Waste Management Infrastructure Gap

Rapid Assessment of Plastic Waste Management Infrastructure Gap in the Philippines

HEALTHY OCEANS AND CLEAN CITIES INITIATIVE

UN HABITAT
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From the People of Japan

IGES
Institute for Global Environmental Strategies

Save Philippine Seas
Because our seas save us.

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List of acronyms and abbreviations

DENR	Department of Environment and Natural Resources
DTP	Devolution Transition Plan
FMCG	Fast-moving consumer goods
GAIA	Global Alliance for Incinerator Alternatives
HDPE	High-density polyethylene
HDV	High Diversion Value
LDV	Low diversion value
LDPE	Low-density polyethylene
LGU	Local government unit
MPW	Mismanaged Plastic Waste
MRF	Material recovery facility
MSW	Municipal solid waste
NPOA-ML	National Plan of Action for the Prevention, Reduction, and Management of Marine Litter
NSWMC	National Solid Waste Management Commission
PARMS	Philippine Alliance for Recycling and Materials Sustainability
PDP	Philippine Development Plan
PP	Polypropylene
PPIA	Public Policy and International Affairs
PET	Polyethylene terephthalate
PS	Polystyrene
PVC	Polyvinyl Chloride
RA	Republic Act
RDF	Refuse-derived fuel
RPF	Refused Plastic Fuel
SE	Southeast
SLF	Sanitary Landfills
SWM	Solid Waste Management
SWMP	Site Waste Management Plan
TPD	Tons per day
WtE	Waste-to-Energy
WWF	World Wide Fund for Nature
ZWTN	Zero Waste to Nature

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Glossary

Baled plastics	Plastic waste went through the baling process to reduce its volume and space in collection vehicles and storage areas, subsequently lowering transportation costs.
Baling	Compression of materials (e.g., plastic waste) into blocks for easier storage and transportation secured by wire strapping.
Co-processing	Co-processing refers to the simultaneous utilization of waste as raw material or source of energy within one single industrial process
Collection rate	Percentage of waste collected and transported for treatment or disposal
Ecobricks	Blocks made from used plastics, commonly flexible and low-value plastics, packed in PET bottles used for building structures and small furniture (e.g., garden walls or chairs).
Flexible Plastics	Plastic materials that are thin and lightweight such as sachets, pouches, and bags.
High-value plastics	Plastic materials with high economic value for recycling and recovery like PP, PET and rigid HDPE.
Low-value plastics	Plastic materials with low economic value for recycling and recovery like the LDPE, flexible HDPE, and others
Mismanaged plastic waste	Refers to uncollected or improperly disposed plastic waste, or those collected plastic waste but not properly recycled nor recovered
Rigid plastics	Plastic materials that are thicker and denser such as bottles, tubs, and trays. These are commonly used for packaging cosmetics, soap and detergent bottles, caps and closures for beverage bottles, ice cream tubs, instant noodle cups, microwavable containers, and PET bottles.
Unbaled plastic	Plastic materials or waste that are placed in sacks without using a baling machine.

Executive Summary

Twenty-one years after the enactment of the Philippines' Ecological Solid Waste Management Act of 2000 or Republic Act (RA) 9003, the country still lacks solid waste management infrastructure. This contributes to the ineffective implementation of the law. The infrastructure gaps exist in waste collection, recovery, recycling, and disposal facilities.

According to the Department of Environment and Natural Resources (DENR), waste segregation at source is not fully implemented and the collection coverage and efficiency is low with an average national collection rate of 54.89%.[1] Although international studies estimate that the main source of plastic leakage in the Philippines is from waste that has already been collected, uncollected plastic waste continues to be a pressing concern in the country.[2] This suggests that the majority of plastic leakage happens due to the lack of infrastructure for recycling and recovery and improper waste disposal. Recognizing the threats of mismanaged plastic waste to the health of cities and oceans, a rapid assessment of plastic waste management physical infrastructure gaps in the Philippines was conducted.

Faced with the lack of national data on relevant baseline information on plastic waste management, the results presented in this paper are an estimate of the required physical infrastructures based on the projected waste generation from 2021 to 2032 and the composition of waste. The gaps were estimated for waste diversion, capacity of existing material recovery facilities (MRFs) and junk shops, collection vehicles, and sanitary landfills. This study aimed to identify and quantitatively estimate the waste management infrastructure gaps for plastic waste in the Philippines to provide a baseline for investments required to bridge and close the gaps and establish a sound waste management system mandated by RA 9003.

This study aimed to identify and quantitatively estimate the waste management infrastructure gaps for plastic waste in the Philippines to provide a baseline for investments required to bridge and close the gaps.

[1] Unpublished Report. Environment Database of the Environmental Management Bureau, DENR. (2021)
[2] McKinsey & Company and Ocean Conservancy. (2015). *Stemming the Tide: Land-based Strategies for a Plastic-Free Ocean.* Retrieved on September 19, 2022 from oceanconservancy.org website: https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf

The estimated values of total infrastructure requirements, existing infrastructure as of 2021, and additional infrastructure needed to meet the requirements until 2032 for plastic waste are shown in the executive summary table below (Summary Table). Plastics in this paper are distinguished between rigid plastics (i.e., thicker plastics, such as bottles, tubs, and trays) and flexible plastics (i.e., thin and lightweight such as sachets, pouches, and bags).

The assessment in this report is based on nationwide data and does not consider the unique geographical characteristics of the local government units (LGUs). Based on the National Solid Waste Management Commission (NSWMC) under the Department of Environment and Natural Resources-Environmental Management Bureau (DENR-EMB) database of 2022, there are about 27,229 barangays/LGUs (or 60%) that do not have access to MRFs and about 1,110 LGUs (or 68%) do not have access to sanitary landfills (SLFs). At 100% collection rate, the estimated number of additional MRFs or additional space to the existing MRFs is about 40,283 units for 2021 and another 9,929 units are needed until 2032 for the rigid plastic wastes.

The assumptions made to determine the total number of MRFs is 50m³ capacity at two or more collections/transfer of waste to recycling plants per year. It is also assumed that the cost of establishing the MRF is about P20,000.0/m², thus, a budgetary requirement of PhP 805.66 million is needed for 2021 with a corresponding incremental increase per year until 2032. The country needs 460 units of collection vehicles with a truckload capacity of 12.0m³ to collect and transfer the stored plastic wastes from the LGUs' MRF to the plastic recycling plant or waste transfer station at the province (two trips per day). This is with the assumption that there are available recycling facilities or transfer stations in each province. The total requirement of collection vehicles for 10 years is about 571. At 54.89% collection rate, the total number of MRFs needed is about 27,458 until 2032 to accommodate the projected waste generation.

For the rigid and flexible plastics, the MRF and collection vehicle requirements are presented in the Summary Table. The 10-year total requirement of MRF at 100% and 54.89% collection rate is about 97,315 and 37,823 vehicles, respectively.

SUMMARY TABLE. SOLID WASTE MANAGEMENT INFRASTRUCTURE REQUIREMENTS

Required Material Recovery Facilities (MRFs)						
Type of Waste	Volume of projected plastic waste (m³/year) - 2021	Volume of projected plastic waste (m³/year) - 2032	Collection Rates	Total MRF Requirement for 10 years (MRF units)	Existing MRFs as of 2021 (Current)	Additional MRFs from 2022 - 2032 (Gap)
Rigid Plastic Waste	2,211,108.00	2,745,791.00	54.89%	27,458	*11,378/**22,111	5,347
	4,028,254.00	5,002,352.00	100.00%	50,204	*11,378./**40,283	9,921
Rigid and Flexible Plastic Waste	6,091,544.00	7,564,581.00	54.89%	37,823	*11,378/**30,458	7,365
	15,673,071.00	19,463,081.00	100.00%	97,315	*11,378/**78,365	18,950
Collection Vehicles (CV) with 12.0 cubic meter truckload capacity per unit (m3/unit)						
Type of Waste	Volume of projected plastic waste (m³/year) - 2021	Volume of projected plastic waste (m³/year) - 2032	Collection Rates	Total CV Requirement for 10 years	Existing CVs as of 2021 (Current) at 2 trips per day	Additional CVs from 2022 - 2032 (Gap)
Baled Rigid Plastic Waste	2,211,108.00	2,745,791.00	54.89%	313	*No Data/**252	61
	4,028,254.00	5,002,352.00	100.00%	571	*No data/**460	111
Unbaled Rigid and Flexible Plastic Waste	6,091,544	7,564,581.00	54.89%	864	*No data/**695	169
	15,673,071.00	19,463,260.00	100.00%	2,222	*No data/**1,789	433

***Existing MRFs or CV | **2021 additional requirement**

For the collection of baled (rigid) and unbaled (rigid + flexibles) plastic waste, the study shows that there is a need for the country to invest in the provision collection vehicles to be distributed to the provinces. Increasing the current collection rate of 54.89% to 100% requires additional 2,222 collection vehicles.

In terms of waste infrastructure gap occurring during disposal, results of this study show that by 2024, the designed capacities of the existing SLF for residuals and mixed wastes will already be fully utilized. With the estimated waste generation of 10,760.31 tons per day (TPD) (2021 as base year) to 13,500 TPD (2032), the country needs to develop about 105 more SLFs (i.e., 1,581.0 hectares with a depth of 10 meters) within 10 years. Assuming that PhP 40-50 million is needed to develop per hectare of SLF, the government needs a budget of about PhP 4.20-5.25 billion.

Addressing waste management infrastructure gaps requires time for planning, securing of funds, and facility development. These additional requirements need to be embedded in national and local investment and sectoral plans to ensure a programmatic approach to manage plastic waste challenges.

