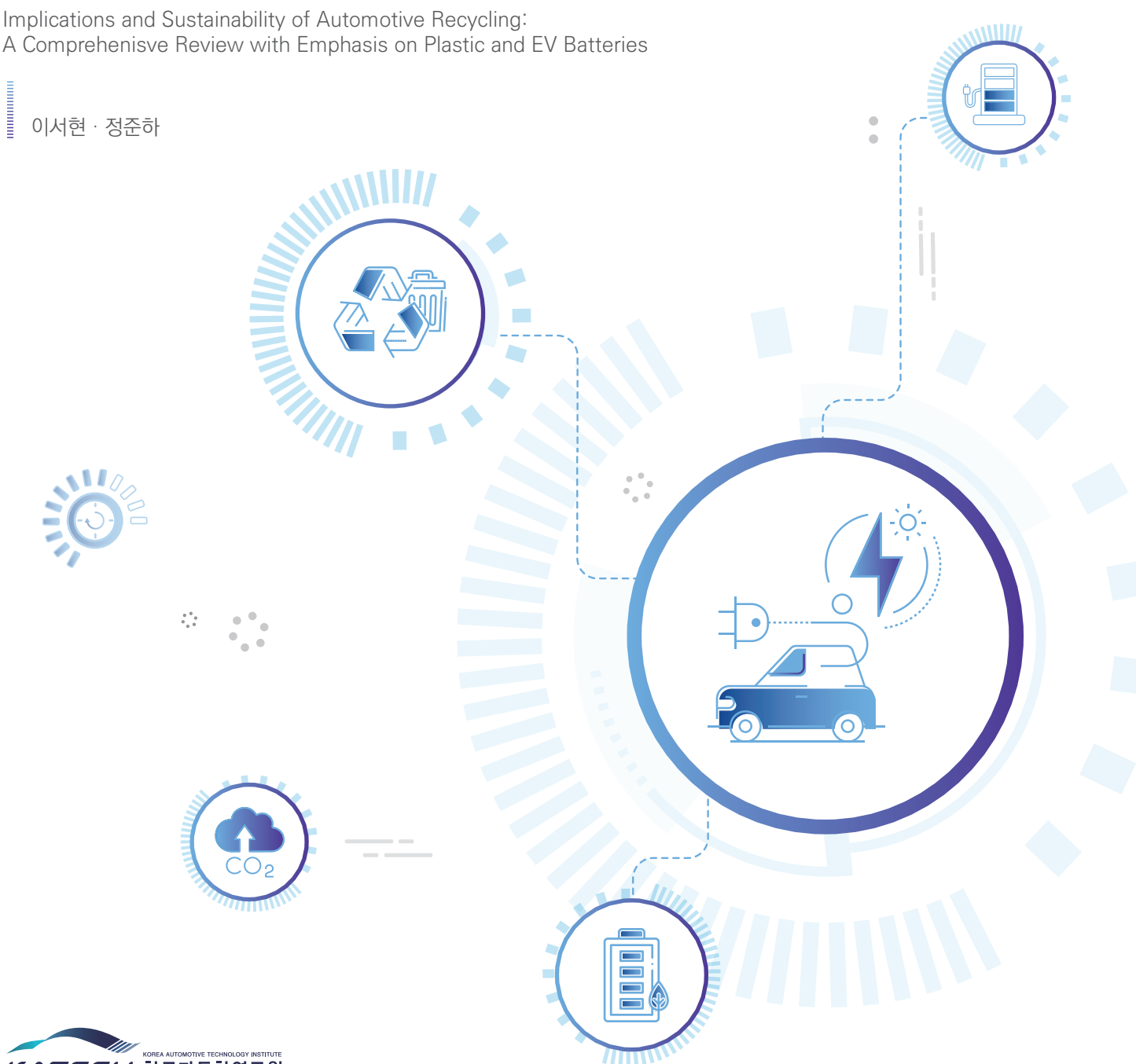


자동차 자원순환의 필요성과 시사점

플라스틱·배터리 재활용을 중심으로

Implications and Sustainability of Automotive Recycling:
A Comprehensive Review with Emphasis on Plastic and EV Batteries

이서현 · 정준하



Abstract

Implication and Sustainability of Automotive Recycling: A Comprehensive Review with Emphasis on Plastic and EV Batteries

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1. Introduction

(Background)

- The need for automotive recycling is increasing among OEMs and parts manufacturers as global policy, led by the EU, continue to be strengthened and supply chain risks emerge.

