Innovations for Plastic Circularity in Korea: Enabling Conditions and Solutions

Supplementary Note for Scaling Innovations for Plastic Circularity with Investment in ASEAN
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<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
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<tr>
<td>AMS</td>
<td>ASEAN Member States</td>
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<td>ASEAN</td>
<td>Association of Southeast Asian Nations</td>
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<td>CNPP</td>
<td>Carbon Neutrality Practice Point</td>
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<td>EPR</td>
<td>Extended Producer Responsibility</td>
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<td>e-TechHive</td>
<td>Environmental Technology Innovation and Research Park</td>
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<td>HDPE</td>
<td>High-density Polyethylene</td>
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<td>IoT</td>
<td>Internet-of-Things</td>
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<td>IP</td>
<td>Intellectual Property</td>
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<td>KCCP</td>
<td>Korea Commission for Corporate Partnership</td>
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<td>KECO</td>
<td>Korea Environment Corporation</td>
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<td>Korea Environmental Industry and Technology Institute</td>
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<td>KEPCO</td>
<td>Korea Electric Power Corporation</td>
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<td>KIAT</td>
<td>Korea Institute for Advancement of Technology</td>
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<td>KOSME</td>
<td>Korea SMEs and Startups Agency</td>
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<td>KOTEK</td>
<td>Korea Technology Finance Corporation</td>
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<td>K-Water</td>
<td>Korea Water Resources Corporation</td>
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<td>LDPE</td>
<td>Low-density Polyethylene</td>
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<td>MFDS</td>
<td>Ministry of Food and Drug Safety</td>
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<td>MOE</td>
<td>Ministry of Environment</td>
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<td>MOSS</td>
<td>Ministry of SMEs and Startups</td>
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<td>MOTIE</td>
<td>Ministry of Trade, Industry, and Energy</td>
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<td>MRFs</td>
<td>Material Recovery Facilities</td>
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<td>MVP</td>
<td>Minimum Viable Product</td>
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<td>NCC</td>
<td>National Cooperation Center</td>
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<td>NIR</td>
<td>Near-infrared Spectroscopy</td>
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<td>ODA</td>
<td>Official Development Assistance</td>
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<td>PET</td>
<td>Polyethylene Terephthalate</td>
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<td>PP</td>
<td>Polypropylene</td>
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<td>PS</td>
<td>Polystyrene</td>
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<td>PVC</td>
<td>Polyvinyl Chloride</td>
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<td>R&amp;D</td>
<td>Research and Development</td>
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<td>RGO</td>
<td>Regenerated Green Oil</td>
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<td>SMEs</td>
<td>Small and Medium-sized Enterprises</td>
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<td>SUP</td>
<td>Single-use Plastic</td>
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<td>TIPA</td>
<td>Korea Technology and Information Promotion Agency for SMEs</td>
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<td>TIPS</td>
<td>Tech Incubator Program for Startups</td>
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**Glossary**

**Innovation:** The meaning of the word “innovation” varies, depending on the prevailing norms in a particular market. In this report, innovation applies to the technologies, materials, and business approaches that are used in the Republic of Korea to tackle the plastic pollution-related challenges that occur upstream, midstream, and downstream in the plastic value chain before plastic waste leaks into the environment or is transferred to a disposal site.

**Material recovery facility (MRF):** A building that receives, sorts, processes, and stores recyclable materials that are to be marketed and shipped to end-users. An MRF accepts materials that are either separated at source, or are mixed; it separates the materials, if needed; and processes and stores them for use as raw material for remanufacturing and reprocessing.

**Plastic circularity:** This term applies to technologies, business models, and other solutions that tackle the plastic pollution challenge by eliminating, reducing, or reusing plastic materials, and keeping them in circulation without their leaking into the environment.

**Plastic waste:** Any discarded plastic (organic, synthetic, or material derived from polymers, resins, or cellulose) that has been generated by an industrial process, or by consumers.¹

**Recycling:** 1) A resource recovery method that involves the collection and treatment of a waste product for use as raw material to manufacture the same product or a similar one. 2) The re-utilization of products or components in their original form as, for example, when used glass bottles are sterilized and refilled for resale.²

**Volume-based waste fee:** A fee introduced by the government of Korea in 1995 to provide an economic incentive for people to reduce their garbage by making them pay removal fees that are based on how much garbage they generate.

**Waste management:** The supervision of waste generation, handling, processing, storage, and transport from its point of generation to its final acceptable form of disposal.³

² Ibid.
³ Ibid.
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CHAPTER 1.  Background

Plastic waste has a serious impact on human health and biodiversity in the countries that are members of the Association of Southeast Asian Nations (ASEAN). In 2021, in just six ASEAN member states (AMS)—Cambodia, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam—the amount of mismanaged plastic waste was at least 8.4 million metric tons. The capacity to manage solid and plastic waste varies across these countries due to differing challenges, but all have high rates of mismanaged plastic packaging. While, Malaysia, Thailand, and Vietnam have improved their solid waste and recycling systems, Cambodia lacks the necessary policies and infrastructure to effectively carry out waste segregation at source, and to collect, treat, and dispose of it. Indonesia and the Philippines, which both have thousands of islands, face other unique challenges that require customized waste management solutions.

Despite the differences in waste management across these six AMS, they share the same significant plastic waste issue—the mismanagement of flexible packaging and other single-use items, such as food wrappers, plastic bags, takeaway cups, and plastic straws. These countries have largely focused on the downstream stage of waste management—clean up and waste treatment—rather than on the upstream stage of reducing the volume of plastic waste. Moreover, their solid waste management systems lack system-level support, economic incentives, and initiatives that enable upstream and midstream management.