1. Introduction

1.1. Background

The Philippines has yet to establish its definitive baseline of plastic waste leakage into the world's oceans. This is part of Strategy 1 of the National Plan of Action for the Prevention, Reduction, and Management of Marine Litter (NPOA-ML). According to the National Solid Waste Management Commission (NSWMC), the NPOA-ML "aims to provide a blueprint to enhance the current efforts of the country in resource and waste management and to bring additional lens to marine litter issues and the control of additional leakage of waste into bodies of water."[1] Available international literature reported that more than one third of the world's ocean plastic comes from the Philippines[2] and that Manila might be the world's largest urban center generating mismanaged plastic waste (MPW).[3] Therefore, it is important to strengthen strategies on preventing plastic pollution especially in areas where the amount of MPW is large and where the probability of plastic leakage is the highest. These areas would be those within the river basin, especially near the river and near the ocean, in non-cultivated flat areas (e.g., paved areas), and areas where the mobilization of plastic waste into the river is high due to high precipitation, winds, floods, and other factors.[4]

It was estimated that 761 thousand tonnes (or 35%) out of the 2,150 thousand tonnes of plastic waste was littered and illegally dumped in the open environment in the Philippines.

EPR SCHEME ASSESSMENT FOR PLASTIC PACKAGING WASTE IN THE PHILIPPINES - WORLD WILDLIFE FUND FOR NATURE (WWF)

[1] National Solid Waste Management Commission (NSWMC). *Resolution Adopting the National Plan of Action for the Prevention, Reduction and Management of Marine Litter* (NPOA-ML). 2021. Retrieved on October 10, 2022 from https://nswmc.emb.gov.ph/wp-content/uploads/2021/10/2021-NSWMC-Resolution-No.-1441-Series-of-2021-NPOA-ML1.pdf

[2] L. J. J. Meijer, T. van Emmerik, R. van der Ent, C. Schmidt, L. Lebreton. (2021). More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. Sci. Adv. 7, eaaz5803. Available at https://www.researchgate.net/publication/351269287.

[3] Lebreton L. and Andrady A. (2019). Future scenarios of global plastic waste generation and disposal. (2019). Palgrave Communications 5, Article number: 6.

[4] L. J. J. Meijer, T. van Emmerik, R. van der Ent, C. Schmidt, L. Lebreton. (2021). More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. Sci. Adv. 7, eaaz5803. Available at https://www.researchgate.net/publication/351269287

The plastic waste leaks from poorly situated, improperly established, or mismanaged disposal sites or from illegal disposal of waste into the environment by haulers. In the Philippines, littering and uncollected waste disposal account for around 26% of marine plastic litter.[5]

Based on the World Wildlife Fund for Nature (WWF) study published in 2020, it was estimated that 761 thousand tonnes (or 35%) out of the 2,150 thousand tonnes of plastic waste in the Philippines was littered and illegally dumped in the open environment. The report also stated that low-value residual plastic waste (48.62%) such as low-density polyethylene (LDPE), flexible high-density polyethylene (HDPE), and other plastics were more likely to leak than high-value plastic (36.65%) such as the polypropylene (PP), polyethylene terephthalate (PET), and rigid HDPE. Polystyrene (PS) and polyvinyl chloride (PVC), which are considered medium-value plastics, comprise only 14.74% of the total plastic leakage.[6] This study shows that a significant amount of plastic leakage is coming from land-based sources. Thus, it is important to find sound strategies in managing waste to improve the collection and transportation system, to increase the recycling and recovery rates of plastic waste, and carry out safe disposal of residual plastic waste in sanitary landfills (SLFs) to effectively close the gaps to prevent marine pollution.

This study highlights the relevance of the provision of appropriate and sufficient infrastructures as an enabling mechanism to effectively implement the waste management policies in the country.

What are rigid plastics?

Rigid plastics are defined as plastic materials that are thicker and denser such as bottles, tubs, and trays. These are commonly used for packaging cosmetics, soap and detergent bottles, caps and closures for beverage bottles, ice cream tubs, instant noodle cups, toothbrushes, microwavable containers, carbonated soft drinks, tea, and water bottles.

[5] McKinsey & Company and Ocean Conservancy. (2015). Stemming the Tide: Land-based Strategies for a Plastic-Free Ocean. Retrieved from oceanconservancy.org website: https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf

[6] WWF. (2020). EPR Scheme Assessment for Plastic Packaging Waste In The Philippines. Retrieved from wwf.org website: https://wwf.org.ph/wp-content/uploads/2020/12/WWF_REPORT_EPR_Philippines_2020.pdf

It is important to find sound strategies in managing waste to improve the collection and transportation system, increase the recycling and recovery rates of plastic waste, and carry out safe disposal of residual plastic waste in SLFs to effectively close the gaps to prevent marine pollution.

The Philippines has implemented many policies and regulations embracing the concepts of sound waste management and plastic waste prevention. One of the most comprehensive laws is the Republic Act (RA) 9003, also known as the Ecological Solid Waste Management Act of 2000. This came into force in 2001. It declares the "policy of the state to adopt a systematic, comprehensive, and ecological solid waste management program which shall ensure the protection of public health and environment."[7] This Act and other waste-related legislations and resolutions provide measures, which, if fully implemented, could have a significant impact in addressing the growing concerns on plastic waste in the country.

However, 21 years since the enactment of RA 9003, the compliance rate on proper waste management remains a challenge.

The uncollected waste, including plastic materials, has continued to leak into the environment (e.g., drainage canal, open land, river, and ocean) and degrade the health of communities, cities, and oceans.

There is no definitive overall or national data on relevant waste management information such as the current waste diversion, capacity of existing materials recovery facilities (MRFs) and junk shops, number and capacity of waste collection vehicles, recycling facilities, among others.

This study highlights the relevance of the provision of appropriate and sufficient infrastructures as an enabling mechanism to effectively implement the waste management policies in the country.
This includes the provision of proper storage bins for specific types of waste to promote waste segregation at source, efficient waste collection and transportation vehicles, adequate facilities to promote reuse, recycling, and recovery, and safe disposal of residuals.

[7] Republic of the Philippines. Republic Act 9003 (RA 9003) Ecological Solid Waste Management Act of 2000.

The second section of the paper discusses the solid waste infrastructure diagram, which illustrates the different components of the municipal solid waste management (SWM) and the interconnectivity of the components. The third section identifies the infrastructure gaps occurring in waste storage (waste source) and collection, recycling, recovery, and disposal. Based on the results of this study, the last part provides the recommendations for future studies.

1.2. Methodology

Due to the lack or limited national data on relevant baseline information on plastic waste management, this study used estimations and assumptions in calculating the infrastructure gaps based on available data and interviews with key informants. In determining the solid waste management infrastructure gap, the following steps were done: 1) collection of secondary data from relevant agencies and other available related materials; and 2) interviews with key informants, which includes representatives from the Department of Environment and Natural Resources (DENR) and the Philippine Alliance for Recycling and Materials Sustainability (PARMS), and recyclers. Based on available information (e.g., projected waste generation, composition of waste), assumptions were used for estimating the capacity of MRFs and loading capacity of the collection vehicles. An MRF with an area of 50m² (5x10m size) and the height of plastic at 2.0m high collection vehicle, its loading capacity of 12.0m³/trip twice year collection of plastic wastes from the MRF to plastic recycling plant in the province were used. Estimates on the number of SLF requirements using different sizes of SLFs were also done for the 10-year projection (or until 2032).

1.3. Scope and Limitations

For the infrastructure requirements for MRFs and collection vehicles, this study focuses only on plastic waste. For the infrastructure gaps in disposal, it covers the facilities required for the residuals and contaminated mixed wastes. Gaps on recycling infrastructures are not covered in this paper due to multiple possible permutations on the type of recycling and the lack of adequate data during the assessment. The assessment in this report is based on nationwide data and does not consider the unique geographical characteristics of the local government units (LGUs).

2. Plastic waste management infrastructure diagram

2.1. Components of the municipal SWM infrastructure for plastics and prioritization of the flows

A generic municipal solid waste (MSW) infrastructure diagram corresponding to the plastic waste flow is presented in Figure 1 to visualize nodes for assessing plastic waste infrastructure gaps. It has four components: the storage from the waste sources prior to waste collection and transportation (yellow area), recycling and repurposing (green area), recovery (blue area), and waste disposal (purple area). The red area represents pollution; it occurs when plastic waste leaks from the SWM stream due to the insufficient SWM infrastructure for the amount of waste generated and/or other reasons.

Waste should be segregated at the source prior to collection and transportation. Recycling and repurposing of plastic waste include material or chemical recycling and using the plastic waste in construction (e.g., the production of ecobricks, asphalt, or furniture). Waste plastic material can be recovered using several technologies such as waste-to-energy (WtE), co-processing of plastics in cement kilns, or other methods such as gasification and pyrolysis. When recycling and recovery of plastic waste are not feasible or available, the waste is disposed of in SLFs.

