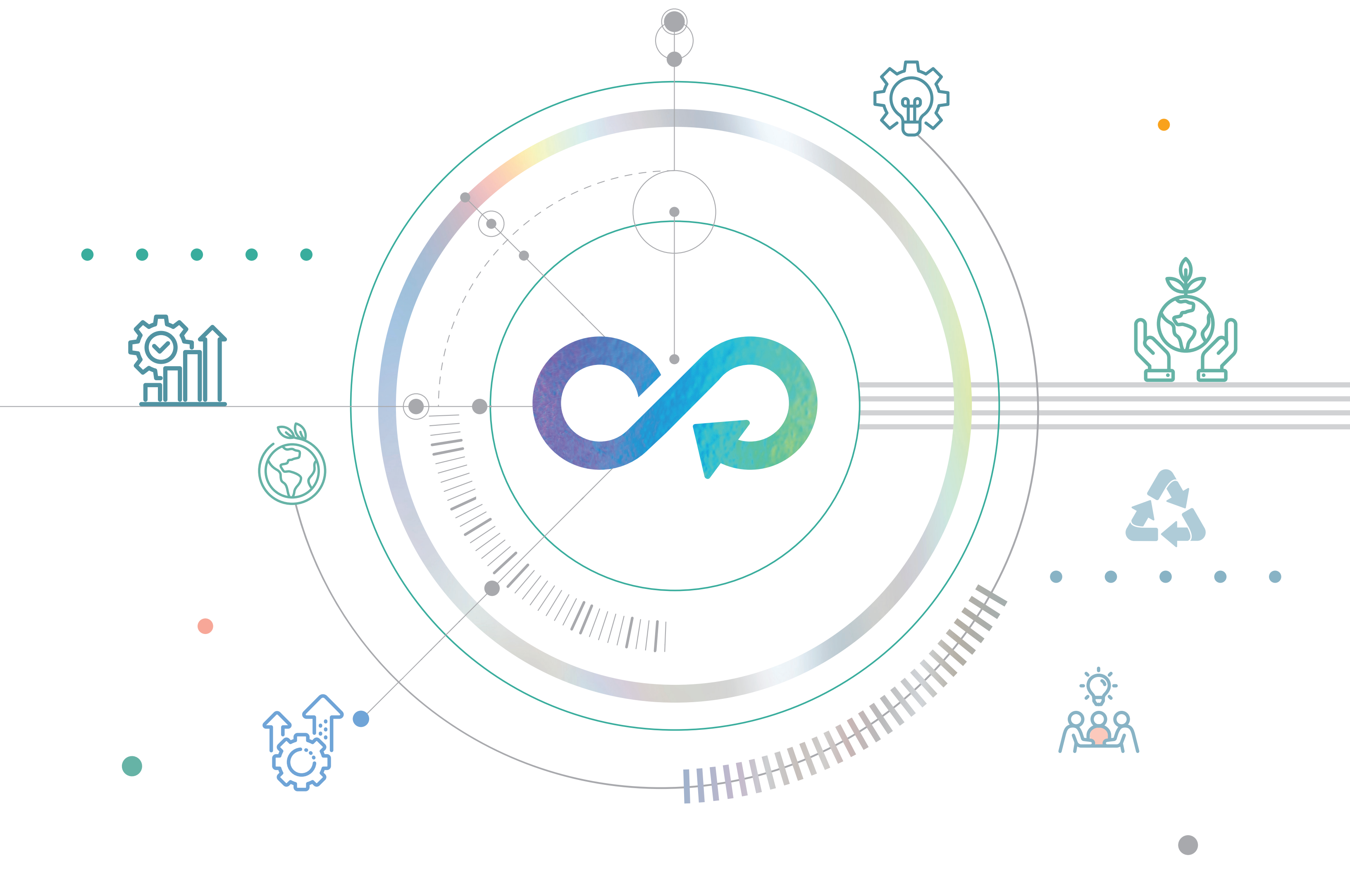
IMSWM Best Practices Report

Advancing ASEAN-Korean cooperation
in Integrated Municipal Solid Waste Management (IMSWM)
for Environmentally Sustainable Cities

Singapore and South Korea



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NATIONAL INSTITUTE OF GREEN TECHNOLOGY

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I Understanding IMSWM

Historically, waste management practices were primarily focused on the physical removal and disposal of waste. This narrow focus often led to unsustainable outcomes, as it failed to account for broader social, economic, and environmental contexts. In response to these shortcomings, Integrated Solid Waste Management (ISWM) emerged in the late 20th century (1960s–1970s), emphasizing the interconnectedness of waste-related operations and promoting a holistic framework that includes reduction, reuse, recycling, and environmentally responsible disposal.

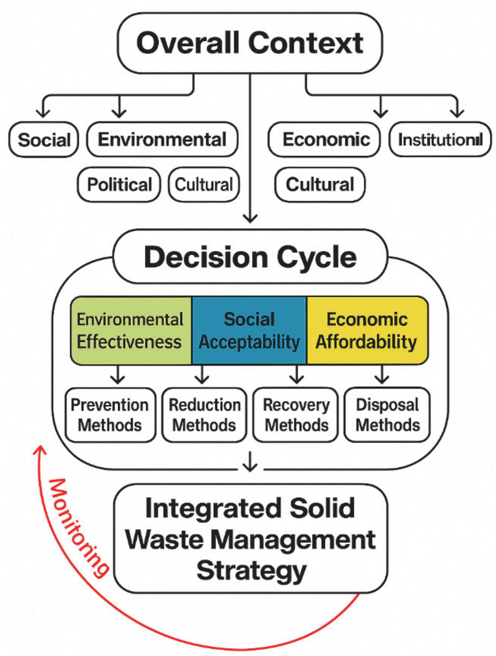
As urban waste streams became more diverse and complex, especially in a rapidly urbanizing context, Integrated Municipal Solid Waste Management (IMSWM) was developed as a more specialized and systemic approach. IMSWM is consistently defined across global institutions and major reports such as those by UNEP, the World Bank, and the US EPA (Table 1) as a holistic, lifecycle-based approach. It emphasizes the conservation of resources, integration of stakeholders, and coordinated management of all waste streams. These widely recognized definitions reflect a shared global understanding of IMSWM as not merely a technical system, but a multidimensional strategy encompassing governance, infrastructure, economics, and environmental performance.

Table 1 Widely-recognized definitions of IMSWM

Source	Definition
UNEP (2017a)	Comprehensive management covering all waste types (municipal, C&D, biomedical, e-waste, etc.) across their full lifecycle, emphasizing resource conservation and recovery
UNEP (2019)	Holistic management integrating technical and non-technical aspects, applying multiple options from generation to disposal across all waste streams
UN-HABITAT (2010)	Systematic approach involving stakeholders, technical waste system elements, and sustainability considerations
World Bank (2018)	Selection and use of suitable technologies, techniques, and management programs to meet defined waste management goals
US EPA (2020)	Strategies integrating diverse approaches to safeguard public health and environmental safety from waste-related hazards

IMSWM encompasses multiple, interrelated dimensions—environmental, social, economic, and institutional—that influence the management of waste throughout its entire lifecycle. The environmental dimension includes not only pollution control and resource conservation, but also climate change mitigation through reduced methane emissions and leakage prevention across the waste value chain. These dimensions form part of a broader framework in which every waste management decision must be made (Figure 1). A truly integrated system addresses the full waste management value chain, from generation to disposal, while aligning with broader goals such as resource conservation, technology innovation, and social inclusion. Effective IMSWM systems should be integrated (in terms of materials, sources, and treatment methods), market-oriented (ensuring recovered materials and energy have viable end uses), and flexible—allowing for continuous improvement and adaptation (McDougall et al., 2001).

Figure 1 Integrated Solid Waste Management Paradigm



Source: Reconstructed by author based on Marshall & Farahnakhsh, 2013

Central to IMSWM is a fundamental shift in perspective, recognizing waste as a resource. This shift aligns with the global transition towards a circular economy, which aims to minimize waste and maximize resource recovery across the entire product lifecycle. Circular economy principles inherently embedded in IMSWM help improve environmental outcomes while also fostering resilient economic systems and sustainable development pathways. This systems-based approach provides ASEAN countries with an opportunity to reframe waste not as a burden, but as a strategic asset in the transition toward a greener, more inclusive future.

Ⅱ Waste Management in ASEAN

1 Current status

Waste generation rates vary across ASEAN Member States, reflecting diverse economic profiles. Recent national statistics show that Malaysia and Thailand report municipal solid waste (MSW) generation of approximately 1.17 and 1.15 kg per capita per day, respectively, followed by Brunei at 1.14 kg per capita per day. By contrast, Singapore’s domestic waste generation is reported at 0.85 kg per capita per day, potentially reflecting the effects of waste minimization measures, while other ASEAN Member States generally range between 0.50 and 0.90 kg per capita per day (DOSM, 2025; JASTRe, 2024; NEA, 2025; PCD, 2024). These differences reflect each country's economic level, consumption patterns, and the development of their waste management systems. Waste generation in ASEAN cities has increased rapidly over the last decade, and it is expected to rise by 71% from 2016 to 2050, reaching an annual waste generation of 255.8 million tons by 2050 (World Bank, 2018). Although such estimates rely on regional approximations and may vary across individual countries, this projection underscores the significant challenges ASEAN faces.

Organic waste constitutes the largest proportion of waste in most ASEAN countries, accounting for 50% to 80%, primarily due to the high proportion of food and garden waste. Plastic waste, representing 8% to 12% of total waste, also poses a considerable challenge. In six ASEAN countries alone, more than 31 million tons of plastic waste were generated in a single year (US-ASEAN Business Council, 2023). The extensive use of single-use plastics and packaging materials, driven by changing lifestyles, contributes significantly to this stream. Plastic waste management remains inadequate, with substantial leakage from insufficiently regulated disposal sites.

Waste collection systems in ASEAN suffer from pronounced disparities, exhibiting higher collection rates in major urban areas while rural and lower-income urban neighborhoods frequently lack sufficient coverage, resulting in significant environmental leakage (Akenji & Bengtsson, 2019). Waste disposal predominantly relies on open dumping and poorly managed landfills, exacerbating environmental pollution and public health risks. Recycling infrastructure remains underdeveloped, with recycling rates ranging from merely 10% to 33%, excluding Singapore.

Policy enforcement of IMSWM within ASEAN faces critical barriers, including limited financial and technical resources, inadequate enabling policies supporting recovery and recycling, and prevalent informality in the waste sector. Weak institutional frameworks, inadequate infrastructure, political system influences, insufficient technological adoption, and limited public awareness and participation further complicate effective implementation (ASEAN Secretariat, 2022). Additionally, current approaches largely adopt a linear waste management paradigm (collection-disposal) that overlooks the principles of a circular economy and fails to adequately integrate climate change mitigation measures, significantly constraining sustainable and resilient waste management progress in the region.