In the 1970s, the Republic of Korea faced similar waste management concerns as those currently plaguing the six AMS: lack of waste segregation, lack of recycling infrastructure, and lack of waste disposal. Korea’s problems with solid and plastic waste management were rising rapidly in the 1970s due to country’s increasing population and growing economic prosperity, which generated significantly more waste—the key components of which were construction waste, electronics, and single-use plastics (SUPs). During the 1970s, Korean households discharged more than 3.06 kg of waste per day. Due to the country’s significant waste management improvements, by 2017, households’ waste disposal rate had fallen to a daily average of just 1.02 kg.

Korea has been able to significantly reduce its waste generation and increase its recycling rate through successfully developing and implementing key policies and regulations on waste circularity, as well as providing institutional support that has facilitated significant improvements in waste collection, transport, and the recovery of plastics. This paper presents information on several innovations that Korean entities have employed to improve plastic circularity and the related policies that have paved the way for their implementation.

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4 Meijer et al. 2021. “Over 1000 rivers accountable for 80% of global riverine plastic emissions into the ocean.”
5 Pheakdey et al. 2022. “Challenges and Priorities of Municipal Solid Waste Management in Cambodia.”
In the 1980s, Korea’s solid waste policy focused on safe waste treatment. The Waste Management Act of 1986 largely concerned waste disposal. However, since then, Korea’s waste management policy has evolved. Starting in the 1990s, the country has emphasized recycling, and from 2000 onwards, resource recirculation. The 1992 Act on the Promotion of Saving and Recycling of Resources concerned the more efficient use of resources through recycling. The Act’s instruments require reducing the volume of waste, increasing the rate of recycling, and ensuring environmentally sound waste treatment. In 1995, the Adjustment of the Waste Management Act introduced the Volume-based Waste Fee, which imposes disposal charges based on the volume of waste. This Act is considered to have made the greatest contribution of all legislation by substantially reducing Korea’s waste generation and increasing the country’s recycling rate. Waste segregation at source also began with this Act, and has resulted in high quality and uncontaminated recyclables.

Other policies that have contributed to Korea’s success in improving plastic circularity include the 2003 Extended Producer Responsibility (EPR) Act, which obligates producers to assume full financial responsibility for treating the waste from their products and packaging over their entire lifespan; the 2003 Construction Waste Recycling Promotion Act; the 2005 Food Waste Landfill Ban; and the 2008 regulations on Resource Circulation of Electrical and Electronic Equipment and Vehicles. In 2016, the Framework Act of Resource Circulation was enacted to promote the sustainable management of waste through all stages of a product’s lifespan from manufacturing through to safe disposal. In 2018, Comprehensive Measures for Waste Recycling introduced a series of specific actions to be carried out at each stage of the resource cycle from production, consumption, and collection/separation, to recycling and disposal.
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The Government of Korea first focused on increasing recycling to reduce plastic waste leakage in the environment and improve the disposal of recyclable plastic. Next, it focused on the different stages of production and consumption, such as the 1993 overpackaging ban and the 2019 SUP bag ban at the consumption stage. In 2019, following the amendment of the 1992 Act on the Promotion of Saving and Recycling of Resources, the packaging material and structure evaluation system was introduced. This system requires producers to evaluate the materials, structure, and ease of recycling for their products and packaging. It also provides incentives through varying EPR fees and encourages consumers to purchase products that are easy to recycle. Additional policies that have improved plastic circularity in Korea are free-of-charge pick up for separated recyclables, eco-labeling/green certificates, and the creation of markets for recycled products.

In Korea, both the central and local governments are major consumers of goods and services. The 1992 Act on Promotion of Saving and Recycling of Resources recommended that, as much as possible, public institutions purchase eco-labeled or recycled products to encourage the growth of the market for recycled and eco-friendly products. In 2005, the Ministry of Environment (MOE) promulgated the Act on Promotion of the Purchase of Environment-friendly Products, which introduced a green public procurement scheme. To date (May 2024), about 190 government entities provide the MOE with annual reports on how much they spend on green products. Starting in 2023, polyethylene terephthalate (PET) bottles must be manufactured with at least 3 percent of their plastic coming from recovered PET. Also, in 2023, the Recycling Industry Growth Fund was created to foster and support the recycling industry.

As noted above, since 2019, producers have been required to analyze the recycling potential of their product or packaging, including the label, container, cap, and other parts. The Korea Environment Corporation (KECO) checks these self-assessments to confirm the analysis. KECO then classifies products and packaging as “excellent,” “good,” “average,” or “poor” (difficult) based on the ease of recycling, and products and packaging must be labeled accordingly. In addition to the grade assigned by KECO, labels must provide information on the primary and miscellaneous materials used in production.

The packaging material and structure evaluation system has resulted in innovative changes in packaging design—for example, the change from colored PET bottles to transparent PET bottles, and from plastic labels to no labels or to easily removed labels.

Korea’s 2050 Carbon Neutral Strategy, which was developed in 2020, promotes circularity through the maximization of resource efficiency and the minimization of resource inputs. This covers a product’s entire lifespan from the extraction of resources to make the product, through its production, distribution, and consumption, to its recycling and disposal.