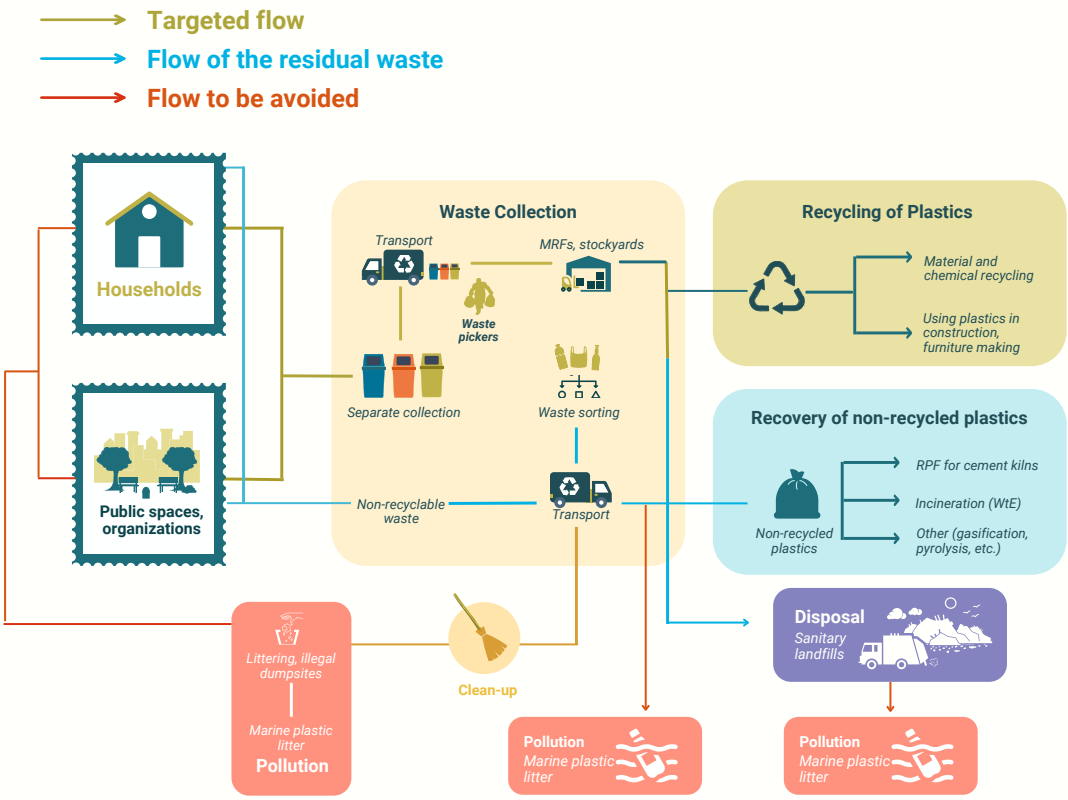


FIGURE 1. PLASTIC WASTE INFRASTRUCTURE DIAGRAM
Abbreviations: MRF - material recovery facility, RPF - Refused Plastic Fuel , WtE - Waste-to-energy

To support environmentally sound waste management, it is necessary to manage each SWM functional element along the targeted flow (green line in the diagram). Following the targeted flow, it ensures that segregation at source is practiced and enforced, the collection of waste is carried out in a proper and segregated manner, plastic waste is recycled or diverted as much as possible, and any residual waste is properly landfilled.

Direct plastic pollution occurrences are marked red in Figure 1. Routes that lead to these occurrences are marked with red lines representing the unacceptable flow of plastic waste to be closely monitored and prevented. Incidents that cause direct plastic pollution are littering, open dumping, hauler dumping, and plastic emission from improperly managed landfills.

2.2. Interconnectivity of the components

The SWM infrastructure diagram can help identify gaps in the established local SWM infrastructure. The gaps can lead to the pollution of plastic waste and possibly to marine plastic litter. If citizens are to segregate waste at source using appropriate storage containers and waste is properly collected with no illegal dumping, littering will be prevented. However, if the city's waste services are not well established, and if the garbage is not frequently collected for disposal or recycling, then waste accumulates and can cause pollution. If citizens practice waste segregation, their efforts become nulled or wasted if the already-segregated wastes are collected together and disposed of as mixed waste at the landfill, which can be often seen in practice. One of the probable reasons for this practice are insufficient facilities such as unavailability of containers for proper storage of waste according to types, as well as insufficient number of collection vehicles, MRFs, and recycling and recovery facilities.

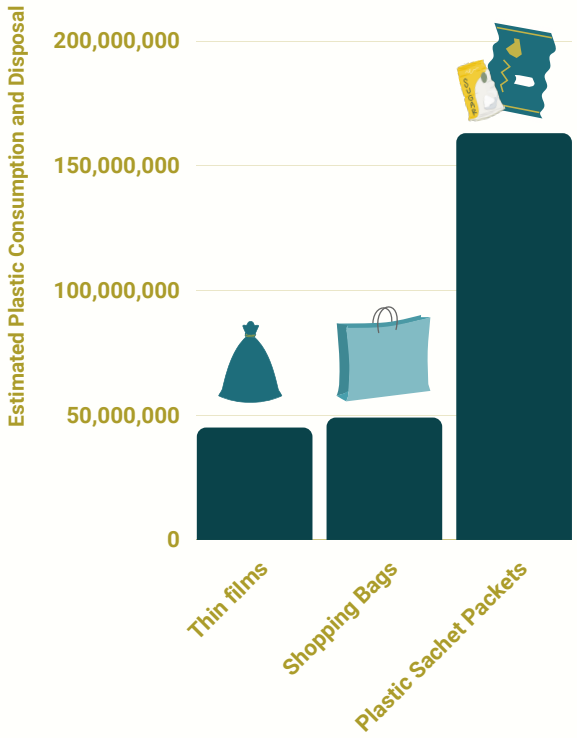
The lack of recycling facilities and insufficient adoption of circular economy practices also influence the whole waste flow within the SWM infrastructure, contributing to the increased amount of residual waste filling up landfills and increasing the probability of pollution, especially for mismanaged disposal sites. It is crucial that the national and local governments give importance to all the segments of the SWM infrastructure and not only focus on one. For example, governments must not only encourage segregation at source, but also ensure that there will be enough waste management infrastructure from waste storage to collection and transport, recycling and recovery and disposal.

3. Identifying the waste management infrastructure gaps to reduce plastic waste pollution

The growing population, increased consumption, and expanding urbanization contribute to the increasing generation of plastic waste in the Philippines. This in turn makes the SWM requirements more demanding and complex.[8] The waste management infrastructure for plastic waste must be adequate for the generated plastic waste amounts to prevent any kind of waste leakage. This also means that waste management infrastructure needs to adapt to any increase in generated plastic waste amounts.

A 2019 study by the Global Alliance for Incinerator Alternatives estimated that Filipinos use and dispose of more than 163 million plastic sachet packets, 49 million shopping bags (or roughly 17.5 billion pieces a year), and 45 million thin films daily.[9]

Only a small percentage of this plastic waste is recycled and recovered since most of them are considered residual plastics.



The infrastructure gaps between barangays and municipalities affect the effective implementation of SWM in the country. Pursuant to the Local Government Code of 1991 (RA 7160), RA 9003 mandates that LGUs shall be primarily responsible for the implementation of this Act. The barangay is responsible for the collection of biodegradables, and compostable and reusable wastes, while the city and municipality are responsible for the collection of non-recyclables and special wastes (Section 10). RA 9003 also promotes waste minimization through resource conservation, segregation at source, recycling, and resource recovery (Section 15).

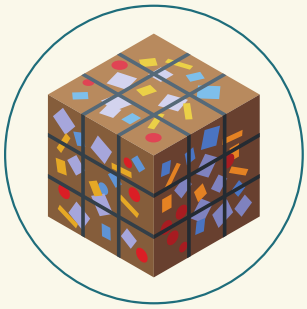
Considering the projected waste generation from 2021-2032 and the volume of plastic waste generated per day, this study provides the estimated number of collection vehicles, and the number of MRFs and its cost requirement for baled (rigid) and unbaled (rigid and flexible) plastic waste at 100% and 54.89% collection rates. It also shows the remaining capacity of SLF at the current waste disposal and the SLF requirement for the daily waste generation.

[8] Agaton, C.B., Guno C.S., Villanueva, R.O. and Villanueva, R.O. (2020). Economic analysis of waste-to-energy investment in the Philippines: A real options approach. Applied Energy, Elsevier, vol. 275 (C).

[9] WWF. (2020). EPR Scheme Assessment for Plastic Packaging Waste In The Philippines. Retrieved from wwf.org website: https://wwf.org.ph/wp-content/uploads/2020/12/WWF_REPORT_EPR_Philippines_2020.pdf

What is baling?

Baling is the compression of materials (e.g., plastic waste) into blocks for easier storage and transportation secured by wire strapping. Baled plastic waste reduces the volume and space in the collection vehicles and at the storage area subsequently lowering the transportation costs. Unbaled plastic materials are placed in sacks without using a baling machine.

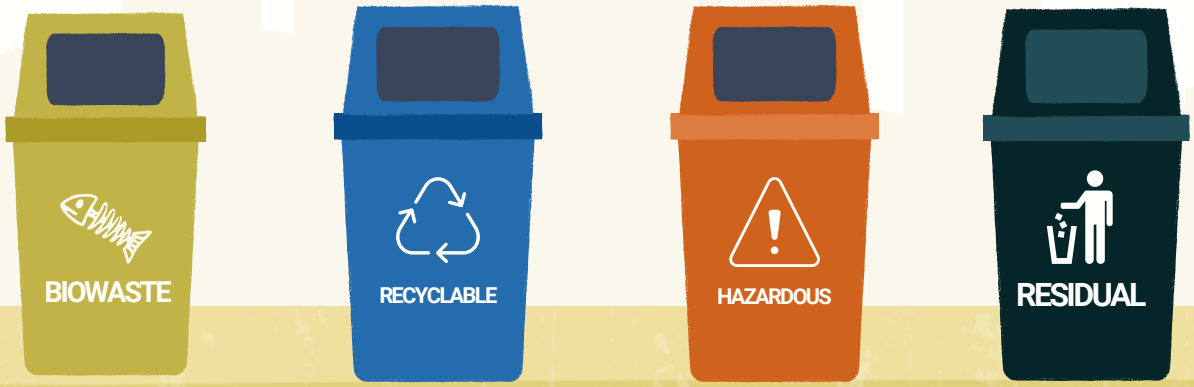


3.1. Waste management infrastructure gaps occurring in waste storage (waste source) and waste collection

Plastic waste, excluding bulky waste such as used appliances, is partially collected either as a recyclable or residual in the MSW characterization.[10] Plastics in the residual waste stream are usually multi-layered composite plastic packaging typical of processed food and other goods, sachets, shopping bags, thin film bags, and other packaging and disposable plastic-based materials. If waste segregation at source were not practiced, more plastic waste will end up as residuals.