2. Overview of Automotive Recycling and the Policy Trends

(Overview of Automotive Recycling)

- (ELVs) Vehicles use a vast amount of resources during their production. After being used, they may be scrapped if they don't meet the relevant environmental and economical standards.

〈Table 1〉 Classification of End of Life Vehicles(ELVs)

Classification	Process
Vehicles that are inoperable domestically due to regulations and are suitable for scrap because the repair costs are higher than their current value, and: ① they are inoperable also in overseas due to their poor condition, or ② export is impossible because the expenses(transport costs, etc.) outweigh the profits	Scrap
Vehicles that are inoperable domestically due to regulations and suitable for scrap because repair costs are higher than their value, but can be exported because they are operable overseas (due to more relaxed regulations, or cheaper repair costs due to lower labor costs)	Scrap or Export

- (Recycling) End-of-Life Vehicle(ELV) and its resources are either remanufactured, reused or recycled, depending on their condition.

〈Table 2〉 Classification of Recycling Methods

Definition	
Remanufacturing	Among the activities that make “recyclable resources*” to recyclable, reusable condition, activity that restore the resources their original performance(or better) through processes such as disassembly, inspection, maintenance, and reassembly, etc.
Reuse	Activity that allows “recyclable resources” to be reused in their current condition or after minor repairs
Recycle	Reusing or recycling waste materials
Circulation Use	Using whole or some of “recyclable resources” as raw material * Raw materials which consist of whole or some of “recyclable resources” are defined as “recycled raw materials”

* The meaning of ‘recyclable resources’ is defined in Article 2, Subparagraph 2 of the 「ACT ON THE PROMOTION OF SAVING AND RECYCLING OF RESOURCES」

- (ELV Recycling Process) In South Korea, ELVs and their resources are recycled through automotive dismantling recyclers, scrap recyclers, ASR(Automotive Shredder Residue) recyclers, and waste gas treatment business operators, sequentially.
- (Vehicle Electrification and Recycling) Due to the motorization and electrification of vehicles, the use of metals, plastics, and electronic components is expected to grow exponentially. However, these materials are difficult to recycle, making automotive recycling even more arduous.

◆ (Global Policy on Automotive Recycling)

- (Trends) As regulatory obligations and their scope continue to strengthen, the need to consider resource circulation during the product design stage and to share supply chain data is increasing.

〈Table 3〉 European Union’s Core Policies Regarding Automotive Recycling

Policy	Effective Date	Overview
Eco Design Regulation	2024.7	<ul style="list-style-type: none"> • Promote circular product design, taking into consideration the product durability and reusability • Disclosure of recycling information, such as annual waste volume • Mandatory attachment of Digital Product Passport(DPP)
Battery Regulation	2023.8	<ul style="list-style-type: none"> • Introduction of Digital Battery Passport • Mandatory usage of recycled raw materials in battery production • Requirement for battery producers to collect and recycle EoL batteries
ELV Regulation (Proposed amendment to current ELV directive)	TBD (Proposal released 2023.7)	Current ELV directive is to be strengthened, including: <ul style="list-style-type: none"> • A ban on the export of ELVs(Vehicle that is inoperable in EU due to regulations and suitable for scrap because repair costs are higher than their value, but can be exported because they are operable overseas) • Mandatory use of recycled plastic in vehicle production • Mandatory recycling of plastics originated from ELV • A requirement for the removal of e-drive motors, electronic components, EoL batteries and other sixteen kinds of parts

- (South Korean Policies①) Eco-Assurance System(EcoAS) and Extended Producer Responsibility (EPR) are in effect for the automotive recycling, with the legal framework to foster the growth of EoL battery reuse and recycle industries is being established.
- (South Korean Policy Changes②) While vehicles are not subject to EPR, five types of plastic-based vehicle maintenance parts became subject to EPR in 2023. Including all types of EoL batteries in the EPR list was considered but not implemented. However, adding LFP batteries alone to the EPR list is currently under consideration.