The Carbon Neutrality Practice Point (CNPP) system, which is stipulated in Article 67 of the Framework Act on Carbon Neutrality and Green Growth for Coping with the Climate Crisis, incentivizes consumers to practice various eco-friendly activities, including reusing products. Between 2022 and 2023, the government’s budget for the CNPP system tripled from $1.8 million to $6.8 million (won 2.4 billion to won 8.9 billion). Figure 2.1 shows the financial incentives provided to the public for their environmentally friendly actions:

Participants can earn up to 70,000 won, per person, per year, and choose the type of reward they want (cash or credit card points). KECO manages the CNPP system in collaboration with companies that provide consumers with points and receive budget support from KECO. The CNPP system partially finances the incentives for using Almang Market’s reusable products and Oysterable’s reusable cups.

Korea’s commitment to “product lifecycle and design management” and “a plastic-free society and sustainable

10 Korea has several certified testing institutions for conducting these evaluations for producers—for example, the Korea Testing and Research Institute, and the Korea Testing Certification Institute.

11 Almang Market is a zero-waste shop that sells eco-friendly products in bulk. Consumers bring their own containers. https://almang.modoo.at/

12 Oysterable, which is the leading Internet of Things circular economy solution company in Korea, provides recycling/reuse infrastructure that is designed to solve solid and plastic waste problems. https://oysterable.com/home-en.
measures” is evident through its policies and technologies. In 2023, Korea announced that in 2024 it will start enforcing its comprehensive plan, *New Industrial Growth Strategies through Revitalizing the Circulation Economy*, which is intended to spearhead the mandatory use of recycled materials and the development of industries that use plastic waste. This comprehensive plan highlights the expansion of accreditation for resource circulation; mandates for recycling materials; access to convenient infrastructure, such as unmanned recovery facilities; and a compensation system for the collection of high-quality plastic waste. In addition, this plan promotes automating material recovery facilities (MRFs); establishing a supply chain link between large enterprises and small and medium enterprises (SMEs) that recycle; managing full life-cycle circulation; introducing a rating system for recycled materials and resource efficiency; and developing circular economy clusters such as those in Busan and on Jeju Island. With these foundational policies and infrastructure in place, Korea is well-positioned to lead the way toward a more sustainable and circular economy future.
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CHAPTER 3

Institutional Support for Circularity

The agencies that are responsible for encouraging innovative solutions for plastic circularity are led by the MOE; Ministry of Trade, Industry, and Energy (MOTIE); and Ministry of SMEs and Startups (MOSS). These three ministries support the work of the Korea Environmental Industry and Technology Institute (KEITI); Korea Institute for Advancement of Technology (KIAT); Korea SMEs and Startups Agency (KOSME); and Korea Technology and Information Promotion Agency for SMEs (TIPA). The support provided by MOE, MOTIE, and MOSS comprises: (i) finance, (ii) technology protection and development, (iii) capacity building/technology transfer, (iv) comprehensive incubation/commercialization/industry promotion, and (v) international cooperation to achieve stable markets abroad.

3.1. Financial support

*Environmental Policy Fund:* Through the KEITI Environmental Policy Loan program, MOE supports environmental conservation efforts, resource circulation, and the strengthening of the environmental industry. This loan program provides long-term, low-interest loans to environmental sector enterprises to facilitate their development of innovations and growth. Between 2009 and 2018, the total for disbursed loans was $1.52 billion. Based on the Waste Management Act’s Article 2, No. 9,
and Article 17 of the Waste Reduction Facility, the KEITI loan program includes a Recycling Industry Growth Fund that is designated to foster economic development.  

*Policy Fund:* KOSME provides hybrid finance that combines both investment and low-interest loans for high-tech businesses with potential at the startup, growth, and restarting stages. Its Income Sharing Loan enables companies to repay the loan through a percentage of their income based on sales performance and the Growth Sharing Loan offers convertible bonds and loans at a low interest rate. KOSME also offers Business Restart Funds that support restructuring and restarting for struggling but promising businesses; funds for research to commercialize SMEs’ innovative technology; and Business Stabilization Funds for SMEs that are affected by a natural disaster or other difficulty.

### 3.2. Technology Development

The 2011 Act for Advancing Collaborative Efforts Between Large Corporations and SMEs protects SMEs from having their work taken over by larger and better-financed corporations. In 2021, when the Mandatory Recycling Ratio was implemented, large petrochemical corporations began to venture into waste sorting and recycling, which threatened SMEs’ recycling businesses. In response, organizations representing the SMEs petitioned the Korea Commission for Corporate Partnership (KCCP) to designate plastic recycling exclusively for SMEs. In October 2022, the KCCP, which arbitrates disputes between large corporations and SMEs, negotiated an agreement that designates SMEs responsible for physically shredding plastic waste, while petrochemical companies with the technical expertise and finances are responsible for chemical recycling—which often requires working with hazardous substances such as acids and solvents.

KEITI has 30 years of experience developing technologies for sorting plastic waste and producing alternatives to plastic. The MOSS technology protection program, which protects innovative technologies from being stolen, provides a safe environment for SMEs to conduct the research required to develop and disseminate their innovative technologies. The technology protection program that MOSS operates ensures that SMEs are paid fairly for the technologies they develop because MOSS will prosecute any infringement. As part of its program, MOSS provides affordable advice for SMEs about how to properly register ownership of their technology. MOSS also operates the SME Technical Dispute Mediation/Arbitration Committee that advises SMEs on how to stop infringement of their technology.