The waste collection part of waste management comprises waste pick-up, transfer of waste, and sorting of waste at MRFs (see Figure 1, yellow area). After waste segregation by the households and establishments, there are cases where already segregated waste is mixed together during collection. To address this concern, some LGUs adopted the use of the nationally-accepted color-coding scheme for containers based on the classification of waste: blue for recyclables, green for bio waste, black for residuals, yellow for infectious, and red for other hazardous waste in the MSW stream. Other LGUs designate specific days for waste collection according to the type of waste. These strategies are consistent with the guidelines cited in Section 24 of the RA 9003. For selected Southeast Asian countries, including the Philippines, it was estimated that about 7 kgs of plastic waste leaked to the ocean between collection and disposal for every metric ton of collected waste.[11]

[10] Environmental Management Bureau-Department of Environment and Natural Resources. (2018). National Solid Waste Management Status Report 2008-2018.
[11] McKinsey & Company and Ocean Conservancy. (2015). Stemming the Tide: Land-based Strategies for a Plastic-Free Ocean. Retrieved from oceanconservancy.org website: https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf



It is noticeable that collection efficiencies are higher in urbanized regions compared to less urbanized regions.[12] This can be attributed to the availability of collection services and accessibility of recycling facilities in urban cities. There is lack or limited collection services and recycling and disposal facilities in isolated or island communities. Being archipelagic in nature, many smaller populated islands are not easily accessible, which limits the provision of waste collection services in the area. Their waste generation might be lower, but not negligible. Islands that are popular travel destinations (e.g., Boracay Island) generate more waste due to the influx of tourists.[13]

> For the selected Southeast Asian countries, including the Philippines, it was estimated that about 7 kgs of plastic waste leaked to the ocean between collection and disposal for every metric ton of collected waste.

Due to the lack of baseline information on the current number of collection vehicles, this study used the projected waste generation from 2021 to 2032 and the waste composition to estimate the required number of collection vehicles for the generated baled rigid plastic waste and the unbaled rigid and flexible plastic at 100% and 54.89% collection rate. Based on the NSWMC's data on the composition of waste, 28% of waste generated is composed of recyclables, 10.55% of which are plastic waste.[14]

For baled plastic waste (rigid), Table 1 shows the required number of collection vehicles at 12.0m³ truckload per trip at three trips per day if collection is within the LGU locality, from the barangay MRF to the centralized MRF or when the vehicles are assigned at the municipality/city , and at two trips per day if collection is from centralized MRF of the municipality/city to plastic recycling facility/transfer stations within the province or when the vehicles are assigned at the province.

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[12] WWF. (2020). EPR Scheme Assessment for Plastic Packaging Waste In The Philippines, https://wwf.org.ph/wp-content/uploads/2020/12/WWF_REPORT_EPR_Philippines_2020.pdf

[13] Razon, C. J. (2019). Carrying Capacity of Boracay Island (Philippines) using Waste Mass Flow Analysis. 4th Symposium of the Asian Regional Branch of International Waste Working Group. Bangkok.

[14] National Solid Waste Management. (2018). National Solid Waste Management Status Report 2008-2018. Retrieved from nswmc.emb.gov.ph website: https://eeid.emb.gov.ph/wp-content/uploads/2020/07/SOLIDWASTE-LAYOUT_final.pdf

At three trips per day, 381 collection vehicles with a capacity of total truck load of 12.0m³/trip are needed within 10 years for baled rigid plastic waste at 100% collection rate. For Year 1, there is a need to procure 307 units of collection vehicles, then in succeeding years, about six units shall be added per year to the waste collection fleet. At two trips per day, 571 collection vehicles are needed within 10 years. For Year 1, there is a need to procure about 460 units of collection vehicles, then in succeeding years, about 10 units should be added.

TABLE 1. NUMBER OF COLLECTION VEHICLES REQUIRED FOR BALED PLASTIC WASTE (RIGID) AT 100% COLLECTION RATE

Year	Projected waste generation	Recyclable waste 28% based on the waste composition*	Recyclable Plastic Waste (10.55% of Recyclables)	Volume of Plastic Waste (m³/year)	Volume of Plastic Waste (m³/day)	**Number of Collection Vehicles	Collection Vehicles Increment /year @ 3 trips/day	Collection Vehicles Require-ment @ 2trips/day	Collection Vehicles Increment @ 2trips/day
	Tons/Year	Tons/Year	Tons/Year	m³/year	m³/day	Unit	Unit	Unit	Unit
2021	21,843,798.0	6,116,263.07	645,266.0	4,028,254.0	11,036.0	307	307	460	460
2022	22,271,691.0	6,236,073.0	657,906.0	4,107,162.0	11,253.0	313	6	469	9
2023	22,709,320.0	6,358,610.0	670,833.0	4,187,866.0	11,474.0	319	6	478	9
2024	23,156,940.0	6,483,943.0	684,056.0	4,270,412.0	11,700.0	325	6	487	9
2025	23,614,809.0	6,612,146.0	697,581.0	4,354,849.0	11,931.0	331	6	497	10
2026	24,087,105.0	6,744,389.0	711,533.0	4,441,946.0	12,170.0	338	7	507	10
2027	24,568,847.0	6,879,277.0	725,764.0	4,530,785.0	12,413.0	345	7	517	10
2028	25,060,224.0	7,016,863.0	740,279.0	4,621,400.0	12,661.0	352	7	528	10
2029	25,561,429.0	7,157,200.0	755,085.0	4,713,828.0	12,915.0	359	7	538	11
2030	26,072,657.0	7,300,344.0	770,186.0	4,808,105.0	13,173.0	366	7	549	11
2031	26,594,110.0	7,446,351.0	785,590.0	4,904,267.0	13,436.0	373	7	560	11
2032	27,125,993.0	7,595,278.0	801,302.0	5,002,352.0	13,705.0	381	7	571	11

Notes:
Total Waste Truck Load capacity/unit = 12.0m³

Size of the truck = 3.5m x 1.70m at 2.0m height of plastic wastes

Number of waste collection vehicles required to haul the volume of plastic waste = Volume of waste per day divided by the capacity of the vehicles and the frequency of collections or the assigned number of trips per unit

Column 2 is taken from the NSWMC database (2022) from the year 2022-2025, while the rest are based on the author's estimated computation. Based on the NSWMC projected waste generation from 2021-2025, there is about a 2% increase per year. Hence, it becomes the basis for estimating the projected waste generation from 2026-2032.

**Based on the DENR SWM Status Report (2008 - 2018), the amount of recyclable waste is about 28% of the total projected waste generation (or about 0.55% of the recyclables are plastic wastes as shown in Column 4).*

For unbaled plastic waste (rigid and flexible), Table 2 shows the estimated volume of unbaled plastic waste (rigid and flexible) using assumptions based on available data from relevant sources (e.g., interviews from recyclers).

TABLE 2. VOLUME OF UNBALED PLASTIC WASTE (RIGID AND FLEXIBLE) PER YEAR

Year	Projected waste generation (Tons/Year)	Residual Waste (17.98%) (Tons/Year)	¹Recyclable waste 28% based on the waste composition (Tons/Year)	*Volume Rigid Plastic Waste (10.55% of Recyclables) (Tons/Year)	Volume of Rigid Plastic Waste (m³/year)	**Volume of Flexible Waste (9% of the Residual) (Tons/Year)	**Volume of Flexible Waste (9% of the Residual) (Tons/Year)	Total Volume of Plastic Waste (Rigid & Flexible) (Tons/Year)	Total Volume of Plastic Waste (Rigid & Flexible) (m³/Year)
2021	21,843,798.0	3,927,515.0	6,116,263.0	645,266.0	8,603,544.0	353,476.0	7,069,523.0	998,742.0	15,673,071.0
2022	22,271,691.0	4,004,450.0	6,236,074.0	657,906.0	8,772,077.0	360,401.0	7,208,010.0	1,018,306.0	15,980,087.0
2023	22,709,320.0	4,083,136.0	6,358,610.0	670,833.0	8,944,444.0	367,482.0	7,349,645.0	1,038,316.0	16,294,089.0
2024	23,156,940.0	4,163,618.0	6,483,943.0	684,056.0	9,120,747.0	374,726.0	7,494,512.0	1,058,782.0	16,615,259.0
2025	23,614,809.0	4,245,943.0	6,612,147.0	697,581.0	9,301,086.0	382,135.0	7,642,697.0	1,079,716.0	16,943,783.0
2026	24,087,105.0	4,330,862.0	6,744,389.0	711,533.0	9,487,108.0	389,778.0	7,795,551.0	1,101,311.0	17,282,659.0
2027	24,568,847.0	4,417,479.0	6,879,277.0	725,764.0	9,676,850.0	397,573.0	7,951,462.0	1,123,337.0	17,628,312.0
2028	25,060,224.0	4,505,828.0	7,016,863.0	740,279.0	9,870,387.0	405,525.0	8,110,491.0	1,145,804.0	17,980,878.0
2029	25,561,429.0	4,595,945.0	7,157,200.0	755,085.0	10,067,795.0	413,635.0	8,272,701.0	1,168,720.0	18,340,495.0
2030	26,072,657.0	4,687,864.0	7,300,344.0	770,186.0	10,269,151.0	421,908.0	8,438,155.0	1,192,094.0	18,707,305.0
2031	26,594,110.0	4,781,621.0	7,446,351.0	785,590.0	10,474,534.0	430,346.0	8,606,918.0	1,215,936.0	19,081,452.0
2032	27,125,993.0	4,877,253.0	7,595,278.0	801,302.0	10,684,024.0	438,953.0	8,779,056.0	1,240,255.0	19,463,081.0

Notes:
** Rigid Plastic Waste (DENR SWM Data: 2013-2018)*
***Flexible waste (residual with potential) = 9% of the total residual (taken from the Assessment of the Implementation of the ESWM for Home Owners Associations in Metro Manila Towards Proposed Enhanced Strategies funded by the World Bank)*
Rigid Plastic Baled = 160 kg/km³
Rigid Plastic Unbaled = 75 kg/km³

Sources of Data:
- *United recyclers Organization of the Philippines: Manual Baling = 40-55 kg/m³*
- *GMA Cavite MRF: Manual Baling = 70 kg/m³*

Mean density is 50 kg/m³
Capacity of MRF for Plastic Waste = 50m³ (5.0mX5.0m x2.0)
Number of MRF as of 2022 = 11,738 serving 16,817 LGUs
Column 2 is taken from the NSWMC database (2022) from the year 2022-2025, while the rest are based on the author's estimated computation. Based on the NSWMC projected waste generation from 2021-2025, there is about a 2% increase per year. Hence, it becomes the basis for estimating the projected waste generation from 2026-2032.
¹Based on the DENR SWM Status Report (2008 - 2018), the amount of recyclable waste is about 28% of the total projected waste generation (or about 0.55% of the recyclables are plastic wastes as shown in Column 4).