〈Table 4〉 South Korea’s Core Policies Regarding Automotive Recycling

Classification		Overview
ELVs & Plastics	EcoAS	<ul style="list-style-type: none"> • (OEMs, Vehicle importers) Must comply with hazardous substance content standards and provide relevant recycling information (including the dismantling process, location of hazardous materials to be removed, and composition of synthetic polymer compounds, etc.) to recyclers • (Recyclers) Must recycle ELVs and their parts as much as possible to meet the ELV recycling target of 95%
	EPR	<ul style="list-style-type: none"> • Assigns the responsibility for the recovery and recycling of waste materials, such as plastics, to product producers • EoL batteries are not included, unlike the EU • Five types of plastic-based vehicle maintenance parts(bumpers, moldings and garnishes, under covers, washer and coolant tanks) are included in 2023
EoL Batteries	Electrical Appliances and Consumer Products Safety Control Act	<ul style="list-style-type: none"> • Distribution of EoL batteries for reuse is only permitted if they pass safety inspections, which are to be conducted by designated agencies • Designation of EoL battery inspection agencies(9 agencies available, as of August 2024.)
	Act on Promotion of Transition to Circular Economy and Society	<ul style="list-style-type: none"> • Designation of EoL batteries as ‘circular resources’* rather than waste, reducing regulatory burden for companies <p>* Only for the purposes of remanufacturing and reuse(recycling is not included)</p>
	Law·Policy·Infrastructure Building Plan for EoL Battery Reuse and Recycle Industries	<ul style="list-style-type: none"> • Establishment of various battery life cycle management systems, to be developed by different government ministries: <ul style="list-style-type: none"> (MOTIE) Battery supply chain data, trade information system (EoL battery distribution and reuse history, etc.) (ME) Integrated EV life cycle environmental information system(battery recharge information, battery recycling history, etc.) (MOLIT) EV battery safety certification management system(battery safety certification, performance evaluation, remanufacturing history) • An integrated platform, connecting aforementioned systems • Introduction of certification system for recycled raw materials (production and usage) • Introduction of battery pre-removal evaluation system • Establishment of distribution system for EoL batteries(incl. the establishment of specialized business registration, trade and storage standards, and transaction information system)

3. Current Status of Automotive Recycling

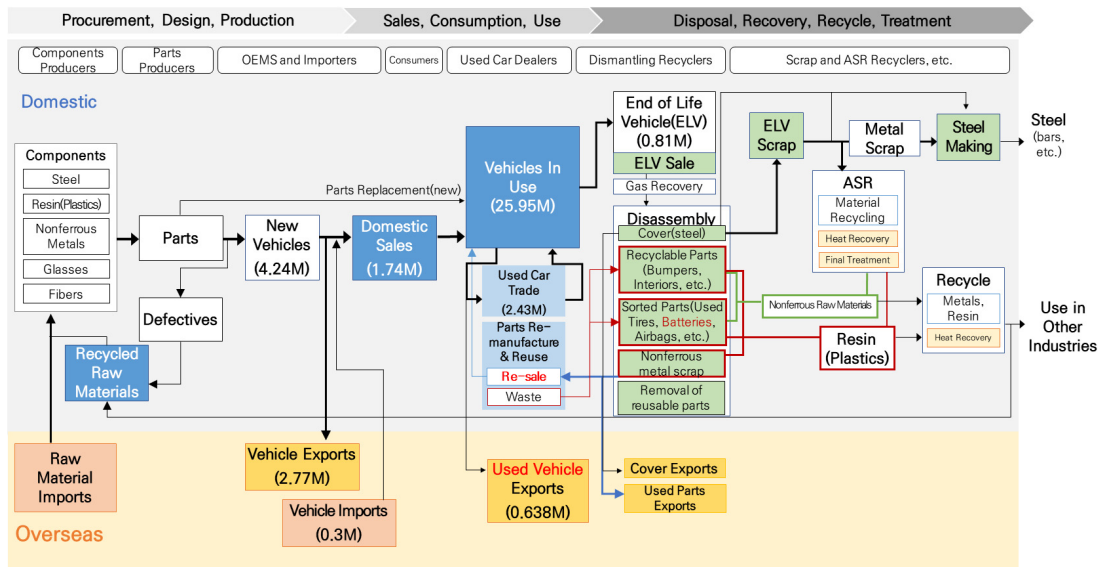
◆ (Automotive Recycling in South Korea)