### 3.3. Capacity Building

Capacity building is essential to fostering technological innovation and developing skilled professionals. KEITI operates initiatives that are designed to equip technology developers with the core knowledge and skills they need to develop and implement innovative technologies. One of KEITI’s noteworthy initiatives is the Training Program for Environmental Assessment of Recycling, which enables unemployed individuals to develop the skills they need to effectively assess and oversee recycling processes.

KEITI also offers the Data Provision for Environmental Industry and Technology Development Program, which furnishes consumer-oriented information and supplementary services that support the environmental industry, technological advancements, and policy initiatives. By providing access to relevant data and information, KEITI improves the capacity of stakeholders to make informed decisions and take appropriate actions.

KIAT manages the i-Tube System, which is a research and development (R&D) infrastructure-sharing system that facilitates private sector technology innovation by providing access to research equipment, human resources

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13 The Recycling Industry Growth Fund, which KEITI oversees, is a strategic effort to bolster Korea’s recycling sector. This fund aims to enhance the sustainability and technological advancement of the recycling industry, and thereby contribute to the broader objectives of environmental preservation, and promoting the circular economy.

14 KOMES (Korea SMEs and Startups Agency). n.d. “Policy Fund.”

15 KEITI (Korea Environmental Industry and Technology Institute). 2023. “Fostering environmental companies.”

16 Ibid.
and services, and encourages collaboration between private companies and public R&D institutions. The companies that are selected to participate in the i-Tube System get technical support in developing and testing their innovations, as well as consulting services, and the government pays 70 percent of the cost. By providing affordable access to R&D infrastructure and expertise, the i-Tube System aims to accelerate the development of innovations, boost the competitiveness of Korean companies, and drive economic growth in strategic industries.

Another approach that promotes innovation is technology transfer. With assistance from the MOTIE, large corporations such as Samsung Electronics, SK, and POSCO, as well as public institutions such as the Korea Electric Power Corporation (KEPCO) and Korea Water Resources Corporation (K-Water), share or transfer their technologies/patents to SMEs or mid-sized companies for no cost. Through the Technology Transfer Promotion Program and the Technology Sharing Program, recipient companies can leverage technologies to create innovations that meet the needs of their business.17

In addition, the Korea Technology Finance Corporation (KOTEK) operates an open-technology innovation project called Tech-Bridge that facilitates technology transfer and commercialization. Public sector technologies of interest to SMEs are connected through the Tech-Bridge platform, which provides a network, online database, and database search tool, which has over 320,000 entries about intellectual property (IP) rights and new inventions.18

3.4. Commercialization Support

Commercialization of SMEs with Environmental Technology: This KEITI program offers multi-dimensional support to help environmental technology companies accelerate the commercialization of their innovations by providing finance, capacity building, and consulting services. Since 2010, KEITI’s program, which is based on the Environmental Technology and Environmental Industry Support Act’s Article 6, and the Enforcement Decree’s Article 17, has provided services to SMEs with potential to commercialize their environmental technology, which includes circular economy businesses that are working on “plastic-free” innovations. The services provided include consulting, technology adaptation, certification, and market-entry.19

Incubating green companies (KEITI’s e-TechHive): Since 2017, KEITI has supported environmental start-ups and SMEs through its Environmental Technology Innovation and Research Park (e-TechHive).20 These include venture capitalists, SMEs, research institutes, academic institutions, NGOs, and others that are interested in researching and developing environmental technologies. By 2022, e-TechHive had accommodated 130 companies and provided them with benefits that comprise support throughout the entire innovation development process. This includes facilities and consulting services through e-TechHive’s Business Doctor Support Program that assists with R&D, applying for patents, networking, partnerships, recruiting staff, and paying staff salaries.

3.5. International Cooperation

Korea is expanding its scope to develop international standards and explore new technologies abroad. The following activities show how KIAT and KEITI are supporting innovations.

Cooperation with the European Union and ASEAN: KIAT runs co-funding programs such as Eurostar, which provides selected companies with up to $0.8 million (won 1 billion) in technology development finance spread over 3 years. These funds finance technology transfer to ASEAN industries, as well as joint research with academic and other research institutes. KIAT monitors these Korean-funded initiatives and evaluates them using the standards of the MOTIE.

18 For more information see: KOTEK (Korea Technology Finance Corporation). n.d. “Major Services.”
19 For more information see: KEITI (Korea Environmental Industry and Technology Institute). n.d. “Fostering environmental companies.”
20 For more information see: e-TechHive. n.d. “Supporting Business.”
National Cooperation Centers (NCCs): KIAT facilitates global cooperation and technology consulting through NCCs. Under this program, KIAT provides support for Korean companies in finding overseas partners and it conducts project planning and joint global research by: (i) facilitating technical seminars and workshops, (ii) finding partners, and (iii) facilitating collaborative R&D.

Bilateral Overseas Development Assistance (ODA): Through its bilateral ODA project, KIAT transfers technologies and develops markets for Korean companies by providing them with guidance on how to overcome challenges with their production sites in developing countries. Most of these ODA projects focus on industrial technologies, and particularly on those that are concerned with innovations in manufacturing and energy.

Global Network: KIAT supports innovation outside Korea through its global networks, such as GT Online, the K-TAG Platform, and an annual matching event called Global Tech Korea. These initiatives provide information on policy and technology market trends, R&D projects, and matchmaking opportunities, including introducing Korean engineers who are willing to provide consulting services overseas. These activities provide opportunities to examine innovative strategies with international companies and promote global cooperation.
CHAPTER 4.
Innovations that Improve Circularity

Innovations for waste collection, transport, and recovery of plastics range from simple, basic modifications of existing methodologies for collection and transport, to others that use artificial intelligence (AI) to improve the identification, classification, sorting, and recovery of various types of plastic.