2 Shift towards IMSWM

Across the ASEAN region, there is a growing consensus that traditional, disposal-oriented waste management models are no longer sustainable. Rising waste generation, mounting environmental and health pressures, and global climate and circular economy commitments have pushed governments toward IMSWM. This approach moves beyond end-of-pipe solutions to encompass system-wide reforms that integrate waste reduction, reuse, recycling, recovery, and leakage prevention within broader climate and resource management strategies.

■ Policy Landscape: National Strategies and Regional Cooperation

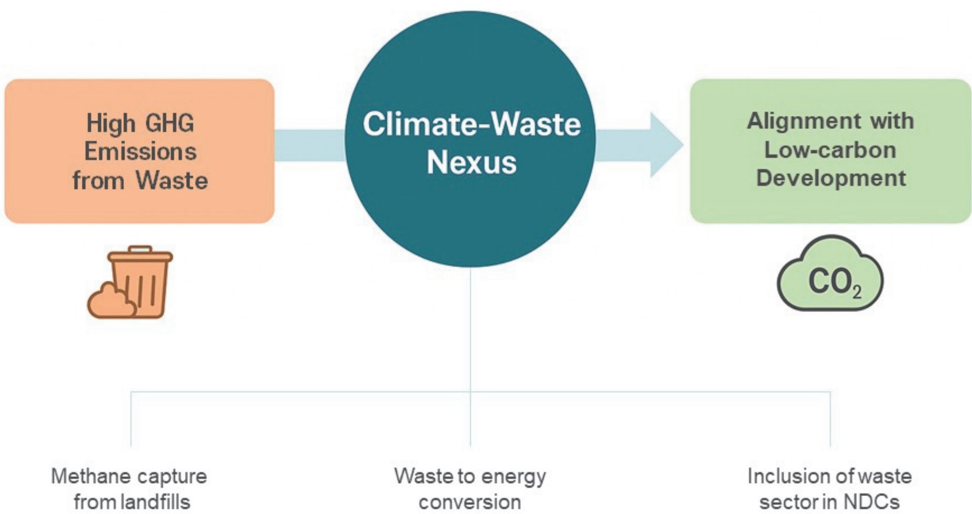
Many ASEAN Member States have adopted comprehensive frameworks to operationalize this shift. Indonesia's National Action Plan for Waste Management and Thailand's National Solid Waste Management Master Plan define ambitious targets and implementation roadmaps. Waste-to-Energy (WtE) initiatives, 3R-based strategies, and Extended Producer Responsibility (EPR) schemes are gaining momentum, supported by expanding infrastructure investment.

At the international level, waste management is increasingly viewed as a transboundary issue, with collaboration platforms such as the ASEAN Framework on Environmentally Sustainable Cities (ESC), the ASEAN Working Group on ESC (AWGESC), and the ASEAN + 3 Marine Plastics Debris Initiative promoting shared learning, policy alignment, and technology transfer. Broader frameworks like the ASEAN Strategic Plan on Environment (ASPEN) and the ASEAN Regional Action Plan on Combating Marine Debris guide coordinated multilateral action.

■ Climate-Waste Nexus

The waste sector is now recognized as a significant source of greenhouse gas (GHG) emissions, particularly methane from landfills and open dumping, which links IMSWM directly to national climate change mitigation and adaptation agendas. Integrating waste management into climate strategies allows ASEAN countries to pursue low-carbon and climate-resilient development pathways. Most member states have integrated waste management into their Nationally Determined Contributions (NDCs), highlighting the strategic importance of addressing waste as part of their climate commitments.

Figure 2 Integrating Waste Management into Climate Strategies



■ Implementation Challenges: Waste Leakages and System Inefficiencies

Despite policy progress, implementation challenges persist across the region. Waste leakages throughout the collection, transport, and disposal stages remain a critical concern. Inefficient systems and informal practices often lead to uncontrolled dumping and leakage into waterways and marine environments, creating multiple impacts. These leakages not only contribute to environmental degradation but also exacerbate climate-related vulnerabilities through uncontrolled methane emissions and the loss of potentially recoverable resources. Strengthening IMSWM is therefore essential to address this triple challenge—minimizing leakages, reducing GHG emissions from mismanaged waste, and capturing value through resource recovery.

■ An Integrated Framework: Linking Climate, Circularity, and Leakage Prevention

To operationalize these shifts, IMSWM must be understood not only as a waste management framework but also as a cross-cutting system that simultaneously addresses three interlinked objectives: circular economy transition (maximizing resource recovery and minimizing waste generation), climate change mitigation (reducing GHG emissions from waste), and leakage prevention (ensuring controlled management throughout the waste value chain). In practice, these three dimensions are deeply interlinked, and effective waste governance must simultaneously reduce emissions, prevent leakage, and recover resources. The following table summarizes these interlinkages and highlights potential indicators that can guide monitoring and policy alignment across the ASEAN region.

Table 2 Guidelines Table: CC·CE·Leakages — Linkages & Key Indicators

Pillar	Main Contents / Linkages	Key Indicators
Circular Economy (CE)	Establish the hierarchy of reduce–reuse–recycle–energy recovery–safe landfill, while strengthening upstream levers (resource efficiency, product design, EPR).	Recycling/material recovery rate; quality index (contamination); EPR coverage and compliance; single-use reduction performance; share of end-markets absorbing secondary materials.
Climate Change (CC)	The transition to IMSWM integrates NDC-aligned mitigation pathways—landfill avoidance, methane abatement, and the recovery of electricity/heat—into policy and infrastructure.	Landfill avoided / methane reduced; WtE electricity and heat output; compliance with emission standards; inclusion of the waste sector in NDCs.
Leakages	To curb leakages from collection gaps, open dumping, and the informal sector, expand collection and treatment infrastructure while enforcing engineered landfill and emission control standards.	Urban–rural collection gap; share of open dumping/substandard landfills; leachate and air-pollutant measurements; real-time monitoring coverage; degree of formal integration of the informal sector

Ⅲ IMSWM Best Practices

1 Overview of Singapore and South Korea's IMSWM

Singapore and South Korea were selected as best practice cases for this report due to their advanced and systematized approaches to IMSWM, offering valuable reference points for ASEAN countries striving toward sustainable and resilient waste systems. While each operates under a distinct governance model and urban context, both countries exemplify long-term commitment, innovation, and multi-stakeholder engagement in managing municipal waste.

Singapore, a highly urbanized city-state with severe land constraints, has developed a centralized and technologically driven waste management system. Its policies prioritize incineration with energy recovery, advanced sorting infrastructure, and efficient logistics, supported by strong government oversight and private sector participation. Notable examples include Sembcorp's integrated collection, recycling, and automated MRF operations and its Energy-from-Waste Plant on Jurong Island, which transforms industrial waste into thermal energy for surrounding industries. These cases demonstrate how innovation, policy alignment, and market mechanisms are integrated to achieve efficiency and environmental outcomes.

South Korea, though also highly urbanized, has taken an alternative approach by embedding waste treatment facilities into everyday urban life and promoting citizen participation from the planning stage. With strong central government leadership and evolving national legislation, Korea has emphasized resource circulation and local-level infrastructure integration. Projects such as Hanam Union Park, which combines underground waste treatment with public amenities, and World Cup Park, which transformed a former landfill into an ecological landmark, illustrate how waste facilities can serve both environmental and social purposes when aligned with urban development goals.

This chapter introduces each country's IMSWM policies and systems, followed by real- world case studies. Each case is then analyzed through the lens of climate mitigation, circular economy, and leakage prevention. The aim is not only to highlight technical achievements but also to identify structural, institutional, and cultural factors that can inform ASEAN's evolving waste management strategies. While Korea and Singapore are high-income countries, their cases were selected not for direct replication but as references to demonstrate adaptable policy frameworks, institutional coordination, and multi-stakeholder engagement strategies. Core approaches—such as volume-based pricing, public-private partnerships, or urban-integrated waste facilities—can be tailored to ASEAN cities' diverse contexts and capacities.

2 Singapore

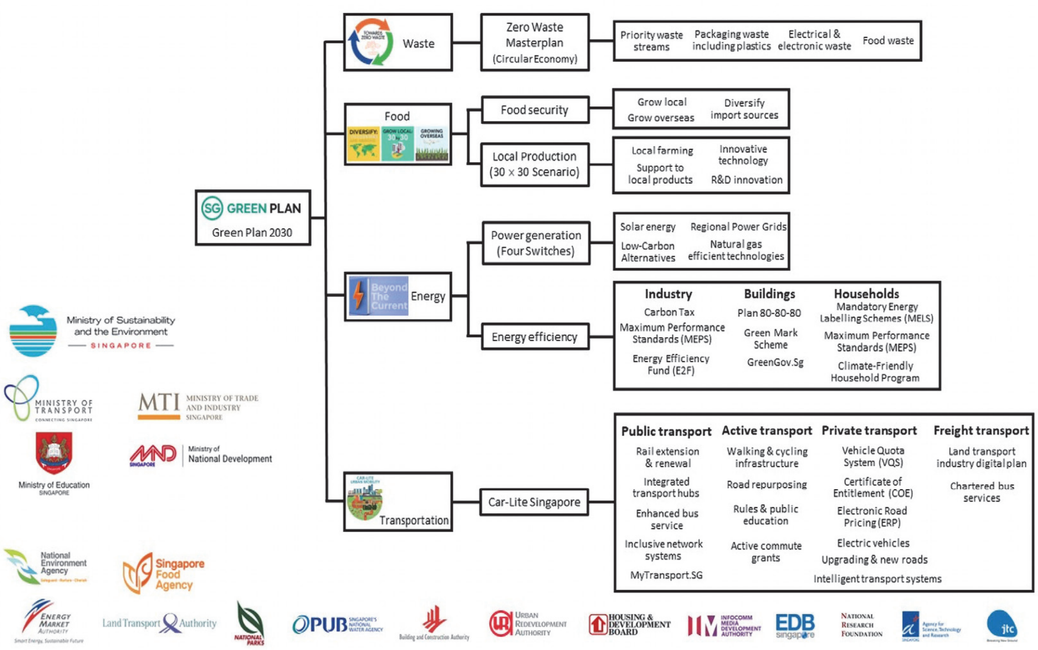
All information pertaining to Singapore in this report is based on the author's independent research from publicly available sources.

2.1. IMSWM Policies and Mechanisms

■ Current policies

Singapore's waste management policies have significantly evolved over the years, reflecting the nation's commitment to sustainability and environmental responsibility. Figure 3 presents Singapore's Green Plan 2030, which prioritizes waste management within its sustainability framework and involves the engagement of government agencies, including the Ministry of Sustainability and Environment, the Ministry of Transport, the Ministry of Trade and Industry, and the Ministry of National Development.