◎ (Scope) This research focuses on the domestic circulation of ELVs, specifically plastic and EoL batteries. The latest trends in global policies and vehicle electrification are taken into consideration.

① End-of-Life Vehicle(ELV)

- (Status) S. Korea has a relatively well-established ELV management structure compared to other countries, with almost all ELVs processed by registered recyclers.
- (Issue) However, the recycling rate of ELVs and their resources in S. Korea is assumed to be relatively low. The development of ASR treatment technology is proposed as a solution.
- (Outlook) As the number of EoL EVs is expected to rise, investments and support are needed for recyclers, as they require additional infrastructure and technology to process these EVs.

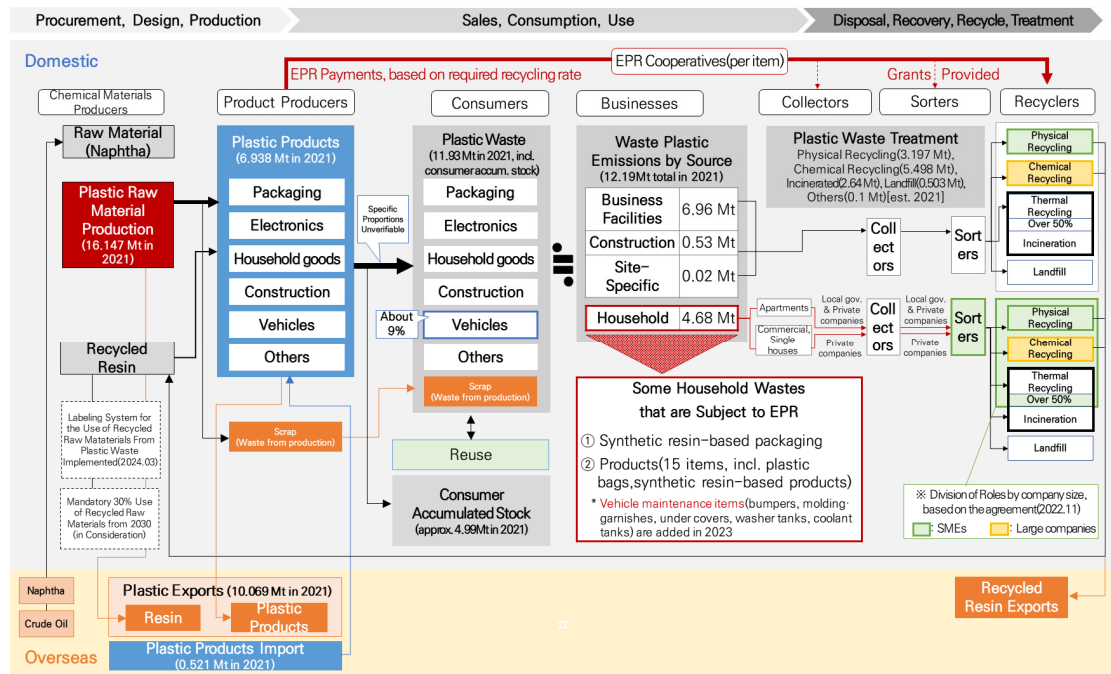
[Figure 1] Overview of Automotive Circulation Flow in South Korea