4.1. Collection

High rates of uncollected waste and low recycling rates in rural and remote areas are common challenges across Cambodia, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. Collection is considered one of the most critical steps in the waste management value chain as it secures the resources necessary for recycling. With their low recycling rate due to unsegregated waste collection, these six AMS need to promote the development of infrastructure for the efficient separation of waste so that when waste is collected, recyclable items are not contaminated.

The allocation of space for segregation at source is an important issue—for recycling to be effective, different types of waste must be collected separately. This often means that extra funds are needed for site acquisition and the construction of facilities. The Korean government has addressed this issue by authorizing the setting up of temporary discharge spots in parking lots or other empty spaces on designated days. These designated days, usually once or twice per week, are determined by the relevant apartment complex or municipality. This practice of leveraging empty space is suitable for the six AMS as they have a limited budget and this practice minimizes the need to build and maintain facilities for
segregation at source. In an apartment discharge station, residents prepare large bags with each type of recyclable waste so that these are ready for pick up by a waste truck. In areas of major cities with detached houses or townhouses, where empty space is scarce, minimum-sized segregation centers can be set up with bins for each type of recyclable waste.\(^{21}\) To avoid waste overflow in these small facilities, specific days are set for discarding each type of recyclable waste.

In Korean agricultural areas and on islands with a low population density, waste stations similar to those in detached housing areas are installed (Figure 4.1). For example, on

\(^{21}\) The individual bins for recyclable items are for vinyl, cans, paper, plastic, transparent PET bottles, Styrofoam, and glass.
Jeju Island, local governments operate waste segregation facilities called Clean House. Residents can find a nearby Clean House location through the Clean Jeju app or the Jeju municipalities’ website.

4.2. Waste Transport

Source segregation is not widely implemented in most of the six AMS in question. Typically, informal workers handle the collection of recyclables and mixed waste is collected and loaded onto trucks that compact the garbage. Despite efforts to encourage consumers to follow recycling guidelines, the separation of waste continues to be a problem. Where segregation at source does take place, only transparent PET bottles, Styrofoam, and plastic film are separated, which means that waste requires further sorting at MRFs. The use of compression vehicles for collection reduces the volume of separated recyclable waste and it reduces the cost of waste transportation. However, compressing waste before it is properly separated contaminates recyclable materials, hinders the sorting process at MRFs, and constitutes a barrier in recycling.

In 2017, Korea shifted to standard collection vehicles instead of vehicles that compress waste to increase recycling. This transition has been more successful in apartment complexes where private companies effectively segregate waste for recycling (Figure 4.2). However, in areas with detached housing, due to municipalities’ waste management finance constraints, the switch to standard collection vehicles has been slower.

Since December 2021, the use of compression vehicles for collecting and transporting recyclables has been prohibited in Korea.

4.3. Labeling

While Korea has established effective segregation and collection practices, there are still limitations in segregating plastic materials. Although six types of plastic—high-density polyethylene (HDPE), low-density polyethylene (LDPE), PET, polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC)—are labeled on each product to indicate their resin composition, other types of plastic are not.

22 A 3.5-ton compression truck can load 3 tons of compressed waste. In contrast, the same-sized truck, which does not compress waste can only load 1 to 1.5 tons. This means that to replace compression trucks, additional vehicles must be deployed. This increases costs to pay for the additional trucks and the salaries of the three sets of workers that are required for each truck.
and the discharge criteria do not align with the labeling system. Also, while some products, such as transparent PET bottles, Styrofoam, and plastic films are segregated, LDPE, PP, PS, and PVC products are not.

Since consumers are already required to separate various types of waste, compelling them to segregate all plastics would be too demanding. Also, the label “Other” on some plastics creates confusion and results in the mixing of various recyclables, which hampers the recycling process. To address these issues and provide clarity, the government has introduced a new labeling system, which indicates the recyclability level of each product.

### 4.4. Sorting

Despite diligent segregation efforts, recyclable waste is usually mixed at MRFs. Separately collected waste becomes mixed in the trucks during transportation because vehicles for a single type of recyclable are not commonly deployed. As of 2020, there were 198 public MRFs operating across Korea, with 70 percent of these facilities sorting waste, manually, using a conveyor belt. Workers who are skilled at sorting and reclamation play a critical role in further segregating waste by identifying and manually separating the different types of plastic. However, due to the difficult working conditions and relatively low wages, Korea has a shortage of these skilled workers. Moreover, most MRFs have not been upgraded to improve their facilities because waste management is not a high priority in many municipalities. In addition, due to municipalities’ limited budget and space, they cannot install the costly equipment required to mechanically sort each type of plastic. Only a few modernized MRFs use advanced technologies such as magnetic separation, color sorting, gravity sorting, and near infrared (NIR) sorting to complement their manual sorting. Even with these technologies, manual separation is still required to remove large pieces that could disrupt MRFs’ automated machines. In the future, for greater efficiency, accuracy, and safety, sorting processes could be carried out by robots.

