the same plant, enabling standardization of recycling processes

NEDO's research trends utilizing emulsion flow method



Initiative Overview

- ✓ NEDO is working on rare earth separation and refining technology development project from components and materials in 2023-2027
- ✓ Dy and Tb are added to enhance neodymium magnet performance, but when mixed, they cannot demonstrate their original performance. NEDO is developing technology to separate Dy and Tb from each other with high precision using emulsion flow equipment

Universities	Saga University, Kobe University, Kagoshima University, Osaka University
Companies, etc.	National Institute of Advanced Industrial Science and Technology, Santoku Corporation, Emulsion Flow Technologies, Japan Atomic Energy Agency

Source: Both charts were compiled by Industry Research Department, Mizuho Bank, Ltd. based on Emulsion Flow Technologies and NEDO materials

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