2 Plastic

- **(Global plastic usage and waste)** The automotive industry ranked 3rd in plastic usage among all industries. The proportion of plastic used in new vehicle is expected to rise (currently 10% by weight and 50% by volume). However, most of the plastic from ELVs is difficult to reuse or recycle, leading to a predominance of incineration.
- **(Domestic plastic usage and waste)** Plastic usage and emissions within the Korean automotive industry are unverifiable due to a lack of statistical data. However, the usage of recycled plastic in vehicle production and the recycling rate of plastic originating from ELVs are both low.
- **(Global policy trends)** Major countries are introducing policies such as mandates for the use of recycled raw materials in the production of new plastics. Given the extensive use of plastic in vehicles, these trends are expected to have huge impact on the automotive industry.
- **(Status)** Demand for high-quality raw materials suitable for recycled plastic production is anticipated to rise exponentially. However, since the domestic recycling industry is primarily composed of SMEs, obtaining a sufficient amount of high-quality raw materials remains a challenge. Nevertheless, based on the recent mutual growth agreement between large companies and SMEs, gradual improvement can be expected.
- **(Outlook)** The recycling rate of plastic is expected to gradually increase, driven by the revision of EPR in 2023 and the target for the use of recycled plastics by OEMs. (20% by 2030, up from the current 2%)

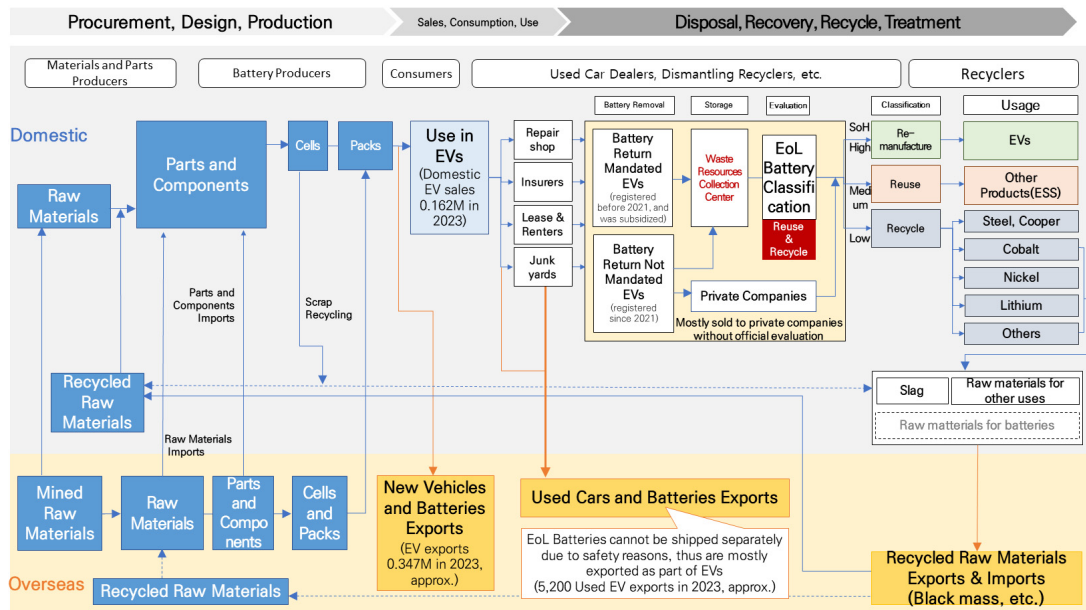
[Figure 2] Overview of Plastic Circulation Flow in South Korea