#### AI-based Sorting Robots

ACI is a Korean company that specializes in petrochemical and environmental engineering, working primarily on waste treatment and recycling. ACI has developed an AI sorting system called Dr. B that can identify 67 different types of items, and using robotic arms, it sorts the targeted plastic waste based on its material, color, and even its specific brand. Dr. B can process up to three pieces of waste per second, and it can achieve sorting rates of up to 180 picks per minute. The system provides real-time monitoring capabilities, including operational data such as the system’s running time, waste characteristics, motor performance, and the status of the different receptacles that contain sorted waste. Dr. B also has an automated data reporting system that analyzes waste characteristics and trends, and periodically generates reports.

ACI has provided waste collection and sorting facilities for over 60 municipalities over 18 years. The government of Dobong-gu District in Seoul spent $4.3 million (won 5.6 billion) to modernize its resource circulation center to incorporate ACI’s resource reclamation package, which uses various sorting processes such as gravity separation and a compressing device. The Dobong-gu MRF, which has the highest resource recovery rate of Korea’s government-operated facilities, handles approximately 50 metric tons per day. In 2021, VL Investment (a private equity fund) invested $5.3 million (won 7 billion) in ACI, which came through the Future Environmental Industry Fund that the MOE created as part of its Fund of Funds. VL Investment is planning to invest another $15.2 million

23 “Other” is the label for plastic that is mixed with materials such aluminum or rubber, or that is hard to define since several types of plastic were used.

24 NIR uses the wavelength signature of specific resins to distinguish them from each other, but it does not distinguish colors. NIR sorting is employed at both MRFs and plastic reclamation facilities (APR [Association of Plastic Recyclers]. 2018. “Near Infrared (NIR) Sorting in the Plastics Recycling Process”).

(won 20 billion) in ACI in the near future. This planned investment shows that large corporations are keen on obtaining high-quality feedstock and that ACI is capable of meeting these demands.

**Ultra-small MRFs equipped with an AI-based Sorting Robot**

ACI recently introduced the iTainer-Robot, which is an innovative solution that uses AI-based technology to segregate recyclable waste during the collection phase. The robot is designed for use in public places where visitors generate large volumes of waste. It segregates all types of waste on-site without manual intervention. When recyclable waste is deposited into the iTainer-Robot without prior segregation, AI robots equipped with technology similar to Dr. B automatically sort the waste into transparent PET bottles, colored PET bottles, HDPE, PS, PP, cans, glass, paper, and milk cartons (Figure 4.3).

In addition, the iTainer-Robot’s system has a program that makes payments and provides rewards. This can impose charges for non-recyclable waste and provide rewards to incentivize recyclable waste. An AI-based counting sensor quickly identifies the types of waste and calculates charges and rewards as it sorts waste into its respective bin. These bins are also equipped with compressors that reduce the volume of waste.

While the iTainer-Robot’s price per unit is high—$385,000 (won 500 million)—the system is cost-effective when compared to constructing an MRF. The equipment that ACI has provided for the Dobong-gu MRF, which carries out collection, sorting, and compressing sorted waste, cost $4.3 million (won 5.6 billion) and it requires a substantial area (1,208 square meters). However, the much smaller iTainer-Robot processes 2 metric tons of waste per day and its advantages include minimal space, labor-free operation, cost efficiency, and data-driven waste management.

**Figure 4.3. Diagram of the iTainer robot-aided Recovery of Recyclables**

Source: ACI [https://www.youtube.com/watch?v=rpeb3ZYuAbHl](https://www.youtube.com/watch?v=rpeb3ZYuAbHl)
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AI-based Specific Single-source Item Collection and Sorting (Transparent PET Bottles)

Due to Korea’s enforcement of its recycled content mandate in 2023 and the prohibition of importing plastic waste, securing good feedstock has become critical for bottle producers so that they can continue operating. In 2020, to promote the recovery of clean, single-source feedstock during the waste discharge and collection phases, the Korean government piloted the segregation of transparent PET bottles. This initiative was scaled up in low-rise housing areas in 2021. The public now recognize that transparent PET bottles are a valuable resource, which has contributed to the development of innovative recycling SMEs.

SuperBin, developed by Nephron, is a reverse vending machine that collects beverage cans and PET bottles in the world’s first AI-based recyclable waste recovery machine (Figure 4.4). The SuperBin supports the circular economy by providing individuals with financial rewards when they return recyclable waste so that it can become a resource for making new recyclable products. Nephron’s machine has a mobile app that pays $0.75 (about won 10) for each returned bottle and can.

SuperBin. n.d. “SuperBin creates a world where waste becomes money and recycling becomes play.”

Nephron’s AI-based image technology can identify waste items using its database of 700,000 beverage containers that are made of metal or PET. As of July 2023, the system had processed 90 million images of containers. Even when the shape of a container or its barcode has been damaged, Nephron’s technology achieves 92 percent accuracy in recognizing waste—a level that will continue to improve over time through deep learning and the use of historical big data.

Nephron only accepts clean, transparent bottles that have had their labels removed, which complies with the government’s guidelines on the separate discharge of PET bottles. The machine will not accept bottles that have liquid in them or that still have labels. The compressor inside the SuperBin reduces the volume of PET bottles to one-third of the original amount. This allows the machine to collect up to 1,500 PET bottles and cans before these must be removed. A central operating system monitors the operations of each SuperBin in real time, including the amount of material stored in the machine, efficiently identifying when the machine should be cleared out and its materials collected. The central operating system also instantly detects malfunctions so that maintenance staff can address these problems remotely.

As of July 2023, 900 SuperBins had been deployed in public places in Korea, including parks, community centers,
government buildings, schools, convenience stores, and department stores. Corporations such as Samsung Display, Naver, and Kakao have installed SuperBins in their office buildings. A total of 500,000 people use Nephron’s machines each month and the monthly average for recovery is 300 metric tons.