TABLE 3. VOLUME OF UNBALED PLASTIC WASTE (RIGID AND FLEXIBLE) PER DAY

			Volume of Rigid Plastic Waste				Volume of Flexible Waste			
Year	Projected waste generation (Tons/Year)	[1]Recyclable waste 28% based on the waste composition (Tons/Year)	Recyclable Rigid Plastic Waste (10.55% of Recyclables) (Tons/Year)	Volume of Rigid Plastic Waste (m^3/year)	Volume of Rigid Plastic Waste (m^3/day)	Volume of Residual Waste (17.98%) (Tons/Year)	Volume of Flexible Waste (9.0% of the Residuals) (Tons/Year)	Volume of Flexible Waste (9.0% of the Residuals) (m^3/Year)	Volume of Flexible Waste (9.0% of the Residuals) (m^3/day)	Total Volume of Plastic Waste (Rigid + Flexible) (m^3/day)
2021	21,843,798.0	6,116,263.0	645,265.0	8,603,544.0	23,571.0	3,927,515.0	353,476.0	7,069,527.0	19,369.0	42,940.0
2022	22,271,691.0	6,236,074.0	657,906.0	8,772,077.0	24,033.0	4,004,450.0	360,401.0	7,208,010.0	19,748.0	43,781.0
2023	22,709,320.0	6,358,610.0	670,833.0	8,944,444.0	24,505.0	4,083,136.0	367,482.0	7,349,645.0	20,136.0	44,641.0
2024	23,156,940.0	6,483,943.0	684,056.0	9,120,747.0	24,988.0	4,163,618.0	374,726.0	7,494,512.0	20,533.0	45,521.0
2025	23,614,809.0	6,612,147.0	697,581.0	9,301,086.0	25,482.0	4,245,943.0	382,135.0	7,642,697.0	20,939.0	46,421.0
2026	24,087,105.0	6,744,389.0	711,533.0	9,487,108.0	25,992.0	4,330,862.0	389,778.0	7,795,551.0	21,358.0	47,350.0
2027	24,568,847.0	6,879,277.0	725,764.0	9,676,850.0	26,512.0	4,417,479.0	397,573.0	7,951,462.0	21,785.0	48,297.0
2028	25,060,224.0	7,016,863.0	740,279.0	9,870,387.0	27,042.0	4,505,828.0	405,525.0	8,110,491.0	22,221.0	49,263.0
2029	25,561,429.0	7,157,200.0	755,085.0	10,067,795.0	27,583.0	4,595,945.0	413,635.0	8,272,701.0	22,665.0	50,248.0
2030	26,072,657.0	7,300,344.0	770,186.0	10,269,151.0	28,135.0	4,687,864.0	421,908.0	8,438,155.0	23,118.0	51,253.0
2031	26,594,110.0	7,446,351.0	785,590.0	10,474,534.0	28,697.0	4,781,621.0	430,346.0	8,606,918.0	23,581.0	52,278.0
2032	27,125,993.0	7,595,278.0	801,302.0	10,684,024.0	29,271.0	4,877,253.0	438,953.0	8,779,056.0	24,052.0	53,324.0

Based on the volume of rigid and flexible plastic waste as shown in Tables 2 and 3, the estimated number of collection vehicles requirement are shown in Tables 4 and 5 for the three (3) and two (2) trips per day at 100% and 54.89% collection rate, respectively.

TABLE 4. NUMBER OF COLLECTION VEHICLES REQUIRED FOR UNBALED PLASTIC WASTE (RIGID AND FLEXIBLE) AT 100% COLLECTION RATE

Year	Projected waste generation (Tons/Year)	Volume of Residual Waste (17.98%) (Tons/Year)	Recyclable waste 28% based on the waste composition (Tons/Year)	Total Volume of Plastic Wastes (Rigid + Flexible)m³/day	Number of Collection Vehicles			
					*Collection Vehicles Requirement @ 3 trips/day (Unit)	Collection Vehicles Increment by Year (Unit)	**Collection Vehicles Requirement @ 2 trips/day (Unit)	Collection Vehicles Increment by Year (Unit)
2021	21,843,798.0	3,927,515.0	6,116,263.0	42,940.0	1,193	1,193	1,789	1,789
2022	22,271,691.0	4,004,450.0	6,236,074.0	43,781.0	1,216	23	1,824	35
2023	22,709,320.0	4,083,136.0	6,358,610.0	44,641.0	1,240	24	1,860	36
2024	23,156,940.0	4,163,618.0	6,483,943.0	45,521.0	1,264	24	1,897	37
2025	23,614,809.0	4,245,943.0	6,612,147.0	46,421.0	1,289	25	1,934	38
2026	24,087,105.0	4,330,862.0	6,744,389.0	47,350.0	1,315	26	1,973	39
2027	24,568,847.0	4,417,479.0	6,879,277.0	48,297.0	1,342	26	2,012	39
2028	25,060,224.0	4,505,828.0	7,016,863.0	49,263.0	1,368	27	2,053	40
2029	25,561,429.0	4,595,945.0	7,157,200.0	50,248.0	1,396	27	2,094	41
2030	26,072,657.0	4,687,864.0	7,300,344.0	51,253.0	1,424	28	2,136	42
2031	26,594,110.0	4,781,621.0	7,446,351.0	52,278.0	1,452	28	2,178	43
2032	27,125,993.0	4,877,253.0	7,595,278.0	53,324.0	1,481	29	2,222	44

Notes:
*Number of trips/unit/day = 3 (within the locality of LGU municipality/city)
**Number of trips/unit/day = 2 (within the provincial LGU serving all municipalities /cities)
Waste collection capacity/unit or truckload = 12.0m³ /trip
Assumption: Each province has one recycling facility or transfer station

In the case of 100% collection rate of unbaled rigid and flexible plastic waste, a total of 1,481 collection vehicles with a total capacity load of 12.0m³ per trip are needed within 10 years (or at 2032) if the collection is three times a day within the LGU cities/municipalities. A total 2,222 collection vehicles is needed for 10 years if the provincial government will do the collection of plastics wastes from the central MRF of the municipalities/cities to plastic recycling plant or transfer station within the province at 100% collection rate.

TABLE 5. NUMBER OF COLLECTION VEHICLES REQUIRED FOR UNBALED PLASTIC WASTE (RIGID AND FLEXIBLE) AT 54.89% COLLECTION RATE

Year	Total Volume		Number of Collection Vehicles			
	Rigid and Flexible Waste (m^3/year)	Rigid and Flexible Waste (m^3/day)	Collection Vehicle at 3 trips (Unit)	Increment per Year (Unit)	Collection Vehicle at 2 trips (Unit)	Increment per Year (Unit)
2021	6,091,544.00	16,689.00	464	464	695	695
2022	6,210,870.00	17,016.00	473	9	709	14
2023	6,332,911.00	17,350.00	482	9	723	14
2024	6,457,738.00	17,692.00	491	9	737	14
2025	6,585,423.00	18,042.00	501	10	752	15
2026	6,717,131.00	18,403.00	511	10	767	15
2027	6,851,474.00	18,771.00	521	10	782	15
2028	6,988,504.00	19,147.00	532	10	798	16
2029	7,128,274.00	19,530.00	542	11	814	16
2030	7,270,839.00	19,920.00	553	11	830	16
2031	7,416,256.00	20,319.00	564	11	847	17
2032	7,564,581.00	20,725.00	576	11	864	17

Notes:
Volume of truckload/trip = 12.0m^3
Size of the collection vehicle = 3.5mx1.67m at 2.0 height of plastic waste

At a 54.89% collection rate of unbaled flexible and rigid plastics, Table 5 shows that if the municipality/city will be doing the collection of three trips per day, the requirement is about 464 units of collection vehicles with a truckload capacity of 12.0m^3 in 2021 or about 576 by the year 2032. If the provincial government will do the collection of two trips/day, they should have invested and procured about 695 units in 2021 or prepare about 864 units of collection vehicles by the year 2032. The distribution of numbers for the respective MRFs and collection vehicles will depend on the total volume of plastic waste collected and stored. The cities and municipalities should invest in the provision of baling machines to save resources in the collection and transport of rigid plastic materials.

To avoid contamination of plastic waste, this paper recommends having separate storage bins and collection vehicles for plastic waste. The number of collection vehicles shown in the tables above is in addition to the existing collection vehicles in the country.

3.2. Waste management infrastructure gaps occurring in waste recycling and recovery area

The RA 9003 mandates the establishment of an MRF in every barangay or cluster of barangays (Section 32), and an SLF as final disposal site for solid residual waste of city and municipality or cluster of cities and municipalities (Section 17). As defined in Section 3 of the Act, an MRF includes solid waste transfer stations or sorting stations, drop-off centers, a composting facility, and a recycling facility. However, as shown in Figure 2 below, as of 2022 only 16,817 barangays (about 40% of barangays) are served by MRFs. There are still about 60% of barangays that do not have access to MRF (Figure 2).