Figure 3 Singapore's Green Plan 2030



Source: Velasco, 2024

The Zero Waste Masterplan aims to reduce the amount of waste sent to landfill by 30%. To achieve this target, the Zero Waste Masterplan maps out the key strategies to adopt a circular economy approach, maximizing resource recovery and minimizing waste generation. These include regulatory measures such as Extended Producer Responsibility (EPR) schemes, as well as educational and engagement efforts with people, private, and public sector partners.

The NEWSand project repurposes incineration bottom ash for use in construction, thereby extending the lifespan of Semakau Landfill. The National Environment Agency (NEA) enforces waste policies, promotes the 3Rs (Reduce, Reuse, Recycle), fosters industry collaboration, and oversees legislative measures, such as the Environmental Public Health Act (EPHA) and the Resource Sustainability Act (RSA), as part of a holistic approach to waste management.

Singapore is advancing its sustainability agenda through the Tuas Nexus, an integrated facility that combines the Integrated Waste Management Facility (IWMF) with the Tuas Water Reclamation Plant (TWRP). It will enhance energy recovery and resource efficiency by co- locating wastewater treatment and solid waste management, supporting Singapore’s circular economy and low-carbon objectives.

Singapore's coordinated and forward-looking policy framework, which brings together legislation, technology, and multi-sector partnerships, serves as a valuable case study. Singapore’s integrated and proactive stance provides valuable lessons on how institutional alignment and long-term planning can drive impactful waste management reforms.

■ Mechanism

In Singapore, waste collection is regulated through a structured licensing framework overseen by the NEA. Public Waste Collection (PWC) licensees are appointed by the NEA through open tenders to serve domestic and trade premises across different geographical sectors. General Waste Collectors (GWCs), which primarily handle commercial and industrial waste, are separately licensed by NEA.

Singapore currently operates four WTE plants—TuasOne, Senoko, Tuas South, and Keppel Seghers Tuas Plant (KSTP)—which collectively generate approximately 938 million kWh of electricity annually, accounting for 2-3% of the nation’s total power generation. However, not all waste is incinerable. Non-incinerable waste and incineration ash are transported via the Tuas Marine Transfer Station (TMTS) to the Semakau Landfill, which serves as the final disposal site. Commissioned in 1999, Semakau Landfill is one of the world’s first offshore landfills, designed with an impermeable membrane and a marine clay lining to prevent leachate leakage.

Figure 4 **Semakau landfill**

< Semakau Landfill > **< Incineration ash handling on a floating platform >**

Source: NEA, n.d. and Chong, 2020

To further enhance recycling efforts, Sarimbun Recycling Park (SRP) was set up to support land-intensive recycling activities such as recycling of construction, demolition and plastic waste. Additionally, there is also a metal recovery facility operated by REMEX Minerals Singapore Pte Ltd near TMTS, where it facilitates the extraction of ferrous and non-ferrous metals from incineration bottom ash.

2.2. Case Study 1: Sembcorp's efficient SWM flow and automated MRF

■ Overview

Sembcorp, through its subsidiary SembWaste, is a key contributor to Singapore's IMSWM system. By advancing waste collection and recycling technologies, including the development of Asia's first automated Materials Recovery Facility (MRF), SembWaste supports the implementation of the nation's 3Rs policy and the progression of sustainable waste management practices.

■ Background

Singapore's National Recycling Programme (NRP), launched in 2001, aimed to address the increasing generation of waste through sustainable waste management initiatives, including the promotion of the 3Rs (Reduce, Reuse, Recycle). During this period, Sembcorp strategically expanded its waste management operations, leveraging market liberalization to acquire key industry players, invest in advanced recycling technologies, and establish Singapore's first automated Materials Recovery Facilities (MRF), contributing to national waste minimization and recycling efforts.

■ Operation

SembWaste operates eight strategically located waste management facilities, integrating smart waste management, waste-to-resource conversion, and recycling services. Through fleet electrification, GPS-enabled route optimization, and IT-based logistics systems, SembWaste has enhanced operational efficiency, reducing reserve capacity from 40% to 4%. Additionally, Asia's first automated Materials Recovery Facility (MRF), with a $7 million investment, processes 50 tons of waste per day. However, 40% of the contents collected from recycling bins/chutes are non-recyclable and are either incinerated or landfilled .

Table 3 Summary of SembWaste's IMSWM

Aspect	Details
Facilities	8 strategically located plants specializing in smart waste management, waste-to-resource, and recycling services.
Fleet	25 new electric trucks with 18 fast-charging stations and approximately 300 conventional combustion trucks.
Technological Integration	Route optimization, fleet rationalization, Integrated Waste Information System (i-Wis), GPS tracking, real-time updates, C3i Center.
Service Areas	Fluctuate with competitive bidding; currently include Clementi-Bukit Merah and City-Punggol.
Public Engagement	'ezi' mobile app for locating Cash-For-Trash stations, recycling tips, and event information.
Automated MRF	Asia's first automated MRF ($7 million investment), 14 workers, processes 50 tons/day, 40% non-recyclable materials sent to incineration/landfill.
Operational Standards	High corporate standards, efficient service in densely populated areas.
Financing	Primarily through fees collected from residential and commercial entities as mandated by the NEA. Monthly refuse collection fee: $9.81 for HDB/private apartments, $32.67 for landed homes.

Source: Compiled by the author from Sembcorp Industries. (2024, n.d.), Davina (2021), Lim (2002), IPI-Singapore. (n.d.), Clean & Green Singapore. (n.d.), NEA (2024)

■ Enabling factors

Public Participation

Sembcorp actively engages with governments, regulators, and local communities through meetings and briefings, ensuring transparency. Their waste management operations involve monthly meetings with town councils. To promote public participation, NEA has introduced various policies and campaigns, such as "Cash-for-Trash" initiatives and the installation of recycling bins. Cash-for-Trash and recycling bins are required in the scope of service of PWC contracts.

Financial Sustainability

SembWaste's main revenue comes from collection fees and the sale of recyclables. Financial performance varies based on service area coverage, population density, and tender success. Costs include operations, technology investments, and compliance with NEA regulations. The wet waste management market, valued at $78.2 billion in 2021, is expected to reach $123.5 billion by 2030.

Private Sector Participation

SembWaste provides highly formalized waste management services, excluding the unregulated informal sector (such as "karung guni" collectors). The first automated MRF in Asia, operated by SembWaste in a joint venture with Visy, symbolizes a rare yet strong collaboration among the three factors: the public sector, the private sector, and the local community.

Policies

The Zero Waste Masterplan aims for a 70% overall recycling rate by 2030. With the NRP, Sembcorp successfully expanded its MRF and waste management business.

Institutional Environment

The National Environment Agency (NEA) enforces national policies and manages waste collection and disposal services by holding jurisdiction over the licensing of waste management facilities and by promoting recycling activities. Public-private partnerships (PPPs) with companies like Sembcorp exemplify a favorable institutional environment, ensuring transparency, financial viability, and sustainability.

Environmental and Public Health

Sembcorp's Materials Recovery Facility (MRF) reduces landfill dependency, contributing to improved air quality, enhanced disease control, and broader public health benefits.

■ Risks

SembWaste's IMSWM approach encompasses both upstream and downstream waste processes but is subject to multiple risks as a Public Waste Collector (PWC). The physical nature of waste collection and sorting at the Materials Recovery Facilities (MRFs) exposes workers to health risks from industrial accidents or hazards. Sembcorp's annual reports noted one or two serious traffic accidents involving waste collection vehicles each year.

Additionally, high staff turnover and the need for continuous training to keep up with the latest technology and industry standards pose considerable costs and ongoing challenges. To address these issues, Sembcorp invested $100,000 in a training center for its staff. SembWaste has also resolved fines and penalties for violations of environmental and health regulations, highlighting compliance challenges.

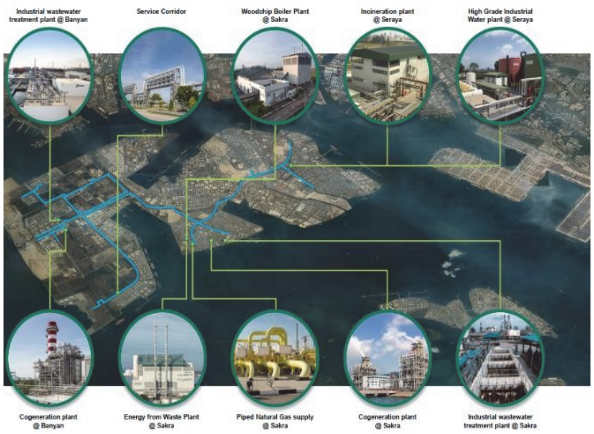
Limited public participation in recycling results in only 60% of waste from blue bins being effectively recovered, undermining MRF efficiency and anticipated economies of scale.

2.3. Case Study 2: Energy-from-Waste Plant

■ Overview

The Energy-from-Waste (EfW) Plant, commissioned in 2018, utilizes industrial and commercial waste to generate processed steam, supplying 140 tons per hour via a 31 km pipeline network on Jurong Island. Developed with a $250 million investment, the facility contributes to emission reduction by mitigating 50,000 tons of CO_2 annually (Sembcorp Industries, 2024), while integrating advanced waste recovery technologies and an automated pipeline monitoring system to enhance operational efficiency and sustainability.