4.5. Supportive Technologies Used in PET Bottle Single-source Collection.

A PET bottle is made with PET, HDPE, and PP (see Figure 4.5). If transparent PET bottles are collected separately, preventing contamination, high-quality recycled materials can be produced with less pre-treatment washing and drying required. By eliminating sorting and pre-treatment, the cost of producing flakes and pellets for recycling is lower. When waste PET bottles are mixed with their PP labels and/or their HDPE caps and rings, the waste bottles must go through pre-treatment processes, despite the efforts made at the waste generation and collection stages. This takes away the social benefits of segregated collection. 27

Jusin Global Tech developed the PETRO machine series to collect transparent PET bottles and recycle 100 percent of them without using a water-related process to separate the PET and PP components. This improves water and energy efficiency in the sorting and drying processes, saving money. PETRO has an AI-based PET bottle collection system, which is similar to Nephron’s SuperBin. PETRO’s unique technology, EZ cap, enables 100 percent single-source collection of PET bottles by collecting their caps and rings separately. This ultimately contributes to shortening the pre-treatment process of materials before recycling.

As a result of regulations that evaluate the structure of packaging material, which is linked with EPR incentives, easily removable labels have been introduced. When the AI-based sensor in the EZ cap is applied, it can identify 200 different brands and shapes of PET bottles, and then the PETRO machine automatically cuts off the rings of different types of bottles (Figure 4.6). Developing this AI-based technology to automatically cut off a bottle’s ring was challenging because it required extensive deep learning to identify the shapes and designs of newly released bottles. By eliminating manual separation and gravity separation in the recycling process, Jusin Global Tech’s solutions have contributed to reducing the cost of producing plastic flakes by 50 percent.

4.6. Refill/Reuse

Island countries such as Indonesia and the Philippines face specific challenges in undertaking recycling. Communities on small islands are under-resourced and lack basic waste management capacity, which impedes their recycling. In addition, the high cost of transporting waste to recycling by boat makes recycling financially unsustainable. One of the options for addressing plastic pollution in island countries is reducing the use of plastic by introducing refill and reuse solutions. 29

27 Dedicated pre-treatment infrastructure for transparent PET bottles is necessary, but it has not been widely introduced in Korea.
28 Jusin Global Tech is a startup with manufacturing technology that provides solutions for plastic injection molding. https://www.jsglobaltech.com/english
Refill shops, also called package-free or bulk stores, offer products in refillable or plastic-free containers, and provide refill services if customers bring their own packaging. While several examples of such shops can be found in Cambodia, Indonesia, the Philippines, Thailand, and Vietnam, their ability to scale is limited by challenges in acquiring customers, the need to adhere to health and safety regulations, and the lack of incentives that encourage reuse and refill.

In Korea, refill stores primarily supply personal hygiene products. Containers for these products are difficult to recycle because they are made from several types of plastic, and they contain other materials such as the metal springs in the device for pumping out the product.

In 2021, Korea’s MOE and the Ministry of Food and Drug Safety (MFDS) prepared support measures to encourage the development of refill shops that provide four types of hygiene products (shampoo, conditioner, body cleanser, and liquid soap). The MFDS has also issued guidelines on sanitary management to prevent hygiene problems from developing because containers are reused repeatedly. MOE has also issued guidelines on standard multiple-use containers, which require them to be easy to clean and recycle, and MOE has piloted the use of standard containers in small- and medium-sized stores. The producers of standard containers for cosmetic refill shops should benefit from paying lower EPR charges. Consumers that use refill stores are also rewarded for contributing to carbon neutrality through a system with points that can be redeemed for discounts on future purchases, utility bill reductions, or converted into financial donations for environmental causes. As a result, the number of refill stores had increased from 10 in July 2021 to more than 200 in February 2023.

Korea’s first refill shops, Almang Market, are among the few zero-waste, self-sustaining shops that operate with no government support. Unlike other refill shops that only sell hygiene products, Almang, which means “kernel” (something with no shell), sells a variety of products with no packaging—personal products, such as shampoo, liquid soap, and sunblock cream; cooking supplies, such as olive oil and balsamic vinegar; and tea leaves, coffee beans, and nuts (Figure 4.7). Because Almang Market would find it difficult to sell all of its large bulk orders before their expiration date, the company shares its orders with other zero-waste stores. As part of a group of 150 zero-waste refill stores, Almang Market connects with product sellers, recyclers, and the creators of upcycled products. By encouraging producers and consumers to change their behavior, it has contributed to reducing plastic consumption and increasing recycling. In 2021, Almang Market’s headquarters and its second branch reduced the use of 75,000 100 ml containers, and collected 8,274 kg of recyclable waste, including plastic bottle caps and milk cartons, which were sent to recycling companies.

30 MOE (Ministry of Environment) Republic of Korea. n.d. “Guideline for washing and hygiene of multiple-use containers.”

31 Park. 2023. “What are the complaints and betrayal of the eco-friendly ‘Refill Station’?”

32 For more information see: https://almang.modoo.at/

33 Kim. 2022. “Courageous man, take only the lining.”

31
4.7. Reusable Cup/Container Recovery System

In Korea, although the use of SUP cups and utensils is banned in cafes and restaurants, SUP cups are not banned for takeaway drinks, so these still end up as waste. Oysterable, an environmental startup company, operates an Internet-of-Things (IoT) resource recovery system called Lalaloop that provides (i) resource recovery devices; (ii) a compensation app called Today’s Recycle that is used for resource recirculation; (iii) a console that analyzes and manages resource recovery data; and (iv) Lalaloop ID that tracks and manages goods. Approximately 600 Lalaloop resource recovery devices, including recyclable waste recovery devices, have been installed nationwide in Korea (Figure 4.8).