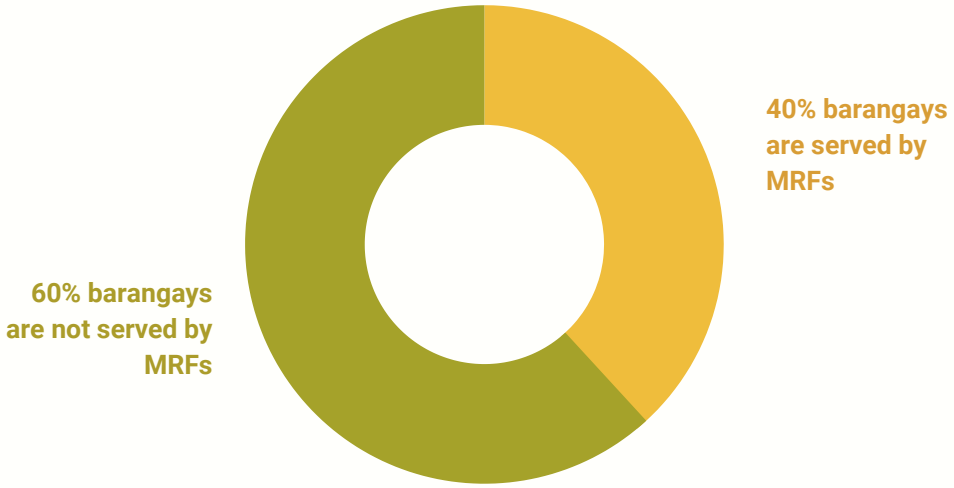

FIGURE 2: NUMBER OF BARANGAYS SERVED BY MRF

Source: The number of MRFs and the barangays/LGUs served by MRFs came from NSWMC Database, 2022

Notes:
11,738 (NSWMC, 2022) - Number of MRFs in the Philippines
An estimated 28% of barangays have their own MRF/s
16,817 barangays are served by MRFs
27,229 barangays are not served by MRFs

The Act further states that each LGU is required to divert at least 25% of all solid waste from waste disposal facilities through reuse, recycling, and composting activities and other resource recovering activities. In 2017, the Philippine Development Plan set the national solid waste diversion rate target to 80% by 2022.[15] In 2019, the recycling rate of post-industrial and post-consumer plastics was estimated to be 9%. The highest rates were for rigid HDPE (31%) followed by clear PET bottles (24%) and PP (19%).[16]

[15] National Economic and Development Authority (NEDA). 2017. Philippine Development Plan 2017-2022. (2017). Retrieved September 27, 2022, from https://pdp.neda.gov.ph/philippine-development-plan-2017-2022/
[16] WWF. (2020). EPR Scheme Assessment for Plastic Packaging Waste In The Philippines. Retrieved from wwf.org website: https://wwf.org.ph/wp-content/uploads/2020/12/WWF_REPORT_EPR_Philippines_2020.pdf

Eighty percent (80%) of plastic waste is low-value plastics (e.g., multilayer plastic, sachets, plastic bags, etc.) which mostly end up at the disposal facilities.[17] Among the types of plastic waste, this fraction is most difficult to recycle, but they can still be recovered using technologies such as co-processing. There is an immense yet untapped potential for waste recovery that can process considerable amounts of the plastic waste and help meet diversion targets.

In this study, the identification of the infrastructure gaps for the MRFs focus on the plastic component of waste, particularly for the rigid and flexible. For baled plastic waste (rigid), Tables 6 and 7 show the number of MRFs required per year and the total cost requirement using the 100% and 54.89% collection rate, respectively. The LGUs need to invest in the construction of additional MRFs to be used only for storage of plastic waste. These MRFs are in addition to the existing MRFs being utilized by the LGUs. These facilities can be constructed by expanding the existing MRF or as separate facilities.

TABLE 6: VOLUME OF RIGID PLASTIC WASTE AND NUMBER OF MRFS REQUIRED AT 100% COLLECTION RATE

Year	Projected waste generation (tons/year)	[1]Recyclable waste 28% based on the waste composition (tons/year)	Recyclable (Rigid) Plastic Wastes (10.55% of Recyclables) (tons/year)	Volume of Rigid Plastic Waste (m^3/year)	Volume of Plastic Waste (m^3/0.50year)	Number of MRFs @ 50m^3/cap/.5 year (5.0x5.0m)	MRF Increment per year	Total Cost of MRFs (PHP)
2021	21,843,798.0	6,116,263.0	645,265.0	4,028,254.0	2,014,127.0	40,283	40,283	805,660,000.0
2022	22,271,691.0	6,236,074.0	657,906.0	4,107,162.0	2,053,581.0	41,072	789	15,781,700.0
2023	22,709,320.0	6,358,610.0	670,833.0	4,187,866.0	2,093,933.0	41,879	807	16,140,806.0
2024	23,156,940.0	6,483,943.0	684,056.0	4,270,412.0	2,135,206.0	42,704	825	16,509,248.0
2025	23,614,809.0	6,612,147.0	697,581.0	4,354,849.0	2,177,424.0	43,548	844	16,887,298.0
2026	24,087,105.0	6,744,389.0	711,533.0	4,441,94t.0	2,220,973.0	44,419	871	17,419,395.0
2027	24,568,847.0	6,879,277.0	725,764.0	4,530,785.0	2,265,392.-	45,308	888	17,767,783.0
2028	25,060,224.0	7,016,863.0	740,279.0	4,621,400.0	2,310,700.0	46,214	906	18,123,139.0
2029	25,561,429.0	7,157,200.0	755,085.0	4,713,828.0	2,356,914.0	47,138	924	18,485,601.0
2030	26,072,657.0	7,300,344.0	770,186.0	4,808,105.0	2,404,052.0	48,081	943	18,855,314.0
2031	26,594,110.0	7,446,351.0	785,590.0	4,904,267.0	2,452,134.0	49,043	962	19,232,420.0
2032	27,125,993.0	7,595,278.0	801,302.0	5,002,352.0	2,501,176.0	50,024	981	19,617,068.0

Notes:

Column 2 is taken from the NSWMC database (2022) from the year 2022-2025, while the rest are based on the author's estimated computation. Based on the NSWMC projected waste generation from 2021-2025, there is about a 2% increase per year. Hence, it becomes the basis for estimating the projected waste generation from 2026-2032.

[1]Based on the DENR SWM Status Report (2008 - 2018), the amount of recyclable waste is about 28% of the total projected waste generation (or about 0.55% of the recyclables are plastic wastes as shown in Column 4).

[17] McKinsey & Company and Ocean Conservancy. (2015). Stemming the Tide: Land-based Strategies for a Plastic-Free Ocean. Retrieved from oceanconservancy.org website: https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf

As shown in Table 6, the assumed space requirement for plastic waste to the existing MRF is 50m³ (5.0m x 5.0m x 2.0m) and the assumed cost of MRF per square meter is PhP20,000. Bales of plastic should be compressed to a minimum bulk density of 160.187kg/m³, which is the bale density using mechanical process.[18] Maximum density of bales is to be agreed upon through individual contracts between buyers and sellers or plastic waste. Increased bulk density may improve transportation efficiency, but over-compression may adversely affect the ability of a buyer to separate, sort, and reprocess the material. Recyclable plastics are generally categorized as rigid plastic wastes. It is also assumed that all plastic wastes are collected within six months and transported to the recycling plant/transfer station.

Using the same assumptions from Table 6, Table 7 shows the volume of rigid plastic waste and the number of MRFs and the corresponding cost requirement at 54.89% collection rate.

TABLE 7. VOLUME OF RIGID PLASTIC WASTES AND NUMBER OF MRFS AT 54.89% COLLECTION RATE

Year	Projected waste generation (Tons/Year)	Volume of waste collected at 54.89% collection rate (Tons/Year)	Volume of recyclable/ Rigid) waste (28%) (Tons/Year)	Volume of Rigid plastic waste (10.55%) (Tons/Year)	Volume of Plastic Waste (m³/year)	Volume of Plastic Waste (m³/0.5 year)	Number of MRF	Increment of MRF per Year	Cost (PHP)
2021	21,843,798	11,990,061	3,357,217	354,186	2,211,108	1,105,554	22,111	22,111	442,220,000.00
2022	22,271,691	12,224,931	3,422,981	361,124	2,254,421	1,127,211	22,544	433	8,662,575.00
2023	22,709,320	12,465,146	3,490,241	368,220	2,298,720	1,149,360	22,987	443	8,859,688.00
2024	23,156,940	12,710,844	3,559,036	375,478	2,344,029	1,172,015	23,440	453	9,061,926.00
2025	23,614,809	12,962,169	3,629,407	382,902	2,390,377	1,195,188	23,904	463	9,269,438.00
2026	24,087,105	13,221,412	3,701,995	390,561	2,438,184	1,219,092	24,382	478	9,561,506.00
2027	24,568,847	13,485,840	3,776,035	398,372	2,486,948	1,243,474	24,869	488	9,752,736.00
2028	25,060,224	13,755,557	3,851,556	406,339	2,536,687	1,268,343	25,367	497	9,947,791.00
2029	25,561,429	14,030,668	3,928,587	414,466	2,587,420	1,293,710	25,874	507	10,146,747.00
2030	26,072,657	14,311,282	4,007,159	422,755	2,639,169	1,319,584	26,392	517	10,349,682.00
2031	26,594,110	14,597,507	4,087,302	431,210	2,691,952	1,345,976	26,920	528	10,556,675.00
2032	27,125,993	14,889,457	4,169,048	439,835	2,745,791	1,372,896	27,458	538	10,767,809.00

Notes:

Column 2 is taken from the NSWMC database (2022) from the year 2022-2025, while the rest are based on the author's estimated computation. Based on the NSWMC projected waste generation from 2021-2025, there is about a 2% increase per year. Hence, it becomes the basis for estimating the projected waste generation from 2026-2032.