Figure 5 The EfW plant



< Location of the project >

<The EfW plant>

Source: Sembcorp Industries, 2020 and Sembcorp's website

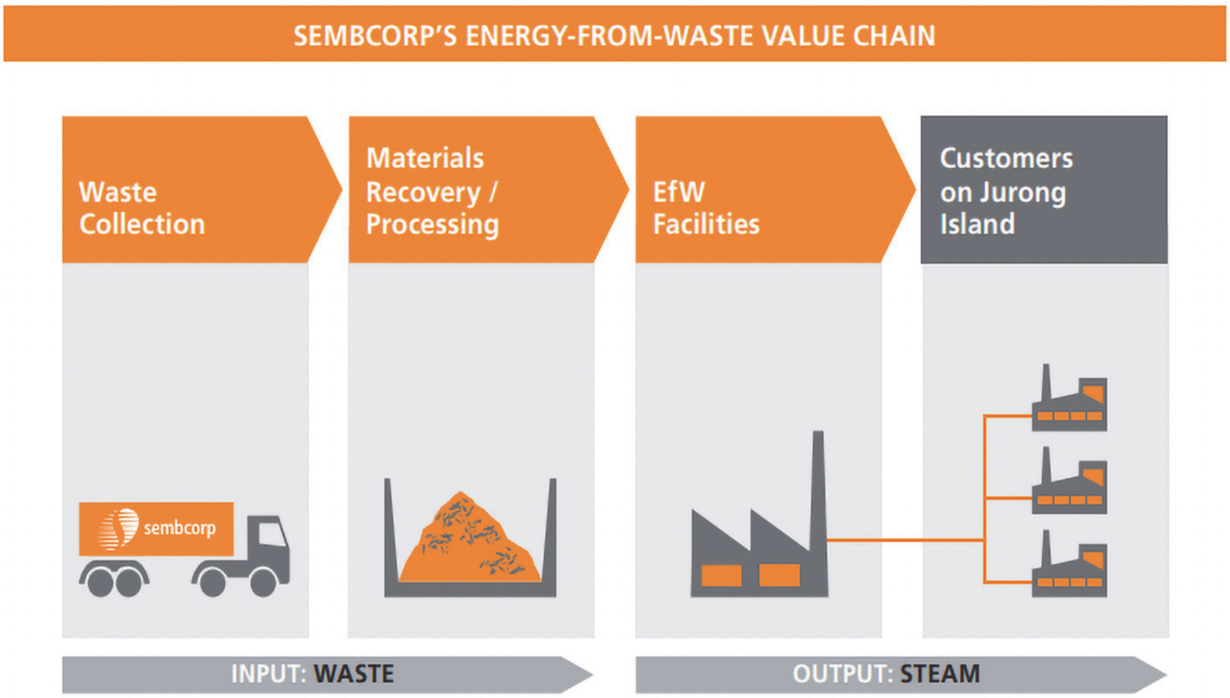
■ Background

Jurong Island, Singapore's petrochemical and energy hub, formed the 'Vision Zero Cluster' to aim for zero harm to anyone by aligning itself with the island's sustainable development goals under the Green Economy Plan of the Singapore Green Plan 2030. The Energy-from- Waste (EfW) Plant is a crucial part of this vision, symbolizing private sector participation in the waste management value chain and representing industrial decarbonization efforts toward Singapore's net-zero ambition. This plant, the largest EfW plant in Singapore, generates 308,728 tons of steam annually for the petrochemical industry, reducing CO_2 emissions by up to 70,000 tons per year. Developed with a $250 million investment, the EfW plants contribute to a circular economy by converting industrial waste into an alternative fuel source.

■ Operation

Recyclables are collected and transported to the MRF to be sorted for recycling. Non- recyclable waste is then incinerated at high temperatures in EfW facilities, converting it into thermal energy. The generated steam is supplied to customers on Jurong Island.

Figure 6 Value chain of the EfW plant



Source: Sembcorp Industries, 2013

■ Enabling factors

Public Participation

As the plant is situated within a government-designated heavy industrial zone, direct public participation is not applicable. However, as a publicly listed entity, Sembcorp upholds corporate transparency through investor relations, annual reports, and financial disclosures.

Financial Sustainability

Revenue is generated through thermal heat sales and carbon credits. Feedstock costs, a significant operational expense, are minimized through SembWaste's internal waste management system, which repurposes wood waste as an alternative revenue source.

Private Sector Participation

The private stakeholders in the plant project are Sembcorp and its customers. The plant benefits all stakeholders mutually in terms of business profitability, carbon footprint reduction, and compliance with Singapore's Green Plan. Consequently, the plant has seen active participation from the private sector, with its capacity tripling over a few consecutive years and the rate of annual heat production increasing consistently.

Policy Support

The Carbon Pricing Act and various incentive schemes, including the Resource Efficiency Grant and Emissions Reduction Investment Allowance, have facilitated private investment in low-carbon energy solutions. These policies reinforce Sembcorp's sustainability strategy and long-term financial viability.

Institutional Environment

Institutional support, likely provided by JTC Corporation, ensures regulatory compliance, infrastructure development, and logistical integration. These measures align with Jurong Island's sustainability framework, which prioritizes safety, environmental responsibility, and resource efficiency.

Environmental and Public Health

The EfW plant operates under strict emission regulations, ensuring that thermal waste treatment remains an environmentally sustainable and economically viable energy solution. Compliance with public health and environmental standards mitigates any potential adverse effects.

■ Risks

The EfW plant's integrated design and critical role in Jurong Island's industrial heat supply mean that risks in one area can quickly cascade into others. Technological mismatches with local conditions could require costly retrofits, while feedstock variability, such as seasonal changes in woodchip quality, can affect boiler efficiency and emission control performance. These issues, if unresolved, risk reducing output reliability for petrochemical customers.

Environmental performance is tightly linked to operational stability. Any failure in emission capture or improper handling of incineration bottom ash could compromise air quality, trigger regulatory penalties, and undermine public trust in Singapore's low-carbon strategy. Maintaining strict compliance demands continuous monitoring, skilled operators, and well- funded maintenance programs.

Moreover, planning and permitting processes remain sensitive to public and governmental scrutiny over potential air, noise, and water impacts, especially as the facility's capacity grows. Over the long term, market exposure to energy price fluctuations, the emergence of disruptive waste-to-energy technologies, and shifts in regulatory frameworks could require significant reinvestment to keep the plant competitive and compliant.

2.4. Cross-Cutting Analysis: Climate Change, Circular Economy, and Leakage Prevention

Singapore's best practice cases demonstrate how plant-level waste management applications can simultaneously advance climate mitigation, circular resource use, and waste leakage prevention. The automated materials recovery facility (MRF) reduces greenhouse gas emissions by diverting recyclables from incineration and improving logistics efficiency through mechanized sorting and optimized collection routes. At the same time, higher-quality material recovery strengthens downstream recycling markets by reducing contamination and stabilizing recyclable outputs. From a leakage prevention perspective, the MRF functions as a system control point that captures recyclable materials lost through improper source separation, preventing their escape into residual waste streams.

Similarly, the Energy-from-Waste (EfW) facility on Jurong Island integrates controlled waste treatment with energy recovery, avoiding methane emissions from landfill disposal while supplying recovered thermal energy to nearby industrial users. For non-recyclable industrial waste fractions, this application provides a practical circular solution by converting residual waste into usable energy. By consolidating industrial waste flows within a regulated and traceable treatment pathway, the facility also minimizes risks of waste leakage associated with illegal dumping or informal handling. Together, these cases illustrate how operational features embedded in waste treatment facilities—not policy instruments alone—can deliver climate, circular economy, and leakage-control outcomes within an urban IMSWM system.

3 South Korea

3.1. Evolution of IMSWM policies and Sectoral Progress

■ Evolution of IMSWM policies

Korea's waste management and resource circulation policy has undergone a significant transformation over the past four decades. It has progressed from a primary focus on safe waste disposal (1980s), to waste recycling (1990s–early 2000s), and finally to the current emphasis on resource circulation (mid-2000s onward).

Figure 7 Timeline of Key Legislation on Korea's waste management

Source: Reconstructed by the author based on KME(2018)

In the 1980s, the Waste Control Act (1986) laid the groundwork for safe treatment and management standards. During the 1990s to early 2000s, a number of recycling-related legislations were introduced, including the Act on the Promotion of Saving and Recycling of Resources (1992), Transboundary Movement of Waste Act (1994), Waste Treatment Facility Promotion Act (1995), and the Construction Waste Recycling Promotion Act (2003). These facilitated systematic recycling mechanisms, including the introduction of the Extended Producer Responsibility (EPR) scheme. From the mid-2000s, policies shifted towards a circular economy model. The Act on Resource Circulation of Electrical and Electronic Equipment and Vehicles (2007) expanded the EPR framework. In 2016, the Framework Act on Resource Circulation was enacted to build a legislative foundation for a full transition to a circular economy and was implemented in 2018.

■ Sectoral policy developments

Korea's transition toward a resource-circulating society has progressed along three key policy areas: waste reduction and reuse, recycling, and energy recovery. Each of these areas has seen policy innovation, but they also face structural and operational challenges that must be addressed to advance a sustainable and circular waste management system.

Initial waste reduction measures included a mix of regulatory and economic instruments, such as restrictions on single-use products, volume-based waste fee systems, and deposit- refund schemes for refillable containers. These initiatives aimed to influence consumer behavior and encourage producers to reduce waste at the source. While these measures laid an important foundation, their impact has been uneven. For instance, the deposit-refund system for disposable cups, introduced in 2003 to promote reuse, was abolished in 2008 due to implementation inefficiencies and weak public support. Voluntary waste reduction programs for industrial sectors have also lacked binding targets, resulting in limited accountability and effectiveness. These shortcomings highlight the need to strengthen regulatory enforcement and develop more robust incentive structures that integrate reduction and reuse principles into both production and consumption systems.

Recycling has been a central focus of Korea's resource circulation policy. The government has implemented advanced mechanisms such as mandatory source separation, waste charges, producer responsibility schemes, and environmental assessments for recycling practices. These policies have succeeded in expanding the scale of recycling activities and increasing public participation. However, the system remains oriented toward quantitative outcomes, with insufficient attention to the quality of recycled materials or the creation of high-value secondary markets. This gap became particularly apparent in 2018, when a sudden halt in plastic waste collection disrupted municipal collection services. The incident underscored the importance of stabilizing the recycling market, strengthening oversight, and promoting material recovery pathways that are economically viable and environmentally sound.

Since the mid-2000s, energy recovery has also been actively promoted, particularly through biogas production, solid refuse fuel (SRF), and eco-energy towns. Despite these efforts, biogas systems often suffer from low efficiency and utilization. The use of SRF has also sparked environmental concerns and local opposition. These issues call for improved management and more transparent planning. Importantly, energy recovery should remain secondary to material recycling and only be pursued when reduction and reuse are not feasible, in line with the waste management hierarchy.

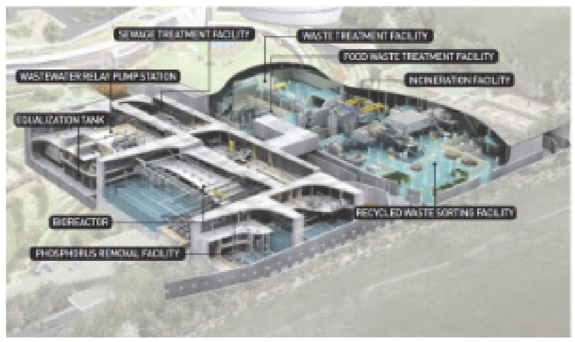
3.2. Case Study 1: Hanam Union Park

■ Overview

Hanam Union Park is an innovative environmental infrastructure project in Korea that optimizes land use by placing waste management facilities below ground, while the above- ground area is dedicated to recreational and cultural amenities. The underground complex includes an incineration plant, a waste sorting facility, a food waste recycling plant, and a sewage treatment system. Above ground, the park features a multipurpose gym, an outdoor stage, and a children's pool.