There are 120 Oysterable reusable cup recovery systems, nationwide, in Korea, which operate primarily in Starbucks coffee shops. Between July 2021 and December 2022, the reusable cup recovery systems in Starbucks in Seoul and on Jeju Island avoided the use of about 5.8 million SUP cups. Oysterable launched its reusable container recovery machines, Lalaloop Dish in 2023, and since then the machines have been installed in university dormitories and convenience stores in Seoul. When ordering delivery food, users who request Lalaloop’s multiple-use containers can conveniently return these to Lalaloop’s unmanned reclaiming machines.

MOSS has provided a series of assistance packages to support Oysterable, including the Early-stage Startup Package, Steppingstone (First Step) Project, and Tech Incubator Program for Startups (TIPS). This assistance has enabled Oysterable to secure funding for product development and launch a minimum viable product (MVP). MOSS has provided tailored support packages for companies based on their growth stage, including those that have just launched or are at the early startup stage. MOSS’s support packages comprise:

35 Lalaloop ID is a recognition code printed on recyclable and reusable commodities. Oysterable use various recognition technologies, such as a quick-response (QR) code, barcode, radio-frequency identification (RFI), or a digital watermark, to track reusable products’ production, distribution, and disposal.

36 An MVP is an initial version of a waste management solution that possesses the minimum features necessary to function, effectively, and satisfy early adopters. An MVP, which is expected to undergo a number of improvements, focuses initially on core functionalities such as efficient collection, segregation, and disposal methods. MVPs not only streamline resource allocation and reduce upfront investment risks, but they also foster innovation through continuous learning and adaptation to evolving waste management practices.
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• The Pre-startup Package: This package provides essential assistance for aspiring innovators who want to start a business, as well as entrepreneurship training, mentoring from experts, prototype development, and marketing.

• The Early-stage Startup Package: This package is for startups with promising ideas and technologies that have been operating for 3 years and are ready for commercialization. It provides up to about $76,000 (won 100 million) for prototype production, acquiring intellectual property rights, and marketing.

• The Startup Scale-up Package: This package assists companies that have been operating for 3 to 7 years. It supports commercialization by providing up to $230,000 (won 300 million) and facilitating collaboration with a large enterprise.

MOSS also has Startup Growth Technology Development Programs that revitalize technology startups and promote their growth by supporting their R&D. Eligible applicants for the latter include entrepreneurs that have been in business for fewer than 7 years and have sales of less than $1.5 (won 2 billion).

4.8. Eco-friendly Depolymerization Technology

City Oil Field’s regenerated green oil (RGO) technology turns plastic waste back into a petroleum product by using wave energy at a low temperature that emulsifies plastic waste. The company has developed a specialized ceramic ball that is heated to 280 degrees Celsius to create energy of a specific wavelength that separates oil vapor from the other materials found in plastic waste. The vaporized oil is collected as a liquid through a cooling process that transforms it into heavy oil. The oil is then put through a secondary process that refines it into light oil, which can be used as fuel for power plants, or the heavy oil can be turned into naphtha—a raw material for producing plastics. When mixed waste is used as the input, only the plastic waste will be converted into oil. The remaining

37 City Oil Field. n.d. “Key Technology of City Oil Field.”
38 If plastic waste (PET, PP, and PS) is used as an input, more than 80 percent of the weight of the waste can be converted into oil. For example, the recycled oil yield rate for the plastic nets or the vinyl used in greenhouses is 90 to 95 percent. For the household waste in volume-based waste fee bags that goes to landfills, the light oil yield rate is 40 to 60 percent.
biological waste is converted into high-calorie carbon powders that can be used as raw materials for solid fuel. Metals, glass, and aluminum remain in their original form with no physical change.

City Oil Field has been successfully putting its RGO technology into practice. In 2023, at a facility in Incheon City Oil Field and Sudokwon Landfill Corporation carried out an R&D pilot with six metric tons of waste (Figure 4.9), and City Oil Field’s first commercial plant was completed in Gwangyang in August 2023. The company also began constructing a plant in Jeongeup, with assistance from KECO. In addition, the RGO technology is currently being replicated in Indonesia and the United Kingdom.

When heating the reactor with electricity, the RGO technology does not generate greenhouse gas emissions, with the exception of scope 2 emissions. It is cost-effective and it operates with a minimum number of staff.

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39 Annually, the plant can treat 8,000 tons of general waste (unsegregated plastic waste) and produce 4,700 tons of high-quality oil.
Like its Asian neighbors, Korea faced waste management and plastic pollution issues when its economy began to grow in the 1970s. Although the maturity of solid and plastic waste management systems varies across the six AMS highlighted in this report, the policies, institutional support, and capacity building initiatives that have proven successful in Korea could be successfully localized to benefit each. Korea’s innovations, which range from basic waste management techniques to applies AI, could be adapted and adopted.

How successfully Cambodia, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam can apply Korea’s improvements in basic solid waste management, as well as its improvements in recovering and reusing plastics, will depend on how well Korea’s policies, regulations, and initiatives suit local conditions; whether they are effectively implemented; and whether these efforts are sustained.
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