3 End-of-Life(EoL) Batteries

- **(Battery usage and waste)** While the adoption of Electric Vehicle(EV) continues to rise, EoL batteries are expected to be discharged in large quantities starting in 2030. For instance, the current output of EoL batteries(14,000 unit) in South Korea is expected to grow to 108,000 unit by 2030. Hence, achieving economies of scale by securing raw materials remains a top priority, to foster the growth of EoL battery reuse and recycling industries.
- **(Domestic policy)** The South Korean government has amended its EV subsidy recovery policy to ensure that EoL EVs and their batteries are primarily circulated domestically. If an EV is deregistered before completing the mandatory operation period—especially for export reasons—the last owner of the EV must return a portion of the subsidy.
- **(Status)** Previously, EoL batteries from scrapped EVs were required to be return to the relevant local governments. However, EVs registered since 2021 are exempt from this rule, thus leaving a gap in the management of EoL batteries.
- **(Outlook)** After being removed from EVs, EoL batteries are classified and sent to remanufacturing, reuse, or recycling industries based on their state of health(SoH). While the battery recycling industry has garnered some attention recently, the remanufacturing and reuse industries are also expected to grow exponentially in the future.

[Figure 3] Overview of End of Life(EoL) Battery Circulation Flow in South Korea



◆ (Automotive Recycling in Major Countries)

◎ (Scope) The EU and China are researched, as they lead on global policy making and EV sales, respectively. China is also the fastest to establish EoL battery recovery system.

1 EU

- (ELV) Despite having world-leading recycling technologies, the EU has a relatively inferior ELV management system, with one-third of ELVs considered to be missing. To address the issue, the EU proposed the ELV regulation to reinforce its management structure and plans to develop an integrated ELV management system.
- (Plastic) The ELV regulation will mandate a 25% use of recycled plastics (from ELVs) in vehicle production, and mandate a 30% recycling rate of plastics originated from ELVs.
- (EoL Batteries) The Battery regulation, which came into effect in August 2023, assigns battery manufacturers the responsibility of recovering and recycling EoL batteries, and require proof of the use of recycled raw materials and supply chain due diligence. To facilitate this, cross-industry data sharing platforms, such as Catena-X, are being developed.

2 China

- (ELV) Due to relatively poor ELV management system and the competitiveness of registered recyclers, over 85% of ELVs and their resources are believed to be processed illegally in China. To counteract this problem, the government has initiated a pilot program for automotive EPR and introduced tax reductions for registered dismantling recyclers.
- (Plastic) The overall recovery and recycling rate of plastics is not high, and the policies promoting the use of ELV-originated plastic are considered insufficient. Likewise, the demand for recycled plastics within the local automotive industry is minimal.
- (EoL Batteries) China has established an EoL battery life cycle management system in 2018, the fastest among major countries. However, some amendments are required to enhance its effectiveness.

③ Comparison between major countries

- The comparative analysis between South Korea, the EU, and China are summarized as below.

〈Table 5〉 Comparison of Major Countries' Recycling Status of ELVs and Its Resources

Country	ELVs and Its Resources			
		EoL EVs	EoL Batteries	Plastics
South Korea	<ul style="list-style-type: none"> • Almost all ELVs are processed through registered recyclers • Exports of ELV to developing nations are on the rise 	<ul style="list-style-type: none"> • A significant amount of EoL EVs are being exported 	<ul style="list-style-type: none"> • Due to safety issues, EoL batteries are not traded separately, but as part of the EV • Recycled raw materials are imported en masse from the EU 	<ul style="list-style-type: none"> • The usage rate of recycled plastics in vehicle production is targeted to 20% by 2030, up from the current 2%
EU	<ul style="list-style-type: none"> • One-third of ELVs are considered missing • Exports of ELV to developing nations are on the rise 	<ul style="list-style-type: none"> • Exports to developing nations are on the rise 	<ul style="list-style-type: none"> • Due to safety issues, EoL batteries are not traded separately, but as part of the EV • Recycled raw materials are exported(ex: 20,000 tons of black mass exported to South Korea(out of 30,000 tons)) 	<ul style="list-style-type: none"> • The usage rate of recycled plastics in vehicle production is approximately 8%
China	<ul style="list-style-type: none"> • 85% of ELVs are processed improperly • The export amount of ELVs is limited 	<ul style="list-style-type: none"> • The export of EoL EVs began recently, with most of exported vehicles being almost new NEVs(New Energy Vehicles) 	<ul style="list-style-type: none"> • 75% of EoL batteries are processed improperly by unregistered companies • The import of EoL batteries and black mass is nearly impossible 	<ul style="list-style-type: none"> • Recovery and recycling are almost non-existent