[18] Guidelines for Plastic Scrap: P-2007. (2007). Baled Recycled Plastic Scrap Commercial Guidelines. Scrap specification circular 2007. 36-42. http://www.international-recycling.com/files/USPS2007PlasticsExport.pdf

For unbaled plastic waste (rigid and flexible), Table 8 shows the number of MRFs and the cost requirement at 100% collection rate. With an MRF capacity of 50m³ (assuming the area for additional space is about 25m² and the height of plastic wastes is 2.0m), the total number of additional MRFs needed is about 97,315 at year 2032.

TABLE 8. VOLUME OF RIGID AND FLEXIBLE PLASTIC WASTE AND NUMBER OF MRFS AT 100% COLLECTION RATE

Year	Projected waste generation (Tons/Year)	Volume of waste collected at 54.89% collection rate (Tons/Year)	Volume of recyclable/ Rigid) waste (28%) (Tons/Year)	Volume of Rigid plastic waste (10.55%) (Tons/Year)	Volume of Plastic Waste (m³/year)	Volume of Plastic Waste (m³/0.5 year)	Number of MRF	Increment of MRF per Year	Cost (PHP)
2021	21,843,798.0	11,990,061.0	3,357,217.0	354,186.0	2,211,108.0	1,105,554.0	22,111	22,111	442,220,000.00
2022	22,271,691.0	12,224,931.0	3,422,981.0	361,124.0	2,254,421.0	1,127,211.0	22,544	433	8,662,575.0
2023	22,709,320.0	12,465,146.0	3,490,241.0	368,220.0	2,298,720.0	1,149,360.0	22,987	443	8,859,688.0
2024	23,156,940.0	12,710,844.0	3,559,036.0	375,478.0	2,344,029.0	1,172,015.0	23,440	453	9,061,926.0
2025	23,614,809.0	12,962,169.0	3,629,407.0	382,902.0	2,390,377.0	1,195,188.0	23,904	463	9,269,438.0
2026	24,087,105.0	13,221,412.0	3,701,995.0	390,561.0	2,438,184.0	1,219,092.0	24,382	478	9,561,506.0
2027	24,568,847.0	13,485,840.0	3,776,035.0	398,372.0	2,486,948.0	1,243,474.0	24,869	488	9,752,736.0
2028	25,060,224.0	13,755,557.0	3,851,556.0	406,339.0	2,536,687.0	1,268,343.0	25,367	497	9,947,791.0
2029	25,561,429.0	14,030,668.0	3,928,587.0	414,466.0	2,587,420.0	1,293,710.0	25,874	507	10,146,747.0
2030	26,072,657.0	14,311,282.0	4,007,159.0	422,755.0	2,639,169.0	1,319,584.0	26,392	517	10,349,682.0
2031	26,594,110.0	14,597,507.0	4,087,302.0	431,210.0	2,691,952.0	1,345,976.0	26,920	528	10,556,675.0
2032	27,125,993.0	14,889,457.0	4,169,048.0	439,835.0	2,745,791.0	1,372,896.0	27,458	538	10,767,809.0

Tables 9 and 10 show the volume of rigid and flexible plastic waste and the number of MRFs and their cost requirement at 54.89% collection rate respectively. At this collection rate, the total space requirement (25.0m²) is about 30,458 MRF units. This space requirement is in addition to the existing MRFs. As shown in Table 10, the initial investment (2021) is PhP 609 million and about PhP 12-15 million per year until 2032.

TABLE 9. VOLUME OF RIGID PLASTIC WASTE AND NUMBER OF MRFS AT 54.89% COLLECTION RATE

Year	Projected waste generation (Tons/Year)	Volume of waste collected at 54.89% collection rate (Tons/Year)	Volume of recyclable/ Rigid waste (28%) (Tons/ Year)	Volume of Rigid plastic waste (10.55%) (Tons/Year)	Volume of Plastic Waste (m^3/year)	Volume of Plastic Waste (m^3/0.5 year)	Number of MRF	Increment of MRF per Year	Cost (PHP)
2021	21,843,798.0	11,990,061.0	3,357,217.0	354,186.0	2,211,108.0	1,105,554.0	22,111	22,111	442,220,000.00
2022	22,271,691.0	12,224,931.0	3,422,981.0	361,124.0	2,254,421.0	1,127,211.0	22,544	433	8,662,575.0
2023	22,709,320.0	12,465,146.0	3,490,241.0	368,220.0	2,298,720.0	1,149,360.0	22,987	443	8,859,688.0
2024	23,156,940.0	12,710,844.0	3,559,036.0	375,478.0	2,344,029.0	1,172,015.0	23,440	453	9,061,926.0
2025	23,614,809.0	12,962,169.0	3,629,407.0	382,902.0	2,390,377.0	1,195,188.0	23,904	463	9,269,438.0
2026	24,087,105.0	13,221,412.0	3,701,995.0	390,561.0	2,438,184.0	1,219,092.0	24,382	478	9,561,506.0
2027	24,568,847.0	13,485,840.0	3,776,035.0	398,372.0	2,486,948.0	1,243,474.0	24,869	488	9,752,736.0
2028	25,060,224.0	13,755,557.0	3,851,556.0	406,339.0	2,536,687.0	1,268,343.0	25,367	497	9,947,791.0
2029	25,561,429.0	14,030,668.0	3,928,587.0	414,466.0	2,587,420.0	1,293,710.0	25,874	507	10,146,747.0
2030	26,072,657.0	14,311,282.0	4,007,159.0	422,755.0	2,639,169.0	1,319,584.0	26,392	517	10,349,682.0
2031	26,594,110.0	14,597,507.0	4,087,302.0	431,210.0	2,691,952.0	1,345,976.0	26,920	528	10,556,675.0
2032	27,125,993.0	14,889,457.0	4,169,048.0	439,835.0	2,745,791.0	1,372,896.0	27,458	538	10,767,809.0

TABLE 10. NUMBER OF MRFS AND THEIR COST REQUIREMENT FOR RIGID AND FLEXIBLE PLASTIC WASTE AT 54.89% COLLECTION RATE

Year	Total Volume		Additional Space to the Existing MRF		Cost (Pesos)
	Rigid and Flexible Waste (m^3/year)	Rigid and Flexible Waste (m^3/day)	25.0m^2 at 2.0 m height of Plastic Waste for 6 months (unit)	Increment/ additional Space per year (unit)	
2021	6,091,544	16,689	30,458	30,458	609,160,000.00
2022	6,210,870	17,016	31,054	597	11,932,581.00
2023	6,332,911	17,350	31,665	610	12,204,101.00
2024	6,457,738	17,692	32,289	624	12,482,681.00
2025	6,585,423	18,042	32,927	638	12,768,526.00
2026	6,717,131	18,403	33,586	659	13,170,846.00
2027	6,851,474	18,771	34,257	672	13,434,263.00
2028	6,988,504	19,147	34,943	685	13,702,948.00
2029	7,128,274	19,530	35,641	699	13,977,007.00
2030	7,270,839	19,920	36,354	713	14,256,547.00
2031	7,416,256	20,319	37,081	727	14,541,678.00
2032	7,564,581	20,725	37,823	742	14,832,512.00

Notes:
50m³ - Space Area of 25m² at 2.0meter height of plastics
Volume of truckload/trip = 12.0m³
Size of the collection vehicle = 3.5mx1.67m at 2.0 height of plastic waste

These calculated volumes of rigid and plastic waste should be processed through the plastic recycling facilities. According to PARMS's Zero Waste to Nature report, the baseline data for rigid PP/PE recovery rate is 100%; the rigid PET recycling rate is 40-55%; and only 4-9% are recovered for flexible waste.[19]

3.3. Waste management infrastructure gaps occurring in waste disposal

RA 9003 prohibits littering, throwing, and dumping of waste in public places. Open burning of solid waste, squatting in open dumps and landfills, burying waste in flood-prone areas, and dumping of collected domestic, industrial, commercial and institutional wastes in bulk in areas other than the designated centers or facilities are not allowed (Section 48).

The Act also mandates that no open dumpsites shall be established and that all open dumpsites shall be converted into controlled dumps by year 2004 and that all controlled dumpsites shall be closed by year 2006 following the effectiveness of the Act (Section 37). As an alternative, an SLF shall be constructed as a final disposal site (Section 17). The law prohibits the construction or operation of landfills or any waste disposal facilities on any aquifer, groundwater reservoir or watershed area and or any portions thereof. It further mandates that establishment of controlled dumpsites and SLFs shall follow the guidelines as cited in Sections 39-41 of the Act. However, as shown in Figure 3, only 32% of LGUs have access to SLFs as of 2022, which means about 1,110 LGUs (or about 68% of 1,634 LGUs) have no access to SLFs.

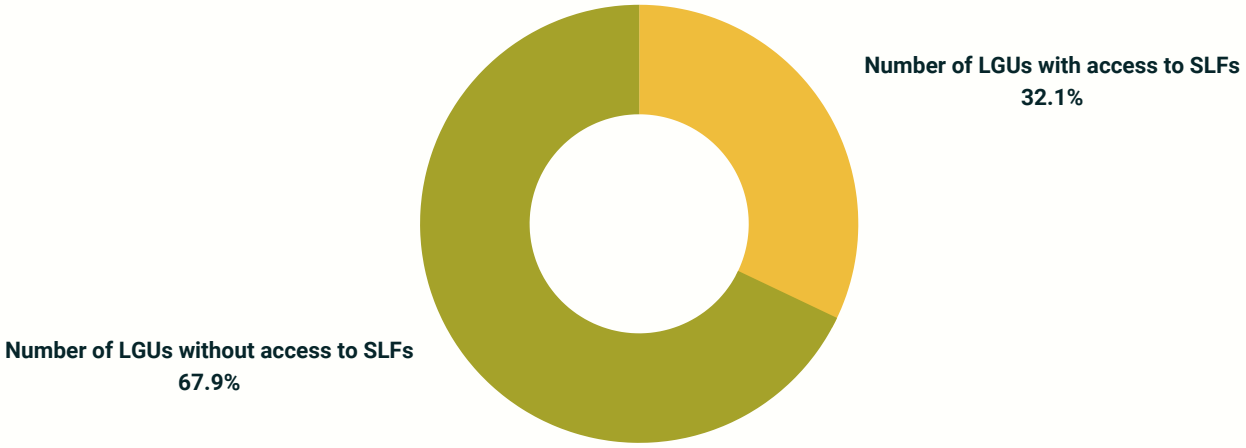

FIGURE 3. NUMBER OF LGUS WITH ACCESS/WITHOUT ACCESS TO SLFS IN THE PHILIPPINES

[19] Philippine Alliance for Recycling and Material Sustainability's (PARMS). 2020. ZWTN Ambisyon 2030: Rigid and Flexible Applications Strategy and Roadmap 2021-2030.