Figure 8 **Hanam Union Park**

< Ground facilities >



< Underground facilities >

Source: Hanam city. Retrieved from https://www.hanam.go.kr/english/contents.do?key=9682

■ Background

Hanam Union Park was developed to modernize outdated waste treatment facilities and address growing infrastructure demands in the Misa District. Previously, an aging food waste treatment facility in Sinjang-dong had caused severe odor issues, leading to public complaints and necessitating an upgrade to the system (Park, 2021). Korea's first underground waste treatment center, built with an investment of KRW 303.1 billion (approximately USD 287.78 million), initially served Misa District and later expanded to all of Hanam City. Excess waste beyond its capacity is transported to the Icheon City incineration plant.

The facility comprises a 4,500m² transfer station, a sludge drying facility with a capacity of 60 tons/day, and an incineration plant with a capacity of 48 tons/day. It also features recycling facilities, including a food waste recycling facility (capable of processing 80 tons/day) and a recyclables sorting facility (capable of processing 50 tons/day). Additionally, its sewage treatment system processes 32,000 tons/day, with a relay pumping station managing up to 110,000 tons/day.

■ Operation

Hanam Union Park operates through an integrated waste management system, which includes incineration, food waste treatment, and recycling. Each of these processes contributes to the park's sustainability goals. The incineration facility efficiently reduces waste volume while generating useful energy. Food waste treatment minimizes organic waste disposal and converts it into usable products. Additionally, the recycling process ensures that valuable materials are recovered, reducing waste and minimizing environmental impact. (see Table 4).

Table 4 Process of Hanam Union Park facilities

Process	Details
Incineration	Waste is shredded and incinerated, heat is recovered as steam, gases are treated, ash is recycled.
Food Waste Treatment	Food waste is crushed, separated, dried, sterilized, cooled, packed, and distributed as dry fodder.
Recycling Process	Recyclable waste is sorted, processed with automated systems, and prepared for reuse.

Source: Hanam city. Retrieved from https://www.hanam.go.kr/english/contents.do?key=10000

■ Enabling factors

Financial sustainability

The sorting facility handles recyclables daily, removing impurities and identifying materials such as plastics, glass, and paper, which are then sold through a bidding process. A portion of organic by-products is sold to feed factories and poultry farms, generating significant annual revenue. Generating over 100 times its operational cost in revenue, Hanam Union Park stands as a model of financial sustainability (Hanam City, n.d.).

Environmental and public health

Strict environmental and public health measures ensure that the facility does not negatively impact nearby residents. This includes a six-stage odor control system, real-time air quality monitoring, and strict emissions regulations. Hanam Union Park adheres to stringent standards, maintaining dioxin emissions below 0.1 ng-TEQ/Sm^3 and wastewater contaminants under 10 pg-TEQ/L (MOLEG, 2019). As a result, complaints about air pollution and odor remain minimal, with only 2–3 cases per year reported from nearby communities (Song, 2024).

Community participation

From the initial stages of installation, Hanam City conducted continuous consultations with its local residents to establish Hanam Union Park. The locals even participated in supervising the construction process and selecting the types of facilities to be installed in Hanam Union Park. With their participation from the project's initial stages, trust was established between Hanam City and its residents. Consequently, in the current operation phase, there have been no significant conflicts despite the absence of any additional incentives.

Landmark and community facilities

Combining NIMBY (Not in my backyard) facilities with FIMBY (Facility in my backyard) facilities can resolve the aversion to NIMBY facilities while satisfying the demand for FIMBY facilities, thereby eliminating any residents' opposition. In particular, Hanam Union Park effectively implemented this strategy by situating the waste treatment facilities underground, making them invisible while installing cultural facilities, such as a park, above ground, thereby transforming it into a city landmark. The NIMBY-FIMBY collaboration has also proven beneficial in other ways. The community park above ground helps prevent a drop in real estate values of residential apartments nearby while providing leisure activities for local residents.

■ Risks

Hanam Union Park, despite being an innovative model for waste management, faces several ongoing risks. One of the primary concerns is the aging infrastructure, which has led to increasing maintenance costs and potential financial burdens. Since the facility is located underground, its expansion remains highly limited. If waste generation continues to increase, securing additional space for waste treatment will become increasingly difficult, posing significant long-term challenges.

Furthermore, the park's underground nature presents additional operational concerns, particularly regarding lighting and ventilation. To maintain a stable environment within the facility, advanced air circulation and lighting systems are essential. Without continuous investment in maintenance, operational efficiency may be affected. While odor control systems and air quality monitoring measures have been implemented, ongoing adjustments are required to ensure their effectiveness.

3.3. Case Study 2: World Cup Park

■ Overview

World Cup Park is an ecological restoration project that transformed the Nanjido dumpsite into a sustainable urban park. The Nanjido dumpsite, which accumulated over 92 million tons of waste over 15 years, has caused severe environmental issues, including leachate leakage, harmful gas emissions, and ground subsidence risks. To address these problems, stabilization measures were implemented, including the construction of barrier walls, leachate purification, landfill covering, gas collection and treatment, and slope stabilization.

From 2002 to 2014, landfill gas was extracted and utilized as boiler fuel, resulting in the production of

43.85 million cubic meters of gas with a total economic value of approximately KRW 8.77 billion (approximately USD 8.33 million). The park also serves as a major ecological and recreational space, hosting over 1,000 confirmed species of flora and fauna and attracting around 10 million visitors annually. Additionally, it contributes to the city's environmental goals by incorporating ecological and aesthetic elements.

Figure 9 Past and Present of World Cup Park

< Before: Nanjido, covered with waste >

<After: World Cup Park>

Source: World Cup Park, Retrieved from https://parks.seoul.go.kr/template/sub/worldcuppark.do

■ Background

Before 1978, Nanjido was a scenic island and a popular recreational area for Seoul citizens. However, between 1978 and 1993, it served as Seoul's primary landfill, accumulating 92 million tons of waste and forming a 100-meter-high garbage mountain (Yim, 2017). This uncontrolled waste disposal led to severe environmental hazards, including leachate contamination, air pollution, and ground instability. Additionally, as Korea transitioned from firewood to coal briquettes in the 1980s, ash waste became the dominant form of household waste, further exacerbating the landfill problem (So, 2022).

In response to severe environmental hazards, the Seoul Metropolitan Government launched stabilization efforts in 1996. Following these efforts, the site was repurposed into an eco-friendly urban park, with construction beginning in 2001 and completed in time for the 2002 World Cup. Since its transformation, ongoing stabilization efforts continue to manage environmental risks at the site.

■ Operation

The operation of World Cup Park follows a structured process, ensuring environmental stabilization, ecological restoration, sustainable energy utilization, and long-term maintenance. The first process is leachate treatment, which involves the installation of a containment wall around the landfill site at depths ranging from 17 to 56 meters. This structure is designed to safely collect and treat leachate before discharging it into the Han River (Joe, 2005).

The second process is topsoil coverage, a process that prevents rainwater infiltration into the landfill.

By adding a protective soil layer, this step suppresses the emission of landfill gases and creates an environment that supports plant growth (Bae, 2020).

The third process is landfill gas management, which focuses on capturing and repurposing gas released from decomposing waste (Oh, 2023). This recovered gas is processed into a renewable energy source, producing heating and cooling energy, which is supplied to the World Cup Stadium and approximately 4,430 households in nearby apartments (Cho, 2005).

The final process is slope stabilization, which ensures the structural integrity of the landfill site. Reinforcing the slopes with engineered barriers and vegetation helps prevent soil erosion and enhances the park’s long-term stability as a green space. Stabilization efforts restored ecological balance through afforestation, with over 130,000 trees planted (Yoo, 2023).

■ Enabling factors

Strong government support

Strong government support and urban planning have ensured the long-term sustainability of World Cup Park. Since its inception, the Seoul Metropolitan Government has managed the park, developing an observation area with the ‘Seoul Ring’ Ferris wheel, implementing park tour programs, and maintaining strict management, including pesticide control. Future plans include an aerial walkway and a gondola linking the park to World Cup Stadium.

Financial Sustainability

The expenditures for landfill stabilization and park development were covered by the city's general funds. These initiatives yielded economic benefits, notably through the collection and utilization of landfill gas and the development of housing sites. Between 2002 and 2013, approximately 232.6 million cubic meters of landfill gas were harnessed as boiler fuel, resulting in annual savings of about KRW 6.86 billion (approximately USD 6.26 million). The Korea District Heating Corporation processed this gas to provide heating for the Seoul World Cup Stadium, nearby residential complexes, and office buildings. As the landfill stabilization progressed, the production of landfill gas has been gradually declining.

Prior to the development of the World Cup Park, the surrounding areas remained largely undeveloped due to persistent odors and environmental pollution, leading to low housing demand. However, the establishment of the ecological park and the implementation of the Digital Media City project significantly improved the local environment and ecosystem, which in turn spurred a rise in land prices of approximately 33%-66% between 1993 and 1996.

Policies

The Nanjido Stabilization Project was a proactive initiative by Seoul to independently manage the dumpsite before national waste regulations were established. Although landfill operations ceased in 1993—prior to the Waste Management Act of 1996 and its amendments— Seoul anticipated future policy changes and preemptively stabilized Nanjido, setting a model for post-landfill management. In 1998, the city launched the development of Sangam New Town, including World Cup Park, as a key project to revitalize the area following the 1997 financial crisis. The political objective was to enhance the surroundings of Sangam World Cup Stadium by transforming Nanjido into an ecological park, addressing environmental concerns through large-scale improvements.

Environmental and Public Health

The Nanjido dumpsite disrupted Nanjicheon's natural functions, transforming it into a leachate-filled drainage system instead of a wetland. The landfill also caused severe environmental hazards, including dust, noise, and methane-induced fires. After stabilization, ecological restoration significantly improved the environment, with the number of plant species increasing from 89 to 502 and the number of animal species increasing from 167 to 731 by 2010.

■ Risks

Despite successful restoration, World Cup Park continues to face structural and environmental challenges. While initial subsidence rates were high, they have since stabilized to an average of 5.1 cm over the past six years, though continuous monitoring remains necessary. Another ongoing issue is the maintenance of over 1,000 wooden structures, which require regular inspections to prevent deterioration from sun exposure, decay, and fire hazards.

A major challenge in the Nanjido Ecological Park project was relocating the urban poor who had lived there. After the landfill closed in 1993, their waste collection businesses ended, but many residents refused to leave. Seoul relocated most of the 1,000 households to permanent housing, though 400 resisted until World Cup site construction began, living in deteriorating shelters. The city provided job assistance and relocation incentives before demolishing the shelters.