〈Table 6〉 Comparison of Major Countries' Policies Regarding ELVs and Its Resources

Country	ELVs and Its Resources			
		End of Life (EoL) EVs	EoL Batteries	Plastic
South Korea	<ul style="list-style-type: none"> Not subject to EPR, but the target recycling rate is set by EcoAS Almost all ELVs are managed properly through ELV registration and management system 	<ul style="list-style-type: none"> Not subject to EPR The EV subsidy recovery policy has been strengthened to discourage EV deregistration for export. 	<ul style="list-style-type: none"> Not subject to EPR EVs registered prior to 2021 are required to return their batteries, but EVs registered since 2021 are exempt from this requirement. A battery life cycle management system is planned (by 2027) 	<ul style="list-style-type: none"> Not subject to EPR, but five plastic-based vehicle maintenance parts (bumpers, moldings and garnishes, under covers, washer tanks, coolant tanks) are subject to EPR
EU	<ul style="list-style-type: none"> Subject to EPR An integrated vehicle registration and management system is planned (by 2029) Limiting exports of inoperable ELV by designating them as wastes is being considered 	<ul style="list-style-type: none"> Subject to EPR An integrated vehicle registration and management system is planned (by 2029) Limiting exports of inoperable ELV by designating them as wastes are being considered 	<ul style="list-style-type: none"> Through the Battery Regulation: <ol style="list-style-type: none"> Application of EPR Mandating the use of recycled raw materials in product production Establishment of a battery life cycle management system Require SLI batteries to be disassembled Limiting the export of black mass by designating it as hazardous waste 	<ul style="list-style-type: none"> Subject to automotive EPR A minimum of 30% (by weight) recycling of plastics originated from ELV is mandatory. A minimum of 25% use of recycled plastic (6.25% from ELV based) in vehicle production from 2030
China	<ul style="list-style-type: none"> Not subject to EPR Introduction of policies to promote the competitiveness of registered dismantling recyclers, such as the application of a simplified tax method for value-added tax 	<ul style="list-style-type: none"> Not subject to EPR NEV batteries are managed by a life cycle management system since 2018 	<ul style="list-style-type: none"> Subject to EPR A battery life cycle management system in operation, with an upgrade planned by the end of 2024 Allowing imports of EoL batteries and black mass is under consideration (to be determined by the end of 2024) 	<ul style="list-style-type: none"> No verifiable policy to promote plastic recycling

4. Status and Outlook of Automotive Recycling Technology

◆ (Plastic Recovery and Recycling)

- **(Status)** Plastic recycling technologies can be classified into physical, chemical, and thermal methods. Considering the environmental regulations concerning the automotive industry, physical and chemical recycling are primarily employed to recycle plastics from ELV and to produce recycled plastics.
- **(Outlook)** Currently, physical recycling is the most widely used methods for producing recycled plastics. However, it has limitations in terms of the scope of application and the quality of the output. Therefore, advancements in plastic recovery and cleaning systems, as well as the development of chemical recycling technology, are suggested.

◆ (EoL Battery Recovery and Recycle)

- (Battery Reuse) Advancements are being made in the fields of battery diagnosis and dismantling, with a focus on applying AI and data analysis techniques to enhance the speed and accuracy of these processes.
- (Battery Recycling) Pyrometallurgy and hydrometallurgy are currently widely used techniques to recover rare metals from EoL batteries. Recent studies have concentrated on improving the economic efficiency and environmental impact of battery recycling.