Notes:
273 Operating SLFs
524 LGUs have access to SLFs
1110 LGUs don't have access to SLFs

Source: NSWMC Database, 2022

Based on the DENR's data, there are 246 SLFs in the country with the designed SLF capacity (m^3) of 59,110,000. Considering the projected waste generation from 2022-2025 and the amount of waste received by the SLFs, the existing SLFs remaining capacity until 2023 is still sufficient (Table 11).[20]

TABLE 11. REMAINING CAPACITY OF THE SLF AT CURRENT RATE OF WASTE DISPOSAL

Year	Projected Waste Generation	Residual Waste (17.98%) for Disposal in SLF				[1]Actual Waste Received		[2] Actual waste received that exceeds the estimated residual waste	Actual Volume of Waste (m^3/year)	Remaining capacity of the SLF at current rate of disposal
		Per Year		Per Day						
	Tons/Year	Tons/Year	m^3/year	Tons/day	m^3/day	TPD	m^3/day	m^3/day	m^3/year	m^3
2021	21,843,798.0	3,927,515.0	12,599,092.0	10,760.0	34,518.0	12,970.0	41,607.0	7,089.0	15,186,461.0	43,923,539.0
2022	22,271,691.0	4,004,450.0	12,845,892.0	10,971.0	35,194.0	13,229.0	42,439.0	7,245.0	15,490,190.0	28,433,348.0
2023	22,709,320.0	4,083,136.0	13,098,309.0	11,187.0	35,886.0	13,494.0	43,288.0	7,402.0	15,799,994.0	12,633,354.0
2024	23,156,940.0	4,163,618.0	13,356,487.0	11,407.0	36,593.0	13,764.0	44,153.0	7,560.0	16,115,994.0	-3,482,640.0
2025	23,614,809.0	4,245,943.0	13,620,578.0	11,633.0	37,317.0	14,039.0	45,036.0	7,720.0	16,438,314.0	-19,920,954.0
2026	24,087,105.0	4,330,862.0	13,892,989.0	11,865.0	38,063.0	14,320.0	45,937.0	7,874.0	16,767,080.0	-36,688,034.0
2027	24,568,847.0	4,417,479.0	14,170,849.0	12,103.0	38,824.0	14,606.0	46,856.0	8,032.0	17,102,422.0	-53,790,456.0
2028	25,060,224.0	4,505,828.0	14,454,266.0	12,345.0	39,601.0	14,899.0	47,793.0	8,192.0	17,444,470.0	-71,234,926.0
2029	25,561,429.0	4,595,945.0	14,743,351.0	12,592.0	40,393.0	15,197.0	48,749.0	8,356.0	17,793,360.0	-89,028,286.0
2030	26,072,657.0	4,687,864.0	15,038,218.0	12,843.0	41,201.0	15,500.0	49,724.0	8,523.0	18,149,227.0	-107,177,513.0
2031	26,594,110.0	4,781,621.0	15,338,983.0	13,100.0	42,025.0	15,810.0	50,718.0	8,694.0	18,512,211.0	-125,689,725.0
2032	27,125,993.0	4,877,253.0	15,645,762.0	13,362.0	42,865.0	16,127.0	51,733.0	8,868.0	18,882,456.0	-144,572,180.0

Notes:
[1] NSWMC Database 2022 (Actual waste received = 12,970.07 tons/day and will increase by 2% by year (estimation)
[2] Estimated difference between the actual waste received and the amount of residual waste. Residual waste of 17.98% plus an amount of mixed wastes

[20] Environmental Management Bureau - Department of Environment and Natural Resources. NSWMC Database. (2022).

Based on the amount of waste disposed of or accepted by the SLF against its designed capacity, the LGUs should immediately start developing SLFs to address potential problems on the management of residual wastes in the next 10 years.

Development of SLFs may take about one to two years, which means that by 2024, there will be a larger deficit of space for disposal of wastes. It is estimated that there will be an annual increase of 2% of actual waste received, thus the value of 13,362.34 tons/day was used in the calculation of the required area for disposal (i.e., SLF). The total land area of 1,581 hectares should be developed for disposal of waste, thus the estimated number of SLF to be required is about 105, distributed into: (a) 15 SLFs of a 5-hectare land area; (b) 30 SLFs of 10- hectares, and (c) 60 SLFs of a 20-hectare land area. Table 15 shows the calculation for the sanitary requirement considering the daily waste generated.

SLF REQUIREMENT FOR A DAILY WASTE GENERATION

Sanitary Landfill Requirement for a daily waste generation of 13,362 tons/day

1. Estimated Landfill Volume (ELV)
= Life Span*Waste Generation

Where:
Life Span = 10 years
Waste Generation = 13,500 tons/day x 365 days/1 year
= 4,927,500.00 tons x 1000 kg/1ton x 1.0m³/311 kg

Note: (Adopting 311kg/m³ as field density of compacted mixed waste)
= 15,806,948.30 m³

Estimated Landfill Volume (ELV) = 10years x15,806,948.30m³
= 158,069,483.00m³

2. Estimated Landfill Volume = Estimated Landfill Area* Depth

Therefore; Estimated Landfill Area = Estimated Landfill Volume / Depth

Note: (Adopting, Depth = 10m; Assumed height of deposited waste, that is, from the base of the land fill to the top of the buried waste)
= 158,069,483.00 m³/10m
= 15,806,948.30 m²*1hectare/10,000.0m²
= 1,580.69.00hectare

Estimated Landfill Area = say 1581 hectares

Note:
Daily Waste Generation by 2032 (13,362 TPD) is used to include the annual increases of 2% waste volume in the determination of the SLF

A minimum of a 5-hectare area for SLF development is recommended because this is more economical compared to a one or 2-hectare area. The establishment of access road, perimeter fence, and leachate treatment facility are required for the operation of the SLF, thus a long-term landfill operation is most acceptable. It is a one-time investment as compared to smaller capacity wherein after its full utilization the LGUs need to look for another site/s for establishing the same infrastructure/features and therefore, it would become an added burden to them. The bigger the land area of the SLF, the better for the LGU in terms of financial investment. Construction of the SLF can be done in phases. Clustering between and among LGUs in establishing waste management infrastructures is also recommended.

Assuming that PhP 40-50 million is needed per hectare to develop an SLF, the government needs a budget of about PhP 4.20-5.25 billion.[21] The budget allocation in each LGUs specifically for waste management is highly recommended. The fiscal support for solid waste management is not fully embedded in the Philippine legislation. With the approval of the Mandanas-Garcia Ruling in 2018, LGUs will have a greater share in terms of fiscal resources. This can be an opportunity to allocate a higher budget on waste management infrastructures. In addition, this ruling also requires LGUs to submit their Devolution Transition Plans from 2022-2024 in support of the full devolution. Since waste management is included in the devolved functions, LGUs can include waste management programs, including waste management infrastructure.

[21] Personal communications. 2022.

4. Recommendations for future studies

This study provides a broad assessment of the total, current and remaining physical infrastructure requirements for plastic waste management in the Philippines in line with the urgency to implement the NPOA-ML. There are a number of limitations insufficiently covered in this analysis.To fully understand and capture the whole picture, the following recommendations are proposed for future studies:

Identification of social infrastructure gaps

Apart from physical infrastructure assessments, social infrastructure gaps need to be assessed. These include factoring in all actors along the plastic waste management value chain such as the informal and semi-formal waste sector, consolidators and apex traders, private sector roles under the new Extended Producer Responsibility (EPR) law, and changing the default behavior and practices of retailers and consumers. This also includes assessment of gaps in training and capability building needs to effectively utilize the physical infrastructures.

Last mile assessment of plastic waste value chain

Plastic wastes recovered and stored at MRFs or junk shops have to be brought to facilities that accommodate material or chemical recycling. However, there are a number of permutations to such facilities and a number of factors influencing where plastic wastes are likely to be brought. Identifying the volume of waste, their last mile destinations (i.e., how much goes to WtE/co-processing, domestically recycled into consumer products, exported for recycling elsewhere, cost implications for logistics, etc.) and their capacities would enhance this study.

Evaluation of waste logistics in the context of the country's topography and existing capacity gaps

Logistics is one of the keys to optimize waste diversion potentials of plastics and other recyclables, especially in an archipelagic country such as the Philippines. In consideration of the country's topography, it is recommended to conduct a study that will inform the creation of an effective waste logistics framework that will guide the identification of strategic infrastructure locations based on existing capacity gaps. Disaggregating infrastructure needs against existing capacities per region or province will help ensure that all communities will have access to services and opportunities to refuse, reduce, reuse, repurpose and recycle plastics.

Conduct a broader infrastructure gap assessment

This study only focused on the existing infrastructure gaps in the context of plastic waste management such as opportunities on the number of MRFs and their capacities, availability of collection vehicles, and access to waste facilities (e.g., SLFs). The future assessments should study the infrastructure gaps existing in the entire solid waste management (i.e., other recyclable wastes, residual wastes, and hazardous wastes) and the waste value chain.

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