3.4. Cross-Cutting Analysis: Climate Change, Circular Economy, and Leakage Prevention

Korea's IMSWM cases highlight how integrated urban facilities and post-closure waste management infrastructure can jointly address climate impacts, resource recovery, and waste leakage prevention. By avoiding landfill disposal of organic waste and reducing transport needs through facility integration, Korea's waste treatment complexes contribute to lower greenhouse gas emissions. Resource recovery from food waste, recyclables, and incineration residues enhances circular resource use while maintaining waste flows within formal management systems. These enclosed and consolidated operations significantly reduce opportunities for waste loss, spillage, or informal diversion during collection and treatment.

In parallel, the rehabilitation of legacy landfill sites demonstrates how historical sources of waste leakage can be structurally eliminated. Methane capture and utilization reduce emissions from previously uncontrolled waste deposits, while engineering containment measures and long-term monitoring prevent residual waste from leaking into surrounding environments. Together, Korea's cases show that effective leakage prevention is not limited to active waste treatment but extends to the stabilization of past disposal sites, reinforcing climate mitigation and circularity across the full waste lifecycle.

In addition to strict controls on waste flows, measures to prevent secondary releases to the environment are implemented through engineering and regulatory approaches. At both the Hanam and Nanjido sites, impermeable barrier walls, multi-stage odour and leachate treatment systems, gas collection and purification units, and continuous environmental monitoring are integral to operations. Collectively, these measures have helped mitigate secondary risks, including groundwater contamination, odour nuisance, and methane emissions. Korea's integrated infrastructure and long-term monitoring frameworks illustrate how environmental safeguards can support climate and circularity objectives while strengthening public acceptance.

4 Key Takeaways from Best Practices

The best practices from Singapore and South Korea demonstrate how Integrated Municipal Solid Waste Management (IMSWM) can be effectively operationalized through the application of integrated waste management approaches within the overall system. When examined through the interconnected lenses of climate change mitigation, circular economy, and waste leakage prevention, the cases highlight how system integration and operational strategies can generate multiple environmental and system-wide benefits simultaneously.

From a climate change perspective, the cases show that targeting high-emission waste streams through appropriate treatment technologies is critical. In Singapore, the Energy- from-Waste (EfW) plant on Jurong Island diverts industrial and commercial waste away from landfilling and converts it into thermal energy supplied directly to surrounding petrochemical facilities. This design not only avoids methane emissions from organic waste decomposition but also reduces fossil fuel demand by integrating waste-derived energy into industrial processes. Similarly, the co-location of treatment functions within integrated waste facilities reduces transport distances, contributing to lower fuel consumption and associated emissions. In South Korea, Hanam Union Park achieves climate mitigation by treating food waste and combustible waste streams within a single integrated complex, converting high-methane waste into energy and reusable outputs. At World Cup Park, the capture and utilization of landfill gas from a former dumpsite illustrates how post-closure landfill management can contribute to long-term emission reduction rather than remaining a residual environmental burden.

Circular economy outcomes in the best practices are driven by the rather than by recycling targets alone. Singapore's automated Materials Recovery Facility (MRF) operated by Sembcorp demonstrates how advanced sorting technologies and optimized logistics can enable large-scale material recovery in dense urban contexts, even where space and downstream manufacturing capacity are limited. Residual waste that cannot be materially recycled is channeled into EfW facilities, ensuring that remaining value is recovered through energy generation. In South Korea, Hanam Union Park exemplifies circularity through the simultaneous recovery of recyclables, the conversion of food waste into animal feed, and the reuse of incineration residues, creating multiple resource loops within a single facility. World Cup Park represents a broader interpretation of circular economy principles by transforming a legacy landfill into a productive ecological and recreational space while extracting residual value through landfill gas recovery and land reuse.

Waste leakage prevention emerges as a core operational strength across both countries, understood specifically as the prevention of waste loss into the environment through collection gaps, open dumping, or poorly managed disposal. Singapore's system emphasizes containment and control across the waste value chain. Effective waste leakage prevention focuses on strict control of waste flows to minimize loss, diversion, and open dumping. In Singapore, centralized logistics and regulated waste flows serve as key safeguards against uncontrolled disposal. As a complementary measure, facilities such as Semakau Landfill are equipped with impermeable liners and continuous monitoring to prevent leachate releases into surrounding waters.

Similarly, the Republic of Korea addresses leakage prevention through integrated siting and the consolidation of waste management functions. Hanam Union Park's underground facility design reduces surface exposure and can help deter illegal dumping by containing multiple treatment functions within a tightly controlled site. To address legacy risks, engineering measures—such as cut-off walls and leachate treatment systems—at World Cup Park (Nanjido) serve as essential pollution controls to contain potential environmental hazards.

Taken together, these best practices illustrate that IMSWM is operationalized most effectively when waste management facilities are designed to intercept high-risk waste streams early, recover material and energy value efficiently, and maintain control over waste flows throughout their lifecycle. Climate change mitigation, circular economy transition, and waste leakage prevention are not separate objectives, but mutually reinforcing outcomes of well-designed and well-operated waste management plants. While Singapore and South Korea operate in distinct institutional and spatial contexts, their experiences offer transferable insights for ASEAN cities seeking to strengthen IMSWM through practical waste management applications that can be aligned with and embedded within broader system-level reforms.

Core Linkages and Policy Implications on CC, CE and Leakages

Singapore

1) Climate Change (CC)

- Linkage: A centralized WtE–thermal demand coupling (e.g., Jurong Island EfW) and the co-location of IWMF with wastewater treatment at Tuas Nexus enable simultaneous landfill avoidance, methane abatement, and recovery of electricity and process heat. Long-term alignment of policy, markets and technology institutionalizes the mitigation pathway.
- **Implications**: Link mitigation commitments to firm off-take for industrial steam/heat, and deploy integrated waste–water infrastructure to lower abatement costs. Metropolitan areas can apply a phased integration approach.

2) Circular Economy (CE)

- **Linkage**: Under the Zero Waste Masterplan and the Resource Sustainability Act (RSA) mandationg EPR, an upgraded recovery chain—automated MRF, NEWSand, ferrous/non-ferrous recovery, and the Sarimbun Recycling Park—anchors a laddered circular system in which residuals are directed to WtE.
- **Implications**: Concurrent reinforcement of upstream measures (EPR, packaging rules) and downstream infrastructure (high-quality sorting and recovery) safeguards circular efficiency and market stability. ASEAN cities should prioritize quality-led recycling in parallel with energy recovery.

3) Leakages

- **Linkage**: At the Semakau offshore landfill, impermeable liners and marine clay barriers—combined with stringent regulatory monitoring—minimize leachate and air-emission leakages. Non-combustible residues and non-incinerables move through a closed TMTS–Semakau transfer and final disposal chain.
- **Implications**: Standardized landfill design and monitoring, together with consolidated transfer systems, can structurally reduce leakage risks where open dumping and weak controls persist.

Republic of Korea

1) Climate Change (CC)

- **Linkage**: At World Cup Park (Nanjido), captured landfill gas is utilized for district heating, while the Hanam Union Park's city-integrated complex reduces transport distances and turns high-methane sources into energy. Continuous post-closure stabilization and monitoring manage residual emission risks.
- **Implications**: Urban jurisdictions with high organic fractions benefit from a combined biogas–district heating package. Full life-cycle governance that includes post-closure management (settlement and gas) is essential.

2) Circular Economy (CE)

- **Linkage**: Upstream instruments—EPR and the volume-based fee system—drive source separation and improve recycling quality. City-integrated infrastructure, as in Hanam, embeds social acceptance into facility design and operation.
- **Implications**: Behavioral and market mechanisms, such as citizen participation combined with pay-as-you-throw schemes, can simultaneously improve recycling quality and cost recovery. ASEAN application should be incremental and context-specific.

3) Leakages

- **Linkage**: At Nanjido, cut-off walls, leachate treatment, gas collection, and slope stabilization—combined with long-term monitoring—transformed a legacy leakage source into an ecological park. Social and environmental risks are managed jointly across siting and operations.
- **Implications**: Combining environmental remediation with urban regeneration delivers both leakage reduction and public co-benefits; this is a practical first step for upgrading existing landfills.

Cross-cutting Note

Across both cases, alignment of policy (clear mandates, long-term plans), technology (fit-for- context solutions), finance (tariffs and PPPs) and citizen engagement is decisive for IMSWM performance. Technology choices should be guided by spatial, economic and institutional fit.

IV Current Status and Key Gaps in ASEAN's IMSWM

The current landscape of IMSWM in ASEAN reveals several gaps, as illustrated by comparison with Singapore and South Korea (Table 5). The primary gaps revolve around weak policy enforcement, fragmented institutional frameworks, limited technology adoption, insufficient financial planning, low public awareness, challenges in the informal sector, a lack of focus on circular economy practices, and inadequate climate mitigation and leakage prevention measures.

To bridge these gaps, ASEAN countries must develop strong, centralized waste management policies supported by dedicated government leadership. Technological advancements, financial sustainability through diversified funding, and heightened public involvement are crucial. Additionally, integrating the informal sector into the formal waste management framework can help streamline operations and reduce environmental risks. Strengthening collection and disposal systems to minimize waste leakages and methane emissions will enhance both environmental and climate resilience. Adopting upstream circular economy practices, rather than merely focusing on downstream waste collection, can further enhance sustainability.

By drawing insights from the best practices of Singapore and South Korea, ASEAN can move toward a more resilient and integrated waste management system, customized to local contexts and capacities.

Table 5 Gap analysis and improvement directions for waste management in ASEAN

Aspect	ASEAN challenges	Singapore & South Korea best practices	Improvement directions
Policy enforcement	Weak enforcement due to political influence, inadequate resources, lack of technology	Strong government leadership with clear policies and long-term commitment	- Strengthen government leadership and commitment - Develop clear, enforceable regulations with adequate funding
Institutional framework	Weak coordination, overlapping responsibilities, lack of clear mandates	Coordinated inter-agency approach with dedicated waste management authorities	- Establish a central coordinating body for waste management - Define clear roles and responsibilities among agencies
Technological innovation	Limited adoption of advanced technologies	Advanced waste management systems	- Increase investment in waste processing

Aspect	ASEAN challenges	Singapore & South Korea best practices	Improvement directions
	due to financial constraints		technologies (e.g., biogas, WTE) - Promote public-private partnerships for funding and technology adoption
Financial sustainability	Insufficient funding, reliance on informal sector, lack of cost recovery mechanisms	Diversified funding approaches: combine user fees, public investment, and private sector participation	- Implement volume- based pricing and cost recovery systems - Introduce integrated billing systems for waste services
Public awareness	Low awareness and limited public participation in waste management	High public engagement through campaigns and educational programs	- Launch nationwide education campaigns on sustainable waste practices - Involve communities in planning and decision-making processes
Informal sector	Significant role but lacks formal integration and regulation, leading to inefficiencies and poor working conditions	Limited informal sector due to structured formal systems	- Formalize and regulate the informal waste sector - Provide training and social protection for informal workers to enhance their integration into formal systems
Climate mitigation and leakage prevention	High methane emissions from landfills and open dumps, inefficient collection and transport systems leading to widespread waste leakages	Integration of waste into NDCs through controlled systems minimizing emissions and leakages	- Integrate waste management into climate strategies - Strengthen collection/ transport systems to prevent leakages - Reduce methane through controlled disposal and WtE
Circular economy	Focus primarily on downstream processes (waste collection and recycling), limited upstream efforts (resource conservation)	Emphasis on upstream solutions like resource conservation and energy recovery	- Encourage upstream interventions such as resource conservation - Strengthen regional collaboration on circular economy practices, especially in recycling strategies

V Recommendations for Enhancing Sustainable IMSWM

IMSWM is a critical tool for ASEAN countries to address rising waste volumes and increasing complexity. Despite its importance, many ASEAN countries continue to face systemic constraints, including underdeveloped legal and institutional frameworks, unstable financing, limited technology uptake, low public awareness, and a lack of informal sector integration. Strengthening IMSWM should therefore be treated as a comprehensive policy instrument to achieve climate neutrality, circular economy goals, and urban resilience.