5. Conclusion and Implications

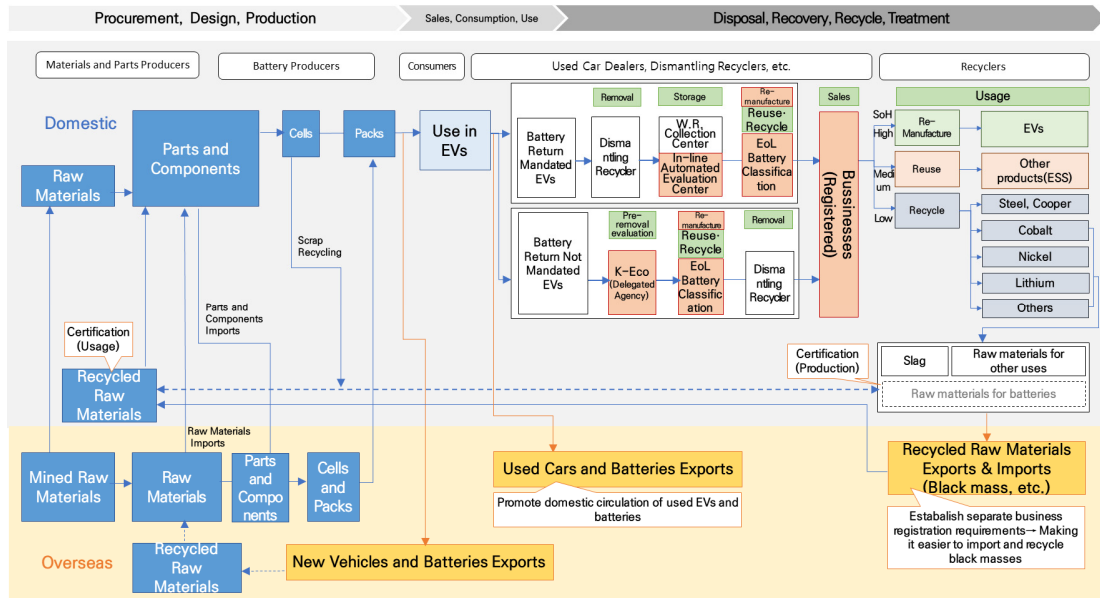
◆ (Promote the Plastic Recycling Within the Automotive Industry)

- Investments are needed in plastic collection, sorting, and cleaning sectors to enhance the efficiency and economic feasibility of plastic recycling.
- In order to meet the regulatory requirements, such as the mandatory use of recycled plastic in vehicle production and the recycling of plastics originated from ELV, advancements in plastic separation and recovery systems, as well as ASR recycling technology, are essential.
- For OEMs, it is crucial to ① achieve the economic feasibility of using recycled plastics in vehicle production, ② ensure that the quality of recycled plastics matches that of new ones, and ③ reduce carbon emissions. In order to accomplish these goals, leveraging chemical recycling technology would be needed, alongside the physical recycling.
- Last but not least, the establishment of an advanced statistical system is vital, not only in understanding an accurate overview of the plastic recycling today, but also in meeting the requirements of international regulations such as the UN plastic treaty.

◆ (Promote the Domestic Circulation of EoL Batteries)

- To bolster the growth of EoL battery reuse and recycle industries, the South Korean government plans to establish relevant law, policy, and infrastructures by 2027. This includes ① a life cycle management system, ② a certification system for the use and production of recycled raw materials, ③ EoL battery pre-removal evaluation system.
- Since acquiring raw materials(EoL batteries) remains a critical task for the aforementioned industries, promoting the domestic circulation of EoL EVs and their batteries is necessary. Encouraging domestic trade of EVs and developing guidelines for EV subsidy recovery policy should be considered.
- To further promote the circulation of EVs and reduce supply chain risks, it's important to foster the growth of remanufacture and reuse of other automotive parts as well, such as e-drive motors.
- When aforementioned framework is established and the recycling of EoL EVs is enhanced, substantial improvement in EoL battery recycling can be expected.

[Figure 4] Expected Improvement in EoL Battery Circulation Flow in South Korea



◆ (Consolidate Cross-Industry Cooperation)

- To effectively address global regulatory requirements, the need for cross-industry data integration is becoming more prominent. Accordingly, domestic companies—including OEMs, parts manufacturers, and raw material manufacturers—need to cooperate.
- Amendments to current regulations may be considered to ensure the quality of recycling information provided by OEMs and vehicle importers.



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