This report puts forward five comprehensive and actionable strategies, grounded in the comparative assessment of best practices from Singapore and South Korea, and calibrated to the socioeconomic, institutional, and technical realities of ASEAN member states.

■ Strengthening Centralized Governance and Institutional Enforcement Capacity

While legal provisions for waste management exist in most ASEAN countries, their implementation capacity remains weak. Institutional fragmentation, overlapping mandates, and insufficient administrative capacity at the subnational level frequently undermine policy coherence. ASEAN countries need to align institutional mandates, establish robust legal frameworks, and enhance coordination across government levels. Creating a central coordinating authority with statutory powers and developing medium- to long-term strategic resource circulation plans, such as Korea's Framework Act on Resource Circulation and Singapore's Resource Sustainability Act, are critical to ensure policy coherence and continuity.

■ Phased Deployment of Localized Appropriate Technologies

One-size-fits-all technology transfer models are not feasible in ASEAN. Instead, ASEAN countries should adopt a phased and context-sensitive technology deployment strategy based on localized appropriate technologies. Given that organic waste accounts for 50–80% of total municipal waste in the region, initial investments should prioritize small-scale biogas digesters, composting units, and basic Refuse-Derived Fuel (RDF) systems. For intermediate to large urban centers, automated Material Recovery Facilities (MRFs) and Waste-to-Energy (WTE) plants may be appropriate, with preference given to community-integrated infrastructures. When adopting advanced technologies, it is important to consider the need for skilled personnel and training systems to support their operation and maintenance.

Crucially, technological interventions should be designed holistically, encompassing the full waste value chain from collection and sorting to recovery. Singapore's Sembcorp-operated automated MRF is a case in point, offering a closed-loop system that integrates logistics optimization, material recovery, and energy generation. ASEAN cities should be supported in establishing modular IMSWM clusters through international partnerships and blended financing arrangements. Public acceptance and secured end-use demand for recovered resources should also be considered when selecting appropriate technologies.

■ Establishing Hybrid Financing Models to Ensure Fiscal Sustainability

Waste budgets in ASEAN are largely reliant on general taxation or external aid, resulting in instability. Government should seek hybrid financing mechanisms that combine public funding, user/tipping fees, and private capital. Korea's volume-based waste fee system and Singapore's integrated billing system have demonstrated success in promoting user responsibility and improving cost recovery. At the same time, PPP models can attract private capital for infrastructure development. Fiscal strategies should not only focus on securing revenue but also on reducing expenditures and activating market functions through facility scale-up, clustering, and extended producer or polluter responsibility frameworks. ASEAN countries should create an enabling investment climate by offering regulatory stability and tax incentives. To implement user and tipping fees or expand producer and polluter responsibility, public cooperation and legislative support are essential, alongside institutional readiness for identifying and engaging responsible actors.

■ Enhancing Citizen Participation and Building Social Acceptability

As demonstrated by Singapore's national environmental education campaigns and Korea's participatory facility planning processes, citizen engagement plays a critical role and should be systematically integrated into waste governance frameworks. Citizens are both generators and consumers who take responsibility for separating recyclables at the source and influence demand for eco-friendly products

Korea's transition from "NIMBY" (Not in My Backyard) to "FIMBY" (Facility in My Backyard) through community co-design of urban waste facilities offers valuable insights. ASEAN countries should adopt community-centered governance frameworks during site selection and facility planning, and expand incentive-based schemes such as recycling point systems and rebate programs to embed public participation into everyday behavior. To enhance public acceptance and long-term engagement, governments should combine awareness-building efforts with appropriate economic incentives.

■ Transitioning Toward a Circular Economy and Strengthening Upstream Interventions

Waste management policies in ASEAN must move beyond end-of-pipe solutions, focusing on collection and disposal to address waste generation and resource use at their source. Expanding EPR frameworks, reducing single-use plastics, and incentivizing product redesign are key measures. Korea's EPR program and reusable packaging regulations are proven examples of how upstream interventions drive systemic change.

The transformation of IMSWM systems in ASEAN developing countries must go beyond ad hoc technological upgrades. A truly integrated framework must holistically encompass legal, fiscal, technological, social, labor, and environmental dimensions, while aligning waste management with national climate and pollution control agendas to reduce methane emissions and prevent leakages throughout the waste value chain. Above all, the principle of incremental integration tailored to local realities must underpin all reform efforts. The cases of Singapore and South Korea are not one-size-fits-all solutions but offer adaptable, multi- scalar models that ASEAN countries can calibrate to their unique contexts.

Going forward, the formulation of national IMSWM roadmaps—that synthesize policy, technology, finance, and community engagement—should be coupled with the development of a regional coordination platform to facilitate knowledge exchange, technology diffusion, and harmonized monitoring. In doing so, ASEAN countries can pave the way toward a more sustainable, inclusive, and resilient urban future.

Table 6 Key Components and Implementation Pathways for IMSWM Strategies

Strategy	Key Component	Reference (SGP/KR)	Policy & Infrastructure Measures
Centralized Governance	Clear mandates, legal frameworks, strategic plans	(SGP) Resource Sustainability Act (KR) Framework Act	Central coordinating authority, inter-agency collaboration
Localized Technologies	Phased deployment, context-sensitive tech	(SGP) Automated MRF (KR) Hanam Union Park	Modular MRF, composting, biogas, WTE
Hybrid Financing	Diversified funding (user/tipping fees, PPP)	(SGP) Integrated billing (KR) Volume-based fees	Cost-recovery systems, PPP incentives
Citizen Participation	Education, incentives, participatory planning	(SGP) National campaigns (KR) NIMBY→FIMBY shift	Recycling rewards, community engagement frameworks
Circular Economy	Upstream interventions, EPR	(SGP) Packaging regulations (KR) EPR	Single-use reduction, producer accountability

References

Agamuthu, P. and Babel, S. (2023). Waste management developments in the last five decades: Asian perspective. Waste Management & Research, 41(12), 1699-1716. https://doi.org/10.1177/0734242X231199938.

Akenji, L. and Bengtsson, M. (2019) Circular Economy and Plastics: A Gap-Analysis in ASEAN Member States; European Commission Directorate General for Environment and Directorate General for International Cooperation and Development: Brussels, Belgium; Association of Southeast Asian Nations (ASEAN): Jakarta, Indonesia Arthur, L., Hondo, D., Hughes, M., & Kohonen, R. (Eds.). (2022). Prospects for transitioning from a linear to circular economy in developing Asia. Asian Development Bank Institute.

Aleluia, J. and Ferrão, P. (2016). Characterization of urban waste management practices in developing Asian countries: A new analytical framework based on waste characteristics and urban dimension. Waste management, 58, 415-429. https://www.sciencedirect.com/science/article/pii/S0956053X16302409?via%3Dihub

Association of Southeast Asian Nations (2022). The ASEAN Toolkit on Sustainable Consumption. Jakarta. Available at https://aseanconsumer.org/file/ASEAN%20SC%20Toolkit/The%20ASEAN%20Sustainable%20Consumption%20Toolkit%20-%207Jun22.pdf.

Aziz, M. F. A. and Ariffin, R. N. R. (2024). The Implementation of Solid Waste Management Policies in Southeast Asia: The Present Situations and Future Recommendations. The Malaysian Journal of Social Administration, 18. https://doi.org/10.22452/18sp/113.159.

Bae, S. (2020). Constructing and Recycling Nanjido Landfill. Master's dissertation. Seoul National University Graduate School.

Cho, P. K. and Lee, S. U. (2016). Waste resources management and utilization policies of korea. Korea Research Institute for Human Settlements, Publications Registration, 11-10510000. https://kdevelopedia.org/Resources/view/04201803210149913.do

Cho, Y. (2005, April 29). [Seoul Story] Nanjido World Cup Park. Seoul Newspaper. Available at https://www.seoul.co.kr/news/Seoul_In/seoul_metro/2005/04/29/20050429056001

Chong, C. (2020, September 25). Turning trash into treasure: NEA seeks to reuse landfill materials. The Straits Times. Available at https://www.straitstimes.com/singapore/turning-trash-to-treasure-nea-seeks-to-reuse-landfill-materials

Clean & Green Singapore (n.d.). Know your contaminants. Web page. Available at https://www.cgs.gov.sg/recycleright/know-your-contaminants

Curea, C. (2017). Sustainable societies and municipal solid waste management in Southeast Asia. In Sustainable Asia: Supporting the Transition to Sustainable Consumption and Production in Asian Developing Countries, 391-415. Available at https://www.oneplanetnetwork.org/sites/default/files/15._sustainable_societies_in_south_east_asia.pdf

Department of Environment, Parks and Recreation (JASTRe). (2024). Brunei Darussalam Waste Management Status 2023. Bandar Seri Begawan: Ministry of Development.

Department of Statistics Malaysia (DOSM). (2025). Compendium of Environment Statistics, Malaysia 2025. Putrajaya: Department of Statistics Malaysia.

Emami, N., Schandl, H. and West, J. (2022). Material Flow Analysis and the State of Circularity in ASEAN economies. CSIRO: Sydney. Available at https://research.csiro.au/sruap/wp-content/uploads/sites/462/2022/08/Circular-Economy-Policy-Brief-co-branded.pdf

Global Green Growth Institute (2020, June 30). GGGI Laos established a waste recycling bank in local schools of Vientiane, Lao PDR. Seoul. Available at https://gggi.org/gggi-laos-established-a-waste-recycling-bank-in-local-schools-of-vientiane-lao-pdr

Global Recycling (n.d.). Cambodia refuses to be a “waste bin”. Web Page. Available at https://global-recycling.info/archives/3212

Hanam City (n.d.). Hanam Union Tower Park. Web Page. Available at https://www.hanam.go.kr/www/contents.do?key=3340

Héry, M. and Malenfer, M. (2020). Development of a circular economy and evolution of working conditions and occupational risks—a strategic foresight study. European Journal of Futures Research, 8(1), 8. https://doi.org/10.1186/s40309-020-00168-7

Hiratsuka-Sasaki, A. and Kojima, M. (2020). Inter-municipal cooperation on solid waste management in Japan: Its challenges and implications for ASEAN countries. In Regional Waste Management-Inter-municipal Cooperation and Public and Private Partnership. ERIA: Jakarta. Available at https://www.eria.org/uploads/media/Research-Project-Report/2020-12-Regional-Waste-Management-in-Asia/09_Ch.3-Inter-municipal-Cooperation-Solid-Waste-Japan.pdf

IPI-Singapore (n.d.). Autonomous solution to sort and recover recyclable waste materials at Sembcorp’s Material Recovery Facilities (MRF). Singapore. https://www.ipi-singapore.org/contents/2020/06/sembcorpautonomous-recyclable-waste-sortingfinal-1592980836.pdf

Kerdlap, P., Low, J. S. C. and Ramakrishna, S. (2019). Zero waste manufacturing: A framework and review of technology, research, and implementation barriers for enabling a circular economy transition in Singapore. Resources, conservation and recycling, 151, 104438. https://doi.org/10.1016/j.resconrec.2019.104438

Korea National Law Information Center (n.d.). Legislation of Excrement and Cleaning Law. Web Page. Available at https://www.law.go.kr/LSW/lsInfoP.do?lsiSeq=456&viewCls=lsRvsDocInfoR#

Korean Ministry of Environment (2017). Stories of resources in everyday life. Sejong. Available at https://www.me.go.kr/home/web/board/read.do?menuId=10181&boardId=791680&boardMasterId=54

________________ (2018). The 1st basic plan for resource circulation (2018- 2027). Sejong. Available at https://me.go.kr/home/web/policy_data/read.do?menuId=10259&seq=7193

________________ (2020). Implementation Plan for the Transformation of Resource Circulation Policy. Sejong. Available at https://www.me.go.kr/home/mob/board/read.do?menuId=10392&boardMasterId=713&boardId=1399860

Kua, H. W., He, X., Tian, H., Goel, A., Xu, T., Liu, W., ... and Wang, C. H. (2022). Life cycle climate change mitigation through next-generation urban waste recovery systems in high-density Asian cities: A Singapore Case Study. Resources, Conservation and Recycling, 181, 106265. https://doi.org/10.1016/j.resconrec.2022.106265

Lim Swee Say (2002, November 13). Speech at the official opening of Sembvisy's material recovery facility, 13 November 2002, 10:00 AM. National Archives of Singapore. Available at https://www.nas.gov.sg/archivesonline/speeches/record-details/4a10f476-4327-11eb-85f4-005056a7c31c

McDougall, F. (2001). Life cycle inventory tools: supporting the development of sustainable solid waste management systems. Corporate Environmental Strategy, 8(2), 142-147. https://doi.org/10.1016/S1066-7938(01)00083-5

McDougall, F. R., White, P. R., Franke, M. and Hindle, P. (2008). Integrated solid waste management: a life cycle inventory. Wiley: New York. Available at https://www.wiley.com/en-us/Integrated+Solid+Waste+Management%3A+A+Life+Cycle+Inventory%2C+2nd+Edition-p-9780632058891

National Environment Agency (2024). Revision of household refuse collection fees from 1 July 2024. Web page. Available at https://www.nea.gov.sg/media/news/advisories/index/revision-of-household-refuse-collection-fees-from-1-july-2024

________________. (2025). Waste Statistics and Overall Recycling Rates for 2024. Singapore: National Environment Agency. Retrieved from https://www.nea.gov.sg/our-services/waste-management/waste-statistics-and-overall-recycling

Oh, S. M. (2023). Remembrance of Nanjido: Space, archive, and history of the world cup park. The Journal of Asian Studies, 82(2), 163-183. https://doi.org/10.1215/00219118-10290630

Park, C. (2021). Is the transformation of Hanam Union Park & Tower, a collection of hated facilities, guilty?. Kookto Journal (June 21). Available at http://www.kooktojournal.news/4413

Pollution Control Department (2024). Thailand State of Pollution Report 2023. Bangkok: Ministry of Natural Resources and Environment.

Quaker United Nations Office (2023). Trade and Plastics: Enabling Inclusive Socio- Economic Growth in ASEAN. Geneva. Available at https://quno.org/sites/default/files/resources/Trade%20and%20Plastics-Enabling%20Inclusive%20Socio-economic%20growth%20in%20South%20East%20Asia%20Regular%20Logo%20version_0.pdf

Sembcorp Industries (2013). Annual Report. Available at https://www.sembcorp.com/creating-shareholder-value/results-and-publications/?yearKey=29abdb9a-b24c-4018-940b-d24cb1375c05&numofresults=20

________________(2020). Annual Report. Singapore. Available at https://www.sembcorp.com/creating-shareholder-value/results-and-publications/?yearKey=9266113c-0ee1-42d4-9f84-5a068209ba34&numofresults=20

________________(2024). SembWaste's commitment to circular economy. Web Page. Available at https://www.sembcorp.com/sg/news-and-insights/insights-and-stories/singapore/sembwastes-commitment-to-circular-economy/#:~:text=At%20SembWaste%2C%20we%20are%20dedicated%20to%20evaluating%20the,collecting%2C%20processing%2C%20recycling%2C%20and%20recovering%20energy%20from%20waste.

________________(n.d.). Public waste and recycling. Web Page. Available at https://www.sembcorp.com/sg/our-solutions-in-singapore/integrated-urban-solutions/waste-and-waste-to-resource/public-waste-and-recycling/

Seoul Solution (2015). Landfill Recovery Project: Transformation of Landfill to Ecological Park. Web Page. Available at https://seoulsolution.kr/en/content/landfill-recovery-project-transformation-landfill-ecological-park#:~:text=This%20project%20focused%20on%20four%20areas%20of%20development%3A,also%20began%20shaping%20this%20land%20into%20a%20park

Singapore Environment Council (2022). Unlocking Sustainable Packaging Opportunities in Singapore. Singapore. Available at https://www.sec.org.sg/pdf/reports/unlocking-sustainable-packaging-opportunities-in-Singapore.pdf

So, J. (2022, May 15). "The Revolution of Fuel": Briquettes Pour Out Massive Urban Waste. Hankookilbo. Available at https://www.hankookilbo.com/News/Read/A2022050916340005134

Song, H. (2024, January 24). "Seoul's Undesirable and Hated Facilities, Where To? Is 'Incineration Plant' a Hated Facility? The Secret to Hanam 'Union Park's' Success". New Daily. Available at https://www.newdaily.co.kr/site/data/html/2024/01/24/2024012400093.html

Soudachanh, S., Campitelli, A. and Salhofer, S. (2024). Identifying Priorities for the Development of Waste Management Systems in ASEAN Cities. Waste, 2(1), 102-121. https://doi.org/10.3390/waste2010006

State of Green (2015). Waste-to-energy plant in Jurong Island, Singapore. Web Page. Available at https://stateofgreen.com/en/solutions/waste-to-energy-plant-in-jurong-island-singapore/

Tham, D. (2021, June 9). More sustainable, smarter waste collection and recycling for City-Punggol households and businesses. Channel NewsAsia. Available at https://news.nestia.com/detail/More-sustainable%2C-smarter-waste-collection-and-recycling-for-City-Punggol-households-and-businesses/6849678

United Nations Economic and Social Commission for Asia and the Pacific (2014). Statistical yearbook for Asia and the Pacific 2014. Bangkok. Available at https://www.unescap.org/sites/default/d8files/knowledge-products/ESCAP-SYB2014-full.pdf

United Nations Environment Programme (2009). Developing Integrated Solid Waste Management Plan-Training Manual Vol. 2: Assessment of Current Waste Management System and Gaps therein. Nairobi. Available at https://wedocs.unep.org/20.500.11822/7609.

United Nations Environment Programme (2017a). Asia waste management outlook. Nairobi. Available at https://www.unep.org/ietc/resources/publication/asia-waste-management-outlook

United Nations Environment Programme (2017b). Waste management in ASEAN countries: Summary report. Nairobi. Available at https://wedocs.unep.org/bitstream/handle/20.500.11822/21134/waste_mgt_asean_summary.pdf?sequence=1&amp%3BisAllowed=

United Nations Environment Programme (2024). Global waste management outlook. Nairobi. Available at https://wedocs.unep.org/bitstream/handle/20.500.11822/44939/global_waste_management_outlook_2024.pdf?sequence=3

United Nations Human Settlements Programme (2010). Solid Waste Management in the World's Cities: Water and Sanitation in the World's Cities 2010 (1st ed). Nairobi. Available at https://doi.org/10.4324/9781849774871

United States Environmental Protection Agency (2020). Best Practices for Solid Waste Management: A Guide for Decision-Makers in Developing Countries. Washington DC. Available at https://www.epa.gov/sites/default/files/2020-10/documents/master_swmg_10-20-20_0.pdf

US-ASEAN Business Council, Inc. (2023). Plastic waste management in ASEAN. Washington DC. Available at https://www.usasean.org/sites/default/files/2023-10/Sustainability%20%282023%29%2C%20Plastics%20Biannual%20Report%20%28Compressed%29.pdf

Velasco, E. (2024). Circular economy in Singapore: waste management, food and agriculture, energy, and transportation. Urban Resilience and Sustainability, 2(2), 110-150. https://www.aimspress.com/article/doi/10.3934/urs.2024007

World Bank (2018). What a waste 2.0: A global snapshot of solid waste management to 2050. Washington, DC: World Bank.

Yan, J. and Feng, C. (2014). Sustainable design-oriented product modularity combined with 6R concept: a case study of rotor laboratory bench. Clean Technologies and Environmental Policy, 16(1), 95-109. https://doi.org/10.1007/s10098-013-0597-3

Yim, D. (2017, November 10). Incinerator transformed into an eco-friendly attraction. Yonhap News Agency. Available at https://www.yna.co.kr/view/AKR20171026177300805

Yoo, K. (2010). Action Plan to Foster Seoul's Municipal Solid Waste (MSW) Treatment Industry for "Zero Waste". The Seoul Institute: Seoul. Available at https://www.si.re.kr/bbs/view.do?key=2024100154&pstSn=1011020003#none

Yoo, Y. (2023, July 10). Activist growing a forest on 'garbage mountain': "Grateful to the wildlife living here". SBS NEWS. Available at https://news.sbs.co.kr/news/endPage.do?news_id=N1007260974